Cruise Report for Underway Geophysics Program HLY 05-03
5 August 2005; Dutch Harbor, Alaska to
30 September, 2005; Tromso, Norway

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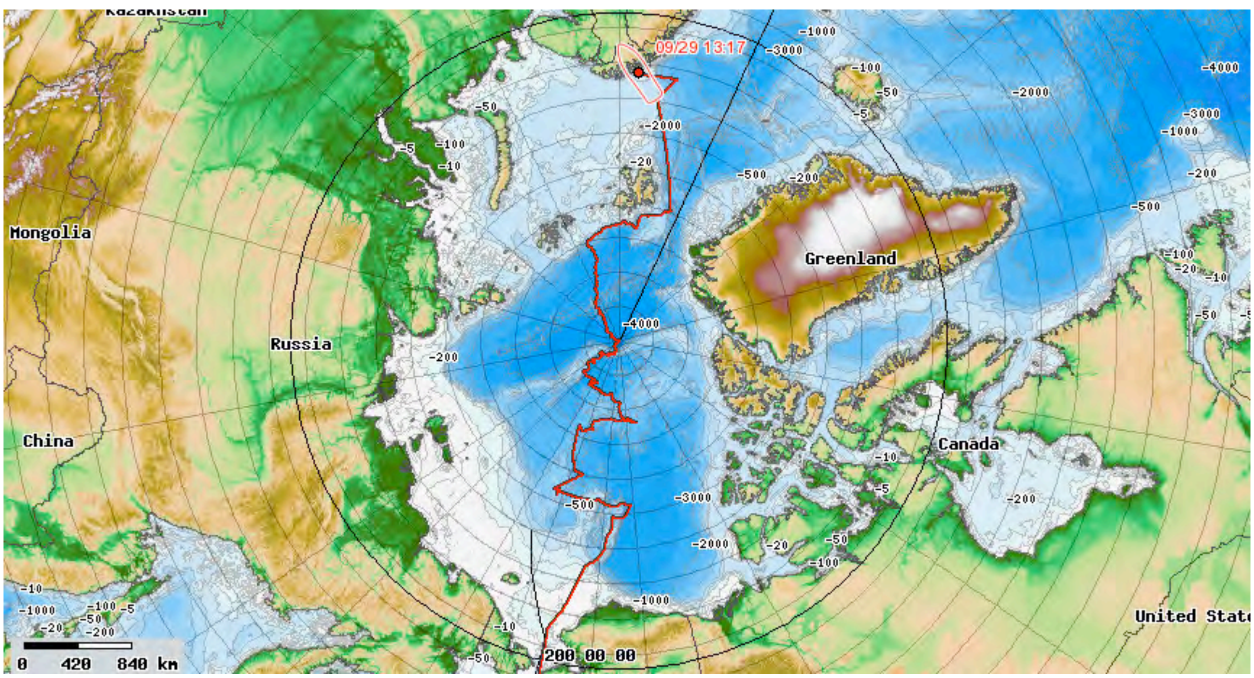
Bernard Coakley
co-Chief Scientist
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99775
bernard.coakley@gi.alaska.edu

Yngve Kristoffersen
Department of Earth Science
University of Bergen
Allegaten 41
N-5007 Bergen
yngve.kristoffersen@geo.uib.no

John Hopper
Texas A&M University
Dept. of Geology and Geophysics
College Station, TX 77843
hopper@geo.tamu.edu



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USCG Healy WAGB-20

Introduction

The history of the Arctic Ocean is preserved in the pattern of plateaus and sub-basins that segment it and written in the sediments beneath the seafloor. While it is clearly an oceanic basin, to date there is only a single mutually agreed upon plate boundary, the Gakkel Ridge. As a result, reconstructions of the paleo-geography of the northern hemisphere prior to Cenozoic times are largely hypothetical. The data collected during this cruise will help identify these Arctic plate boundaries, continuing the process of deciphering the tectonic history of the Mesozoic Arctic Ocean. This history will provide the context for better understanding the large tectonic features, such as Lomonosov Ridge, the Alpha-Mendeleev Ridge, Makarov Basin, the Canada Basin and a number of continental margin features that have recently begun to be well mapped [Figure 1]. In turn, what is learned from the marine geology will provide critical information towards understanding the terrestrial geologic evolution of major features in the northern hemisphere (e.g., the Brooks Range and North Slope of Alaska).

The stratigraphic record of the Arctic Ocean is revealed in the ~2200 km of multi-channel seismic reflection data collected during this cruise. These sediments contain a unique paleoceanographic and climatic record. Dramatic climate changes have occurred since the Cretaceous, when dinosaurs roamed the north (Tarduno et al., 1998), through the Pleistocene, when ice sheets extended out into the basin and scoured the basin highs. Very little of the Cenozoic and almost none of the Mesozoic record has been sampled. Deciphering this history will complement the sediment and ice cores taken at lower latitudes and extend the limited historical time series for the high arctic, making it possible to study truly global paleo-climate for the first time and permit the construction of actualistic models for earth climate during periods of high carbon dioxide concentration.

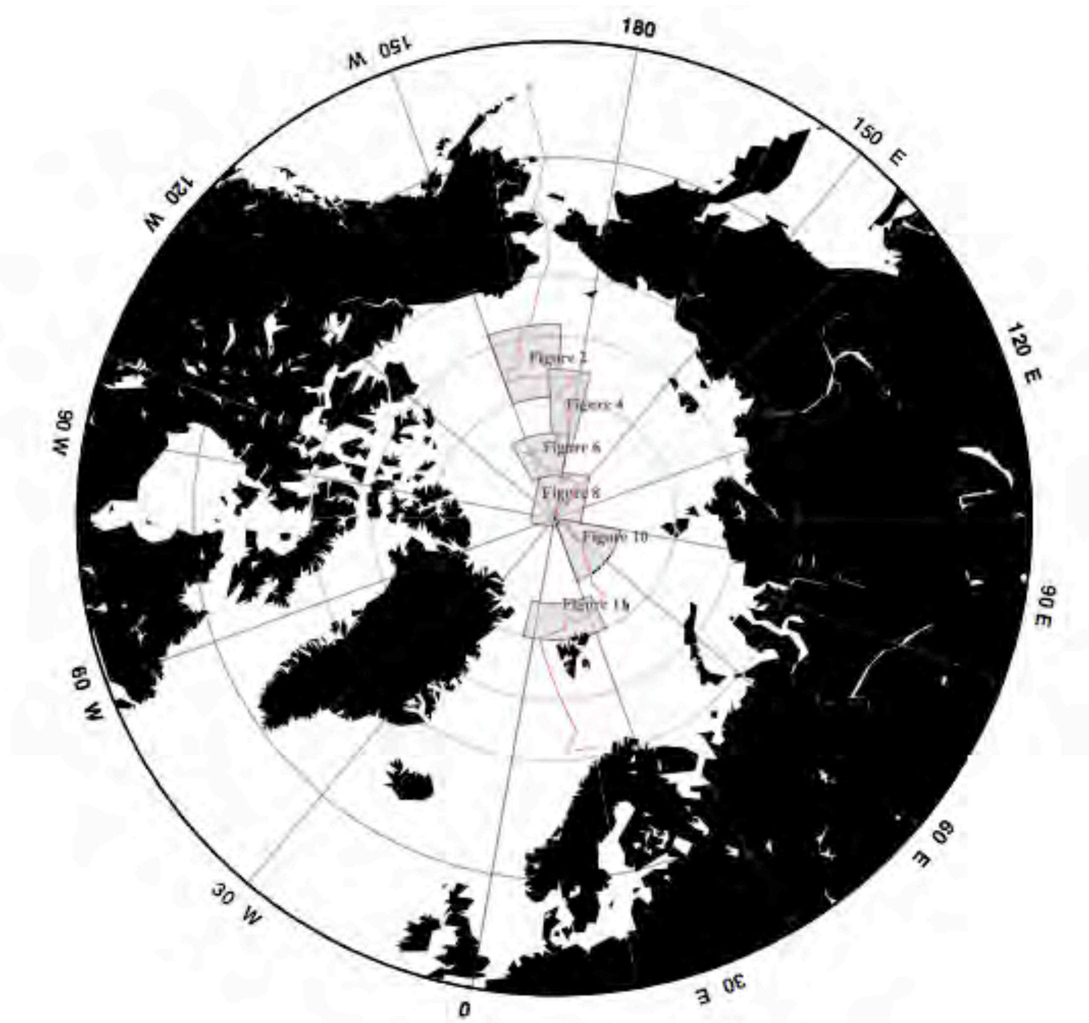


Figure 1 – The track of USCG Healy during cruise 05-03. Detailed index maps in subsequent figures are indicated by boxes and labels.

Rationale for the Cruise

A number of basic scientific problems to be addressed are unique to the Arctic Ocean while others are framed by studies conducted at lower latitudes. The history of the Amerasian Basin is largely unknown, except for what has been inferred from studies of its margins. The data collected during this cruise will be used to study the basins and ridges crossed during the transit and search for potential plate boundaries in the central basin.

While the focus of this project is on the structure and stratigraphy of the Arctic Ocean, the data will have uses beyond the work proposed here. In particular, the integrated data set collected from USCG *Healy* will be the beginning of a comprehensive site survey database for the Arctic Ocean.

Objectives

Each of the features crossed by Healy during 05-03 presents distinct scientific opportunities. The quality and quantity of data collected over these features, as dictated by ice conditions and instrument failure or wear (particularly loss of channels crushed in the streamer) defines whether or not it was possible to test particular hypotheses about the structure and history.

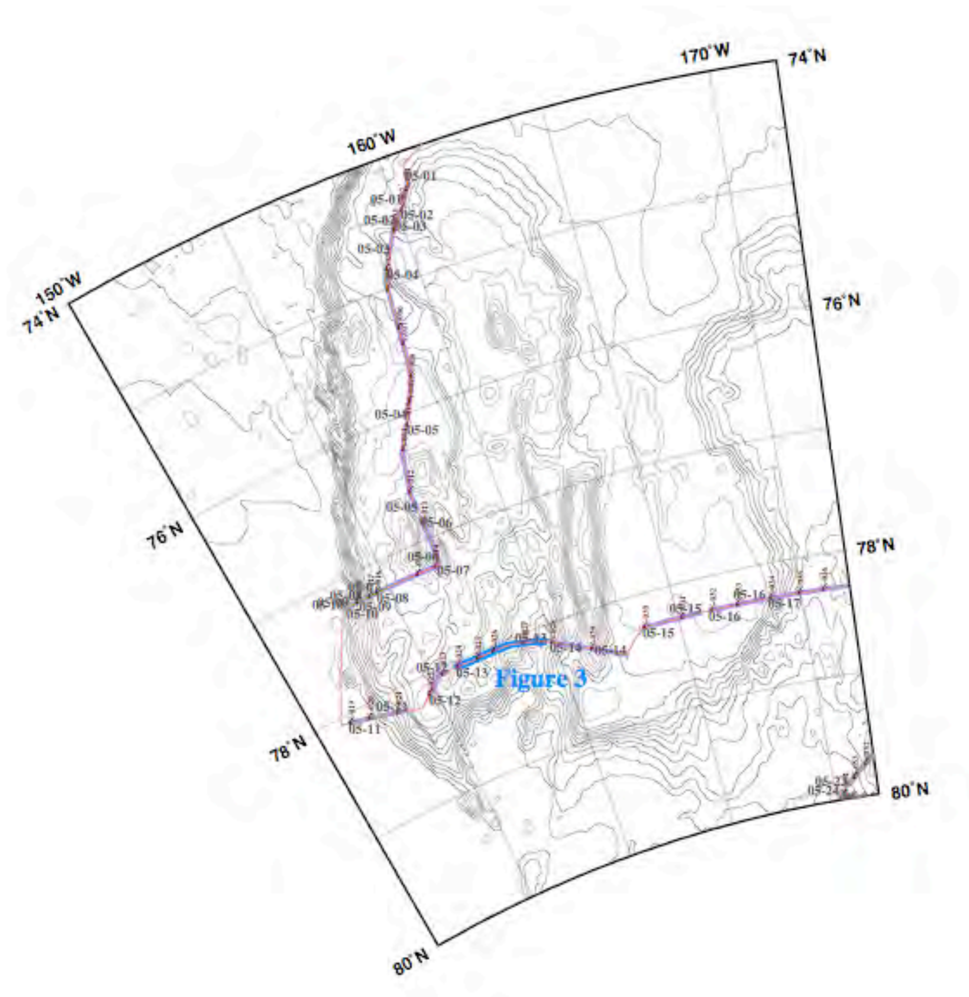


Figure 2 – Track of Healy across the Chukchi Borderland. MCS profiles start and endpoints and sonobuoy drops points are labeled. IBCAO bathymetry (Jakobsson et al., 2000) is plotted on this and all subsequent index maps. MCS profile shown in Figure 3 is highlighted.

Chukchi Borderland

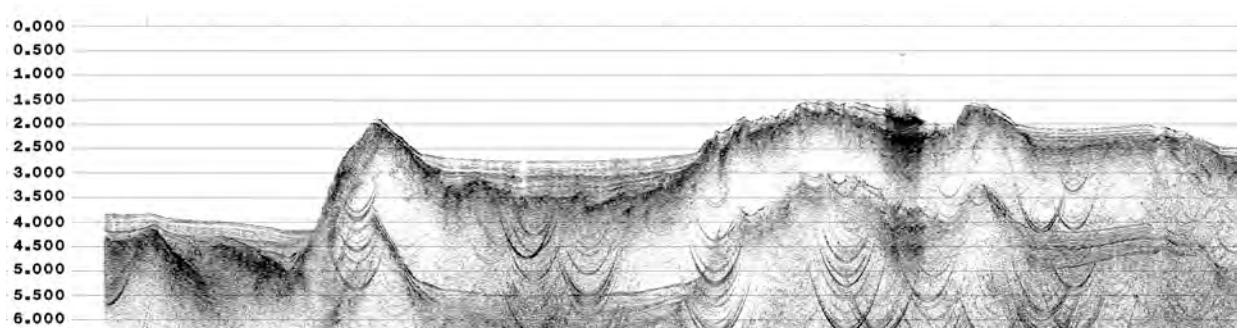
The combined Northwind Ridge and Chukchi Borderland is a single continental fragment, dissected by extension (Grantz et al., 1990) [Figure 2]. The origin of this feature is uncertain, but the Mesozoic and Paleozoic sediments exposed on the flanks of Northwind Ridge appear to correlate with sequences of similar age and lithology exposed in the Canadian Arctic Archipelago, which is on the opposite side of the Amerasian Basin (Grantz et al., 1998). A relict mid-ocean ridge deeply buried below the turbidites of the Canada Basin [Figure 1], as hypothesized by Brozena et al. (1998) from extensive aero-geophysical data sets, might help explain the transit of this continental complex across the basin, but there must be other plate boundaries as well. These boundaries would have connected this spreading center to the other concurrently active plate boundaries and must separate the oceanic lithosphere of the Canada Basin from this high, continental plateau. During the course of this cruise, the *USCG Healy* transited across the extensional complex itself and the steep transition from the plateau to the deep Nautilus Basin.

Objectives

To examine the stratigraphy of the Borderland, the structure of its highs and sub-basins, collect data useful for future scientific drilling and study the margins of this bathymetric high.

Results

Two long, continuous profiles were collected across the Chukchi Borderland [Figure 3]. The first paralleled the Northwind Ridge. The second crossed the feature and imaged the transition to the Mendeleev Ridge. Many extensional structures were seen in the MCS profiles. Working with the existing bathymetric and gravity data sets, it will be possible to construct a provisional structure map of the Borderland.



Figures 3 – Line 05-13 [see Figure 2] The hyperbola evident in the record are a result of transient noise in the record. Post-cruise hand editing of the traces eliminated most of these spurious features in the MCS profiles.

The stratigraphy was well imaged, revealing a complex multi-stage history capped by an extensive sediment mantle [Figure 3], suggesting a long period of tectonic inactivity since the deformation of the Borderland. This stratigraphy indicates multiple objectives in the Cenozoic and, probably, the Mesozoic for scientific drilling. Extensive erosional unconformities, probably attributable to the glacial history of the shallow Borderland may support offset drilling strategies for constructing long composite records.

The combined sonobuoy, gravity, bathymetry and MCS data constrain the relationship between the plateau and the adjacent oceanic lithosphere and the deep structure of the Borderland itself, providing additional information about the Mesozoic tectonics that created the Amerasian Basin.

Mendeleev Ridge

By current consensus, the Alpha-Mendeleev Ridge [Figures 4 and 5] is a single structure, hypothesized to have formed by the transit of the Iceland hotspot beneath the Amerasian Basin (Lawver and Muller, 1994). If this is true, the Arctic Ocean has a simple banded structure of parallel ridges. This hypothesis has never been evaluated due to the lack of data across the Mendeleev Ridge.

The Alpha Ridge is widely held to be an oceanic plateau (Jackson et al., 1986). This is compatible with the geophysical data collected to date. Dredged rock samples of altered alkaline basalt (van Wagoner et al., 1986) and basalt of MORB-like affinities recovered by piston coring (Jokat et al., 2003) as well as the onshore volcanic province exposed on Axel Heiberg Island are compatible with this hypothesis.

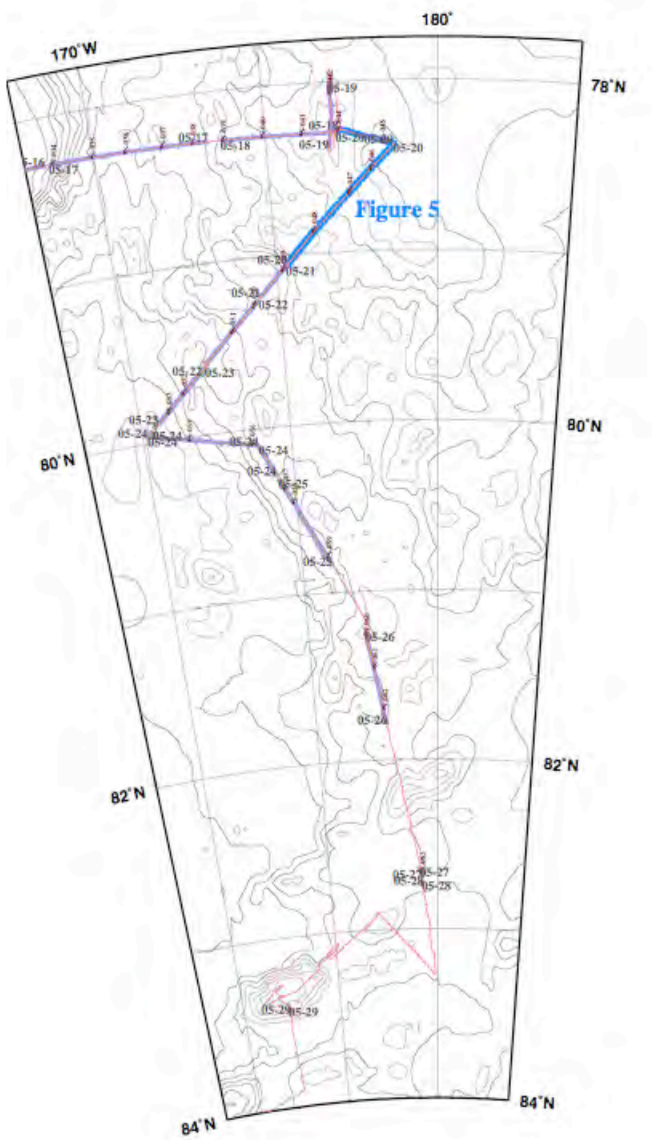


Figure 4 – Location map for Mendeleev Ridge survey. Location of MCS profile shown in Figure 5 is shown in blue.

The Mendeleev Ridge is not so well known. Russian investigators have collected most of the data from this segment of the Arctic Ocean. Recent Russian investigations have put the Mendeleev Ridge in an interesting light. A profile collected from Russian drift station NP-26 reveals a stepped profile along the convolute drift track followed by NP-26. Dredges obtained during a cruise conducted during the summer of 2002 recovered substantial quantities of limestone, dolostone and sandstone from the Mendeleev Ridge at approximately 82 N (unpublished data from a presentation by Kaban'kov et al. given in St Petersburg, summer 2003). The limestones contained Paleozoic fossils, which would rule out a Mesozoic volcanism as the primary origin for the Mendeleev Ridge.

Objectives

If the Mendeleev Ridge is a continental feature, the tectonic history of the Amerasian basin will have to be completely re-evaluated. The integrated data set collected from USCG *Healy* during this program is an excellent opportunity to study the ridge as well as its affinities and relations with adjacent tectonic provinces.

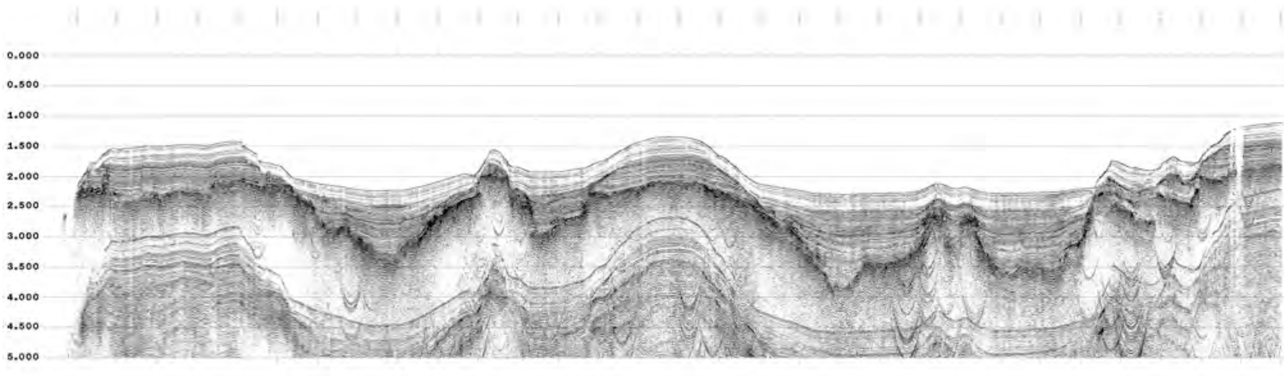


Figure 5 – Line 05-20 across the Mendeleev Ridge [see Figure 4 for location].

Results

The structures revealed in the MCS profiles collected on the Mendeleev Ridge show a pervasive overprint of extensional tectonics on the ridge. With these data, it will be possible to create a draft structural map by following features along strike from the MCS crossings.

Stratigraphy on the ridge was surprisingly complex, showing, through the existence of multiple unconformities within the sedimentary package, a multi-stage depositional history that would be unique for a simple volcanic plateau. The continuation of the undeformed sedimentary drape seen on Chukchi indicates a long period of tectonic inactivity. The absence of this along the ridge and the sediment waves observed in this location support recent erosion due to deep currents near Cooperation Gap.

Alpha Ridge

As the ships moved north, paralleling the axis of the Alpha-Mendeleev Ridge, progressively more difficult ice conditions were encountered [Figure 6], which eventually made it impossible to collect further seismic reflection data. The data collected during this part of the cruise provide some interesting glimpses of the structure and stratigraphy, which may, in context provided by other data, improve understanding of this rarely visited region.

Objectives

To collect a suite of data across the transition between the Alpha and Mendeleev Ridges.

Results

The data acquired in this area are not sufficient to seriously study the structure or history of the regions. There are two striking observations that can be made with these data. The first is the pervasive extension seen in across this feature. As far as is known, ignoring what may be a small strike-slip feature on the Mendeleev Ridge, there is no evidence of compression or shortening anywhere in the Amerasian Basin. The second feature of interest is the termination of the mantle-bedded sedimentary drape [Figure 7] in the deepest place in the transition from Mendeleev to the Alpha Ridge. This drape is seen throughout the Amerasian Basin and is absent from the high standing Chukchi Borderland, due to glacial erosion (Jakobsson et al., 2005), the Lomonosov Ridge (Polyak, et al., 2001; Kristoffersen et al., 2004), due to the impact of an ice sheet and here in the deep basin.

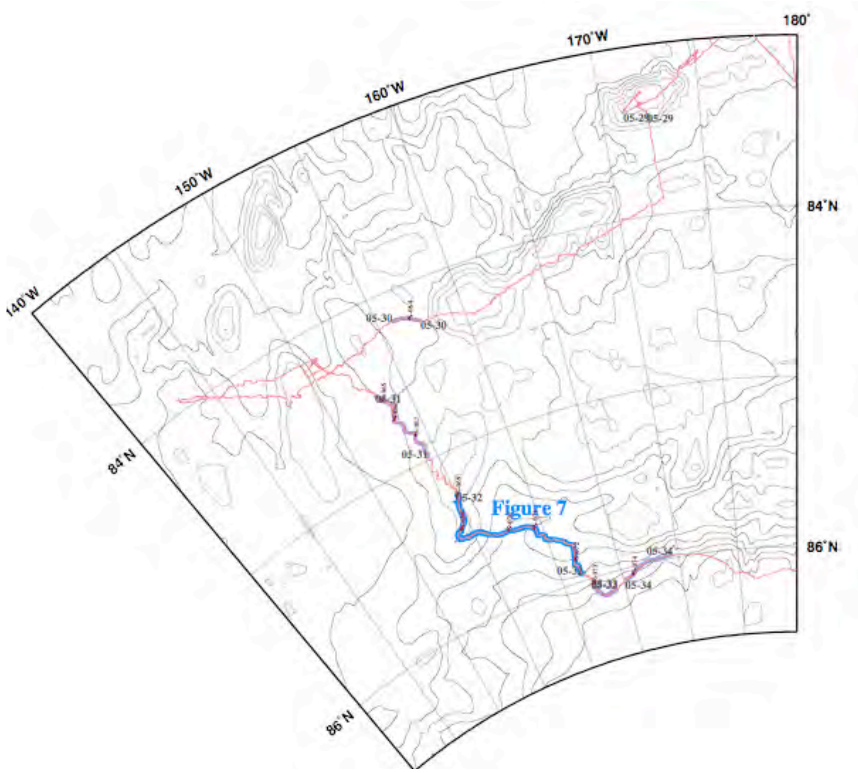


Figure 6 – Location map for Alpha Ridge Survey. Location of MCS profile reproduce in Figure 7 is indicated.

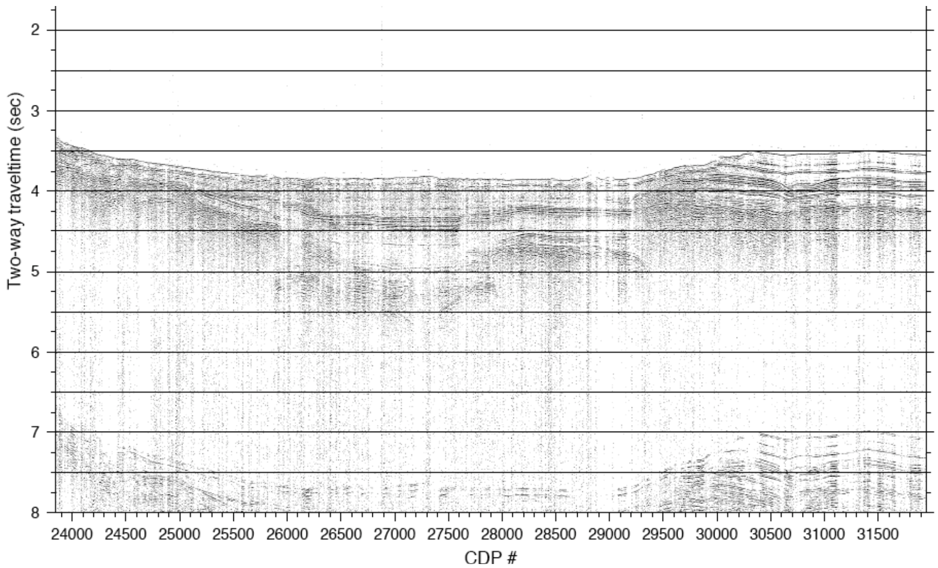


Figure 7 – Profile 05-32 across the low dividing the Alpha and Mendeleev Ridges (known informally as Cooperation Gap). Note erosional truncation of the deep-water sediments near CDP #30000.

Makarov Basin

Plate tectonic models which favor formation of the Amerasia Basin by rotation of an Arctic Alaska and Chukhota block away from the present Canadian Arctic continental margin beginning in the Late Jurassic and ending by mid-Aptian time (Grantz et al., 1998; Lawver et al., 2002) predict a major shear zone to be found along or seaward of the contemporary European polar margin where the present Lomonosov Ridge formed the outer shelf [Figure 6]. The implied amount of shear exceeds 1.500 km. If later seafloor spreading occurred in the Makarov Basin (Taylor et al., 1981) parts of this feature may have been relocated from the foot of the Lomonosov Ridge to the flank of Alpha Ridge.

Objectives

To define the nature of the crust and structures which may relate to a fossil plate boundary. The proposed survey track was designed to provide three crossings of a linear topographic feature and associated gravity anomaly projecting west from the Marvin Spur.

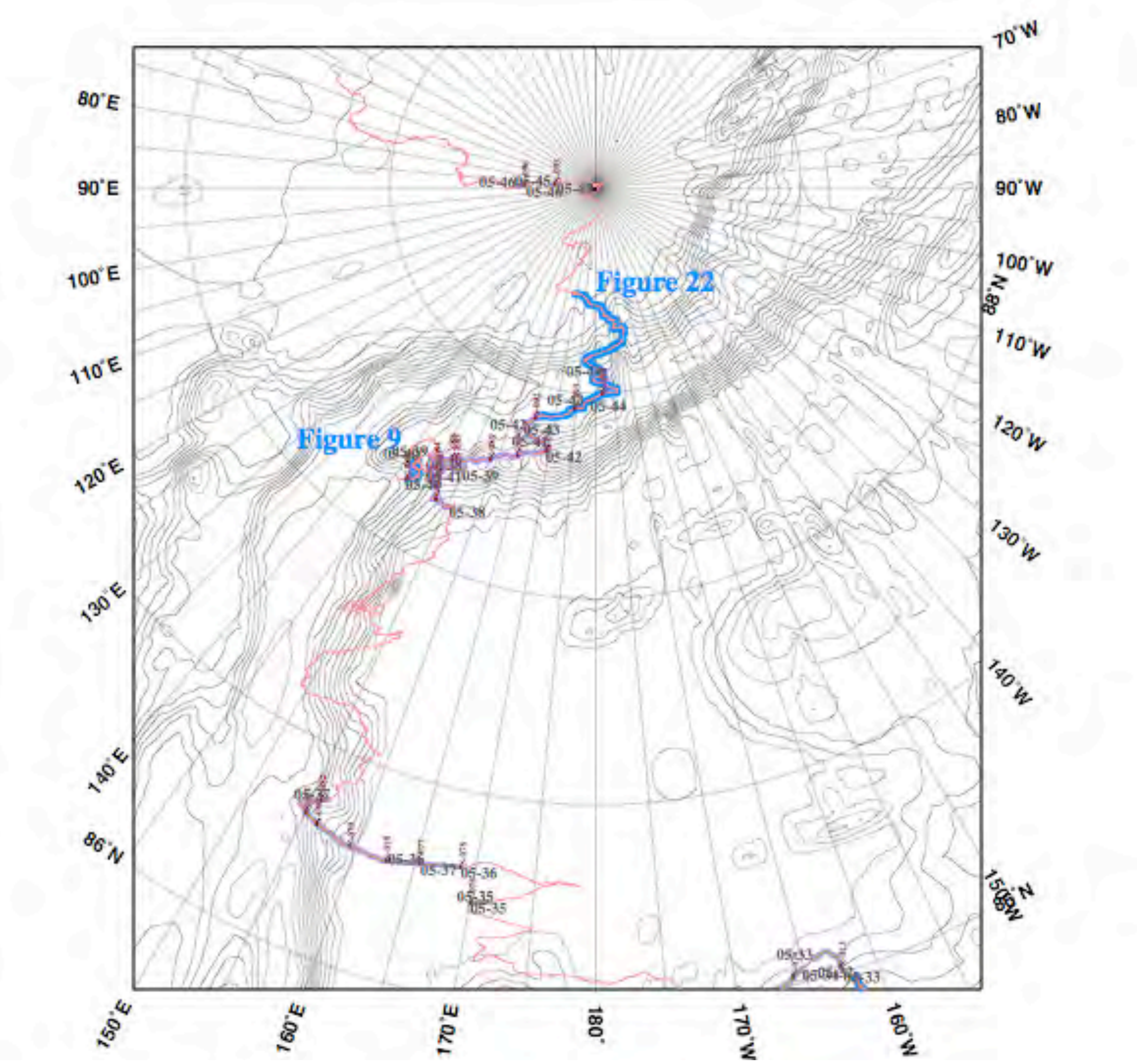


Figure 8 – Track across the Makarov Basin and Lomonosov Ridge. Most of the track through this phase of the cruise was dictated by attempting to avoid multi-year ice in across the Alpha Ridge and Makarov Basin towards the north and east.

Results

Ice conditions permitted only a single seismic traverse across the Makarov (line 05-36). Deposits in the basin are characterized by a 1.7 sec. (max. 2 sec.) thick section of flat lying, laterally uniform strata, most likely turbidites which onlap the lower slope of Lomonosov Ridge. Apart from effects of differential compaction at the foot of the ridge, there is no evidence of tilt of the basin floor throughout the section. Changes in attitude of the basin floor through time would be expected from differential subsidence between the older Alpha Ridge side of the basin relative to the younger Lomonosov Ridge where more than 1 km of Cenozoic subsidence is documented by ACEX-drilling. The basal part of the turbidites is infilling subdued topographic lows in the underlying rocks which have no clear internal reflections. This acoustic basement may be oceanic crust or could well be older rocks of continental affinity. Seismic velocities derived from sonobuoys would shed light on this issue.

Lomonosov Ridge

Improved bathymetry (Jakobsson et al., 2000) and detailed aeromagnetic data show the high standing Lomonosov Ridge [Figure 8] to be formed by an en echelon series of fault blocks. A side step in the ridge trend near the North Pole is associated with a saddle point, which extends nearly one thousand meters below the ridge crest. Water masses above 1200-1500 m can flow unrestricted in the Arctic Ocean while the presence of Lomonosov Ridge restricts waters below the crestal depth to circulate internally within the Eurasia and Amerasia basins. The saddle point may facilitate inter-basin exchange of intermediate water [stratigraphy show in Figure 7]. Swath bathymetry and seismic reflection data aligned with the strike of the Lomonosov Ridge and crossing the saddle would define the impact of bottom flow regimes on sediment deposition and provide a record the history of water mass communication.

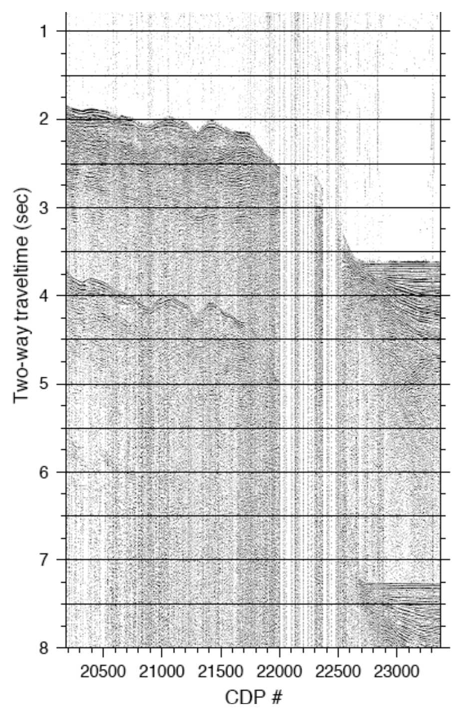


Figure 9 – MCS line 05-40 [see Figure 8]. White vertical lines are data dropouts caused by ice influence on the guns or streamer.

Objectives

By investigation of the closed high on the Lomonosov Ridge, establish the recent and past topographic relief of a cross-ridge pathway and study structural control of the passage.

Results

The new bathymetric and seismic data show that the saddle point in the Lomonosov Ridge [Figure 8] is formed by down-faulted blocks on the Eurasia Basin side and the Makarov Basin side framing a ca. 100 km long and ca. 20 km wide perched basin about 700 m deeper than the enclosing thresholds. The trend of the basin is aligned with the trend of the main ridge. The normal fault bounding the north side of the southern ridge and faults within the basin are all facing the Eurasia Basin. The southern ridge is composed of sediments dipping towards Makarov Basin. The section is truncated at the top by a horizontal erosional unconformity at 1.6 -1.7 sec. depth and overlain by a sediment drape that is 0.2 sec. thick below the peak of the ridge and tapered towards the ridge perimeter.

The sediments within the basin seem to comprise a greater than 300 msec. thick section of flat-lying turbidites over a more chaotic section which also may be more than 300 msec. thick, probably representing post rift and syn-rift deposits, respectively. The basin is mantled by approximately 2 km of older sediments. Although, the data are incomplete, the threshold on the Makarov basin side appear to be an erosional feature while a sediment drift may be present on the corresponding threshold on the Eurasia Basin side.

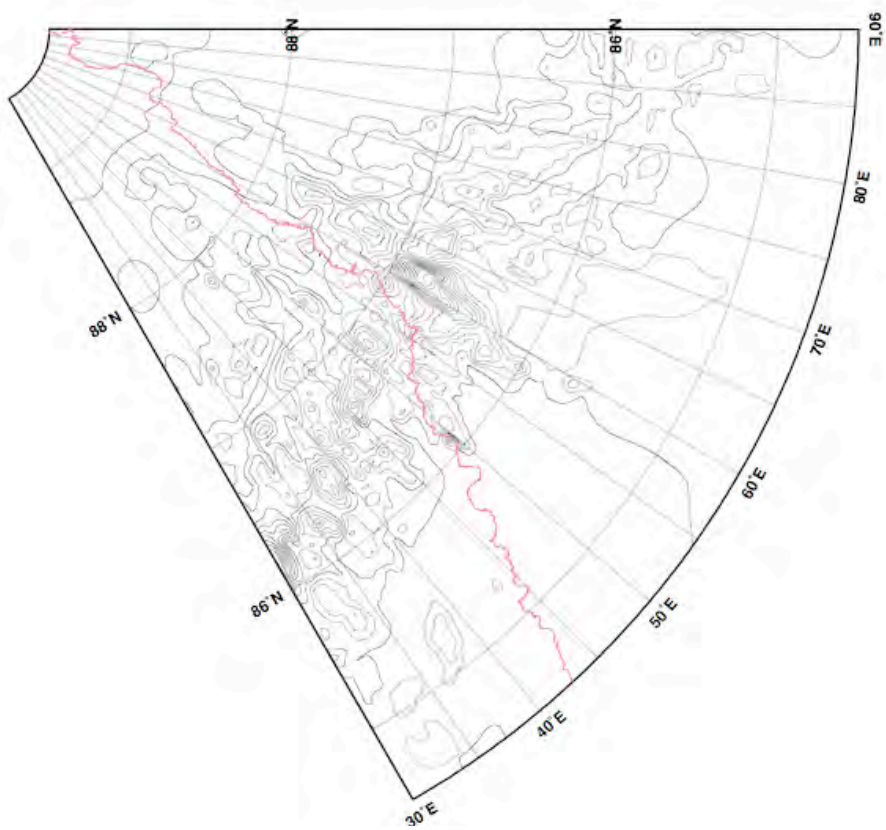


Figure 10 – Track across the Eurasian Basin. Heavy ice conditions restricted data acquisition.

Gakkel Ridge

The Gakkel Ridge [Figure 8] is the slowest opening portion of the global mid-ocean ridge spreading system. It is also the least studied, both in terms of geochemical sampling and in geophysical data. Within the Amundsen Basin, a 1 km step in basement topography coincident with Chron 20 has been reported (Weigelt and Jokat, 2001) that may be associated with a sudden slow-down in spreading rate (Vogt et al., 1979). A single profile within the Nansen basin suggests that the step is not present there over crust of the same age. We planned an additional crossing over this feature to further document its regional significance.

The results from the SCICEX expeditions (Edwards and Coakley, 2003) combined with results from the more recent AMORE expedition (Michael et al., 2003) have established that oceanic crust in the Eurasian Basin is anomalously thin. The available data are consistent with crustal thicknesses of only 3-4 km, roughly half that for average oceanic crust. Weigelt and Jokat (2001) report that seismic layer 3 is missing from areas where the crust is this thin. The AMORE survey further established that the ridge is magmatically segmented. Along some sections of the ridge, only peridotites and altered peridotites were recovered, suggesting that some segments may be completely amagmatic.

Objectives

The planned crossing of the Gakkel Ridge was designed to collect wide-angle data as well as reflection data across the best-defined volcanic/amagmatic boundary described in the AMORE results,

Results

Ice conditions on the Gakkel Ridge were very difficult compared to the 2001 AMORE program, which took place at approximately the same time of year. Ten-tenths multi-year ice and the nearly complete lack of significant leads meant that this leg was a difficult transit rather than an opportunity to collect any MCS or wide-angle data. The bathymetry and gravity data collected during this leg will be useful, but are probably not sufficient to test any important hypotheses about the active processes on this ridge.

Figure 11 – Ship track across the Yermak Plateau. Healy emerged from the pack ice at about 81° N and headed south to Tromso.

Yermak Plateau

The Arctic Ocean existed as a closed basin for nearly one hundred million years before a deep-water connection to the North Atlantic was established through the Fram Strait. The first indication of an Arctic-Atlantic seaway is suggested by the occurrences in northern Alaska and Ellesmere Land of late Paleocene mollusks and ostracodes previously known only in northern Europe (Marincovich et al., 1990). Direct control on the evolution of the Fram Strait gateway is almost non-existent. The only useful record consists of sediments from Site 909 in the deep central part of the Fram Strait. These sediments suggest that there were no dramatic changes in bottom water activity during early Miocene to Pliocene (Myhre et al., 1995; Thiede et al., 1996). ODP Leg 151 drilling on the southern part of Yermak Plateau (Site 910, 911 and 912) [Figure 9] reached sediments dated as 3 Ma at the base of the deepest site (507 mbsf). Seismic reflection data have located a large 2 km thick sediment drift along the northern flank of Yermak Plateau (Jokat et al., 1995). The drift must have been deposited by inflowing Atlantic water. Scientific drilling would enable precise control on gateway evolution as well as provide a more rigorous reference for assessments of the impact of the Arctic tele-connection on the global thermo-haline circulation through the Cenozoic.

Objectives

While the northeastern half of the drift area is covered by SCICEX swath bathymetry and sidescan sonar, additional seismic reflection data are needed to generate an IODP proposal for scientific drilling. MCS data could also help establish the existence of a relict plate boundary beneath the Plateau.

Results

Ice conditions on the Yermak Plateau eliminated the possibility of collecting MCS data. The additional gravity and bathymetry data acquired could help test the plate boundary hypothesis.

Underway Data Sets

The USCG icebreaker Healy has SeaBeam 2112 swath bathymetric system and an Odec Bathy-2000 and a Knudsen 320 B/R bottom sounders installed on board. A Bell BGM-3 gravimeter, loaned by NAVOCEANO in Bay St. Louis, Mississippi was installed for the cruise in the IC Gyro space, near the gym facilities. The quality of these data sets varied widely, depending on ice conditions and ship operations.

The BGM-3 gravimeter and SeaBeam were operated continuously throughout the cruise. Based on recent experience, the Knudsen 320 B/R bottom sounder was used in preference to the ODEC Bathy-2000. While heavy ice resulted in data gaps, it maintained excellent lock on the bottom even through these gaps. Both the SeaBeam and Knudsen data were used to pick core locations.

As ice conditions permitted, airguns and a streamer were deployed from the fantail, making it possible to collect multi-channel seismic reflection data and, by using sonobuoys, wide offset (up to 25 km) acoustic data. While excellent conditions on the Chukchi Borderland and Mendeleev Ridge made it possible to collect an excellent data set, heavy ice along the remainder of the track restricted or eliminated possibilities for acquiring these data.

Data acquisition was continuously monitored throughout the cruise by watchstanders. The watchstanders took 12-hour watches (5:30 to 17:30 and 17:30 to 5:30). They were responsible for monitoring all of the underway equipment. During each watch, they would adjust acquisition parameters for the SeaBeam and Knudsen, ensure that data files were being updated, note anomalies or changes in operations in the e-log and find help if an instrument malfunctioned.

While minor malfunctions occasionally interrupted data acquisition, these gaps were typically no more than a few minutes. There were no major instrument failures during the cruise.

Multi-Channel Seismic (MCS) Reflection

Multi-Channel Seismic reflection data acquisition by icebreakers in the Arctic Ocean is an almost impossible undertaking from the perspective of the rigorous quality criteria of modern seismic industry standards. In 7-9/10 of ice cover, practical survey limitations include:

• the vessel is mostly constrained to follow patchy leads which frequently may involve up to 90° turns, survey speed is 3-4 knots;

• practical active streamer length is 200-300 m (16-24 ch.) towed at 100-150 m offset;

• limited control on source depth and cable depth (no birds for depth control).

Nevertheless, more than 6,600 kilometers of good seismic data has obtained to date by single and two-ship icebreaker operations prior to this cruise (Kristoffersen and Mikkelsen, 2004). Acquisition of ~2200 km of data during HLY 05-03 increases the total database by 33% (All lines are listed in Appendix B).

MCS Hardware

The strategy for acquisition of multi-channel seismic data from a single icebreaker was building on experience from cruises with Polarstern in 1991, and Oden in 1996 and 2001. The seismic source is towed below a paravane [Figure 11], which provide a downward pull required to keep hoses and cables as close to the stern as possible. The paravane is attached to a ca. 16 meter long (12 cm diameter) armored heavy hose [Figure 12]. The pull due to drag in the water is taken up by a 15 mm wire running along the hose. A flange [Figure 13] on the deck end of the hose is locked in a bay bolted to the deck. The seismic streamer feeds thorough the protective hose whereas trigger cables and hose for air supply are attached to the backside. In this way tangling of streamer and towlines for the source cannot occur.

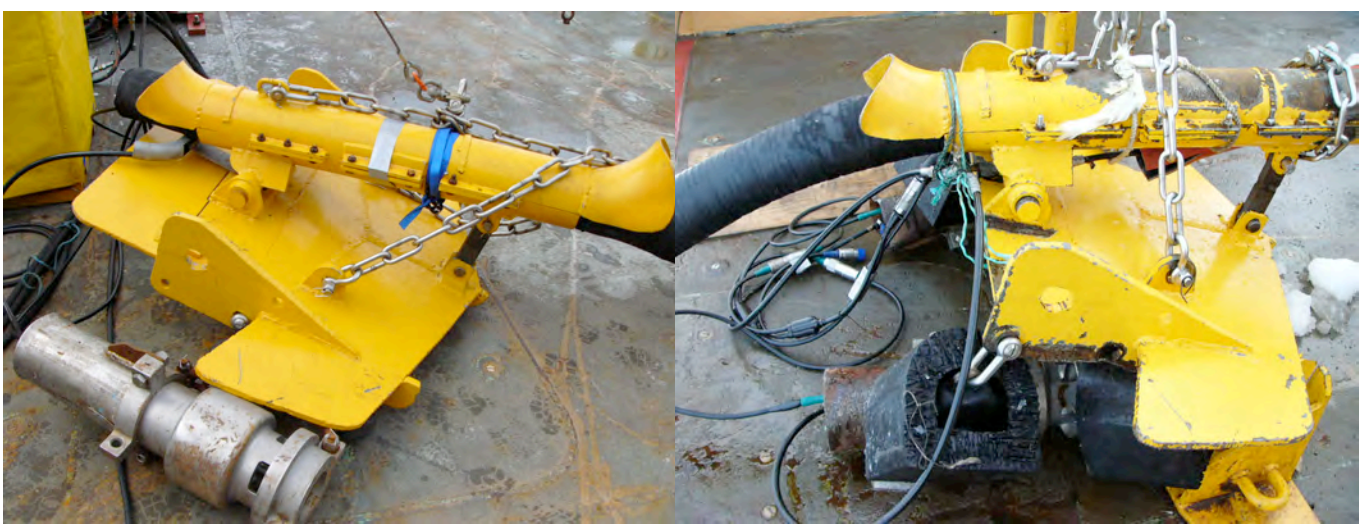


Figure 12 – These two 240 cubic inch airguns were used throughout the cruise. The angle of the yellow wing, which is controlled by the vertical metal bar attached to its' leading edge, controlled the towing depth of the guns and streamer. The large "D" shaped rubber bumpers were inserted between the guns and wing to reduce impact wear on the wing and attachment hardware.

Figure 13 – Deploying the guns and streamer.

Figure 14 – While the MCS gear was deployed, a watch was stationed on the fantail to make sure towing did not result in fouling of the gear. This watch was in direct communication with the bridge, which was instructed to stop upon their request. This did not always work well owing to occasional poor radio reception and misunderstandings.

Throughout the cruise, the seismic source was two 250 cubic inch (4 liter) Sodera G-guns fired simultaneously. Until the start of line 05-37 the guns were fired every 20 seconds. After the start of 05-37, the guns were fired every 22 seconds, to achieve full pressure on each shot. A protective hood was mounted over the solenoid and air inlet connection. The seismic energy level was partly dictated by available compressor capacity and is sufficient to obtain distinct basement reflections from below 2 km of sediments. Compressed air was delivered by four diesel driven Junker reciprocating piston compressors (2 x 1.8 m^3/min, 1 x 1.5 m^3/min) housed in a 10 foot container. The compressor was cooled by water from the sea chest.

In 7/10-10/10 of ice, the practical length of the analog seismic cable is 200-300 meters (16-24 channels) towed at 150 m offset. Pack ice emerging from under the transom can force the guns to the surface. When this occurs, the guns and very often the entire cable will ride over the same piece of ice. The wake is heavily populated by chunks of ice moving randomly in the subsiding propeller wash and the likelihood for the exposed seismic cable to be pinched between blocks becomes great. Very often more than 50 meter of streamer may be riding over ice in several places. In this scenario, the risk of losing equipment increases with the length of the cable.

A small 3.5 ton meter hydraulic crane and an auxiliary winch to move the heavy hose facilitated deployment and recovery of the seismic gear. Also the streamer winch was controlled from the same stand. Past experience has shown that use of the ship's crane and A-frame for deployment of the towed gear has too long response time and is too slow. One person operates the crane and winch to bring the equipment in and out while one or two persons oversee that lead-in signal cables, air hose and towing wire do not snag on objects or deck mounts in the process.

Figure 15 – Towing in an open lead. These are excellent conditions for MCS data acquisition.

Operational experiences

Towing seismic equipment in heavy ice requires constant observation by a person [Figure 13] on the fantail. This person also has the option to remotely disable trigging of the guns if they happened to be riding over ice at the shot instant. Towing the seismic source and cable in uniform ice up to 1 meter thick ice presented few problems and data quality was excellent [Figure 14]. However, pressure ridges of any significance require more thrust and the paravane is tossed around in the violent propeller wash. Initially, we experienced frequent incidents of air leaks and damaged trigger lines at the end of the airguns. The covers made for the guns to protect air intake and solenoid were severely battered and the cover mounts broken from the guns beating against the underside of the paravane. The protective covers were made stronger and welded to the gun instead of bolted. The modification practically eliminated this source of cable breaks. In addition we obtained and inserted spacers of D-channel heavy rubber between the gun and the paravane.

Blocks of ice many meters on the side emerging in the propeller wash from under the fantail frequently force the paravane and guns out of the water. These situations are potentially dangerous as in three cases the paravane snagged on the ice during the climb and the 15 mm tow wire (breaking strength 18 tons) snapped. At the front of the paravane, most often the armored hose absorbs the impact. After some time the hose was permanently flattened and left insufficient for clear passage for the streamer. After sustaining damage on one heavy hose, we mounted two 40 cm long sections of cylindrical stainless steel covers at this critical place and the problem went away.

Figure 16 – The streamer was left on the ice twice during the cruise for a loss of 5 streamer sections. This would happen when ice got under the airguns, lifting them out of the water. The streamer, threaded through the wing carrying the guns, would follow, dragged across the ice. If ice crowded into the wake, it could pinch and strand the steamer on the ice surface.

As the survey progressed, the brackets connecting the paravane and guns to the heavy hose started to crack in the welds. The shock wave from the guns impacting the underside of the paravane generates a violent jolt and the effect of this becomes quite apparent after more than 50.000 shots [Figure 11b]. The construction needs to be more open close to the guns.

When the ship's motion is impeded by ice and further progress requires limited backing and ramming it is possible to back slowly for half a boat length or so while leaving the cable and guns in the water. In two instances the ship inadvertently backed into ice floes and in one case permanently damaged the protective hose. Although time consuming, it is advisable to recover all gear if ramming is required.

In general, the seismic source appears to survive the most violent beating, but the most vulnerable part of the seismic gear is the streamer. While the streamer is riding over ice blocks in the closing wake, the cable skin becomes locked at choke points and is pulled back relative to the interior of the cable. More severely, the plastic spacers within the cable are crushed and in turn damage the bundled hydrophone wires. The result is loss of live channels. On this cruise 700 m of seismic streamer was permanently disabled. Five hundred meters were lost, pulled off by the ice [Figure 15].

Healy is relatively narrow at the water line below the stern. Large ice floes often emerge aft directly from under the hull. The acceleration acquired through suppressed buoyancy makes it almost impossible to divert these blocks in a matter of seconds. By comparison Oden has a wider wake and also leaves a wider relatively ice free passage near the stern. It is possible to acquire seismic data from Healy using maximum thrust from two engines as long as the vessel is able to move forward continuously.

In summary, although we were able to collect a relatively large amount of seismic multi-channel data, the whole towing arrangement needs to be reconsidered in the future. Healy has ample deck space for mounting a more robust hydraulically operated handling system, which would also insure that the equipment enters the water close to the stern.

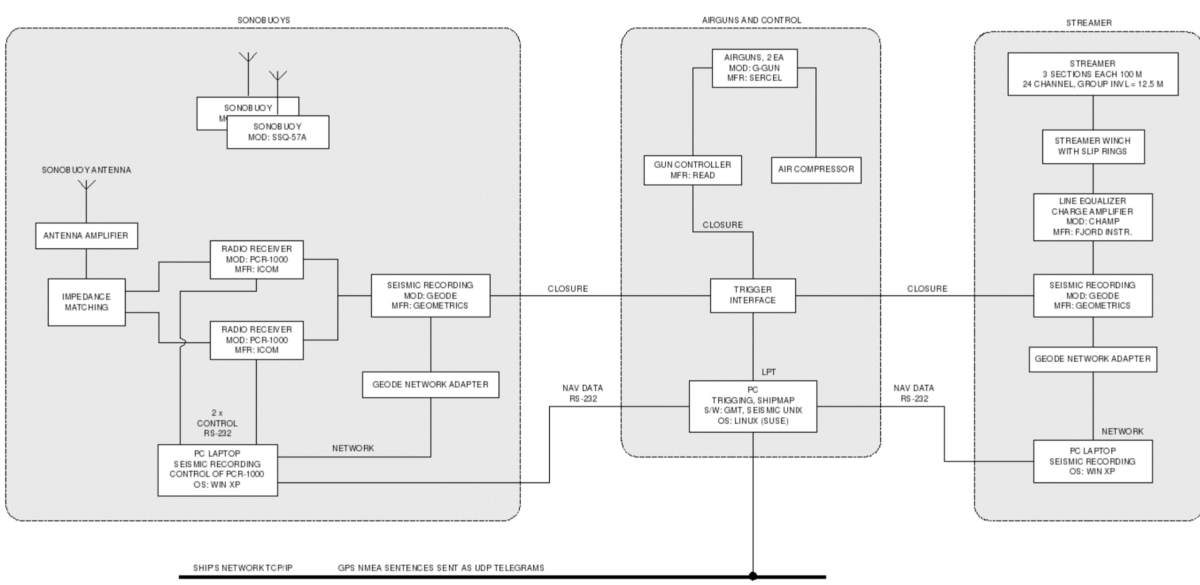


Figure 17 – Block Diagram of the MCS acquisition system for HLY 05-03.

The seismic acquisition system

The core of the seismic acquisition system is a PC (Linux) that triggers the guns and activates the two recording systems for the streamer and the sonobuoys [Figure 17]. It also feeds these subsystems with properly formatted position information from the ship's science data network. The guns were fired every 20 seconds (changed to 22 seconds at the beginning of line 05-37), giving an average shot distance of approx 50 meters, depending on the speed over ground.

A 16 to 24 channel analog streamer, Geco HSSG with a group length of 12.5 meters, received the signal. The start-up configuration was 3 active sections of 100 meters and 3 lead-in cables of 50 meters each. Ice conditions at the beginning of the survey were light. As more difficult ice was encountered, the last active section was removed which left 16 channels and a total towing length of 300 meters. Wear and tear on the streamer was, at times, intense. Blocks of ice brought the cable to the surface, and collisions of moving ice blocks in the turbulent wake created choke points. The number of working channels varied and was sometimes as low as five. After being equalized, the streamer signals were digitized in a Geode seismograph (Geometrics Inc.) and stored on disk on the accompanying Windows-based laptop PC.

The data files were shared on the ship's science data network, so that other people could work on the data in real time and provide plots and analyses. A designated laptop PC running Linux was also used to provide a near-trace display and a display of the last shot. This QC system is not included in the diagram. The data file format is SEG-Y. The sample interval was 1 ms. Record length was 16 seconds.

Figure 18 – Aftcon on Healy with MCS and sonobouy acquisition systems installed.

Processing

A real-time seismic system was established to perform basic quality control and to provide continuous, instant backup of the data. The main acquisition system consisted of two Geometrics Geodes connected to laptop computers running Windows-XP. One laptop was to record the MCS data and the second was for recording the sonobuoy receivers. To facilitate real-time archiving and processing, the laptops were connected to the ship's gigabit network with fixed IP addresses. The gigabit network switch eventually failed and was replace by a 100Mb switch. One of the two Geodes failed on Aug 20. The working Geode was reconfigured to record the sonobuoys on channel 24 after this.

The Bergen group was setup in the "aft con" (science lab overlooking the fantail along with all the winch controls). This setup included all the equipment needed for seismic acquisition (e.g. triggering, gun controllers, Geometrics Geodes etc.) as well as a Linux computer running the program Seismic Unix for additional data displays. Data processing and quality control were setup down the hall in the "Future Lab" (a room which will be made into a lab someday). This setup consisted of two Powerbook G4's and a G5 iMac all running SIOSEIS. The G5 iMac served as the main computer for processing and backup. A 400 GByte internal hard drive was used for primary data storage. A 250 GByte external drive was available for additional backups. The G5 also had a fixed IP address and monitored the Bergen group laptops during data acquisition.

Initial processing.

The initial processing consisted exclusively of data copying and quality control plots. As data were written to disk on the Bergen laptops, a SIOSEIS job running on the iMac monitored the files and copied new shots as they were acquired. This provided a real-time backup of all data. In addition, the iMac did a daily backup of all new data to the external disk. During the real-time copying, every other shot was written to a separate file called "latest shot" for quality control monitoring. Although this file was continually overwritten by new data, at any time it could be plotted to examine the most the recent shot acquired.

The Bergen group recorded in SEG-Y rather than the SEG-D format. The existing real-time input in SIOSEIS used the SEG-D format, so process DISKIN was modified to keep track of the SEG-Y file disk address, then close the input file, sleep for a few seconds, then open and position the SEG-Y file before reading again.

Initially, the "latest_shot" file was plotted on demand on the iMac for quality control. A script to plot a single trace from the entire line was developed, including converting the SIOSEIS raster file to an HP RTL file and plotting on the large format HP plotter in the computer lab. Because the Bergen group found these plots useful for monitoring the data, we installed an additional Linux laptop in the aft-con and developed a set of scripts that continuously looped through the data and generated new plots in near real-time. Single trace plots of the previous 500 shots were displayed along with a plot of the "latest_shot" file. These plots were typically 1-3 minutes behind the actual data acquisition. Display to the Linux laptop was via ImageMagick.

Underway Data Processing

After the end of each line, the navigation log files written by the Geometrics system were copied to the iMac together with the relevant data files from the ship's logging system for extracting water depths. The Healy's computer system broadcasts the POS/MV position as a UDP packet on port 33101. The Geometrics laptop inserted this information along with a time tag into the normal Geometrics log file. SIOSEIS read the log file and used this fix as the position of the shot in processing. There was no check that the time of the fix was close to the time of the shot. (The fix was the last fix received at the time of the shot). The laptop computers were not time synchronized initially, but were set with NTP (network time protocol) after the first week of shooting. Before NTP was installed, shot time was not well synchronized to the navigation, Using the navigation from the log is the best that can be done.

The shot point number or trigger count was also written the Geometrics log file along with the position information. Because a shot can trigger without being recorded, the shot point number is distinct from the file number, or SEG-D FFID, which only increments for each shot recorded to disk. A subroutine was written for SIOSEIS's process GEOM that moves the FFID from SEG-Y word 3 to word 5 and places the shot number into word 3. This routine also converted the shot long/lat into 100ths of an arcsecond and wrote them into SEG-Y x/y coordinates in words 19 and 20 (along with the scalar in short word 36). Complicating this procedure was that the Geometrics produced duplicate FFIDs occasionally - typically when starting a new SEG-Y file in the middle of acquisition. These instances are noted in the line log. The Geometrics also does not "flush" the log write buffers after each write so there can be a large delay before the log entry is actually written to disk. This latter problem primarily interfered with end-of-line work, since the buffer would contain navigation and shot point number information that would not get flushed until the next line was started. Once this problem with Geometrics was discovered, we started a procedure at the end of each line to write a dummy shot to an extra SEG-Y file, forcing the buffers from the previous line to be flushed to disk.

Many SIOSEIS processes use parameters that are given relative to the water bottom, so the same subroutine searched and read the SeaBeam centerbeam file for the water depth and put it in SEG-Y word 16. The routine was modified later to use the Knudsen depth file because SeaBeam was inoperable for a while. The last good depth is used whenever SeaBeam was unable to determine a depth.

The assigned shot-receiver offsets assume a simple 2-D geometry. The first break of the direct arrival on the near channel for the first several shots of each line was checked to make sure that the reported "distance to near channel" on the line logs is correct. For the early data collection where we encountered light ice, the 2-D assumption is good. In some of the later lines, especially the data over the Lomonosov Ridge, some form of crooked line geometry may be necessary for binning the reflection points.

The data were then brute stacked using a simple stacking velocity function tied to the water bottom. The brute stacks were then constant-velocity migrated at 1500 m/s. For the lines with relatively clean data, this aids in preliminary identification of the basement reflector. For reason described below, however, most of these migrations contain considerable amounts of noise.

Initially, we were planning to restack all data with better velocity estimates based on semblance and constant-velocity stack analyses followed by preliminary migrations. In our preliminary work on the data, we identified several noise problems to be dealt with before this is possible. The first problem is low frequency, low velocity noise that is seen propagating down the streamer. This most likely arises from the towing depressor pulling on the streamer. Because this noise propagates down the streamer at between 1000-1400 m/s, it is relatively simple to suppress it by *f-k* filtering the shot gathers. On the early data with 24 working channels, this worked quite well. As we lost streamer sections and good channels leading into the Lomonosov Ridge, we had insufficient spatial sampling to do this.

A second, more difficult problem is the noise spikes seen throughout the data sets. These noise bursts are a serious problem that effectively limits further processing. It is not possible to do any *f-k* based processing or migration effectively until they have been removed. The origin of the noise remains unclear, but current speculation centers on the possibility that Healy is an electronically noisy ship. Exactly where the noise enters the system is also unclear, but it probably has multiple points of entry both before and after digitizing, causing many different problems. While standard de-spiking filters are able to kill some of these, we were unable to find sets of parameters that effectively removed them without also removing good data. A majority of the noise bursts have frequency and amplitude characteristics comparable to real seismic events. We concluded that manually editing them out was the only way to ensure that they are completely eliminated.

We began the editing process at sea with limited success, primarily because we could not get any simple interactive picking tools to function in a sensible way. The SIOPLT program for trace editing did not work on any computers on the Healy since SIOPLT was written for 8bit displays and all modern displays are 24 bit. We tried several other options, none of which was satisfactory. After several days of tedious work by Paul, John, Dayton, and Vibeke, we were only able to get manual trace edits for the first 10 lines started. After this first pass, subsequent *f-k* filters and migrations showed that more trace editing was still required. It was decided that further trace editing would have to done after the cruise when we have access to other tools.

On the early data sets, we also started some preliminary stacking analysis to refine the brute stacks. Semblance proved useful in some areas despite the short offsets and it appears that reasonable sediment stacking velocities can be determined from the velocity spectra. In addition, a first pass pick of the basement was made. These picks should provide a useful starting point for final processing of the data sets.

The main scripts used for processing are provided in Appendix C.

Other changes to SIOSEIS while on HLY0503 were:

1) Change process stack to discard zero amplitudes from the stack average.

2) Real-time geometry (type 9 or 14) computed the DFLS (distance from last shot) incorrectly after a missing shot.

3) Parameter ENDMUTE was added to process despike to zero the remainder of the trace after a spike is detected.

4) The maximum number of semblance velocities was increased in process VELAN.

5) The maximum number of samples per traces was increase from 16384 to 32768 (signed 16 bit integer to unsigned) so that long Knudsen traces (22222 samples) can be convert to envelope using a 32K fft.

Sonobuoy wide-offset data

Seismic refraction experiments in the Arctic Ocean have traditionally been carried out with helicopter support from drifting ice stations. The lines were typically 50 to 100 km long with shot spacing rarely less than 5 km (Jackson et al., 1990). The use of sonobuoys deployed from icebreakers has been a vast improvement in spatial sampling out to 25 km offset. Sonobuoy measurements provide the most efficient way to obtain velocity information from the sediments and upper crust. At abyssal depths this method is limited to the upper layers of the oceanic crust because FM carrier loss usually occurs between 20-30 km due to pressure ridges of ice obstructing the line of sight for efficient VHF transmission. Along each of the profiles, sonobuoy data will constrain velocities, useful for stacking and migration of MCS data and for calibrating and constraining gravity models to determine the distribution of density with depth.

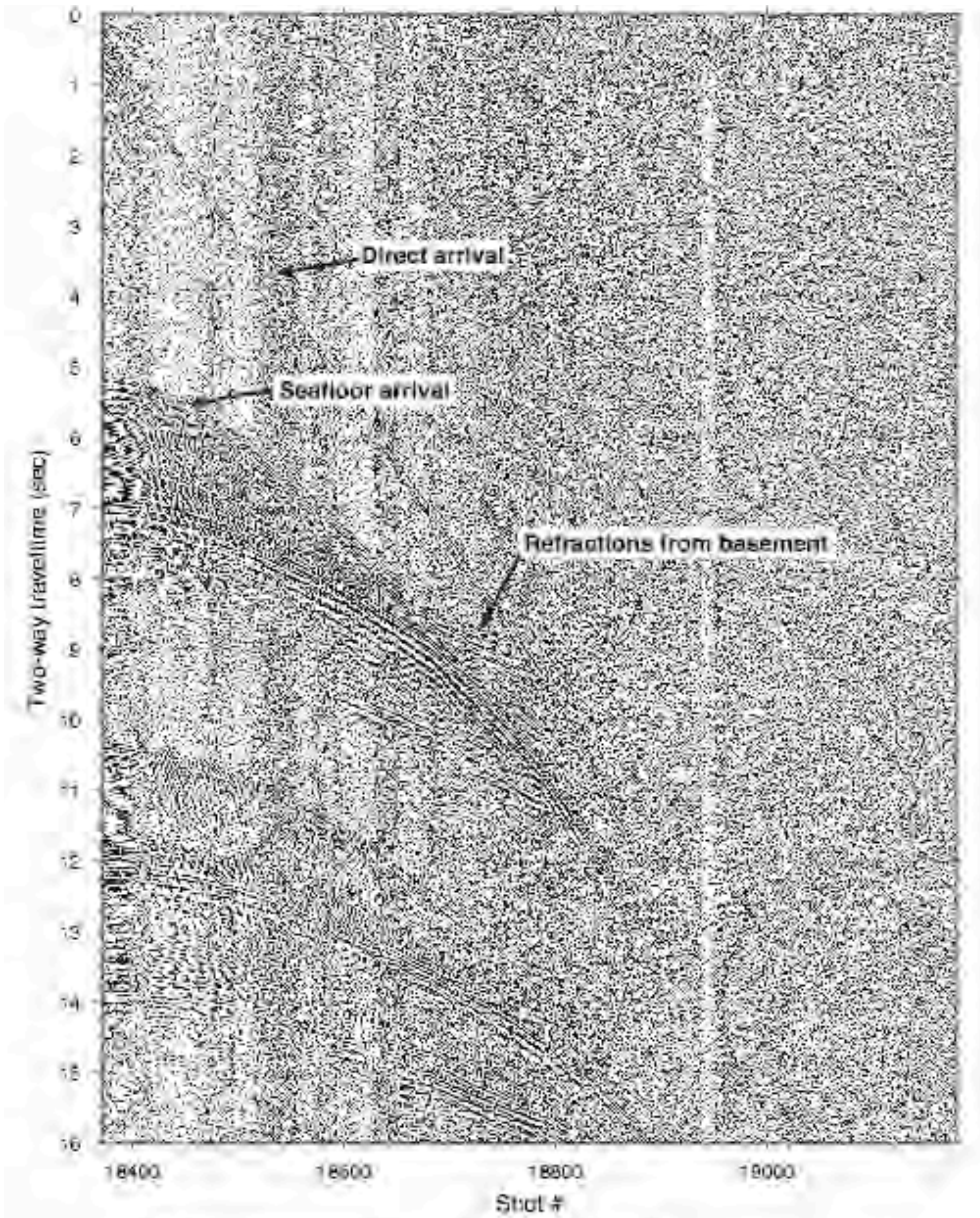


Figure 19 – Sonobuoy SO-19 record. Drop location shown on Figure 4. See Appendix D. Fading of returns indicates the shot strength is the primary limitation on the sonobuoy wide angle data.

For the cruise 200 new AN/SSQ 57 SPC sonobuoys were purchased from Sparton Electronics (www.sparton.com). These were supplemented by 98 US Navy surplus sonobuoys (approximately 15 years old) provided by Lamont-Doherty. The Sparton sonobuoys were found to be quite reliable, whereas 4 of 6 of Lamont buoys failed. Sonobuoy's were deployed and recorded continuously during MCS acquisition. During the cruise, approximately 100 sonobuoys were launched (see Appendix D). It had been expected to collect more MCS data during this cruise than was possible. The restrictions imposed by the ice and the decision to use one active receiver substantially reduced the number of sonobuoys we were able to deploy.

Sonobuoys were hand launched from the fantail after removal of a spring loaded end cap. Removal of the cap exposed the parachute, which slowed the descent of the sonobuoy through the water column until the seawater batteries activated. Once activated, compressed carbon dioxide inflated the buoyant chambers, lifting the buoy up to the surface.

Sparton buoys were set to deploy their hydrophone at 90 feet (except were noted in Appendix D) and operate for eight hours. The transmission frequency was set arbitrarily during the first part of the cruise. Later in the cruise, after some interference problems were recognized in the sonobuoy data, the least noisy channel was selected. The surplus buoys were set for 60 feet and eight hours and had a pre-assigned transmission frequency.

In relatively open water, with loose ice, launching was not difficult. To prevent the hydrophone from fouling the towed MCS gear, it was necessary to throw the buoys from one or the other side of the ship. Typically the buoys were thrown from the port side of the fantail. In tighter ice conditions, with a closing wake behind the ship, it was more difficult to launch the buoys so that they were not either crushed, or held down or blocked from transmission by the nearby ice. The failures of the Sparton buoys were probably due to ice problems.

VHF signals from the sonobuoys were received with a Yagi antenna and fed through a pre-amplifier (160 – 175 Mhz). The antenna was initially positioned on the 04 deck above the helicopter control room about 18.3 meters above the water line. With this arrangement, it was possible to record data out to ranges of 15-20 km before losing contact with the sonobuoy. We switched the antenna to a position above the aloft-con, an enclosed crow's nest roughly three stories above the bridge deck used for driving the ship in ice. This was 32 meters above the water line. After this change, we recorded several sonobuoys out to ranges of 25-30 km without a problem.

After the cruise was underway, the lead MMO onboard (Beth Haley) received an e-mail from the source of the receivers, pre-amplifier and antenna (Charles Greene, Greenridge Electronics). This message raised concerns about placing the antenna within 10 meters of any other RF transmitting antennas. To avoid burning out the electronics, only one receiver was used after the antenna was moved to aloft-con. This limited wide-angle data acquisition to a single sonobuoy at any one time. After operating the receiver without incident for a few weeks, the second receiver was re-attached to the antenna cable, but there was no opportunity to use it in the Eurasian Basin.

From the antenna, the sonobuoy transmission was passed to a calibrated ICOM PCR-1000 receiver modified to yield a flat frequency response down to 10Hz. Receiver tuning was accomplished through the WinRadio receiver application. The audio from these receivers was retransmitted on a standard FM broadcast channel (90 MHz), as well as being fed into the digitizer. The retransmitted signal made it possible the marine mammal observers to monitor the water column for mammal sounds with portable FM pocket receivers from the bridge. (The FM broadcast system is not included in Figure 16.) In the beginning a separate Geode seismograph system was used for the sonobuoy signals, as shown in the diagram above. After the streamer length was reduced, channels 17~24 on the streamer recording system became available for other use such as the sonobuoy receivers (channels 23 and 24). This change is not shown in Figure 16. Using only one digitizer system simplified the recording and logging procedures.

Prior to the Geometrics Geode failure, the sonobuoy acquisition system recorded continuously on channels 1 and 2. We did not attempt a real-time copy of this data, but instead copied the SEGY and log files at the end of each line. After the Geometrics unit failed and we began recording on MCS channel 24, we were also doing a realtime copy of the sonobuoys. After the completion of each line, the sonobuoy channels were copied into a sonobuoy data directory and plots of each channel were made. From these plots, the first and last good traces of each sonobuoy were determined and a new SEGY file created for each buoy that contained only the shots recorded by that buoy. Extracting each sonobuoy into separate SEGY files should simplify subsequent processing.

Ranges were not assigned while underway. Because the exact position of the sonobuoy is unknown, the best strategy will be to use the direct arrival to calculate a range from the ship, whose position is known for each shot. On all the buoys with useful data, a clear direct arrival is observed for the entire recording time. Most sonobuoys were not limited by radio range issues, but instead seem to have stopped receiving returns well before the line of sight limit was reached. Since this restricts the refraction results to the shallow section, a stronger source would be recommended for future cruises.

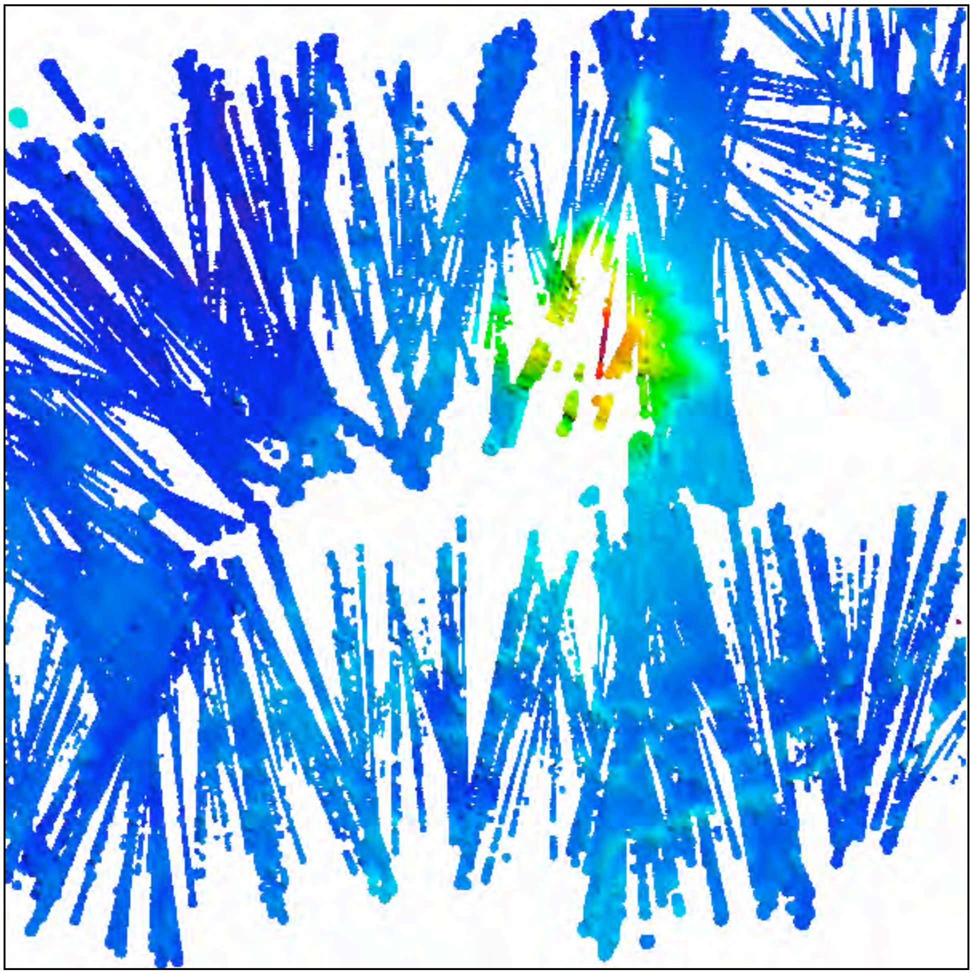


Figure 20 – A 15 km square area from Alpha-Mendeleev Ridge. Coverage was often poor due to data loss when ice was swept under the hull. Frayed appearance of swaths is an indication of intermittent data dropouts caused by ice swept under the hull. Incomplete coverage is characteristic of swath data collected while back and ramming in heavy ice. Even though the ship passed over the same segment of seafloor multiple times, it was not fully imaged.

Multibeam Swath Bathymetry

The swath bathymetry data were acquired with the multi-beam echosounder SeaBeam model 2112. The system was run continuously from Dutch Harbor to Tromso. The raw SeaBeam data were logged by surveyor, an SGI workstation and delivered to the network. The data are publicly available through the network attached storage device hly-snap1. Each day's data were processed with mbsystem (Caress and Chayes, 2002) software.

Infrequent data gaps occur during times when the SeaBeam required maintenance or when the system failed. Most of these gaps are brief, but there were also a few that lasted more than an hour. The vast majority of the gaps found in the final bathymetry plots are the result of filtering applied to correct for the noisy sonar environment created during backing and ramming.

Ashtech navigation was logged in the SeaBeam files. Occasionally the Ashtech system had its own problems that required brief stops and restarts. Some of these events necessitated the manual editing of the navigation data to remove obviously erroneous output (unexplainable jumps to "origin" at 0 Lat, 0 Long, for example). The raw data were not altered in this evolution, merely set aside and supplanted with the edited data for subsequent charting work.

Most of the data collected for this program was not particularly sensitive to the details of ship operation. Gravity, swath bathymetry and chirp data were collected all the way across the basin. In thick ice, the blocks swept under the hull would periodically occlude the transducers, preventing the transmission and reception of acoustic signals. Noise from the ice probably also had some effect on the detection of seafloor returns. In heavy ice the swath data looked ragged [Figure 20], rarely was the full swath width recovered, but system continued to collect data across the basin. Data gaps were somewhat filled in (in map view) in heavy ice by backing and ramming.

Processing

Processing was done in two independent tracks. Mbsystem (Caress and Chayes, 2002) was used to batch process multi-beam bathymetry for quick-look for quality control. CARIS HIPS/SIPS was used for beam editing, resulting in a more finished data set. Keeping up with data acquisition was critical to have data on hand for underway applications and to document the operation of the SeaBeam 2112.

Mbsystem

The raw Sea beam data are then put through a two-step filter using mbsystem to produce the mb41-formatted output that the rest of our charting scheme uses. The first McLean checks to make sure there are a minimum number of beams (30) in the ping. By eliminating these pings, where noise has been picked as a bottom return, simplifies subsequent editing. A second call to McLean flags beams based upon deviation from a mean depth (0.8-1.2), deviation from a range of depths (change of 1% of median depth between pings separated by a distance of 20% of mean depth), beams which exceed a set slope (1.5), and outer beams that are rail beams.

Finally, the entire dataset has been girded to produce 1:100,000 and 1:25,000 scale charts of the entire track with a 25 m cell size. At multi-core and piston core sites 1:10,000 scale charts were produced with a 10 m cell size. Postscript and PDF versions of all these charts in US Letter size and A0 size were then generated as a final product.

CARIS HIPS/SIPS 5.4

The vessel configuration used during HLY 04-05 was used. The vessel file name is USCGHEALY.hvf. The sensors roll, pitch, heave, gyro, navigation and swath 1 were activated. The sensor offsets were entered to the acquiring system during the acquisition setup.

A project named HLY0503_UPS was generated in base a day data structure. The Universal Polar Stereographic as projection system was configured, which has value 0 degree at Equator and 90 degrees at North Pole, and WGS84 was the ellipsoid of reference system selected as well. It was necessary to replace the file mapdef.dat, which reside in at HIPS/System to make sure the

Universal Polar Stereographic Projection would plot correctly. CARIS Project files are available from the lead author of this report.

The raw data are stored in filenames of the form sb2005JDhhmm.mb41, where JD is Julian Day and hhmm are hours and minutes in GMT, were pick up from the server and converted to CARIS readable format. Each hour of each Julian Day had a unique file, which was referred to the corresponding project and vessel defined in 2.1 and 2.2. Side scan sonar data were converted for each line simultaneously.

In order to organize the processed data and to make sure all changes produced in the worksheet were saved, a session was created for each Julian Day. These files have the name HOTRAX_session number.hsf. This permits faster data access, avoiding the overhead of loading the complete project each time.

Auxiliary sensor data cleaning was not done since those corrections were applied during acquisition. Sound velocity correction was not applied during processing since it was applied during the acquisition data stage. Since the tide loading is a mandatory step in the processing workflow, and for this kind of survey, the zerotide.tid file was selected from the directory. It was applied to each line. When motion, navigation, refraction and tide correction where applied to each observed sounding, the merging step was performed to produce a final depth. A new field sheet for each session was created. The files have the undersea feature name or the Julian Day number in other cases (JDNN).

Base surfaces were not deliverables, since CARIS processed lines were used directly to make the maps. The base surface was generated as a first view to check out the data quality and the cleaning effort to put in order to take out bad soundings. Scales of 1:25,000, horizontal and vertical resolution of 100 meters for this porpoise were used. The base surfaces were named like the field sheet with underscore and scale (eg. JD222_25m)

The swath editing was applied manually to each line working on the rear view window and checking out one on one each single swath. The examination of the base surface was performed subdividing a field sheet into smaller areas to clean up spikes. Once the bad soundings were removed from the field sheet, the base surface was recomputed to rebuild it. The holes in the base surface were filled out by mean the interpolation using the average of neighboring pixels. In this case a matrix of 5x5 and 8 neighbors were used.

The processing of the multi-beam data corresponding to 24 hours of acquisition was carried out systematically with CARIS HIPS&SIPS 5.4 during a watch of 12 hours. The processed lines were delivered at the end of each Julian Day. CARIS ran without problems and it was quite sensible to failures in navigation and multi-beam acquisition systems. There was a small discrepancy between CARIS and GIS polar stereographic projections, and in some cases it caused some differences of coordinates.

Chirp Sub-bottom Profiler

The Knudsen sub-bottom profiler was selected over the Odec profiler after a brief comparison (see http://sioseis.ucsd.edu/notes.html). While Jakobsson and Darby had used the Knudsen previously, it is a poorly understood instrument, and it's capabilities were extended during HLY0503. The biggest misconception is the "depth" displayed on the monitor. The velocity is a settable parameter, but Dale Chayes from LDEO, who "oversees" Seabeam, Knudsen, and PosMV, mandates a velocity of 1500m/s. Thus, the depth on the Knudsen is always different from the SeaBeam.

The Knudsen BR-320 functioned well in the ice, maintaining lock on the bottom even in heavy ice conditions [Figure 21]. The primary effect of heavy ice was to introduce gaps into the data. The Knudsen's performance in ice was far superior to the ODEC Bathy-2000, which requires extensive intervention to maintain bottom lock while icebreaking.

Operation

In order to make intelligent settings on the system, the user must understand how it works. The Knudsen must be operated in the LF (Low Frequency or 3-6kHz) option since the HF (High Frequency or 10.5-13.5kHz) option interferes with the 12kHz. SeaBeam system. All Knudsen post-processing was done from SEG-Y files.

The first big breakthrough was when Steve Roberts read in Lee Ellett's setup instructions for SIO ships stating that TVG (time varying gain) is an essential setting. Lee recommends always using TVG referenced to the water bottom. The setting is found on the pull down "Sounder" menu. TVG improves the displayed data and is included in the KEB files but not in the SEG-Y files. Lee's guide may be downloaded from http://sioseis.ucsd.edu/guide.pdf.

A 3-6 kHz sweep signal is transmitted over a "pulse length" time (3, 12, or 24 milliseconds). This is also called a "ping". The longer the pulse length, the more the energy transmitted. A shorter pulse improves vertical resolution. Thus, a short pulse should be used in shallow water and a longer one in deep water. The ping transmission rate varies with the depth of the water so that two pings are not in the water at the same time and thus interfere with each other (e.g. In 750m of water the TWT (two way travel time) is 1 second, thus consecutive pings must be more that 1 second apart).

The transmitted signal "power" may be adjusted (1-4). If the power is set too high, the received signal could be clipped. Thus, the outgoing signal strength is a combination of "pulse length" and "power".

The reflected signal is received by the same set of transducers that transmitted the signal (16 transducers on the Healy in a 4x4 array, yielding a beam width estimated to be 30 degrees). The "gain" of the transducers can be set to gain values 1-255 or AGC (automatic gain control). Knudsen recommends using AGC when the bottom detection algorithm is having trouble. On board Healy, AGC is never used. Setting the receive gain too high can cause clipping (square waving) of the recorded data.

The transmit power and receive gain are analog gains – before the received signal is digitized. The analog signal is digitized at a 24 kHz sampling rate (sample interval of .041666 milliseconds) since 24kHz is the Nyquist frequency and prevents aliasing of the 12kHz signal. The digitized received reflected signal is then correlated with a replica of the transmitted signal, resulting in a "compressed" form. Knudsen does some strange buffering and resampling before writing the data to the optional SEG-Y formatted file (Knudsen adheres to the SEG-Y strictly).

The next steps are undocumented and have been reconstructed from study of the output files. The received signal is split into two signals. One signal is phase shifted 90 degrees to form the Hilbert transform. The original signal and the Hilbert transform are then combined as alternating samples to form the "analytic signal" or complex trace. The complex modulus is taken and the "envelope" is formed. The 320B uses the envelope to find the water depth, displays a "window" of the data on the monitor and writes the windowed data to a disk file in the "KEB" format.

The "range" setting on the screen is the amount of data, or window size, used for depth picking, display, and for the KEB disk file. The "phase" setting is the position of the window in the entire received data series. For example, a range setting of 500 will use 500m of data. Moving the phase indicates which 500m.

Three data files were recorded continuously on HLY0503; KEB, KEA, SGY. KEB files are Knudsen Engineering Binary files, which are used by Knudsen's post processing software (Post-Survey). KEA file are Knudsen Engineering ASCII files, which may be required by the Post-Survey program as well as the KEB files (the documentation says a LOG file is produced and required by Post-Survey, but there are no LOG files).

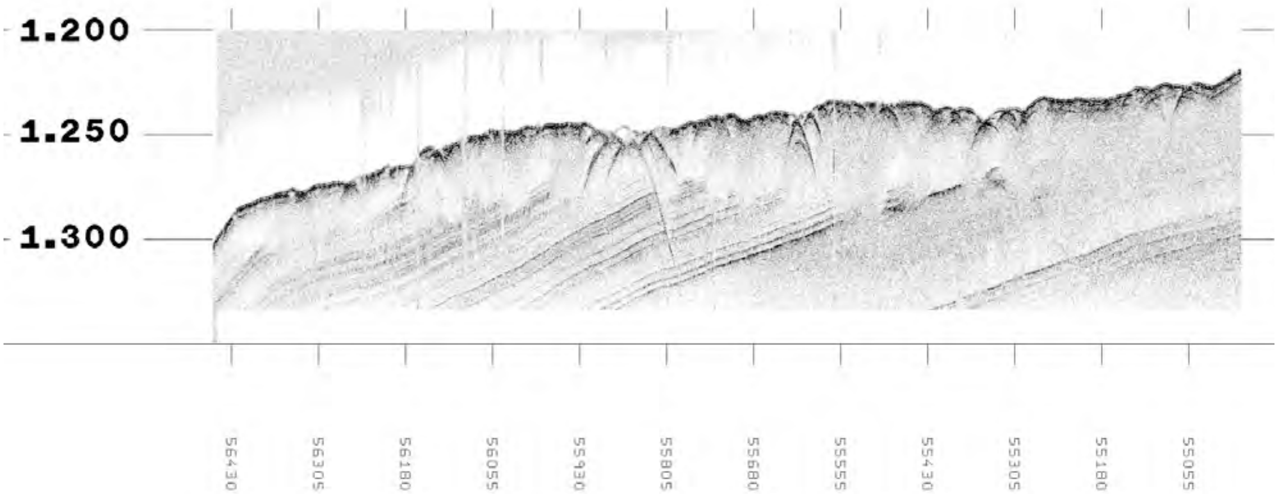


Figure 21 - Erosion on the Chukchi Plateau below a drape of gouged glacial sediments as imaged by the Knudsen B/R 320.

The MST/ETs are responsible for powering the unit up and for switching it between chirp mode and pinger mode. Consultants Handley and Roberts diagnosed any failures. The one major hardware failure was cured by the ETs reseating the Knudsen boards/cards and reconnecting the disconnected cooling fans.

Processing

A discussion of chirp systems and chirp signal processing may be found at http://sioseis.ucsd.edu/notes.html. The processing done on HLY0503 consisted of forming the envelope from the correlates in the SEG-Y files, performing a 25mil AGC, and grayscale plotting.

Several idiosyncrasies were discovered and reported to Knudsen Engineering;

The lat/long in the SEG-Y trace header is incorrect because it uses a scaling factor of 1000 when converting degrees to arcseconds, which causes a 32 bit integer overflow.

Not enough data is recorded and the sub-bottom events are truncated, especially in areas of rapid bathymetric deepening. The penetration from the Knudsen exceeds the data recording length.

The min/max depths for searching seem to be honored in manual mode, whereas the manual says they are used in auto-phase mode only.

Auto-phase mode triggers lots of small SEG-Y files and also requires frequent operator intervention because of file name conflicts.

Gravity Anomaly Data

The Bell BGM-3 (Bell and Watts, 1986) gravimeter was made available to this program under a loan agreement negotiated between NSF and NAVOCEANO. The gravimeter and support electronics were installed by Bernard Coakley and Randy Herr (NAVOCEANO) in a portable rack in the IC Gyro room, which straddles the centerline of the ship, on the third level. The NAVOCEANO data logging computer was provided with NMEA strings from the ship's own GPS system (GGA, VTG and ZDA) via a serial connection. These data permit the NAVOCEANO data-logging computer to maintain time synchronization to GPS satellites and continuously reduce gravity data while underway. The raw gravity "counts", which are not logged by the NAVOCEANO computer, were provided via a 2nd serial connection to the Healy data logging computer, supporting redundant data logging for the gravimeter output stream for post-cruise data reduction through their SCS program. Integration of the gravimeter with the ship's information system was achieved with the support of E.M. McFadden (USCG Seattle).

The National Geospatial Intelligence Agency (NGA) agreed to fund gravity data acquisition during the Summer 2004 USCG Healy program to augment their gravity data holdings in the Arctic. With the agreement of the CO (Dan Oliver) and the support of all the summer program chief scientists (Jackie Grebmeier, Larry Mayer, Lee Cooper and Rob Pickart) a Bell BGM-3 underway marine gravimeter was installed in Seattle on 15 and 16 March 2004.

NGA declined to fund gravity data acquisition for the 2005 summer season on USCG Healy. NAVOCEANO, pleased by the quantity and quality of data obtained during the 2004 season, agreed to leave the gravimeter onboard at no charge to the project. On this basis, the gravimeter was operated continuously during the summer 2005 season, collecting data during the various Healy transit legs, in the western Arctic Ocean during Healy 05-01 and 05-02 and during the cross-basin transect HLY 05-03.

The Bell BGM-3 gravimeter operated flawlessly throughout the cross-basin transect, only showing occasional Platform Data Not Valid (DNV) conditions during backing and ramming operations. Typically the rapid transient horizontal accelerations experienced during these times introduce spikes into the raw record and can, when the time scale of motion was short compared to the platform response time, cause the platform to maintain itself off vertical as it attempts to compensation for the platform accelerations [Figure 22]. When the platform is off vertical, the ship's horizontal accelerations contaminate the prime accelerometer causing a DC shift in the reduced gravity data.

The gravity data were reduced using the POS/MV navigation data. Preliminary reduction conducted while on board shows the excellent quality of the data. The Data were reduced using the script gravReduction. This script accesses the necessary navigation and gravimeter output files to calculate Free Air gravity anomaly values at a one minute interval along the track. A four minute Gaussian filter was used to estimate the vertical accelerations from the 1 Hz integer values generated by the gravimeter's data buffer. De-spiking was accomplished with an eight minute median filter. Reduction was completed in December 2005 after the Healy returned to Seattle, making it possible to do a closing gravity tie.

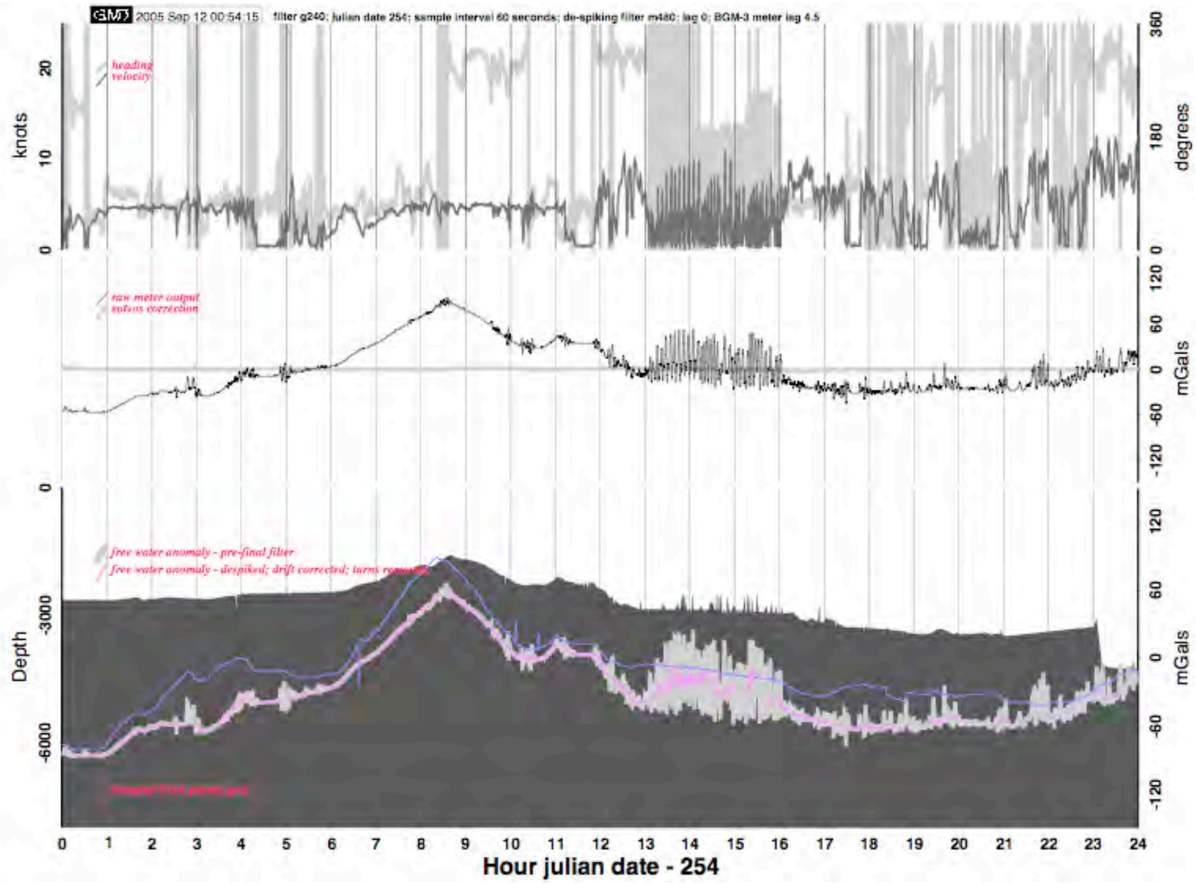


Figure 22 - Gravity anomaly data collected during back and ramming operations (hours 13-16), which caused off-level errors on the platform. Profile location indicated on Figure 8.

Opening and closing ties were both taken as the USCG dock in Seattle. Over the 190 days USCGC Healy was underway, total meter drift was 2.3 mGals or about 0.012 mGals per day.

Gaps in the reduced data occur at the end of each day. This is due to a few missing seconds of gravity data at the end of each day. These values are lost during the change from one day file to the next. Other gaps in the reduced data occurred at 7:00 and 19:00 each day. The cause of this problem and its solution are discussed in the section on the Science Data Network.

ADCP 75 and 150 kHz

Both of the hull-mounted ADCPs were run continuously throughout the cruise. Watchstanders were expected to ensure that the screens were updating. When updating ceased, the watchstanders were expected to find assistance for re-starting these instruments. Both instruments were fairly reliable, freezing up once every few days. Operator inattention to the ADCPs meant that gaps of a few hours often occurred when the system froze up.

Since there was no one identified, on or off the ship, as having an interest in the ADCP data, no further examination, processing or quality control were done with these data while underway.

Ship Operations

During the cruise Healy encountered a variety of ice conditions. This variability and our response to it dramatically affected the quality and quantity of data we were able to collect. Open loose ice, as encountered prior to the Oden rendezvous enabled us to collect excellent data from all systems. During most of the second half of the cruise, data acquisition was restricted by thick, continuous ice. During this part of the cruise, heavy, compressed ice swept down under the hull, blocking the SeaBeam and Knudsen transducers. These data sets are intermittent where the Healy encountered heavy ice, due to the physical blockage of the transducers and perhaps due to the broadband noise of icebreaking.

In heavy ice conditions, the ice swept under the bow travels along the contours of the hull, held down by adjacent ice floes. This buoyant ice emerges from under the transom with significant force, endangering the MCS acquisition equipment streamed there. Blocks ranging from refrigerator to room sized can lift the gear up out of the water, causing the guns and paravane to drag across the exposed surface of the ice. Often the streamer would follow the guns. During this time, the streamer is very vulnerable to ice damage or removal. Ice blocks often crowded the wake, making it hard to launch sonobuoys, and very easy to pinch the streamer where it drapes off the ice back into the water.

From observation it was determined that the optimal ship speed for data acquisition was between 4 and 4.5 knots. Faster speeds increased the flow noise recorded by the streamer. Slower speeds caused the streamer to sag in the water along its length an unfavorable geometry for data processing, which assumes constant streamer depth.

The need to regulate speed was communicated to the underway watch and to the crew and officers of Healy, but it was difficult to get the ship drivers to maintain the constant, slower speeds. While additional speed was sometimes necessary to break through obstacles, it was often necessary to remind the watch to return to the preferred speed range. This situation improved during the cruise, but required continuous vigilance and communication with the ice con.

After relative easy ice on the Chukchi Borderland and Mendeleev Ridge, the struggle against the pack defined what was accomplished during the second phase of the trip. Ice was less of an impediment for the coring program, which relied on recovering particular points in the neighborhood of specific seafloor features, than it was for the underway geophysics program, which requires continuous favorable or controllable ice conditions to obtain high quality data. A number of factors combined to complicate MCS data acquisition during this cruise.

Understanding these factors will help planning future cruises, so a summary of experience from this cruise is offered below.

The Cruise “Across the Top”

This cruise was originally conceived as an oceanographic transect across the Arctic Ocean on Oden. Healy was recruited to ensure the safe mutual passage across the basin and augment the overall science program with marine geology. It was decided that the two ships would pursue complementary science programs along separate tracks to the flanks of the Alpha Ridge, where the heaviest ice would be encountered. From that point forward, until easy ice was encountered, across the Lomonosov Ridge, the two ships would work in tandem. After that point, the two ships would separate to pursue their independent science programs.

For this project, Oden supported the oceanographic station work, primarily hydrocasts. The Healy supported coring and underway geophysics. The tracks were defined to meet the distinct objectives of the complementary science programs, Oden planning a beeline across the basin. Healy taking a more circuitous route, crossing the Chukchi Borderland and the Mendeleev Ridge en route to the rendezvous.

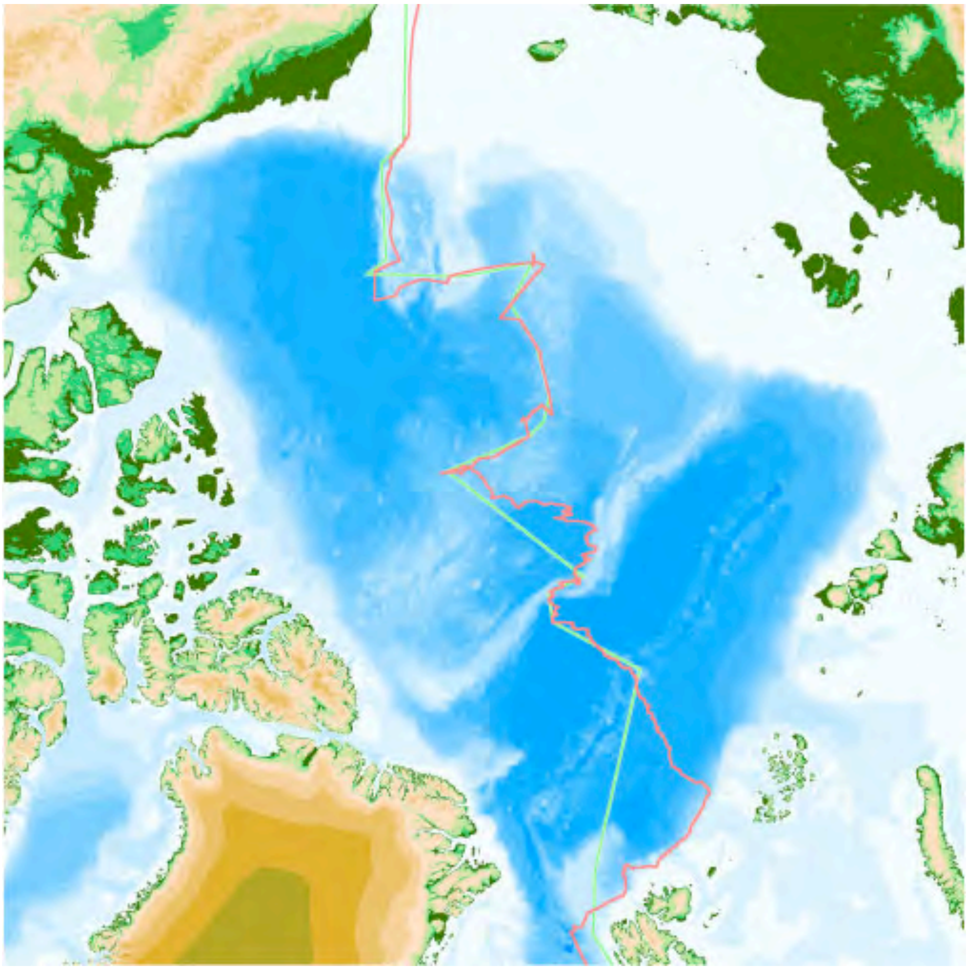


Figure 23 – Planned ship track and sailed track, which was dictated by heavy ice conditions, particularly in the Makarov and Eurasian Basins.

While the "division of labor" between Healy and Oden avoided a repeat of the disastrous 1994 trans-Arctic section on Polar Sea, the schedule requirements necessary to achieve a timely transit late in the season often made it necessary to sail the shortest path between successive stations, which, due to ice conditions or location, was rarely useful for the underway geophysics program. From the point of view of public relations, the appeal of a basin crossing section and North Pole visit is strong, but from a pragmatic point of view, it would probably be more productive to have had two individual cruises with more restricted geographic focus (eg. Chukchi Borderland-Mendeleev Ridge or Eurasian Basin). This would avoid the late season urgency to get out of the ice before being frozen in.

Oden leading

Acquisition of MCS data across the Alpha Ridge, Makarov Basin and Lomonosov Ridge assumed that Oden would lead across these features, through the heaviest ice expected on the transit. In practice, this did not work out, owing to ice conditions and the contrasting capabilities of the two icebreakers.

The Oden is a capable icebreaker that depends, in part, on its' maneuverability to select the most open route through the ice. Healy is less maneuverable and, as a result, was often unable to follow the track left by Oden. To follow Oden, Healy often had to break through heavy ice, putting the towed gear at risk.

Healy leading

Healy is a more powerful icebreaker than Oden. In some circumstances it was necessary for Healy to take the lead through heavy ice and ridges. It was not possible to tow the MCS gear at these times. The passage of large ice blocks under the hull also was detrimental to the multi-beam and chirp data acquisition.

Heavy ice in the Eurasian and Makarov Basins

To collect high quality geophysical data it is necessary to be able to select tracks across bathymetric features. Heavy ice in the Makarov Basin directed both ships towards the west, away from concentrations of multi-year ice and onto the flanks of the Lomonosov Ridge. Sailing along the Lomonosov Ridge was not ideal for data acquisition, though some useful data was obtained. Relatively open ice conditions on the central Lomonosov Ridge made it possible to collect a few poorly oriented lines. After the North Pole visit, only a few short segments of data were acquired in open leads. The heavy continuous ice in the Eurasia Basin was an obstacle to the advance of both ships and made it impossible to collect further MCS data. This was surprising given that the AMORE expedition in 2001 (Jokat et al. 2003; Michael et al., 2003) was able to obtain continuous full-width swath bathymetry later in the year. It had been expected that similar conditions would enable study of the segmentation of the Gakkel Ridge observed through dredging in 2001.

Science Data Network

The Science Data Network[1] (SDN) performed very well on this leg with only one serious interruption to operations of approximately one hour, caused by a failed 3Com switch. This switch negatively impacted data acquisition of the MCS due to the disruption of UDP datagrams on which the MCS was relying for Navigational Data.

Scientific Computer System (SCS)

The data acquisition system performed well, it's unique programmatic quirks not withstanding.[2] As of the time of this report the SCS system has operated without incident for 1162 hours and 29 minutes with only 4 minutes of down time to add sensors. Roughly 64gb of data has been logged at the rate of 1.39gb/day. These down times were coordinated with the Chief Scientist while on coring stations to mitigate the loss of acquisition.

SCS has its quirks but is developed by NOAA and has a dedicated programmer as well as support from its founding developers. SCS has many useful features and NOAA has been responsive to feed back as well as providing troubleshooting support when called on. It is expected that, with continued use and input from the science community, SCS could be further improved, supported and possibly ported to other platforms.

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[1] In this report SDN applies only to the network infrastructure, email, windows networking, general purpose workstations and the SCS data logger. Systems installed and maintained by LDEO are not addressed here.

[2] SCS requires a stop/start of acquisition in order to add or modify sensors. SCS loses several seconds of data when the logs roll over. SCS can not currently use TCP sockets to receive data.

Network Attached Storage

One problem with the data logging system was found early in the cruise. There was a loss of several seconds of data twice a day in all of the logs being generated by SCS. It turned out to be a feature that was implemented on the network attached storage system in an effort to provide a more robust disaster recovery strategy. The NAS device was set to take a "snapshot" every twelve hours so that in the event of recovery operations the system could be restored to this last snapshot. The loss of data correlated exactly to the times when this snapshot was taking place. The "feature" was turned off and this loss of data was eliminated.

More thorough and automated data quality monitoring of logged data is still necessary. This error was in ALL of the data for this year until caught by the co-Chief Scientist. Closer attention to the quality of data obtained during the shake down cruises should have caught this prior the ship ever leaving Seattle.

Internet & Email

Internet was limited during this leg due to the northern latitudes. However, even when the Inmarsat was available in the first weeks of this cruise there were problems with connections and throughput. Email worked almost flawlessly throughout the cruise, relying on a four channel Iridium Inverse Multiplexer from General Dynamics. This unit provided the transport for both email and file transfers via FTP for both the science party as well as email for the crew of Healy. While message sizes were limited (to 150 kBytes for the science party and 50 kBytes for the crew) speeds of delivery were often on a par with shore-based systems. Only a slight degradation of throughput was noticed during a period of high solar flare activity. File transfer via FTP could be conducted at approximately 1mb per hour. This was used daily to transfer Ice imagery from the National Ice Center as well as photos and slide presentations for embarked journalists.

The Coast Guard should install a second Iridium IMUX unit to provide this transport to the ship during operations in high latitudes. Furthermore, the CG should provide a secure means to allow the CG and SDN networks on board to send and receive email without the wasteful necessity to transfer data to shore and back to the ship. This restricts email sizes on the science network to 150kb, making collaboration with groups onshore difficult at best.

Network Infrastructure

Last year the SDN was switched to a new fiber backbone, allowing the SDN to be physically separated from the CG network. This allowed the SDN to have direct control and management of its network infrastructure. Managed control made it possible for the administrator to quickly isolate and replace a failed switch. Unfortunately a similar switch with Gigabit capability was not available. New switches have already been procured and will be installed during this off-season.

Wireless Access Points (WAP's) are now part of the SDN and appear to be working well. Many users made use of wireless networking in their staterooms, the science lounge as well as within lab spaces. Some reports of intermittent connectivity were reported from staterooms. One WAP failed in the last two weeks of the cruise and was replaced with a spare. Security was provided by MAC authentication via a Radius server. Users were minimally impacted and had only to provide their wireless MAC address to the SDN administrator.

The HP Office Jet color printer/scanner/fax machines are not suited for their use on Healy. Ink Jet printers sit for too many months in the off-season and get clogged and produce poor color output. This places all of the color printing on the one large Lexmark 910 color printer.

Investigate and improve coverage in the berthing areas if possible and necessary. Determine if it is possible to implement an initial web based self registration such as those found in Hotels or Convention Centers. Replace the aging and poorly operating HP Office Jets with medium capacity color laser printers. Purchase a good departmental network capable copier/scanner for science use.

Oden/Healy Communications

Wireless communications between the Healy and Oden were provided by LDEO provided SWAP (Ship to Ship or Ship to Shore wireless access protocol) nodes for both ships. They were pre-configured and given to Healy and shipped to Oden. Despite our best efforts in determining ports and protocols that would need to pass between the ships, some configuration changes were necessary, though trivial once the ships were working together.

Initial radio contact was made at a distance of 15.9nm, however routing and data links did not establish until the ships were generally within 10 – 11nm of each other. All in all SWAP worked well. The exception had to do with antennas and placements. Both ships had antennas placed on port and starboard sides of interfering structures and often when the ships were turned to each other so that these structures blocked the line of site of the antennas the transmissions would be lost. This would occur at distances as close as 500 meters. When linked the wireless links provided adequate bandwidth to support viewing Healy's Map-Surfer GIS application as well as for Healy to be able to query Oden's SQL database. Success to date supports continued growth and development of SWAP within the UNOLS fleet and improve coverage.

Science Technical Support

The ship's equipment performed well throughout the cruise. The few minor problems encountered during the trip were rapidly recognized by the watchstanders and remedied by the ship's technical support staff.

Seabeam 2112

The Seabeam worked well for most of the cruise and a lot of good data was gathered. The system worked well in ice, although data quality suffered in heavy ice, especially during backing and ramming.

The Seabeam was operated, while in ice with the Gates in Manual and the Sonar Power, Ping Gain, and Pulse Width set to manual. This tactic has worked well maintaining a bottom return. It is still necessary to set the Surface Sound Velocity to a value greater than 1440.5m/s to prevent the beam forming from failing. Part way into the cruise 1440.5m/s was no longer sufficient and that this value needed to be increased to ~1447. Since the system uses POS/MV for the heading source, the data at the start of the cruise had a 10 degree error until the survey parameters were adjusted.

There was a problem with Longitude that manifested itself after the North Pole was reached. The NMEA string that was fed to the Seabeam was not padded with leading zeros. This resulted in the Seabeam parsing the value incorrectly, for example 95.64 degrees was parsed as 956.4 degrees. The system could not cope with these numbers and control was lost. Unfortunately the failure mode resulted in loss of the diagnostic tests as well as control. This made troubleshooting difficult. In addition to the loss of control, the system also disabled the power amps. This was not obvious. Eventually normal operation was resumed.

Knudsen 320 B/R

The Knudsen was used for the whole cruise. The Bathy 2000 was briefly turned on to compare it with the Knudsen. Most of the time the Knudsen was operated in LF mode and good sub bottom profiles were obtained with good penetration. The Knudsen did suffer a spate of locking up. The ETs opened the Deck Unit up, found the fan to be disconnected, reconnected it and reseated all the cards. The unit worked well, without further intervention, for the remainder of the cruise.

POS/MV GPS-Ship's Orientation Reference

The POSMV POS Computer System was replaced with a loan unit from Applanix before the start of this cruise. At the start of the cruise a Heading offset of approximately 10 degrees with respect to the Ashtech heading reference was observed. The survey parameters were adjusted at approx 1930Z on 11 August. This reduced the heading offset to about 2 degrees with respect to the Ashtech. This offset appears to have remained stable for the rest of the cruise. The POS/MV did exhibit some problems with at high latitudes, with the heading error increasing to about 0.2degrees, and the pitch and roll error increasing to about 0.1 degrees.

Ashtech GPS

Ashtech has worked fairly well this trip. It was the best attitude reference on board at very high latitudes. Ashtech stopped out putting data during the early part of the cruise and was reset at about 1700Z on 10 August. At this time a POSMV was observed to have a 10 degree off set with respect to the Ashtech. The POSMV survey parameters were adjusted and the heading offset was reduced to about 2 degrees.

Ashtech has been reporting empty values for attitude and heading information on several occasions this trip, Normally rebooting the system clears the problem

Thermosalinograph (TSG)

The TSG has worked well this trip. It was shut down once to evict a dead fish from the debubbler, and the opportunity was taken to open the TSG up and check that it was clear of foreign objects at the same time. It was found to be clean.

Scufa

The Scufa Flourometer in the Bio Chem Lab failed due to internal water ingress and was replaced by the unit in the Aft Hose reel room.

Uncontaminated Seawater

The new uncontaminated science seawater system worked well this cruise. Twice there has been a reduction in head pressure, but the system has continued to run. The system has not been blocked with ice during this trip. No water was provided to the foredeck during this trip from the system.

Hull Temp

A Sea Bird Electronics magnetic mount hull temperature sensor has been temporarily mounted in the Aft Hose Reel Room on the shell plating below the water line to evaluate its performance. It has consistently recorded a temperature that is about 2 degrees higher than the TSG. It has been noticed that the internally mounted temperature reading increases slightly when the ship is stopped.

Map Surfer

An interactive web-mapping tool was developed and installed prior to the first Healy science cruise and was actively supported on this cruise. New layers were developed and maintained such as the Oden real-time track, automated IBS waypoints, Radarsat, DMSP Visible and SSM/I Sea Ice, NOAA HRPT, Seabeam, etc. The site was heavily used with an average of over 5,000 hits per day. The site was also made available to the Oden via the SWAP wireless network connection. It was an excellent resource for underway track planning.

Ice Report Forms

A Sea-Ice Observation Web Form was installed and maintained in support of the ice observation program. This site was used by the ice observing group to log ice conditions while underway. The site has worked well with no significant problems.

Terascan/Gyro

The Terascan received heading information from the Integrated Bridge System. During Flight Ops, the IBS heading input is switched to Gyro to provide heading to the Tacan. Since we were operating at high latitudes, the Gyro Error was up to 100 degrees. The Terascan could not track satellites under these conditions.

For all of last year the DMSP image quality was noticeably degraded. However the NOAA hrpt imagery remained good. Other than the issue with the bad gyro input the DMSP image quality appears to be greatly improved over last year.

SeaSpace groomed the system early this year before the beginning of the science cruises so it is possible that these software updates resolved the problem. However, NOAA hrpt appears to be experiencing a new intermittent problem at high latitudes where only a small segment of a pass will be processed with the rest skipped. We've been in contact with SeaSpace regarding this issue but so far there has been no determination of the cause.

A post-processing laptop with a Terascan 3.3 software license was maintained. This system was used to generate custom imagery for the MapSurfer and data archive. The system worked very well on this cruise with no significant problems. This license was provided by Seaspace for evaluation during this cruise and will expire after this cruise. If this functionality is desired in the future a full license will need to be obtained.

Gravimeter

The Gravimeter has been working well during this cruise. The DNV light was lit on the Gravimeter buffer at the start of the cruise. This was found to be due to a loose connector. After the connector was reseated, the light went out and has remained out for the trip.

ADCP

The ADCPs have been working well. Both systems have suffered random lockups, the 150kHz unit has been worse than the 75kHz unit in this regard. The 150kHz was stable at the beginning of the cruise, then suffered about a week of erratic behavior and then has been on the whole stable since then. Fault finding was attempted, but is very difficult due to the random nature of this fault.

Multi-Channel Seismic Reflection (MCS)

The MCS lead in was run through the existing cableways and may have affected by EMC. A dedicated science cable pass through is needed for sensitive equipment, away from power cables and other sources of electrical noise.

Sonobuoy Receiver.

Difficulty was experienced in finding a suitable location for the GreenRidge Sonobuoy Receiver due to the manufacturer insisting that the unit be mounted at least 10m from any transmitter. If Sonobuoys are going to be used on future cruises, it would be worth looking at alternative receivers to see if they had better front end protection.

Aft Conn Marine VHF Radio

The new Marine VHF radio was very useful. Unfortunately it can be impossible to communicate with Aloft Conn. This may be due to the window-mounted antenna having problems operating through a heated window. The installation needs to be looked at to improve performance.

Incidental Harassment Authorization Compliance

Four marine mammal observers (MMOs) participated in the *Healy* 0503 cruise to implement monitoring and mitigation measures in compliance with the Marine Mammal Protection Act (MMPA) during seismic operations. Exposure to very strong sounds may cause temporary or permanent hearing impairment in marine mammals. The current National Marine Fisheries Service (NMFS) policy states that pinnipeds (seals) and cetaceans (whales, porpoises and dolphins) should not be exposed to impulsive sounds greater than or equal to 190 and 180 dB, respectively. The areas where 190 and 180 dB sound levels would occur during operation of the airguns used during the *Healy* seismic survey were modeled prior to the cruise. The MMOs monitored the area around the ship during seismic operations for marine mammals. If a pinniped was observed approaching or within the area of the 190 dB sound level, the MMO on watch would call for either a power down or shut down of seismic operations. The same would be done when a cetacean was seen approaching or within the area of 180 dB around active airguns. A power down reduces the volume of the airgun-shot, reducing the extent of the noise level; a shut down stops all airgun activity and eliminates the noise. These measures were enacted to prevent or minimize the exposure of marine mammals to high sound levels.

The U.S. Fish and Wildlife Service (USFWS) protect polar bears and walruses. Prior to the cruise, an informal consultation was conducted with USFWS regarding potential interactions with polar bears and Pacific walruses during the seismic survey. The consultation included information regarding the mitigation measures to be employed for marine mammals under the jurisdiction of NMFS. The USFWS concluded that the marine mammal protection measures described for the cruise were appropriate safeguards for polar bears and Pacific walruses. As precautionary measures, the use of the 190 dB sound level safety criterion was used for polar bears and the 180 dB sound level safety criterion was applied for single walruses and small groups of walruses.

Data describing environmental conditions, seismic activity, vessel location, and time were recorded every half hour. For each marine mammal sighting, species identification, mammal's distance to the guns and the mammal's behavior were recorded in addition to the afore-mentioned data.

During the *Healy* 0503 cruise, seismic operations were conducted for approximately 288 hours. MMOs were on watch during all seismic operations and also during non-seismic periods. Marine mammal observations were conducted for a total of 661 hours from the beginning of the seismic survey (10 August) to its conclusion (26 September). During seismic operations, the MMOs observed a total of 65 marine mammals that included 5 bearded seals, 6 polar bears, 31 ringed seals, 2 spotted seals and 21 unidentified seals (Table 1).

MMOs also listened for marine mammal calls by monitoring the acoustic output of sonobuoys deployed periodically during seismic operations. No marine mammal vocalizations were heard during 90.7 hours of listening.

Power downs were called for on three occasions when seals entered the 190 dB sound radius around the operating airguns. The power downs were implemented 12, 17 and 19 August for a ringed seal, a bearded seal and a ringed seal, respectively.

Table 1. Marine mammals observed during seismic operations during the *Healy* 0503 trans-Arctic Ocean cruise.

	Species/Number					
Date 2005	BS	PB	RS	SS	US	Total
10-Aug		1	1			2
12-Aug			2		1	3
14-Aug	1		1			2
16-Aug			1		2	3
17-Aug	1		1			2
18-Aug	1		3		2	6
19-Aug		4	6		3	13
20-Aug					7	7
21-Aug			2		1	3
22-Aug			3		4	7
23-Aug			1			1
29-Aug			1			1
1-Sep	1					1
2-Sep	1		1			2
5-Sep			2		1	3
8-Sep			5	1		6
10-Sep			1	1		2
26-Sep		1				
Total	5	6	31	2	21	65

BS = bearded seal
PB = polar bear
RS = ringed seal
SS = spotted seal
US = unidentified seal

A detailed report was submitted to NMFS early in 2006. The report includes descriptions of the marine mammals observed, the conditions under which they were observed and estimates of how many were likely to have been exposed to different sound levels. Standard survey correction factors for sighting probability and animal occurrence along the track-line were factored into the estimates. The report is available through NMFS or LGL Alaska Research Associates, Inc. (at <alaska@lgl.com>

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Appendix A – Healy 05-03 Cruise Participants

Tore Arthun
University of Bergen
G&G Watchstander
47-92814766
tore.arthun@student.uib.no

Hans Berge
University of Bergen
Mechanical Engineer-MCS System
47-91568656
hkberge@tiscali.no

Glenn Berger
Desert Research Institute
Scientist/Project PI
775-673-7354
glenn.berger@dri.edu

Garry Brass
USARC Executive Director
G&G Watchstander
703-525-0111
g.brass@arctic.gov

Hedda Breien
Oslo University
Journalist/G&G Watchstander
47-95244457
heddabr@student.matnat.uio.no

Vibeke Bruvoll
University of Bergen
G&G Watchstander
47-97719221
vibeke.bruvoll@student.uib.no

Bernard Coakley
University of Alaska
co-chief; Underway Geophysics
907-474-5385
Bernard.Coakley@gi.alaska.edu

Dennis A.Darby
Old Dominion University
co-chief; Coring and sedimentology
757-683-4701
ddarby@odu.edu

Dayton Dove
University of Alaska
G&G Watchstander
907-451-0715
fsdwd1@uaf.edu

Bruce Elder
US Army Cold Regions Research Lab
Ice Program
603-646-4637
bruce.c.elder@erdc.usace.army.mil

Björn Eriksson
Stockholm University
Core Logging Technician
46-8-164718
bjorn.eriksson@geo.su.se

Ruben Fritzon
Vibackeskolan
SPRS Education Outreach
46 60585158
ruben.fritzon@skola.sundsvall.se

Howie Goldstein
Lamont-Doherty Earth Observatory
Marine Mammal Observer #2
301-384-1024
howieg12@hotmail.com

Tom Grenfell
University of Washington
Ice Program
206-543-9411
tcg@atmos.washington.edu

Erik Grindheim
University of Bergen, Norway
Electronics Engineer - MCS
47 95206333
erik@grindheim.net

Eva Grönlund
Swedish Polar Research Secretariat
SPRS Liaison
46 8 673 97 30
eva.gronlund@polar.se

Beth Haley
LGL Ltd
Lead Mammal Observer #1
907-562-3339
bhaley@lgl.com

Will Handley
Lamont-Doherty Earth Observatory
Underway Data Acquisition Tech Support
44-01452 812313
Handleys@compuserve.com

Jeremy Harbeck
University of Washington
Ice Program
425-359-3850
jharbeck@u.washington.edu

David Hassilev
USCG, ESU, Seattle
Science Data Network Administrator
206-217-6592
David.M.Hassilev@uscg.mil

Paul Henkart
Scripps Institute of Oceanography
Realtime MCS Processing
858-534-3487
phenkart@ucsd.edu

John Hopper
Texas A&M University
underway MCS Processing/PI
979-845-0119
hopper@geo.tamu.edu

Dale Hubbard
Oregon State
Coring Technician
541-737-9269
dhubbard@coas.oregonstate.edu

Nina Ivanova
Uppsula University
G&G Watchstander
46-018-4713781
Nina.Ivanova@geo.uu.se

Martin Jakobsson
Stockholm University
Scientist/Project PI
46-816-4719
martin.jakobsson@geo.su.se

Ute Kaden
Homer Hanna High School
TREC Teacher
956-548-7600
Ukaden@aol.com

Takashi Kikuchi
JAMSTEC
Scientist/Project PI
Ice Drift Buoy Program
takashik@jamstec.go.jp

Yngve Kristoffersen
University of Bergen
Scientist/Project PI
47 97318446
Yngve.Kristoffersen@geo.uib.no

Åsa Lövenvald
Swedish Public Radio
Journalist
asa.maria@chello.se

Reidar Lövlie
University of Bergen
Paleomagnetist
47 55 58 3406
reidar.lovlie@geo.uib.no

Fredrik Ludvigsen
Thor Heyerdahl High School, Larvik, Norway
Student/G&G Watchstander
47-98083330
fludvigsen@gmail.com

Karina Monsen
Alta High School, Alta, Norway
Student/G&G Watchstander
47-41314033
karinamonsen@hotmail.com

Jimmy Olemaun
Barrow Arctic Science Consortium
Mammal Observer #4
907-852-5432
jjolemaun@hotmail.com

Don Perovich
US Army Cold Regions Research Lab
Scientist/Ice Program (PI)
603-646-4255
donald.k.perovich@erdc.usace.army.mil

Leonid Polyak
Ohio State University
Scientist/Project PI
614-292-2602
polyak.1@osu.edu

John Rand
Old Dominion University
Grad Student, Sedimentology
757-683-5978
jrand@odu.edu

Walter Reynoso-Peralta
Argentinian Navy/ University New Hampshire
underway multi-beam processing
603-862-3433
wreyper@ccom.unh.edu

Steve Roberts
Lamont-Doherty Earth Observatory
Underway Data Acquisition Technical Support
303-497-2637
sroberts@ucar.edu

Alejandro Sayegh
Lamont-Doherty Earth Observatory
Marine Mammal Observer #3
(58) 295.262.97.52
asayegh@cicvenezuela.com

Emma Sellén
Stockholm University
Grad Student, Stratigraphy
46-708-492052
emma.sellen@geo.su.se

Sandrine Solignac
Universite du Quebec a Montreal
Grad Student, CTD and water sampling
514-987-3000 ext. 1581
sandrinesolignac@yahoo.com

Gene Swope
National Ice Center
Ice Planning
301-394-3038
gswope@natice.noaa.gov

Kazu Tateyama
Hokkaido University
Scientist/Project PI: EM Ice Thickness Profiler
(0157) 26-9466
tateyaka@mail.kitami-it.ac.jp

Germain Tremblay
Canadian Ice Observer
Ice Navigation
418-681-3337
TremblayG@dfo-mpo.gc.ca

Hirokatsu Uno
JAMSTEC
Ice Drift Buoy Program
uno@mwj.co.jp

Åsa Wallin
Stockholm University
Core Logging Technician
46-816-4736
asaw@geo.su.se

Doug White
Hawai'i Mapping Research Group
underway multi-beam processing
808-956-8711
dwhite@soest.hawaii.edu

Paula Zimmerman
Old Dominion University
Grad Student, Paleoclimate
57-683-5978
PZimmerm@odu.edu

Appendix B – MCS Lines

MCS Line Log: HEALY/0503

Shot Interval	Group Interval	Dist Near Ch.	Channels	Samp. Rate
20 sec	12.5 meters	-90 meters	24	1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
01	222	03:45	74 09.388 N	160 37.303 W	386	402	8.196	715	30.107
	222	07:46	74 24.206 N	160 13.286 W	1101	1117			

Comments: 402.sgy is the only file with good data. Three other segy files in Geometrics (1163.sgy, 1265.sgy, 1313.sgy) are garbage files. Log files named "HOTRAX003.xxxx.log".

Missing Shots, Duplicate Files:

Sonobuoys: S001

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
02	222	09:28	74 26.489 N	160 07.860 W	1403	1320	8.196	312	14.388
	222	11:13	74 32.410 N	159 49.257 W	1715	1632			

Comments: Prior to the start listed here, there is an additional segy file in the field data (1313.sgy) with 4 good shots that could be prepended to the line. (Shots 1369,1375-1377;Files1313-1316). Sonobuoy for this line was recorded with an 8 second record length until shot point 1598, after which the record length was increased to 16 seconds.

Missing Shots, Duplicate Files:

Sonobuoys: S002

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
03	222	17:13	74 30.589 N	159 49.433 W	2784	1649	8.196	723	29.236
	222	21:16	74 44.239 N	159 20.070 W	3507	2372			

Comments:

Missing Shots, Duplicate Files:

Sonobuoys: S003

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
04	223	00:40	74 51.302 N	159 04.201 W	4113	2406	8.196	3139	135.874
	223	18:18	76 02.267 N	157 55.492 W	7252	5533			

Comments:

Missing Shots, Duplicate Files: 4413, 4796 - 4797, 4827 - 4829, 4832, 4834, 4929, 5632 - 5633. Duplicate FFID: 3933

Sonobuoys: S004, S005, S006, S007, S008, S009

MCS Line Log: HEALY/0503

Shot Interval 20 sec **Group Interval** 12.5 meters **Dist Near Ch.** -90 meters **Channels** 24 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
05	223	20:53	76 04.769 N	157 51.078 W	7713	5535	8.196	1888	79.360
	224	07:29	76 45.930 N	157 03.423 W	9601	7417			

Comments: There are several shots appended to the last field segy file that appear to belong to the next line. Shots 9959-9963 (Files 7418 - 7422) are time stamped 09:29:45 - 09:31:05, after gun work at end of line. Start of line 06 is about 09:31.

Missing Shots, Duplicate Files: 9313-9316, 9324, 9461

Sonobuoys: S010, S011, S012

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
06	224	09:31	76 48.643 N	157 03.836 W	9965	7423	8.196	1047	43.743
	224	15:24	77 12.153 N	157 04.135 W	11012	8439			

Comments:

Missing Shots, Duplicate Files: 10021-10044, 10151, 10673, 10764, 10766. Duplicate FFID: 8103

Sonobuoys: S013

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
07	225	01:53	77 13.687 N	156 57.407 W	12272	8447	8.196	1466	57.641
	225	10:07	77 13.692 N	154 37.320 W	13738	9902			

Comments: Start of original first log file is garbage. First 7 shots in the file (Files 8440-8446, presumably Shots 12265 - 12271) appear to be good shots, but there is no navigation in the log file for them. They were excluded in subsequent processing, but it would be simple to guess the navigation and use them.

Missing Shots, Duplicate Files: 12330-12335, 13580. Duplicate FFID: 9745

Sonobuoys: S014, S015

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
08	225	11:35	77 13.743 N	154 30.877 W	14000	9905	8.196	350	14.624
	225	13:33	77 13.710 N	153 55.335 W	14350	10228			

Comments:

Missing Shots, Duplicate Files: 14011-14037

Sonobuoys: S016, S017

MCS Line Log: HEALY/0503

Shot Interval 20 sec **Group Interval** 12.5meters **Dist Near Ch.** -90 meters **Channels** 24 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
05	225	14:48	77 13.821 N	153 48.227 W	14575	10231	8.196	241	10.630
	225	16:10	77 13.700 N	153 22.395 W	14816	10472			

Comments:

Missing Shots, Duplicate Files:

Sonobuoys: S018

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
10	225	17:46	77 13.900 N	153 15.665 W	15101	10473	8.196	52	2.271
	225	18:03	77 13.846 N	153 10.149 W	15153	10525			

Comments: Line 10 aborted because of gun problems. Geometrics system contains an additional SEG-Y file with two additional shots that was not copied.

Missing Shots, Duplicate Files:

Sonobuoys: S018

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
11	226	11:53	78 04.053 N	151 18.779 W	18330	10619	12.0	1495	55.133
	226	20:17	78 11.883 N	153 37.697 W	19825	12107			

Comments: First SEG-Y file - shots 18028 to 18366 were recorded to 8.196 seconds. 18369 to end of line recorded to 12 seconds. The data in the first file are mostly unusable. First shot with a seafloor reflection visible through the noise is 18330 and was chosen as SOL here. More shots may need to be edited out.

Missing Shots, Duplicate Files: 18367-18368, 19078-19082

Sonobuoys: S019, S020, S021

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
12	227	01:55	78 09.741 N	154 38.596 W	20831	12115	12.0	730	27.403
	227	06:32	78 02.986 N	155 42.072 W	21561	12935			

Comments: Lots of ice. Got stuck once and many bad shots/traces to be edited. Trace 24 went bad ~day 227/06:00 UTC. No seabeam centerbeam depth from shot 20950 (227/02:36) to shot 21086 (227/03:21).

Missing Shots, Duplicate Files:

Sonobuoys: S022, S023

MCS Line Log: HEALY/0503

Shot Interval 20 sec **Group Interval** 12.5meters **Dist Near Ch.** -90 meters **Channels** 24 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
13	227	08:26	78 02.964 N	156 03.569 W	21991	12936	12.0	2255	85.410
	227	21:06	78 07.822 N	159 44.669 W	24246	15175			

Comments: Channel 24 bad. No seabeam centerbeam depth from shot 22657 (227/12:11) to shot 22710 (227/12:28).

Missing Shots, Duplicate Files: 22085, 23339, 23431-23442, 24060-24061

Sonobuoys: S024, S025, S026, S027

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
14	227	22:17	78 08.479 N	159 50.823 W	24458	15179	12.0	1856	71.019
	228	08:42	78 26.390 N	162 36.842 W	26314	17035			

Comments:

Missing Shots, Duplicate Files:

Sonobuoys: S028, S029

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
15	228	17:10	78 16.107 N	163 31.623 W	27821	17037	12.0	1553	55.339
	229	01:53	78 16.504 N	165 57.875 W	29374	18238			

Comments: Gun problems ended the line. Low pressure in last shots.

Missing Shots, Duplicate Files: 28512-28861, 29328. Duplicate FFID: 18193

Sonobuoys: S030, S031

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
16	229	03:25	78 16.528 N	166 15.692 W	29649	18240	12.0	1253	52.589
	229	10:30	78 16.848 N	168 34.756 W	30902	19492			

Comments:

Missing Shots, Duplicate Files: Duplicate FFID: 19264

Sonobuoys: S032, S033

MCS Line Log: HEALY/0503

Shot Interval 20 sec **Group Interval** 12.5 meters **Dist Near Ch.** -90 meters **Channels** 24 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
17	229	11:30	78 16.715 N	168 41.503 W	31088	19500	12.0	2552	105.623
	230	01:54	78 17.541 N	173 20.966 W	33640	22049			

Comments: Last hour or so of line marked by repeated missed shot triggers due to network problem. Line terminated after gun compressors automatically shut down after not firing for several minutes. Expect data gaps at EOL.

Missing Shots, Duplicate Files: 33026. Duplicate FFIDs: 20819, 21436

Sonobuoys: S034, S035, S036, S037, S038

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
18	230	03:07	78 17.570 N	173 42.910 W	33817	22050	12.0	1785	77.407
	230	13:08	78 16.927 N	177 07.749 W	35602	23834			

Comments:

Missing Shots, Duplicate Files: 34776

Sonobuoys: S039, S040, S041

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
19	230	20:07	78 00.630 N	176 53.409 W	36845	23842	12.0	919	42.783
	231	01:17	78 23.605 N	176 49.067 W	37764	24744			

Comments:

Missing Shots, Duplicate Files: 36846 - 36862

Sonobuoys: S042, S043

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
20a	231	13:41	78 18.005 N	177 01.722 W	39973	24746	12.0	917	38.910
	231	18:50	78 22.528 N	178 42.691 W	40890	25625			

Comments: Note that this line contains a major dog-leg and therefore has been split in two for this line log.

Missing Shots, Duplicate Files: 40112 - 40138, 40142 - 40152

Sonobuoys: S044, S045, S046, S047, S048

MCS Line Log: HEALY/0503

Shot Interval 20 sec **Group Interval** 12.5meters **Dist Near Ch.** -90 meters **Channels** 24 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
20b	231	18:50	78 22.537 N	178 42.817 W	40891	25626	12.0	2376	105.610
	232	08:10	79 03.115 N	175 20.123 W	43267	28001			

Comments: Guns pulled for maintenance. Note that this line contains a major dog-leg and therefore has been split in two for this line log.

Missing Shots, Duplicate Files: 41288

Sonobuoys: S044, S045, S046, S047, S048

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
21	232	09:13	79 03.804 N	175 17.509 W	43455	28005	12.0	564	26.117
	232	12:23	79 13.827 N	174 25.346 W	44019	28568			

Comments:

Missing Shots, Duplicate Files: 43937

Sonobuoys: S049

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
22	232	12:58	79 14.819 N	174 20.445 W	44121	28570	12.0	1346	61.570
	232	20:31	79 38.741 N	172 15.680 W	45467	29916			

Comments:

Missing Shots, Duplicate Files:

Sonobuoys: S050, S051

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
23	233	11:30	79 36.303 N	172 23.926 W	48135	30002	16.0	1073	48.174
	233	17:31	79 53.646 N	170 35.951 W	49208	31072			

Comments: Shot 48604, File 30470 14:07:55 -- Record length increased to 16 seconds and channel 24 is now recording sonobuoys. Duplicate FFID: 30912 for shot 49046 and 49048 - 49047 is missing. Bad GPS navigation in logfiles for shots 48156,48157,48537,48538,48539. Positions were interpolated for geometry assignment.

Missing Shots, Duplicate Files: 48603, 49047. Duplicate FFID: 30912

Sonobuoys: S052, S053

MCS Line Log: HEALY/0503

Shot Interval	Group Interval	Dist Near Ch.	Channels	Samp. Rate
20 sec	12.5meters	-90 meters	24	1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
24a	233	19:49	79 55.808 N	170 21.965 W	49617	31074	16.0	114	4.855
	233	20:27	79 57.470 N	170 10.450 W	49731	31188			

Comments: Two turns occur during this line. Line broken up into 24a, 24b, and 24c for the Line Log.

Missing Shots, Duplicate Files:

Sonobuoys: S054

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
24b	233	20:27	79 57.495 N	170 10.402 W	49732	31189	16.0	1577	72.935
	234	05:18	80 05.892 N	173 51.428 W	51309	32766			

Comments: See previous notes.

Missing Shots, Duplicate Files:

Sonobuoys: S054, S055, S056

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
24c	234	05:18	80 05.912 N	173 51.511 W	51310	32767	16.0	493	22.554
	234	08:04	80 16.856 N	174 22.062 W	51803	33258			

Comments: The last field segy file has 2 shots that appear to belong to line 25 (based on shot point numbers). At some point, channel 1 appears to have gone bad.

Missing Shots, Duplicate Files: 51316. Duplicate FFID: 32772

Sonobuoys: S056

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
25	234	08:44	80 18.326 N	174 25.630 W	51920	33262	16.0	1511	67.000
	234	17:13	80 50.346 N	176 06.077 W	53431	34771			

Comments: Start of line looks odd - spectra from Geometrics looks like red noise. Occassional spikes in random channels. At about file number 33490, the drum was turned a bit - spikes seem to be less of a problem.

Missing Shots, Duplicate Files: 52438. Duplicate FFID: 33779

Sonobuoys: S057, S058, S059

MCS Line Log: HEALY/0503

Shot Interval 20 sec **Group Interval** 12.5meters **Dist Near Ch.** -90 meters **Channels** 24 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
26	235	09:42	81 14.662 N	177 11.272 W	54929	35204	16.0	1462	62.041
	235	17:54	81 47.385 N	177 54.374 W	56391	36574			

Comments: Heavy ice and many ice related problems beginning around 11:30 UTC. Channels 11 and 14 are now bad - almost no signal, just 60 hz noise. Both started around File number 35558 at 11:43. Channel 4 is extremely weak - this may have started during line 25 or 24.

Missing Shots, Duplicate Files: 54966, 54974, 55166, 55254, 55289, 55381, 55384, 55418, 55434-55435, 55442-55443, 55447-55448, 55452, 55479, 55498-55499, 55530, 55547, 55572, 55579, 55586, 55595, 55599, 55613, 55655, 55670, 55739, 55854, 55887, 55893, 55905-55906, 55908, 55911-55945, 56064, 56092, 56121, 56144, 56151-56152, 56191, 56236, 56244, 56250-56254, 56327, 56337-56338, 56348, 56350-56351, 56368, 56378

Sonobuoys: S060, S061, S062

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
27	236	08:10	82 38.311 N	179 09.967 W	58932	36578	16.0	292	7.337
	236	09:48	82 42.188 N	179 15.552 W	59224	36830			

Comments: Streamer getting battered. Many missing shots when gun array powered down while ship stuck in ice. Single trace plots reveal that channels 1, 2, 9, 11, 14, 15, 19, 22, 24 are essentially dead. Very weak signal on Channels 3, 4, 5, 6 and 17. Channels 7, 8, 9, 10, 12, 13, 16, 18, 20, 21, and 23 appear OK.

Missing Shots, Duplicate Files: 58975, 58990, 58994, 58997, 59005-59008, 59015-59030, 59040-59054, 59213

Sonobuoys: S063

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
28	236	11:21	82 43.151 N	179 14.731 W	59498	36832	16.0	80	3.093
	236	11:48	82 44.671 N	179 20.040 W	59578	36908			

Comments: Line aborted when streamer got stuck in ice during a back and ram. Streamer eventually lost.

Missing Shots, Duplicate Files: 59513, 59543, 59552, 59562

Sonobuoys: None

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
29	239	03:02	83 24.362 N	172 19.102 W	70844	37358	16.0	134	4.744
	239	03:47	83 26.876 N	172 22.766 W	70978	37436			

Comments: Deployed 2 sections (16 channels, 200 meters) with no leadin section, first channel is ~ 10 meters behind guns. Only one gun was operational. Ship again stuck in ice and had to back and ram with streamer out, which again got caught on ice and was stuck. Eventually brought back on board through repeated backwards ramming while reeling streamer in.

Missing Shots, Duplicate Files: 70846, 70869-70916, 70939, 70942-70943, 70953, 70963, 70966, 70971

Sonobuoys: None

MCS Line Log: HEALY/0503

Shot Interval 20 sec **Group Interval** 12.5 meters **Dist Near Ch.** -90 meters **Channels** 16 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
30	240	23:23	84 14.102 N	157 24.790 W	78745	37437	16.0	501	18.603
	241	02:12	84 10.424 N	155 52.769 W	79246	37914			

Comments:

Missing Shots, Duplicate Files: 78893, 78919, 79024, 79074, 79079-79080, 79092, 79096, 79110-79115, 79122, 79139, 79150, 79173, 79223, 79226, 79230-79233

Sonobuoys: S064

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
31	244	21:05	84 31.086 N	153 05.997 W	95437	43413	16.0	1355	54.023
	245	04:41	84 59.318 N	154 19.585 W	96792	44750			

Comments: Channels 1-8 (section 1) are OK. Channels 9-12 (2nd section) are spikey.

Missing Shots, Duplicate Files: 96001, 96010-96025, 96056

Sonobuoys: S065, S066, S067

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
32	245	14:00	85 14.674 N	155 03.850 W	98451	44770	16.0	2737	98.995
	246	05:22	85 57.757 N	161 50.591 W	101188	47505			

Comments: Leak in the main line for most of the day - down by ~ 250-500 PSI. First segy file has several shots from earlier noise testing.

Missing Shots, Duplicate Files: 100601. Duplicate FFID: 46189

Sonobuoys: S068, S069, S070, S071, S072

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
33	246	10:26	86 00.320 N	162 22.875 W	102089	47507	16.0	485	17.988
	246	13:09	86 06.099 N	164 15.403 W	102574	47988			

Comments: Last apparent good shot is 102574, last shot in field records is 102610.

Missing Shots, Duplicate Files: 102523, 102544-102545, 102548

Sonobuoys: S073

MCS Line Log: HEALY/0503

Shot Interval 20 sec **Group Interval** 12.5 meters **Dist Near Ch.** -90 meters **Channels** 16 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
34	246	14:06	86 04.090 N	165 08.480 W	102744	48017	16.0	808	35.452
	246	18:39	85 58.812 N	169 32.396 W	103552	48825			

Comments: 16 channels. 4, 8 & 12 weak, 9, 10, 13, 14, 16 appear to be bad.

Missing Shots, Duplicate Files:

Sonobuoys: S074

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
35	247	14:39	86 28.225 N	170 02.357 E	107116	48827	16.0	295	12.620
	247	16:18	86 29.605 N	171 50.520 E	107411	49122			

Comments: On far sections, only channels 11, 12, and 15 are OK.

Missing Shots, Duplicate Files:

Sonobuoys: S075

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
36	248	09:18	86 37.873 N	168 46.437 E	110438	49144	16.0	438	20.103
	248	11:45	86 36.388 N	165 45.072 E	110876	49582			

Comments: Channels 11, 12, 15 are very weak. Channel 16 weak enough to be essentially unusable.
Channels 13, 14 are dead.

Missing Shots, Duplicate Files:

Sonobuoys: S076

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
37	248	11:59	86 36.269 N	165 27.096 E	111001	49591	16.0	2028	60.464
	249	00:24	86 45.590 N	156 29.478 E	113029	51497			

Comments: New line started while Yngve fiddled with gun pressure and firing rate to get more energy and better signal penetration. There may be problems with duplicate shot numbers at the start of the line - initial sort should be based on the file numbers listed here to eliminate the first couple of shots. One segyfile containing two shots was not copied during the gun fiddling. Bad channels: 4. 6. 7. 12. 14, 15, 16. Streamer out (helo operations) ~ ffid 50600.

Missing Shots, Duplicate Files: 111312, 111966-112084, 112618-112619

Sonobuoys: S077, S078, S079, S080, S081, S082

MCS Line Log: HEALY/0503

Shot Interval	Group Interval	Dist Near Ch.	Channels	Samp. Rate
22 sec	12.5 meters	-90 meters	16	1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
38	251	11:36	88 17.849 N	155 15.010 E	122692	51516	16.0	1044	20.860
	251	18:00	88 29.011 N	154 39.640 E	123736	52432			

Comments: Heavy ice around 14:45. Channels 5, 7,8 are dead, 4 & 12 are suspect, 16 is very low. Best channels appear to be 1, 2, 3, 5, 6, 9, 10, 11, 13, 14, 15.

Missing Shots, Duplicate Files: 122722-122845, 123315-123318

Sonobuoys: S083, S084

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
39	251	18:01	88 29.082 N	154 40.352 E	123739	52433	16	512	20.205
	251	21:09	88 27.716 N	147 56.194 E	124251	52944			

Comments:

Missing Shots, Duplicate Files: 124023

Sonobuoys: S085

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
40	252	08:54	88 18.471 N	146 48.412 E	126169	52962	16.0	438	13.139
	252	11:35	88 25.526 N	146 55.921 E	126607	53399			

Comments: Channels 4-8,12, and possibly 16 appear to be bad. First shot, FFID 52961 is a dummy shot.

Missing Shots, Duplicate Files:

Sonobuoys: S086

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
41	252	20:35	88 23.618 N	149 04.806 E	128077	53408	16.0	1698	68.365
	253	06:59	88 43.254 N	169 37.439 E	129775	54985			

Comments: Air-hose burst at FFID 53407. 53408 & 53409 are test shots. Shutdown and data gap at 53471. Channels 1-3, 9,10, 14 are good. 16 is weak, but may usable.

Missing Shots, Duplicate Files: 128081, 128083-128086, 128097, 128138, 128148-128259, 128393, 128443

Sonobuoys: S087, S088, S089, S090

MCS Line Log: HEALY/0503

Shot Interval	Group Interval	Dist Near Ch.	Channels	Samp. Rate
22 sec	12.5 meters	-90 meters	16	1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
42	253	12:13	88 41.742 N	169 17.943 E	130630	54988	16.0	447	15.936
	253	14:58	88 46.636 N	163 59.417 E	131077	55435			

Comments:

Missing Shots, Duplicate Files:

Sonobuoys: S091

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
43	253	21:56	88 47.851 N	163 02.985 E	132215	55437	16	1040	34.497
	254	04:18	88 56.545 N	176 52.809 E	133255	56112			

Comments: Channels 1,2,3,6,9,10 good. jqc_plot shows low applitudes due to hose leak. ~ 1 hour data gap from FFID 55564 to FFID 55565. 55565 starts low due to seals in the area. Channels 1, 2, 3, 9, 10 are good after restarting; 4 & 6 are intermitant; 12 comes and goes.

Missing Shots, Duplicate Files: 132280-132460, 132524-132681, 132967, 132969-132970, 133174-133175, 133177-133179, 133181, 133185-133187, 133191, 133193, 133210-133221

Sonobuoys: S092, S093

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
44	254	06:14	88 58.122 N	178 39.108 E	133569	56119	16.0	789	12.271
	254	11:03	89 04.685 N	178 03.068 W	134358	56802			

Comments: First 30 shots, only one gun firing (FFID 56119 - 56150, Shots 133569 - 133600). Pulled and 40 minute data gap to next shot (133709). Distance above not correct because of date line crossing ...

Missing Shots, Duplicate Files: 133604-133708, 134182

Sonobuoys: S094

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
45	256	06:45	89 48.561 N	083 24.614 E	141489	56841	16	69	3.476
	256	07:10	89 46.961 N	087 54.943 E	141558	56910			

Comments: Only channels 1, 2, 3, 6, and 10 are OK; the rest are dead. Line terminated because of heavy ice ahead.

Missing Shots, Duplicate Files:

Sonobuoys: S095

MCS Line Log: HEALY/0503

Shot Interval 22 sec **Group Interval** 12.5 meters **Dist Near Ch.** -90 meters **Channels** 16 **Samp. Rate** 1.0 msec

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
46	256	10:31	89 39.724 N	088 01.733 E	142106	56915	16.0	121	5.941
	256	11:16	89 36.597 N	089 42.035 E	142227	57035			

Comments: Channels 2, 3, 6, 10, and 12 are OK, the rest are dead. Channel 1 slowly faded during this line.

Missing Shots, Duplicate Files: 142116

Sonobuoys: S096

Line	Julian Day	Time	Latitude	Longitude	Shot	File	Seconds Recorded	Shots Fired	Distance (km)
47	269	10:14	80 28.161 N	007 38.088 E	188606	57045	16	553	7.853
	269	13:38	80 28.776 N	007 12.866 E	189159	57240			

Comments: Streamer lost - probably during deployment. Shutdown from 10:55:31 to 12:37:23 while new streamer section with only 8 channels was attached to the winch and deployed. Heavy ice and very noisy data. After 1 hour decided to give up.

Missing Shots, Duplicate Files: 188718-188993, 189011-189088, 189095, 189130, 189137, 189147

Sonobuoys: S097

Appendix C – SIOSEIS Scripts

Realtime Copy Script:

```
#!/bin/csh -f

if ($#argv != 1) then
  echo "Please specify a line number."
  exit
endif
set LINE=$1
# The Bergen laptop for MCS recording has an IP address of 192.168.10.86
# Below, it is assumed that the OS X Finder is used to connect to the laptop
# using samba.  The SEG-Y data directory for the line should be mounted first.
# Otherwise the syntax below should be IPaddress-n where n is number assigned
# by samba according to the order that folders were mounted.  When the SEG-Y
# file stops update, SIOSEIS will print a message to the screen asking if it
# keep trying or ^C to kill the copy script.

set FILE = `ls -t /Volumes/192.168.10.86 | head -n 1` # the current SEG-Y file
if (! -e /Users/seismic/Data/MCS/Raw/shots/Healy05$LINE) then
   echo "Creating Directory for line Healy05"$LINE
   mkdir /Users/seismic/Data/MCS/Raw/shots/Healy05$LINE
endif

# diskoa simply copies the SEG-Y file (with an ibm to ieee conversion)
# diskob is the latest shot file with a filter and amplitude normalization
# diskoc is the latest shot with no processing
# prout is a screen echo to see that something is happening

sioseis << eof
realtime procs diskin diskoa diskoc filter avenor diskob prout end
diskin
   ipath /Volumes/192.168.10.86/$FILE end
end
diskoa
    opath /Users/seismic/Data/MCS/Raw/shots/Healy05$LINE/$FILE end
end
diskob
    fno 1 lno 999999 noinc 2 rewind yes
    opath /Users/seismic/Data/MCS/Raw/latest_shot end
end
diskoc
    fno 1 lno 999999 noinc 15 rewind yes
    opath /Users/seismic/Data/MCS/Raw/latest_shot-raw end
end
avenor
   sets 3 6 end
end
filter
   ftype 0 pass 10 100 dbdrop 48 end
end
prout
    fno 1 lno 99999 ftr 1 ltr 1 end
end
end
```

```
eof
```

QC monitoring: latest shot (3 scripts)

Plot script:

```
#!/bin/csh
if ($# != 1) then
  echo "usage: qc_plot n-channels"
  exit
endif

# NCH should be the number of active channels in the streamer usually 16 or 24
# The shot is filtered, amplitude normalized, and plotted to a sun raster file
set NCH=$1

sioseis << eof
noecho procs diskin prout filter avenor plot end
diskin
   ftr 1 ltr $NCH
   ipath /Users/seismic/Data/MCS/Raw/latest_shot end
end
prout
    fno 0 lno 9999999 ftr 1 ltr 1 end
end
weight
    twp 24 .2 fno 0 lno 999999 end
end
avenor
   sets 3 6 end
end
filter
   ftype 0 pass 10 100 dbdrop 48 end
end
plot
   nsecs 12 dir ltr
   scalar 3.E-07
   nibs 2859 srpath ../shot.ras
   ann sh&tr taginc 2 ann2 gmt
   vscale 1.0 def .1 trpin 15
   end
end
end
eof

# grab the FFID of the shot for putting on the display
set SHOT=`lsd /Users/seismic/Data/MCS/Raw/latest_shot | tail -1 | awk '{print $1}'`
echo $SHOT"  "$NCH > ../shot.info

# uncomment one, according to personal display preferences
#open -a /Applications/GraphicConverter/GraphicConverter.app ../shot.ras
#display -rotate 90 -resize 50% ../shot.ras
```

Loop that runs script above and prevents displays from grabbing incomplete raster files:

```
#!/bin/csh

set i=0
while ($i < 10)
   touch shot.lock  # prevent display for trying to show an incomplete raster
```

```
   jqc_plot 16   # change to 24 for 3 streamer sections
   rm shot.lock
   sleep 44  # wait around before plotting another shot- should be twice the shot rate
end
```

Display script for the raster file generated above:

```
#!/bin/csh

# This is a loop that generates a display from the raster file produced in the first
script.
# It is intended to be run on multiple or remote displays (e.g. the Bergen laptops
# ran this script after ssh logging in to the iMac.)


set dpid=999999  # set this to a pid that can't possibly exist
set i=0
while ($i <= 1)
    # make sure there is something to plot
  if (!(-e /Users/seismic/Data/MCS/Plots/shot.ras)) then
    echo "There is no raster file to plot."
    exit
  endif
   # make sure the raster file isn't currently being re-generated
  while (-e /Users/seismic/Data/MCS/Plots/shot/shot.lock)
     sleep 5  # wait a bit, try again
  end
  cp /Users/seismic/Data/MCS/Plots/shot.ras /tmp/shot.ras # make a tmp copy just in
case
  set ftime=`stat -f "%m" /Users/seismic/Data/MCS/Plots/shot.ras` # get a time stamp
  set nochange=$ftime
    # find out what shot (FFID) was plotted
  set SHOT=`awk '{print $1}' /Users/seismic/Data/MCS/Plots/shot.info`
  echo "Displaying shot "$SHOT"
    # convert the raster to a rotated and smaller version of itself
  convert -rotate -90 -resize 50% /tmp/shot.ras /tmp/shot2.ras
    # if there is already another display running, kill it
    # but also make sure there is a display (dpid is a valid process),
    # otherwise the kill will fail and force the script to exit
  if (`ps -p $dpid | wc -l` != 1) then
     kill -9 $dpid
  endif
    # display the rotated, small version
  display -title "Shot ${SHOT}" -geometry 300x712+0+0! /tmp/shot2.ras &
  set dpid = $!  # the pid of the display above
    # wait around until it looks like a new raster file has appeared.
  while ($ftime == $nochange)
     sleep 20
     set nochange=`stat -f "%m" /Users/seismic/Data/MCS/Plots/shot.ras`
  end
end
exit  # of course, you'll never get here.  ^C to kill the script
```

QC monitoring - near trace or single channel plots (3 scripts)

These scripts are essentially the same as above. The only documentation provided is for parts that different from the latest shot plotting.

Plot script:

```
#!/bin/csh

if($#argv < 2) then
   echo "usage: pltntr LINENO TRNO"
   exit 1
endif

set LINE=$1
set TRNO = $2
set SEGY=`ls -rt /Users/seismic/Data/MCS/Raw/shots/Healy05$LINE/*.sgy`

# figure out what the last 500 shots are and only plot them
set LSGY=`ls -rt /Users/seismic/Data/MCS/Raw/shots/Healy05$LINE/*.sgy | tail -1`
set LSHOT=`lsd $LSGY | tail -2 | awk '(NR ==1) {print $1}'`
set FSHOT=`expr $LSHOT - 500`
rm sfiles
foreach i($SEGY)
   echo "fno "$FSHOT" lno "$LSHOT >> sfiles
   echo "ipath "$i" end" >> sfiles
end

echo $FSHOT"  "$LSHOT"  "$TRNO > ../near.info

sioseis << eof
procs diskin prout filter agc plot end
diskin
  ftr $TRNO ltr $TRNO
    `cat sfiles`
end
agc
    winlen .5 end
end
weight
   twp 1 0 24 0 end
end
gains
   type 3 alpha 1  end
end
filter
   ftype 0 pass 10 80 dbdrop 48 end
end
prout
   fno 0 lno 999999 ftr $TRNO ltr $TRNO noinc 100 end
end
plot
   scalar 1.e-07  dir ltr
   stime 0.0 nsecs 12 wiggle 0
    ann shotno taginc 15  ann2 gmt
    nibs 2859 vscale 1.5 tlines 0.5
    def .01  trpin 150
    srpath ../near.ras
    end
end
end
eof
```

Loop that runs script above and prevents displays from grabbing incomplete raster files:

```
#!/bin/csh
```

```
if ($#argv != 2) then
   echo "usage: ntr_loop LINENO TRNO"
   exit
endif
set i=0
while ($i < 10)
   touch near.lock
   jpltntr $1 $2
   rm near.lock
   sleep 180
end
```

Display script for the raster file generated above:

```
#!/bin/csh

set i=0
set dpid=999999
while ($i <= 1)
  if (!(-e /Users/seismic/Data/MCS/Plots/near.ras)) then
    echo "There is no raster file to plot."
    exit
  endif
  while (-e /Users/seismic/Data/MCS/Plots/neartr/near.lock)
     sleep 5
  end
  cp /Users/seismic/Data/MCS/Plots/near.ras /tmp/near.ras
  set ftime=`stat -f "%m" /Users/seismic/Data/MCS/Plots/shot.ras`
  set nochange=$ftime
  # find out what shots and channel number was plotted
  set FSHOT=`awk '{print $1}' /Users/seismic/Data/MCS/Plots/near.info`
  set LSHOT=`awk '{print $2}' /Users/seismic/Data/MCS/Plots/near.info`
  set TRNO=`awk '{print $3}' /Users/seismic/Data/MCS/Plots/near.info`
  echo "Displaying shots "$FSHOT"-"$LSHOT": Channel "$TRNO
  convert -rotate -90 -resize 50% /tmp/near.ras /tmp/near2.ras
  if (`ps -p $dpid | wc -l` != 1) then
     kill -9 $dpid
  endif
  display -title "Channel ${TRNO}: Shots $FSHOT - $LSHOT" -geometry 700x712+312+0!
/tmp/near2.ras &
  set dpid = $!
  while ($ftime == $nochange)
     sleep 120
     set nochange=`stat -f "%m" /Users/seismic/Data/MCS/Plots/near.ras`
  end
end
exit
```

Script to assign navigation

```
#!/bin/csh
# This is one of several scripts used to assign navigation, all of which are basically
# the same. This script assumes that some basic QC has been done and that the first
# and last good shots on the line have been identified.  This information should be
# stored in a text file (called "startend" here) in the format
#    LINE-no First-shot Last-shot First-file Last-file Channels,
# where the shot are shot point numbers (trigger counts) and the files are FFID's
# from Geometrics, and Channels is the number of active channels in the streamer.
# In addition, for the data to be read in sequence properly, the timestamp on the
# SEG-Y data files from Geometrics should be in reverse time order, so that the
# most recently acquired data has the most recent timestamp.  If for some reason
# a data file is later recopied, or the timestamps get altered, this script will
# not work as expected.  Use "touch" to put the *.sgy file timestamps in proper order.
# This script will also place some key navigation information from the Geometrics
# logs into a separate "navigation" directory - such as shot to shot distances
# and latitude - longitude positions of the ship for each shot point.

if ($#argv != 1) then
   echo "Usage: mkshnav2.sio line-no"
   exit 1
endif
set LINE=$1
set SEGY=`ls -rt /Users/seismic/Data/MCS/Raw/shots/Healy05$LINE/*.sgy`
set FNO=`awk '($1 == line) {print $4}' line=$LINE startend`
set LNO=`awk '($1 == line) {print $5}' line=$LINE startend`
set CHN=`awk '($1 == line) {print $6}' line=$LINE startend`

# foreach segy file, generate an ipath command for sioseis using the
# FFID limits from the startend file
rm sfiles
foreach i($SEGY)
   echo "fno "$FNO" lno "$LNO" ftr 1 ltr "$CHN" secs 12 ipath "$i" end" >> sfiles
end

if (!(-e /Users/seismic/Data/Nav/Healy05$LINE)) then
   mkdir /Users/seismic/Data/Nav/Healy05$LINE
endif
# if there is a file already created called geometrics_interp.log
# then several problems with the log file have already been identified and fixed.
# In this case, use the edited log file rather than the original.

if (!(-e /Users/seismic/Data/Nav/Old/Healy05$LINE/geometrics_interp.log)) then
   cat /Users/seismic/Data/MCS/Raw/shots/Healy05$LINE/*.log > \
       /Users/seismic/Data/Nav/Healy05$LINE/geometrics.log
else
   cp /Users/seismic/Data/Nav/Old/Healy05$LINE/geometrics_interp.log \
      /Users/seismic/Data/Nav/Healy05$LINE/geometrics.log
endif

sioseis << eof
procs diskin geom header diskoa end
diskin
   `cat sfiles`
end
header
   # seabeam water bottom depth converted to travel-time assumine 1500 m/s
   r50 = l16 / 750.
   fno 0 lno 999999 ftr 0 ltr 999 end
end
geom
   lprint 512
```

```
   epath /Users/seismic/Data/Seabeam/line$LINE.raw
   navfil /Users/seismic/Data/Nav/Healy05$LINE/geometrics.log
   dbrps 6.25 gxp 1 -90 ggx 12.5 type 14 end
end
diskoa
   opath /Users/seismic/Data/MCS/Processed/shots+nav/Healy05$LINE.segy end
end
prout
   indices l3 l4 l5 l6 l16 r50
   fno 0 lno 999999 ftr 1 ltr 1 noinc 50 end
end
end
eof

chmod 444 /Users/seismic/Data/MCS/Processed/shots+nav/Healy05$LINE.segy
echo "Making shot navigation file from logs..."
/Users/seismic/Data/Nav/log2snav.csh $LINE
echo "Making shot to shot distance file ..."
awk '($1 == "shot") {printf("%6d\t%6.2f\n",$2,$4)}' line$LINE.stdout > \
      /Users/seismic/Data/Nav/Healy05$LINE/shot_distances.xy

exit
```

The log2snav.csh script called above:

```
#!/bin/csh
if ($#argv != 1) then
  echo "Usage: log2snav.csh line-no"
  exit -1
endif

set LINE=$1
set NAVPATH=/Users/seismic/Data/Nav
set LOG=$NAVPATH/Healy05$LINE/geometrics.log

rm $NAVPATH/Healy05${LINE}.snav
echo "# Healy05$LINE : longitude  latitude  shot-no" >
$NAVPATH/Healy05${LINE}/shot_nav.ll

awk -F ",[ \t]*|[ \t]+" '(($2 != "FFID") && ($1 >= 1) && ($1 <= 999999))
{printf("%6d\t%s\t%s\t%s\n",$1,$2,$3,$5)}' $LOG > $LOG.tmp

# brnav is just a short program that breaks up the lat/lon information
# into something awk can deal with since the minutes are not separated
# from the degrees field by a space
/Users/seismic/Data/Nav/brnav $LOG.tmp > $LOG.tmp2
awk '{printf("%9.5f\t%9.5f\t%6d\n",-($7+$8/60.),$5+$6/60.,$1)}' $LOG.tmp2 >>
$NAVPATH/Healy05${LINE}/shot_nav.ll
rm $LOG.tmp
rm $LOG.tmp2

exit
```

Script to brute stack the data:

This is a basic brute stacking script that assumes a very simple velocity function tied to the water bottom. This was used for most, but not all of the lines. In some cases, some additional subroutines that killed known bad channels were included. See the MCS line log for a preliminary assessment of bad channels.

```
#!/bin/csh -f

if ($#argv != 1) then
   echo "Usage: brute.sio line-no"
   exit 1
endif

set LINE=$1
set SEGY=/Users/seismic/Data/MCS/Processed/Shots+nav/Healy05$LINE.segy

sioseis << eof
procs diskin gather avenor nmo stack prout diskob end
diskin
    decimf 2
    ipath $SEGY end
end
avenor
  addwb yes sets 0 1.0 end
end
gather
   end
end
prout
    fno 0 lno 999999 noinc 50 end
end
gather
    end
end
nmo
  vintpl 2
  addwb yes
  fno 1 vtp 1490 0.0 1600 0.5 2000 1.5 3200 4.0 end
end
stack
   end
end
diskob
   opath /Users/seismic/Data/MCS/Processed/Stacks/Brute/nofk/Healy05$LINE.segy end
end
end
eof
```

Appendix D - Sonobuoy Log

serial number	type	start date	start time (Z)	channel	depth	end date	end time (Z)	record file	trace	line	data file	1st SP	Time 1st SP (Z)	Last SP	Time last SP (Z)
14028	S	10-Aug-05	06:16:57		90			854.sgy	1		Segy/S001.segy	828	05+222:06:14:34	1095	05+222:07:44:30
Anenna on top of HCO shack.															
14380	S	10-Aug-05	09:30:17					1112.sgy	1						
		10-Aug-05	10:34:01			10-Aug-05	11:13:21	1299.sgy	?		Segy/S002.segy	1409	05+222:09:30:14	1722	05+222:11:15:42
Same as previous, but record length changed to 16 seconds															
	L	10-Aug-05	18:35:37			10-Aug-05	20:19:32	1424.sgy	1	05-03	Segy/S003.segy	3028	05+222:18:35:30	3337	05+222:20:19:26
14335	S	11-Aug-05	00:20:14					1734.sgy	1	05-04	Segy/S004.segy	4112	05+223:00:40:18	4608	05+223:03:27:19
14164	S	11-Aug-05	03:10:36			11-Aug-05	06:38:10	1734.sgy	2	05-04	Segy/S005.segy	4561	05+223:03:11:27	4968	05+223:05:28:35
	L	11-Aug-05	07:41:07	26	60			1734.sgy	1	05-04	No Data				
	L	11-Aug-05	08:09:26	17	60			1734.sgy	1	05-04	Segy/S006.segy	5445	05+223:08:09:16	5812	05+223:10:12:53
14088	S	11-Aug-05	09:56:32			11-Aug-05	12:27:08	1734.sgy	1	05-04	Segy/S007.segy	5769	05+223:09:58:26	6191	05+223:12:20:35
14032	S	11-Aug-05	13:36:33					1734.sgy	1	05-04	Segy/S008.segy	6416	05+223:13:36:20	6881	05+223:16:13:00
14373	S	11-Aug-05	16:21:15	12				1734.sgy	2	05-04	Segy/S009.segy	6905	05+223:16:21:01	7253	05+223:18:18:16
		11-Aug-05	20:55:19					4473.sgy	?	05-05	Segy/S010.segy	7719	05+223:20:55:04	8268	05+223:23:59:52
14107	S	11-Aug-05	23:56:28	56				4473.sgy	2	05-05	Segy/S011.segy	8269	05+224:00:00:12	9029	05+224:04:16:09
14042	S	12-Aug-05	04:57:52	35		12-Aug-05	06:37:15	4473.sgy	1	05-05	Segy/S012.segy	9152	05+224:04:57:34	9447	05+224:06:36:57
14448	S	12-Aug-05	10:07:09	56				4473.sgy	2	05-05	Segy/S013.segy	10114	05+224:10:21:37	10651	05+224:13:22:30
14448	S	12-Aug-05	10:07:09	56			13:22:51	6243.sgy							
14025	S	13-Aug-05	02:24:19	59		13-Aug-05	05:58:12	6781.sgy	1	05-07	Segy/S014.segy	12364	05+225:02:23:53	13001	05+225:05:58:26
14155	S	13-Aug-05	04:53:28	29		13-Aug-05	06:35:51	6781.sgy	2	05-07	Segy/S015.segy	12809	05+225:04:53:48	13109	05+225:06:34:45
	L	13-Aug-05	08:48:55	22						05-07	No Data				
14104	S	13-Aug-05	11:35:17	59				7789.sgy	1	05-08	Segy/S016.segy	14000	05+225:11:34:49	14191	05+225:12:39:13
											Segy/S017.segy	14186	05+225:12:37:27	14351	05+225:13:33:04
Missing record: 225/12:37 to 225/13:33															
14096	S	13-Aug-05	15:11:55	57				8141.sgy	2	05-09	Segy/S018.segy	14644	05+225:15:11:47	14821	05+225:16:11:24
14159	S	14-Aug-05	12:07:28	59				8440.sgy	1	05-11	Segy/S019.segy	18371	05+226:12:07:22	19178	05+226:16:39:13
14097	S	14-Aug-05	15:18:29	57				8440.sgy	2	05-11	Segy/S020.segy	18939	05+226:15:18:42	19550	05+226:18:44:29
14030	S	14-Aug-05	18:49:24	59				8440.sgy	1	05-11	Segy/S021.segy	19571	05+226:18:51:36	19828	05+226:20:18:00
14251	S	15-Aug-05	02:17:23	59				9898.sgy	2	05-12	Segy/S022.segy	20863	05+227:02:06:34	21476	05+227:05:33:02

											Segy/S023.segy	21464	05+227:05:29:01	21651	05+227:06:32:00
Missing record: 227/05:29 to 227/06:32															
14438	S	15-Aug-05	08:36:15	59				10687.sgy	1	05-13	Segy/S024.segy	22019	05+227:08:36:02	22303	05+227:10:11:39
	L	15-Aug-05	11:00:00	17	60			failed		05-13					
14136	S	15-Aug-05	11:30:02	59				10687.sgy	1	05-13	Segy/S025.segy	22535	05+227:11:29:49	22906	05+227:13:34:39
14188	S	15-Aug-05	13:44:19	59				10687.sgy	1	05-13	Segy/S026.segy	22930	05+227:13:42:45	23680	05+227:17:55:23
14488	S	15-Aug-05	17:56:19	57				10687.sgy	2	05-13	Segy/S027.segy	23681	05+227:17:55:43	24249	05+227:21:06:51
14138	S	15-Aug-05	22:33:39	59				12670.sgy	1	05-14	Segy/S028.segy	24506	05+227:22:33:22	25082	05+228:01:47:23
14053	S	16-Aug-05	02:30:06	59				failed		05-14					
14122	S	16-Aug-05	03:46:11	58		16-Aug-05	07:20:31	12670.sgy	2	05-14	Segy/S029.segy	25434	05+228:03:45:53	26068	05+228:07:19:31
											Segy/S030.segy	27871	05+228:17:26:48	28509	05+228:21:01:29
Missing record: 228/17:26 to 228/21:02															
14056	S	16-Aug-05	23:16:36	59				13896.sgy	1	05-15	Segy/S031.segy	28909	05+228:23:16:11	29375	05+229:01:53:11
14140	S	17-Aug-05	03:47:47	59				15004.sgy	1	05-16	Segy/S032.segy	29714	05+229:03:47:20	30266	05+229:06:53:08
14127	S	17-Aug-05	06:55:01	57				15004.sgy	1	05-16	Segy/S033.segy	30268	05+229:06:53:54	30909	05+229:10:29:47
14402	S	17-Aug-05	11:47:01	59				16199.sgy	2	05-17	Segy/S034.segy	31147	05+229:11:49:58	31765	05+229:15:18:04
14054	S	17-Aug-05	15:06:07	61		17-Aug-05	18:21:34	16199.sgy	1	05-17	Segy/S035.segy	31767	05+229:15:18:44	32283	05+229:18:12:37
14149	S	17-Aug-05	18:13:48	59		17-Aug-05	21:36:44	16199.sgy	2	05-17	Segy/S036.segy	32286	05+229:18:13:37	32877	05+229:21:32:26
14119	S	17-Aug-05	21:28:58	62		18-Aug-05	00:31:41	16199.sgy	1	05-17	Segy/S037.segy	32879	05+229:21:33:12	33403	05+230:00:29:27
14441	S	18-Aug-05	00:26:40	57				16199.sgy	2	05-17	Segy/S038.segy	33403	05+230:00:29:27	33640	05+230:01:54:10
14439	S	18-Aug-05	03:15:57	58				18703.sgy	1	05-18	Segy/S039.segy	33842	05+230:03:15:22	34420	05+230:06:30:08
14161	S	18-Aug-05	05:47:52	59				18703.sgy	1	05-18	Segy/S040.segy	34441	05+230:06:37:09	34938	05+230:09:24:35
											Segy/S041.segy	35024	05+230:09:53:34	35560	05+230:12:54:08
14255	S	18-Aug-05	19:00:00	57		19-Aug-05	01:17:00	20361.sgy	1	05-19	Segy/S043.segy	36998	05+230:20:58:21	37766	05+231:01:16:59
Heli-dropped @ 78 9.05 N 177 3.4 W															
14162	S	18-Aug-05	20:41:35	59		19-Aug-05	01:17:00	20361.sgy	2	05-19	Segy/S042.segy	36961	05+230:20:45:56	37766	05+231:01:16:59
Antenna moved to point above aloft con. Using only one receiver as a precaution against burning them out.															
14404	S	19-Aug-05	13:52:59	59		19-Aug-05	17:05:20	21280.sgy	2	05-20	Segy/S044.segy	40026	05+231:13:58:20	40716	05+231:17:50:45
14401	S	19-Aug-05	17:48:05	57		19-Aug-05	21:32:59	21280.sgy	1/2	05-20	Segy/S045.segy	40722	05+231:17:52:45	41400	05+231:21:40:52
switched to trace 2 @ 17:57:52															
14189	S	19-Aug-05	21:34:59	57		20-Aug-05	00:16:36	21280.sgy	2	05-20	Segy/S046.segy	41403	05+231:21:41:52	41859	05+232:00:15:27
14333	S	20-Aug-05	00:19:16	59				21280.sgy	2	05-20	Segy/S047.segy	41884	05+232:00:23:53	42635	05+232:04:36:51
14142	S	20-Aug-05	04:45:47	57		20-Aug-05	07:41:16	21280.sgy	2	05-20	Segy/S048.segy	42659	05+232:04:44:52	43180	05+232:07:40:25
14242	S	20-Aug-05	09:42:53	59	40	20-Aug-05	12:24:14	24306.sgy	2	05-21	Segy/S049.segy	43541	05+232:09:42:01	44020	05+232:12:23:22

					0										
hydrophone @ 400 feet															
14174	S	20-Aug-05	13:20:46	58				24786.sgy	2	05-22	Segy/S050.segy	44255	05+232:13:42:32	44738	05+232:16:25:13
no signal received															
14329	S	20-Aug-05	13:43:05	65				24786.sgy	2	05-22					
14118	S	20-Aug-05	16:26:47	57		20-Aug-05	20:31:39	24786.sgy	2	05-22	Segy/S051.segy	44741	05+232:16:26:14	45470	05+232:20:31:44
14118	S	21-Aug-05	14:14:56	72				30470.sgy	2	05-23	Segy/S052.segy	48626	05+233:14:16:22	48943	05+233:16:03:12
14421	S	21-Aug-05	16:11:32	72				30470.sgy	2	05-23	Segy/S053.segy	48972	05+233:16:12:58	49208	05+233:17:32:28
14130	S	21-Aug-05	20:57:10	62		21-Aug-05	23:38:20	31180.sgy	2	05-24	Segy/S054.segy	49821	05+233:20:58:55	50329	05+233:23:49:31
16497	S	21-Aug-05	23:44:26	62		22-Aug-05	04:04:09	31749.sgy	2	05-24	Segy/S055.segy	50330	05+233:23:49:51	51084	05+234:04:03:49
16496	S	22-Aug-05	04:04:09	59				32253.sgy	2	05-24	Segy/S056.segy	51206	05+234:04:44:54	51803	05+234:08:06:00
16552	S	22-Aug-05	09:08:16	58				33262.sgy	2	05-25					
No data, this may be one of two thrown at ~ the same time, both of which failed.															
14758	S	22-Aug-05	09:47:47	23				33262.sgy	2	05-25	Segy/S057.segy	52105	05+234:09:47:43	52391	05+234:11:24:06
16379	S	22-Aug-05	11:27:45	59		22-Aug-05	15:48:15	33747.sgy	2	05-25	Segy/S058.segy	52408	05+234:11:29:46	53181	05+234:15:50:11
14870	S	22-Aug-05	16:24:36	67		22-Aug-05	17:16:08	34285.sgy		05-25	Segy/S059.segy	53287	05+234:16:25:56	53431	05+234:17:14:21
16434	S	23-Aug-05	09:42:19	72				35204.sgy	2	05-26	Segy/S060.segy	54951	05+235:09:50:40	55386	05+235:12:17:09
?	S	23-Aug-05	12:45:34	59		23-Aug-05	16:05:01	35732.sgy	2	05-26	Segy/S061.segy	55473	05+235:12:46:28	56063	05+235:16:05:14
Channels reconfigured due to failure of one GEODE unit.															
16543	S	23-Aug-05	16:16:27	65		23-Aug-05	17:55:51	36151.sgy	24	05-26	Segy/S062.segy	56100	05+235:16:17:40	56391	05+235:17:55:44
	L	24-Aug-05	08:04:02	17	60			failed	24	05-27	No Data				
14766	S	24-Aug-05	08:15:28	55				failed	24	05-27	No Data				
14511	S	24-Aug-05	09:09:47	56		24-Aug-05	12:03:36	36578.sgy	24	05-27 and 05-28	Segy/S063.segy	59108	05+236:09:10:30	59224	05+236:09:49:35
16217	S	27-Aug-05	03:47:37	45				37357.sgy	24	05-29					
No data; gun shutdown immediately after deployed															
14844	S	29-Aug-05	00:30:38	45				37437.sgy	24	05-30	Segy/S064.segy	78942	05+241:00:31:04	79246	05+241:02:13:27
16526	S	01-Sep-05	21:06:06	38				failed	24	05-31					
16548	S	01-Sep-05	21:50:57	6				43401.sgy	24	05-31	Segy/S065.segy	95573	05+244:21:52:16	95935	05+244:23:54:12
14884	S	02-Sep-05	00:07:55	83				43858.sgy	24	05-31	Segy/S066.segy	95989	05+245:00:12:13	96414	05+245:02:35:21
16565	S	02-Sep-05	02:35:04	83				44318.sgy	24	05-31	Segy/S067.segy	96416	05+245:02:36:01	96773	05+245:04:36:17
16513	S	02-Sep-05	04:37:00	82				44318.sgy	24	05-31					
No data; guns shutdown at 04:42															

16488	S	02-Sep-05	14:08:07	83				44756.sgy	24	05-32	Segy/S068.segy	98475	05+245:14:09:41	98937	05+245:16:45:18
16512	S	02-Sep-05	17:03:57	33				45296.sgy	24	05-32	Segy/S069.segy	98999	05+245:17:06:11	99791	05+245:21:33:03
16487	S	02-Sep-05	21:41:31	83				45758.sgy	24	05-32	Segy/S070.segy	99820	05+245:21:42:49	100142	05+245:23:31:13
16463	S	02-Sep-05	23:32:02	33				46189.sgy	24	05-32	Segy/S071.segy	100149	05+245:23:33:33	100745	05+246:02:54:09
16507	S	03-Sep-05	03:42:10	83				failed	24	05-32					
16116	S	03-Sep-05	03:57:03	27		03-Sep-05	05:22:05	46988.sgy	24	05-32	Segy/S072.segy	100946	05+246:04:01:54	101188	05+246:05:23:26
?	S	03-Sep-05	10:47:20	87				47507.sgy	24	05-33	Segy/S073.segy	102152	05+246:10:48:08	102431	05+246:12:22:11
14516	S	03-Sep-05	12:27:24	83				47507.sgy	24	05-33					
No usable data; Guns shutdown at 13:09															
14508	S	03-Sep-05	14:06:48	33				48017.sgy	24	05-34					
Possibly failed and a new one redeployed at 14:56															
			14:56 -- see above								Segy/S074.segy	102888	05+246:14:56:06	103402	05+246:17:49:15
16346	S	03-Sep-05	17:05:02	32				48546.sgy	24	05-34					
No usable data; Guns shutdown at 18:39; start time to the left is probably wrong															
16221	S	04-Sep-05	14:41:25	83		04-Sep-05	16:19:08	48827.sgy	24	05-35	Segy/S075.segy	107123	05+247:14:42:26	107411	05+247:16:19:29
16198	S	05-Sep-05	09:13:24	83	400	04-Sep-05	11:45:39	49124.sgy	24	05-36	Segy/S076.segy	110438	05+248:09:18:40	110876	05+248:11:46:15
Gun pressure inadequate, change to 22 second shot interval.															
16206	S	05-Sep-05	12:03:32	83	400			49585.sgy	24	05-37	Segy/S077.segy	111012	05+248:12:03:46	111345	05+248:14:06:13
16483	S	05-Sep-05	14:07:28	32				49585.sgy	24	05-37	Segy/S078.segy	111353	05+248:14:09:09	111807	05+248:16:55:59
16492	S	05-Sep-05	16:58:21	33				50151.sgy	24	05-37	Segy/S079.segy	111818	05+248:17:00:01	112374	05+248:20:24:20
14509	S	05-Sep-05	20:30:25	83				50604.sgy	24	05-37	Segy/S080.segy	112392	05+248:20:30:58	112560	05+248:21:32:42
14534	S	05-Sep-05	21:38:02	33				50604.sgy	24	05-37	Segy/S081.segy	112577	05+248:21:38:56	112919	05+248:23:44:37
14376	S	05-Sep-05	23:45:32	83		06-Sep-05	00:29:17	51055.sgy	24	05-37	Segy/S082.segy	112937	05+248:23:51:14	113029	05+249:00:25:02
14166	S	08-Sep-05	12:57:54	32				51515.sgy	24	05-38	Segy/S083.segy	122917	05+251:12:59:16	123465	05+251:16:20:39
14446	S	08-Sep-05	16:20:24	32				52015.sgy	24	05-38	Segy/S084.segy	123468	05+251:16:21:45	123736	05+251:18:00:14
14066	S	08-Sep-05	18:59:53	90		08-Sep-05	21:15:06	52433.sgy	24	05-39	Segy/S085.segy	123903	05+251:19:01:35	124251	05+251:21:09:27
14152	S	09-Sep-05	08:54:00	30				52961.sgy	24	05-40	Segy/S086.segy	126184	05+252:08:59:55	126534	05+252:11:08:37
16217	S	09-Sep-05	21:53:01	32				53472.sgy	24	05-41	Segy/S087.segy	128288	05+252:21:53:08	128602	05+252:23:48:32
14241	S	09-Sep-05	23:51:43	90				53472.sgy	24	05-41	Segy/S088.segy	128610	05+252:23:51:28	128954	05+253:01:57:59
16262	S	10-Sep-05	02:49:47	90				53934.sgy	24	05-41	Segy/S089.segy	129096	05+253:02:50:09	129216	05+253:03:34:15
14067	S	10-Sep-05	04:43:15	30				53934.sgy	24	05-41	Segy/S090.segy	129405	05+253:04:43:42	129775	05+253:06:59:39

14126	S	10-Sep-05	12:16:00	83		10-Sep-05	14:58:04	54988.sgy	24	05-42	Segy/S091.segy	130636	05+253:12:16:04	131077	05+253:14:58:07
14117	S	10-Sep-05	21:56:16	2				failed		05-43					
14183	S	10-Sep-05	23:31:09	5		11-Sep-05	03:15:02	55503.sgy	24	05-43	Segy/S092.segy	132475	05+253:23:31:53	133082	05+254:03:15:00
14058	S	11-Sep-05	03:30:28	28				55972.sgy	24	05-43 and 05-44	Segy/S093.segy	133123	05+254:03:30:05	133255	05+254:04:18:35
14248	S	11-Sep-05	07:20:30	28		11-Sep-05	11:17:33	56154.sgy	24	05-44	Segy/S094.segy	133755	05+254:07:22:18	134358	05+254:11:03:53
14338	S	13-Sep-05	06:54:37	28				56841.sgy	24	05-45	Segy/S095.segy	141511	05+256:06:52:54	141559	05+256:07:10:32
14449	S	13-Sep-05	10:41:44	32		13-Sep-05	11:16:16	56915.sgy	23 & 24	05-46	Segy/S096.segy	142139	05+256:10:43:41	142227	05+256:11:16:00
14146	S	26-Sep-05	10:24:16	18	400			57175.sgy	24	05-47	Segy/S097.segy	188633	05+269:10:23:12	189159	05+269:13:36:34

Appendix E – Knudsen Files

Filename	File Opened (Z)	File Closed (Z)	Recording Range			
env-0005_0048_HF.sgy	05+218:00:48:00.000	05+218:01:28:00.000	0.133	to	0.265	secs.
env-0005_0128_HF.sgy	05+218:01:28:00.000	05+218:01:28:00.000	0.266	to	0.53	secs.
env-0005_0048_LF.sgy	05+218:01:32:00.000	05+218:01:37:00.000	0.133	to	0.266	secs.
env-0005_0137_LF.sgy	05+218:01:37:00.000	05+218:01:39:00.000	0.133	to	0.266	secs.
env-0005_0139_LF.sgy	05+218:01:39:00.000	05+218:01:39:00.000	0.133	to	0.266	secs.
env-0006_0259_LF.sgy	05+218:02:59:00.000	05+218:03:46:00.000	0.166	to	0.233	secs.
env-0006_0346_LF.sgy	05+218:03:46:00.000	05+218:03:47:00.000	0	to	0.466	secs.
env-0006_0347_LF.sgy	05+218:03:47:00.000	05+218:03:47:00.000	0.066	to	0.133	secs.
env-0007_0349_LF.sgy	05+218:03:49:00.000	05+218:03:53:00.000	0	to	0.133	secs.
env-0007_0353_LF.sgy	05+218:03:53:00.000	05+218:03:53:00.000	0.333	to	0.466	secs.
env-0008_0353_LF.sgy	05+218:03:53:00.000	05+218:04:19:00.000	0.1	to	0.233	secs.
env-0008_0419_LF.sgy	05+218:04:19:00.000	05+218:04:31:00.000	0.133	to	0.333	secs.
env-0008_0431_LF.sgy	05+218:04:31:00.000	05+218:04:32:00.000	0.133	to	0.667	secs.
env-0008_0432_LF.sgy	05+218:04:32:00.000	05+218:04:34:00.000	0.066	to	0.199	secs.
env-0008_0434_LF.sgy	05+218:04:34:00.000	05+218:07:54:00.000	0.066	to	0.167	secs.
env-0008_0754_LF.sgy	05+218:07:54:00.000	05+218:08:07:00.000	0.033	to	0.133	secs.
env-0008_0807_LF.sgy	05+218:08:07:00.000	05+218:08:08:00.000	0.026	to	0.053	secs.
env-0008_0808_LF.sgy	05+218:08:08:00.000	05+218:09:06:00.000	0.033	to	0.133	secs.
env-0008_0906_LF.sgy	05+218:09:06:00.000	05+218:09:07:00.000	0	to	0.333	secs.
env-0008_0907_LF.sgy	05+218:09:07:00.000	05+218:09:08:00.000	0	to	0.067	secs.
env-0008_0908_LF.sgy	05+218:09:08:00.000	05+218:09:09:00.000	0	to	0.266	secs.
env-0008_0909_LF.sgy	05+218:09:09:00.000	05+218:10:31:00.000	0	to	0.067	secs.
env-0008_1031_LF.sgy	05+218:10:31:00.000	05+218:10:32:00.000	0.066	to	0.133	secs.
env-0008_1032_LF.sgy	05+218:10:32:00.000	05+218:13:52:00.000	0.066	to	0.133	secs.
env-0008_1352_LF.sgy	05+218:13:52:00.000	05+218:14:45:00.000	0.066	to	0.133	secs.
env-0008_1445_LF.sgy	05+218:14:45:00.000	05+218:14:45:00.000	0.133	to	0.266	secs.
env-0009_1614_LF.sgy	05+218:16:14:00.000	05+218:19:34:00.000	0.033	to	0.1	secs.
env-0009_1934_LF.sgy	05+218:19:34:00.000	05+218:22:54:00.000	0.033	to	0.1	secs.
env-0009_2254_LF.sgy	05+218:22:54:00.000	05+219:02:14:00.000	0.033	to	0.1	secs.
env-0009_0214_LF.sgy	05+219:02:14:00.000	05+219:02:16:00.000	0.033	to	0.1	secs.
env-0009_0216_LF.sgy	05+219:02:16:00.000	05+219:02:33:00.000	0	to	0.199	secs.
env-0009_0233_LF.sgy	05+219:02:33:00.000	05+219:02:57:00.000	0	to	0.067	secs.
env-0009_0257_LF.sgy	05+219:02:57:00.000	05+219:02:57:00.000	0.013	to	0.04	secs.
env-0010_0317_LF.sgy	05+219:03:17:00.000	05+219:04:57:00.000	0	to	0.067	secs.
env-0010_0457_LF.sgy	05+219:04:57:00.000	05+219:06:37:00.000	0	to	0.067	secs.
env-0010_0637_LF.sgy	05+219:06:37:00.000	05+219:06:49:00.000	0	to	0.067	secs.
env-0010_0649_LF.sgy	05+219:06:49:00.000	05+219:06:49:00.000	0	to	0.067	secs.

env-0011_0653_LF.sgy	05+219:06:53:00.000	05+219:06:58:00.000	0	to	0.067	secs.
env-0011_0658_LF.sgy	05+219:06:58:00.000	05+219:06:59:00.000	0	to	0.067	secs.
env-0011_0659_LF.sgy	05+219:06:59:00.000	05+219:07:02:00.000	0	to	0.067	secs.
env-0011_0702_LF.sgy	05+219:07:02:00.000	05+219:08:42:00.000	0	to	0.067	secs.
env-0011_0842_LF.sgy	05+219:08:42:00.000	05+219:10:22:00.000	0	to	0.067	secs.
env-0011_1022_LF.sgy	05+219:10:22:00.000	05+219:12:02:00.000	0	to	0.067	secs.
env-0011_1202_LF.sgy	05+219:12:02:00.000	05+219:13:27:00.000	0	to	0.067	secs.
env-0011_1327_LF.sgy	05+219:13:27:00.000	05+219:13:27:00.000	0	to	0.133	secs.
env-0012_1336_LF.sgy	05+219:13:36:00.000	05+219:13:43:00.000	0.033	to	0.1	secs.
env-0012_1343_LF.sgy	05+219:13:43:00.000	05+219:13:43:00.000	0.066	to	0.199	secs.
env-0013_1350_LF.sgy	05+219:13:50:00.000	05+219:15:30:00.000	0	to	0.067	secs.
env-0013_1530_LF.sgy	05+219:15:30:00.000	05+219:17:10:00.000	0	to	0.067	secs.
env-0013_1710_LF.sgy	05+219:17:10:00.000	05+219:17:30:00.000	0	to	0.067	secs.
env-0013_1730_LF.sgy	05+219:17:30:00.000	05+219:19:10:00.000	0	to	0.133	secs.
env-0013_1910_LF.sgy	05+219:19:10:00.000	05+219:19:50:00.000	0	to	0.133	secs.
env-0013_1950_LF.sgy	05+219:19:50:00.000	05+219:20:10:00.000	0	to	0.133	secs.
env-0013_2010_LF.sgy	05+219:20:10:00.000	05+220:00:20:00.000	0	to	0.133	secs.
env-0013_0020_LF.sgy	05+220:00:20:00.000	05+220:00:20:00.000	0	to	0.133	secs.
env-0014_0020_LF.sgy	05+220:00:20:00.000	05+220:00:20:00.000	0	to	0.133	secs.
env-0015_0021_LF.sgy	05+220:00:21:00.000	05+220:00:22:00.000	0	to	0.133	secs.
env-0015_0022_LF.sgy	05+220:00:22:00.000	05+220:00:24:00.000	0	to	0.067	secs.
env-0015_0024_LF.sgy	05+220:00:24:00.000	05+220:01:46:00.000	0	to	0.067	secs.
env-0015_0146_LF.sgy	05+220:01:46:00.000	05+220:01:46:00.000	0.066	to	0.199	secs.
env-0016_0148_LF.sgy	05+220:01:48:00.000	05+000:00:00:00.000	0.033	to	0.1	secs.
env-0016_0328_LF.sgy	05+220:03:28:00.000	05+220:05:08:00.000	0.033	to	0.1	secs.
env-0016_0508_LF.sgy	05+220:05:08:00.000	05+220:06:48:00.000	0.033	to	0.1	secs.
env-0016_0648_LF.sgy	05+220:06:48:00.000	05+220:08:28:00.000	0.033	to	0.1	secs.
env-0016_0828_LF.sgy	05+220:08:28:00.000	05+220:10:08:00.000	0.033	to	0.1	secs.
env-0016_1008_LF.sgy	05+220:10:08:00.000	05+220:11:48:00.000	0.033	to	0.1	secs.
env-0016_1148_LF.sgy	05+220:11:48:00.000	05+220:13:12:00.000	0	to	0.1	secs.
env-0016_1312_LF.sgy	05+220:13:12:00.000	05+000:00:00:00.000	0	to	11.22	secs.
env-0016_1452_LF.sgy	05+220:14:52:00.000	05+220:16:32:00.000	0	to	0.133	secs.
env-0016_1632_LF.sgy	05+220:16:32:00.000	05+220:17:38:00.000	0	to	0.133	secs.
env-0016_1812_LF.sgy	05+220:18:12:00.000	05+220:18:49:00.000	0	to	0.133	secs.
env-0016_1849_LF.sgy	05+220:18:49:00.000	05+220:20:29:00.000	0	to	0.067	secs.
env-0016_2029_LF.sgy	05+220:20:29:00.000	05+220:22:09:00.000	0.033	to	0.1	secs.
env-0016_2209_LF.sgy	05+220:22:09:00.000	05+220:23:49:00.000	0.033	to	0.1	secs.
env-0016_2349_LF.sgy	05+220:23:49:00.000	05+221:01:29:00.000	0.033	to	0.1	secs.
env-0016_0129_LF.sgy	05+221:01:29:00.000	05+221:01:35:00.000	0.033	to	0.1	secs.
env-0017_0135_LF.sgy	05+221:01:35:00.000	05+221:03:15:00.000	0.033	to	0.1	secs.

env-0017_0315_LF.sgy	05+221:03:15:00.000	05+221:04:55:00.000	0.033	to	0.1	secs.
env-0017_0455_LF.sgy	05+221:04:55:00.000	05+221:06:35:00.000	0.033	to	0.1	secs.
env-0017_0635_LF.sgy	05+221:06:35:00.000	05+221:08:15:00.000	0.033	to	0.1	secs.
env-0017_0815_LF.sgy	05+221:08:15:00.000	05+221:09:55:00.000	0.033	to	0.1	secs.
env-0017_0955_LF.sgy	05+221:09:55:00.000	05+000:75:00:00.000	0.033	to	0.1	secs.
env-0017_1135_LF.sgy	05+221:11:35:00.000	05+221:13:15:00.000	0.033	to	0.133	secs.
env-0017_1315_LF.sgy	05+221:13:15:00.000	05+221:14:27:00.000	0.066	to	0.133	secs.
env-0017_1427_LF.sgy	05+221:14:27:00.000	05+221:16:41:00.000	0	to	0.399	secs.
env-0017_1641_LF.sgy	05+221:16:41:00.000	05+221:19:27:00.000	0.2	to	0.333	secs.
env-0017_1927_LF.sgy	05+221:19:27:00.000	05+221:19:36:00.000	0.266	to	0.399	secs.
env-0017_1936_LF.sgy	05+221:19:36:00.000	05+221:19:36:00.000	0.133	to	0.2	secs.
env-0018_1938_LF.sgy	05+221:19:38:00.000	05+221:19:38:00.000	0.4	to	0.8	secs.
env-0019_1950_LF.sgy	05+221:19:50:00.000	05+221:20:28:00.000	0.333	to	0.466	secs.
env-0019_2028_LF.sgy	05+221:20:28:00.000	05+222:03:08:00.000	0	to	0.466	secs.
env-0019_0308_LF.sgy	05+222:03:08:00.000	05+222:07:59:00.000	0.666	to	0.866	secs.
env-0019_0759_LF.sgy	05+222:07:59:00.000	05+222:08:01:00.000	0.266	to	1.733	secs.
env-0019_0801_LF.sgy	05+222:08:01:00.000	05+222:08:03:00.000	0.666	to	0.933	secs.
env-0019_0803_LF.sgy	05+222:08:03:00.000	05+222:11:25:00.000	0.333	to	0.466	secs.
env-0020_1125_LF.sgy	05+222:11:25:00.000	05+222:13:12:00.000	0.133	to	1.799	secs.
env-0020_1312_LF.sgy	05+222:13:12:00.000	05+222:13:28:00.000	0.666	to	0.799	secs.
env-0021_1328_LF.sgy	05+222:13:28:00.000	05+222:16:56:00.000	0.733	to	0.866	secs.
env-0021_1656_LF.sgy	05+222:16:56:00.000	05+222:16:56:00.000	0.8	to	0.933	secs.
env-0022_1656_LF.sgy	05+222:16:56:00.000	05+223:00:40:00.000	0.8	to	0.933	secs.
env-0022_0040_LF.sgy	05+223:00:40:00.000	05+223:00:40:00.000	3.866	to	4.133	secs.
env-0023_0152_LF.sgy	05+223:01:52:00.000	05+223:05:05:00.000	1	to	1.266	secs.
env-0023_0505_LF.sgy	05+223:05:05:00.000	05+223:05:05:00.000	1.133	to	1.266	secs.
env-0024_0505_LF.sgy	05+223:05:05:00.000	05+223:06:51:00.000	1.133	to	1.266	secs.
env-0024_0651_LF.sgy	05+223:06:51:00.000	05+223:14:55:00.000	0.733	to	1.399	secs.
env-0024_1455_LF.sgy	05+223:14:55:00.000	05+223:16:13:00.000	0.733	to	0.866	secs.
env-0024_1613_LF.sgy	05+223:16:13:00.000	05+223:16:13:00.000	0.733	to	0.866	secs.
env-0025_1613_LF.sgy	05+223:16:14:00.000	05+224:02:18:00.000	0.666	to	0.866	secs.
env-0025_0218_LF.sgy	05+224:02:18:00.000	05+224:03:18:00.000	1.2	to	3.6	secs.
env-0025_0318_LF.sgy	05+224:03:18:00.000	05+224:03:57:00.000	0.866	to	0.999	secs.
env-0026_0357_LF.sgy	05+224:03:57:00.000	05+224:05:23:00.000	1.133	to	1.866	secs.
env-0026_0523_LF.sgy	05+224:05:23:00.000	05+224:10:47:00.000	0.533	to	2.533	secs.
env-0026_1047_LF.sgy	05+224:10:47:00.000	05+224:10:48:00.000	0.533	to	0.8	secs.
env-0026_1048_LF.sgy	05+224:10:48:00.000	05+224:16:15:00.000	0.266	to	0.8	secs.
env-0027_1615_LF.sgy	05+224:16:15:00.000	05+224:22:28:00.000	0.666	to	0.933	secs.
env-0027_2228_LF.sgy	05+224:22:28:00.000	05+224:22:28:00.000	0.333	to	0.466	secs.
env-0028_2231_LF.sgy	05+224:22:31:00.000	05+225:00:53:00.000	0.666	to	0.933	secs.

env-0001_0125_LF.sgy	05+225:01:25:00.000	05+225:02:47:00.000	0.666	to	0.933	secs.
env-0001_0248_LF.sgy	05+225:02:48:00.000	05+225:02:48:00.000	1.666	to	2.333	secs.
env-0002_0248_LF.sgy	05+225:02:48:00.000	05+225:02:49:00.000	0.933	to	1.2	secs.
env-0002_0249_LF.sgy	05+225:02:49:00.000	05+225:02:49:00.000	0	to	2.273	secs.
env-0003_0302_LF.sgy	05+225:03:02:00.000	05+225:13:42:00.000	1.2	to	2.133	secs.
env-0004_1342_LF.sgy	05+225:13:42:00.000	05+225:13:45:00.000	2.4	to	2.667	secs.
env-0005_1345_LF.sgy	05+225:13:45:00.000	05+225:16:40:00.000	2.4	to	2.667	secs.
env-0005_1641_LF.sgy	05+225:16:41:00.000	05+225:16:41:00.000	11	to	11.67	secs.
env-0006_1943_LF.sgy	05+225:19:43:00.000	05+225:23:01:00.000	4.666	to	5.333	secs.
env-0006_2301_LF.sgy	05+225:23:01:00.000	05+226:03:35:00.000	3.2	to	3.467	secs.
env-0007_0335_LF.sgy	05+226:03:35:00.000	05+226:23:30:00.000	1.066	to	5.333	secs.
env-0007_2330_LF.sgy	05+226:23:30:00.000	05+226:23:30:00.000	2.666	to	3.333	secs.
env-0008_0151_LF.sgy	05+227:01:51:00.000	05+227:06:57:00.000	1.066	to	1.333	secs.
env-0008_0657_LF.sgy	05+227:06:57:00.000	05+227:06:59:00.000	1.333	to	12.66	secs.
env-0008_0659_LF.sgy	05+227:06:59:00.000	05+227:09:45:00.000	0.533	to	0.8	secs.
env-0008_0945_LF.sgy	05+227:09:45:00.000	05+227:09:46:00.000	4.666	to	5.333	secs.
env-0008_0946_LF.sgy	05+227:09:46:00.000	05+227:10:41:00.000	1.866	to	2.133	secs.
env-0008_1041_LF.sgy	05+227:10:41:00.000	05+227:10:42:00.000	2	to	2.267	secs.
env-0008_1042_LF.sgy	05+227:10:42:00.000	05+227:22:53:00.000	1.466	to	2.267	secs.
env-0008_2253_LF.sgy	05+227:22:53:00.000	05+227:23:10:00.000	2.666	to	8	secs.
env-0008_2310_LF.sgy	05+227:23:10:00.000	05+228:00:04:00.000	1.066	to	1.333	secs.
env-0008_0004_LF.sgy	05+228:00:04:00.000	05+228:00:28:00.000	1.666	to	7	secs.
env-0008_0028_LF.sgy	05+228:00:28:00.000	05+228:14:27:00.000	0.666	to	1.2	secs.
env-0008_1427_LF.sgy	05+228:14:27:00.000	05+229:03:47:00.000	0.4	to	0.933	secs.
env-0008_0348_LF.sgy	05+229:03:48:00.000	05+229:04:33:00.000	0.4	to	0.667	secs.
env-0008_0433_LF.sgy	05+229:04:33:00.000	05+229:04:33:00.000	0.4	to	0.667	secs.
env-0009_0435_LF.sgy	05+229:04:35:00.000	05+229:11:17:00.000	0.4	to	0.667	secs.
env-0009_1117_LF.sgy	05+229:11:17:00.000	05+229:16:36:00.000	0.8	to	1.067	secs.
env-0009_1636_LF.sgy	05+229:16:36:00.000	05+229:16:36:00.000	3.333	to	3.6	secs.
env-0010_1636_LF.sgy	05+229:16:36:00.000	05+230:08:31:00.000	1.6	to	3.6	secs.
env-0010_0831_LF.sgy	05+230:08:31:00.000	05+230:11:55:00.000	1.066	to	1.867	secs.
env-0010_1155_LF.sgy	05+230:11:55:00.000	05+230:11:55:00.000	1.066	to	1.333	secs.
env-0011_1155_LF.sgy	05+230:11:55:00.000	05+230:11:59:00.000	1.066	to	1.333	secs.
env-0011_1159_LF.sgy	05+230:11:59:00.000	05+230:11:59:00.000	1.066	to	1.333	secs.
env-0012_1159_LF.sgy	05+230:11:59:00.000	05+230:13:44:00.000	0.933	to	1.333	secs.
env-0012_1344_LF.sgy	05+230:13:44:00.000	05+230:13:54:00.000	0.533	to	0.666	secs.
env-0012_1354_LF.sgy	05+230:13:54:00.000	05+230:17:08:00.000	1.066	to	2.533	secs.
env-0013_1708_LF.sgy	05+230:17:08:00.000	05+230:23:58:00.000	1.066	to	1.867	secs.
env-0013_2358_LF.sgy	05+230:23:58:00.000	05+231:01:58:00.000	0.933	to	1.333	secs.
env-0013_0158_LF.sgy	05+231:01:58:00.000	05+231:09:12:00.000	0.533	to	0.666	secs.

env-0013_0912_LF.sgy	05+231:09:12:00.000	05+231:14:09:00.000	1.066	to	1.199	secs.
env-0013_1409_LF.sgy	05+231:14:09:00.000	05+231:14:09:00.000	2.266	to	2.533	secs.
env-0014_1411_LF.sgy	05+231:14:11:00.000	05+231:17:48:00.000	1.066	to	1.333	secs.
env-0014_1748_LF.sgy	05+231:17:48:00.000	05+231:17:48:00.000	2.133	to	2.4	secs.
env-0015_1748_LF.sgy	05+231:17:48:00.000	05+232:07:27:00.000	1.2	to	2.4	secs.
env-0015_0727_LF.sgy	05+232:07:27:00.000	05+232:18:58:00.000	1.333	to	1.6	secs.
env-0015_1858_LF.sgy	05+232:18:58:00.000	05+232:19:00:00.000	1.866	to	1.999	secs.
env-0016_1900_LF.sgy	05+232:19:00:00.000	05+232:20:08:00.000	3.333	to	3.933	secs.
env-0016_2008_LF.sgy	05+232:20:08:00.000	05+232:21:08:00.000	2.666	to	6.933	secs.
env-0016_2108_LF.sgy	05+232:21:08:00.000	05+232:21:10:00.000	1	to	8.333	secs.
env-0016_2110_LF.sgy	05+232:21:10:00.000	05+232:21:39:00.000	2	to	2.267	secs.
env-0016_2139_LF.sgy	05+232:21:39:00.000	05+232:21:41:00.000	3.333	to	9.667	secs.
env-0016_2141_LF.sgy	05+232:21:41:00.000	05+232:21:42:00.000	1.333	to	1.6	secs.
env-0016_2142_LF.sgy	05+232:21:42:00.000	05+232:22:10:00.000	3.333	to	5.667	secs.
env-0016_2210_LF.sgy	05+232:22:10:00.000	05+232:22:10:00.000	1.333	to	1.6	secs.
env-0017_2215_LF.sgy	05+232:22:15:00.000	05+233:02:49:00.000	3.733	to	3.866	secs.
env-0018_0627_LF.sgy	05+233:06:27:00.000	05+233:06:30:00.000	3.733	to	4	secs.
env-0018_0630_LF.sgy	05+233:06:30:00.000	05+234:05:44:00.000	2.666	to	4	secs.
env-0018_0544_LF.sgy	05+234:05:44:00.000	05+234:20:52:00.000	2.8	to	3.2	secs.
env-0018_2052_LF.sgy	05+234:20:52:00.000	05+234:20:54:00.000	3.466	to	3.733	secs.
env-0018_2054_LF.sgy	05+234:20:54:00.000	05+234:20:58:00.000	3	to	9.333	secs.
env-0018_2058_LF.sgy	05+234:20:58:00.000	05+235:01:18:00.000	1.333	to	3.667	secs.
env-0018_0118_LF.sgy	05+235:01:18:00.000	05+235:01:31:00.000	0.8	to	1.067	secs.
env-0018_0131_LF.sgy	05+235:01:31:00.000	05+235:11:27:00.000	2	to	7	secs.
env-0018_1127_LF.sgy	05+235:11:27:00.000	05+236:05:52:00.000	0.933	to	1.333	secs.
env-0018_0552_LF.sgy	05+236:05:52:00.000	05+236:10:48:00.000	2.933	to	3.2	secs.
env-0018_1048_LF.sgy	05+236:10:48:00.000	05+236:11:01:00.000	2.666	to	8	secs.
env-0018_1101_LF.sgy	05+236:11:01:00.000	05+237:07:56:00.000	1.2	to	1.467	secs.
env-0018_0756_LF.sgy	05+237:07:56:00.000	05+238:04:40:00.000	2.8	to	3.333	secs.
env-0018_0440_LF.sgy	05+238:04:40:00.000	05+238:05:15:00.000	2	to	7.667	secs.
env-0018_0515_LF.sgy	05+238:05:15:00.000	05+238:11:54:00.000	0.8	to	1.067	secs.
env-0018_1154_LF.sgy	05+238:11:54:00.000	05+238:11:54:00.000	2.133	to	2.4	secs.
env-0019_1155_LF.sgy	05+238:11:55:00.000	05+239:01:54:00.000	2	to	2.4	secs.
env-0019_0154_LF.sgy	05+239:01:54:00.000	05+239:03:45:00.000	2.133	to	2.4	secs.
env-0019_0345_LF.sgy	05+239:03:45:00.000	05+239:03:53:00.000	3.333	to	5.333	secs.
env-0019_0353_LF.sgy	05+239:03:53:00.000	05+240:00:12:00.000	1.6	to	1.867	secs.
env-0019_0012_LF.sgy	05+240:00:12:00.000	05+240:15:02:00.000	1.733	to	3.467	secs.
env-0019_1502_LF.sgy	05+240:15:02:00.000	05+240:22:08:00.000	1.733	to	2	secs.
env-0019_2208_LF.sgy	05+240:22:08:00.000	05+240:22:09:00.000	2.666	to	7	secs.
env-0020_2209_LF.sgy	05+240:22:09:00.000	05+241:18:42:00.000	2	to	3.333	secs.

env-0020_1842_LF.sgy	05+241:18:42:00.000	05+241:20:52:00.000	2	to	3	secs.
env-0020_2052_LF.sgy	05+241:20:52:00.000	05+242:14:07:00.000	0.933	to	1.2	secs.
env-0020_1407_LF.sgy	05+242:14:07:00.000	05+242:16:01:00.000	3.2	to	3.467	secs.
env-0021_1601_LF.sgy	05+242:16:01:00.000	05+242:18:23:00.000	2.8	to	3.467	secs.
env-0023_1833_LF.sgy	05+242:18:33:00.000	05+242:19:04:00.000	2.8	to	3.2	secs.
env-0023_1905_LF.sgy	05+242:19:05:00.000	05+242:22:37:00.000	2.333	to	6.333	secs.
env-0023_2237_LF.sgy	05+242:22:37:00.000	05+242:22:53:00.000	1.6	to	1.867	secs.
env-0023_2253_LF.sgy	05+242:22:53:00.000	05+243:06:07:00.000	2.333	to	7	secs.
env-0023_0607_LF.sgy	05+243:06:07:00.000	05+243:22:34:00.000	1.6	to	1.867	secs.
env-0023_2235_LF.sgy	05+243:22:35:00.000	05+244:20:31:00.000	2	to	6.333	secs.
env-0023_2031_LF.sgy	05+244:20:31:00.000	05+245:02:32:00.000	2.333	to	3.333	secs.
env-0023_0233_LF.sgy	05+245:02:33:00.000	05+245:02:33:00.000	0	to	2.273	secs.
env-0024_0431_LF.sgy	05+245:04:31:00.000	05+245:07:18:00.000	2.333	to	3	secs.
env-0024_0718_LF.sgy	05+245:07:18:00.000	05+245:07:18:00.000	0.933	to	1.2	secs.
env-0025_0719_LF.sgy	05+245:07:19:00.000	05+246:02:55:00.000	1.666	to	2.667	secs.
env-0025_0255_LF.sgy	05+246:02:55:00.000	05+246:03:09:00.000	3.333	to	4	secs.
env-0025_0309_LF.sgy	05+246:03:09:00.000	05+246:03:09:00.000	1.333	to	1.6	secs.
env-0026_0309_LF.sgy	05+246:03:09:00.000	05+246:15:01:00.000	3.2	to	3.6	secs.
env-0026_1501_LF.sgy	05+246:15:01:00.000	05+247:19:25:00.000	3.333	to	8	secs.
env-0005_1946_LF.sgy	05+247:19:46:00.000	05+247:19:54:00.000	5	to	5.667	secs.
env-0006_1954_LF.sgy	05+247:19:54:00.000	05+247:20:02:00.000	5	to	5.667	secs.
env-0006_2002_LF.sgy	05+247:20:02:00.000	05+248:17:41:00.000	2	to	2.267	secs.
env-0006_1741_LF.sgy	05+248:17:41:00.000	05+248:17:51:00.000	4	to	12	secs.
env-0006_1751_LF.sgy	05+248:17:51:00.000	05+248:17:51:00.000	1.6	to	1.867	secs.
env-0006_1752_LF.sgy	05+248:17:52:00.000	05+249:03:08:00.000	1.333	to	9.333	secs.
env-0006_0308_LF.sgy	05+249:03:08:00.000	05+249:05:10:00.000	2	to	2.667	secs.
env-0006_0510_LF.sgy	05+249:05:10:00.000	05+249:05:10:00.000	9.333	to	10.66	secs.
env-0007_0511_LF.sgy	05+249:05:11:00.000	05+249:05:25:00.000	4.933	to	5.2	secs.
env-0007_0525_LF.sgy	05+249:05:25:00.000	05+249:05:25:00.000	4.666	to	11	secs.
env-0008_0525_LF.sgy	05+249:05:26:00.000	05+249:12:16:00.000	1.333	to	5.333	secs.
env-0008_1216_LF.sgy	05+249:12:16:00.000	05+249:13:35:00.000	0.533	to	0.8	secs.
env-0008_1335_LF.sgy	05+249:13:35:00.000	05+250:15:15:00.000	1.333	to	6.333	secs.
env-0008_1516_LF.sgy	05+250:15:16:00.000	05+250:23:18:00.000	3.333	to	4	secs.
env-0008_2318_LF.sgy	05+250:23:18:00.000	05+250:23:44:00.000	4	to	5.999	secs.
env-0008_2344_LF.sgy	05+250:23:44:00.000	05+250:23:50:00.000	4.333	to	5	secs.
env-0008_2350_LF.sgy	05+250:23:50:00.000	05+251:01:06:00.000	2.666	to	6.666	secs.
env-0008_0106_LF.sgy	05+251:01:06:00.000	05+251:07:30:00.000	1.333	to	2	secs.
env-0008_0730_LF.sgy	05+251:07:30:00.000	05+251:11:32:00.000	2	to	2.267	secs.
env-0008_1132_LF.sgy	05+251:11:32:00.000	05+251:21:24:00.000	1.666	to	11	secs.
env-0009_2128_LF.sgy	05+251:21:38:00.000	05+251:22:49:00.000	3.333	to	4	secs.

env-0005_2306_LF.sgy	05+251:23:06:00.000	05+251:23:14:00.000	2.666	to	3.667	secs.
env-0001_2356_LF.sgy	05+251:23:58:00.000	05+252:00:01:00.000	3.333	to	4	secs.
env-0001_0009_LF.sgy	05+252:00:09:00.000	05+252:00:09:00.000	3.333	to	4	secs.
env-0002_0027_LF.sgy	05+252:00:27:00.000	05+252:00:29:00.000	3.333	to	4	secs.
env-0005_0032_LF.sgy	05+252:00:32:00.000	05+252:00:40:00.000	3.333	to	4	secs.
env-0006_0102_LF.sgy	05+252:01:02:00.000	05+252:01:15:00.000	3.333	to	4	secs.
env-0001_0233_LF.sgy	05+252:02:33:00.000	05+252:02:58:00.000	3.333	to	4	secs.
env-0001_0258_LF.sgy	05+252:02:58:00.000	05+252:05:31:00.000	2.666	to	4	secs.
env-0003_0536_LF.sgy	05+252:05:36:00.000	05+252:06:33:00.000	1.666	to	3.333	secs.
env-0005_0643_LF.sgy	05+252:06:43:00.000	05+252:19:05:00.000	1.333	to	2.333	secs.
env-0005_1905_LF.sgy	05+252:19:05:00.000	05+252:19:49:00.000	2	to	5.333	secs.
env-0005_1949_LF.sgy	05+252:19:49:00.000	05+252:20:09:00.000	1	to	1.667	secs.
env-0005_2009_LF.sgy	05+252:20:09:00.000	05+253:01:49:00.000	1.333	to	6.666	secs.
env-0005_0149_LF.sgy	05+253:01:49:00.000	05+253:06:52:00.000	0.666	to	1.333	secs.
env-0005_0652_LF.sgy	05+253:06:52:00.000	05+253:07:27:00.000	0.4	to	0.667	secs.
env-0005_0727_LF.sgy	05+253:07:27:00.000	05+253:17:07:00.000	1	to	4.333	secs.
env-0005_1828_LF.sgy	05+253:18:28:00.000	05+253:21:21:00.000	1.666	to	2.333	secs.
env-0005_2121_LF.sgy	05+253:21:21:00.000	05+253:21:21:00.000	3.337	to	4.004	secs.
env-0006_2132_LF.sgy	05+253:21:32:00.000	05+254:20:54:00.000	2.033	to	4.067	secs.
env-0006_2054_LF.sgy	05+254:20:54:00.000	05+254:21:45:00.000	4.406	to	5.084	secs.
env-0006_2145_LF.sgy	05+254:21:45:00.000	05+254:21:45:00.000	4.666	to	5.333	secs.
env-0007_2145_LF.sgy	05+254:21:45:00.000	05+254:23:02:00.000	4	to	5.333	secs.
env-0007_2303_LF.sgy	05+254:23:03:00.000	05+254:23:03:00.000	1.6	to	1.867	secs.
env-0008_2303_LF.sgy	05+254:23:03:00.000	05+254:23:04:00.000	4	to	5.333	secs.
env-0008_2304_LF.sgy	05+254:23:04:00.000	05+255:09:47:00.000	1.666	to	2.333	secs.
env-0008_0947_LF.sgy	05+255:09:47:00.000	05+255:17:30:00.000	2.133	to	2.4	secs.
env-0005_1825_LF.sgy	05+255:18:25:00.000	05+255:18:26:00.000	4.666	to	5.999	secs.
env-0001_2341_LF.sgy	05+255:23:41:00.000	05+255:23:42:00.000	4.666	to	5.999	secs.
env-0001_0051_LF.sgy	05+256:00:51:00.000	05+257:12:33:00.000	5.333	to	6	secs.
env-0001_1233_LF.sgy	05+257:12:33:00.000	05+258:10:15:00.000	5.666	to	6.333	secs.
env-0001_0051_HF.sgy	05+258:10:15:00.000	05+258:13:18:00.000	0	to	1.319	secs.
env-0001_1318_LF.sgy	05+258:13:18:00.000	05+258:13:18:00.000	0	to	1.333	secs.
env-0002_1324_LF.sgy	05+258:13:24:00.000	05+258:16:37:00.000	0	to	1.333	secs.
env-0002_1637_LF.sgy	05+258:16:37:00.000	05+258:16:37:00.000	0	to	0.667	secs.
env-0002_1638_LF.sgy	05+258:16:38:00.000	05+259:03:28:00.000	0	to	1.333	secs.
env-0002_0329_LF.sgy	05+259:03:29:00.000	05+259:03:31:00.000	1.333	to	2	secs.
env-0002_0331_LF.sgy	05+259:03:31:00.000	05+260:03:17:00.000	2.666	to	6.333	secs.
env-0002_0317_LF.sgy	05+260:03:17:00.000	05+260:15:04:00.000	4	to	7.999	secs.
env-0002_1504_LF.sgy	05+260:15:04:00.000	05+261:00:55:00.000	3.333	to	4	secs.
env-0002_0056_LF.sgy	05+261:00:56:00.000	05+261:04:17:00.000	4.666	to	11.99	secs.

env-0002_0418_LF.sgy	05+261:04:18:00.000	05+261:04:18:00.000	4	to	5.949	secs.
env-0003_0419_LF.sgy	05+261:04:19:00.000	05+261:04:20:00.000	4.666	to	5.999	secs.
env-0003_0421_LF.sgy	05+261:04:21:00.000	05+261:04:21:00.000	4	to	5.949	secs.
env-0004_0421_LF.sgy	05+261:04:21:00.000	05+261:04:21:00.000	4.666	to	5.999	secs.
env-0004_0422_LF.sgy	05+261:04:22:00.000	05+261:04:30:00.000	4	to	5.949	secs.
env-0004_0430_LF.sgy	05+261:04:30:00.000	05+261:13:04:00.000	2.666	to	5.999	secs.
env-0004_1304_LF.sgy	05+261:13:04:00.000	05+261:13:05:00.000	2.333	to	3	secs.
env-0004_1305_LF.sgy	05+261:13:05:00.000	05+261:13:09:00.000	2.133	to	2.4	secs.
env-0004_1309_LF.sgy	05+261:13:09:00.000	05+261:17:25:00.000	2.333	to	8.333	secs.
env-0004_1725_LF.sgy	05+261:17:25:00.000	05+261:17:28:00.000	1.066	to	1.333	secs.
env-0004_1728_LF.sgy	05+261:17:28:00.000	05+261:20:03:00.000	3	to	8	secs.
env-0004_2003_LF.sgy	05+261:20:03:00.000	05+262:17:46:00.000	2.666	to	8.666	secs.
env-0004_1746_LF.sgy	05+262:17:46:00.000	05+262:17:46:00.000	2	to	2.667	secs.
env-0005_1746_LF.sgy	05+262:17:46:00.000	05+264:02:54:00.000	4	to	5.333	secs.
env-0005_0254_LF.sgy	05+264:02:54:00.000	05+265:12:11:00.000	5	to	5.667	secs.
env-0005_1211_LF.sgy	05+265:12:11:00.000	05+266:07:39:00.000	3.333	to	5.667	secs.
env-0006_1541_LF.sgy	05+266:15:41:00.000	05+267:06:43:00.000	0	to	3	secs.
env-0006_0643_LF.sgy	05+267:06:43:00.000	05+267:06:43:00.000	0	to	0.667	secs.
env-0006_0644_LF.sgy	05+267:06:44:00.000	05+267:06:44:00.000	0	to	0.667	secs.
env-0007_0645_LF.sgy	05+267:06:46:00.000	05+267:11:53:00.000	0.266	to	0.533	secs.
env-0007_1153_LF.sgy	05+267:11:53:00.000	05+267:13:04:00.000	2.266	to	2.533	secs.
env-0007_1304_LF.sgy	05+267:13:04:00.000	05+267:16:57:00.000	1	to	7.333	secs.
env-0007_1658_LF.sgy	05+267:16:58:00.000	05+267:16:58:00.000	2.666	to	3.965	secs.
env-0008_1838_LF.sgy	05+267:18:38:00.000	05+268:15:45:00.000	0.666	to	2.667	secs.
env-0008_1545_LF.sgy	05+268:15:45:00.000	05+268:21:08:00.000	0	to	1.333	secs.
env-0008_2109_LF.sgy	05+268:21:09:00.000	05+268:21:09:00.000	0	to	2.273	secs.
env-0009_2234_LF.sgy	05+268:22:34:00.000	05+269:02:39:00.000	1	to	1.667	secs.
env-0009_0239_LF.sgy	05+269:02:39:00.000	05+269:02:42:00.000	0.4	to	0.667	secs.
env-0010_0242_LF.sgy	05+269:02:42:00.000	05+269:16:02:00.000	0.8	to	1.2	secs.
env-0010_1602_LF.sgy	05+269:16:02:00.000	05+269:17:12:00.000	0.8	to	1.067	secs.
env-0010_1713_LF.sgy	05+269:17:13:00.000	05+269:17:15:00.000	0.666	to	2.667	secs.
env-0010_1715_LF.sgy	05+269:17:15:00.000	05+270:01:29:00.000	0.4	to	0.667	secs.
env-0010_0129_LF.sgy	05+270:01:29:00.000	05+270:22:39:00.000	1.666	to	5.333	secs.
env-0010_2239_LF.sgy	05+270:22:39:00.000	05+271:14:48:00.000	0.333	to	3.333	secs.
env-0010_1448_LF.sgy	05+271:14:48:00.000	05+271:22:47:00.000	0.666	to	1.333	secs.
env-0010_2247_LF.sgy	05+271:22:47:00.000	05+271:23:07:00.000	1.066	to	1.333	secs.