

# *USCGC Healy* Cruise HLY0602

Project title: *Integrated geophysical and geological investigation of the crustal structure of western Canada Basin, Chukchi Borderland and Mendeleev Ridge, Arctic Ocean*

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Principal Investigators: Lawrence Lawver<sup>1</sup> [[lawver@ig.utexas.edu](mailto:lawver@ig.utexas.edu)]  
Harm van Avendonk<sup>1</sup> [[harm@ig.utexas.edu](mailto:harm@ig.utexas.edu)]

Additional Investigators: R. Lawrence Phillips<sup>2</sup>, Matthew Hornbach<sup>1</sup>  
and Peggy Vermeesch<sup>1</sup>

<sup>1</sup> University of Texas at Austin, Institute for Geophysics  
Jackson School of Geosciences  
10100 Burnet Road R2200  
Austin, TX 78758-4445

<sup>2</sup> U.S. Geological Survey (retired)  
1915 East Day Island Blvd.  
University Place, WA 98466-1814

## Chapter 1: Introduction to HLY0602

In 2003, we proposed to NSF to do an integrated geophysical and geological study of the western section of the Amerasian Basin of the Arctic Ocean. We wanted to determine the crustal structure of the deep Canada Basin, Northwind Ridge, Chukchi Borderland, Chukchi Basin, and Mendeleev Ridge. To do this, we proposed to collect seismic refraction data using sea-ice seismometers (S-ISs) that we would place on the ice and use *USCGC Healy* to produce a seismic source to be recorded at the S-ISs. We also wished to collect seismic reflection data to determine depositional history and locate potential drill sites; and to collect gravity data and piston cores to define the sedimentary history of the region. Regional geologic studies, seismic reflection profiling from conventional seismic vessels along the periphery of the Arctic Basin and from icebreakers within the polar ice pack, aerogeophysics, and satellite altimetry data have led many researchers to support the idea that the Amerasia Basin of the Arctic Ocean opened about a pivot point near the Mackenzie Delta. Simple reconstruction of the Amerasia Basin is precluded, however, by the presence of the Chukchi Borderland, an extensive cluster of submarine plateaus in the Amerasia Basin north of the Chukchi shelf, and by Mendeleev Ridge. If both the Borderland and the Alpha/Mendeleev Ridge are constructed of igneous rocks that postdate opening of the Amerasia Basin, simple, rotational closure is not a problem. However, Grantz and others [1998] have cored Phanerozoic sediments, including Cambrian and Ordovician shallow-water marine carbonates from Northwind Ridge that are similar to the basement rocks found beneath the Sverdrup basin of the Canadian Arctic Archipelago.

We wanted to determine if Chukchi Borderland consists of continental crust, because if it does then complicated tectonic scenarios must be devised to explain its present location. The crustal character of the Borderland is therefore critical to understanding the origin and subsequent kinematics for the opening of the Amerasia Basin. Northwind Ridge, the eastern part of the Chukchi Borderland is a high-standing plateau bordered on the east by the tectonically enigmatic Northwind Escarpment. Understanding the crustal character of the Chukchi Borderland and the contrast between it and that of the deep Canada Basin is very important to discerning Arctic tectonics. We proposed a seismic reflection and refraction experiment to resolve the fundamental questions concerning its crustal structure and tectonic evolution of the Amerasia Basin. Seismic profiles from the deeper Canada Basin across the Northwind

Escarpment would have determined whether it operated as a transform margin, convergent margin or rifted, passive margin.

The experiment we proposed required building 20 sea-ice seismometers that we deployed on the ice using helicopters. The hydrophone of the S-ISs was to be deployed through a hole augured through the ice but we found that simply putting it in the water at the edge of the flow was sufficient and much quicker to deploy. A GPS unit in the S-IS provided continuous location and every fifteen minutes the GPS position was updated to the information the datalogger stored that could be queried by radio. The data we recorded will be used in iterative travel time tomographic inversions to delineate details of the velocity structure. The velocity structure will be used in conjunction with existing seismic reflection and geologic data to produce crustal sections of Chukchi Borderland, Chukchi Basin and Mendeleev ridge. The resulting crustal sections will be used to calibrate existing ship, satellite, submarine, and aerogravity data, to construct realistic models, and to address such questions as the tectonic origin and degree of extension in the Chukchi Borderland, the origin of Mendeleev Ridge, and to determine whether there has been convergence between Northwind Ridge and Canada Basin.

**Future work:** Just before our cruise was terminated prematurely, we had found some exciting places to core and sample on the Mendeleev Ridge. The findings may have substantial information concerning climate change. We also found a number of suitable sites for future drilling operations in the region. The IODP drill sites will be used to study the climate history of the Arctic region, ocean circulation patterns, and impact of ice-covered versus ice-free conditions on the biotic evolution of the Arctic. Determination of the crustal structure of Mendeleev Ridge has important implications for Law of the Sea considerations.

**Outreach:** Five graduate students including one from the University of Alaska at Fairbanks, two undergraduate students including one from Moscow State University, one high school student from Torrey Pines High School in California and a high school teacher from Wisconsin Rapids, Wisconsin, participated in our cruise. The graduate students in particular were invaluable to the seismic refraction work since we did not have the two airgun techs on our cruise that were to have been supplied by LDEO.

**UTIG Science Participants**

Lawrence Lawver, Co-chief Scientist, UTIG  
Harm van Avendonk, Co-chief Scientist, UTIG  
Lawrence Phillips, Sedimentologist, USGS (retired)  
Mark Wiederspahn, System Analyst, UTIG  
Matt Hornbach, Scientist, UTIG  
Peggy Vermeesch, Post-doc, UTIG  
Anatoly Mironov, Technical Support, UTIG  
Marcy Davis, SeaBeam support, UTIG  
Steffen Saustrop, Seismic system support, UTIG  
Steven Stevenoski, Seismic system support, High School teacher, Wisconsin Rapids, WI  
Paul Henkart, CHIRP data support, UCSD-Scripps

**Students**

Chase Asher, UT undergraduate  
Kevin Bain, UT graduate  
Kelley Brumley, UAF graduate  
Max Henkart, Torrey Pines High School, Del Mar, CA  
Margaret Kroehler, UT graduate  
Matt McDonald, UT graduate  
Kirill Miloradovskiy, Moscow State University  
Russell Young, UT graduate

**Oregon State Coring Team**

Chris Moser, Head coring tech  
Dale Hubbard, coring tech  
Paul Walczak, apprentice coring tech

**Marine Mammal Observers**

Beth Haley, LGL Inc.  
Claudio Fossati, LGL Inc.  
Alejandro Sayegh, LGL Inc.

**Local Observer**

Jimmy Jones Olemaun, Barrow, AK

**Other support**

Dale Chayes, LDEO  
Steve Roberts, Software Eng., UCAR, Boulder, CO  
Robert Shepard, Gravity Tech, Fugro, Inc., Houston, TX  
Hilary Timm, intern, Cal Poly San Luis Obispo

### **Chapter 3: HLY0602 Pre-Cruise preparation**

Our proposal was funded in 2004. We initiated design of the Sea-Ice Seismometers (S-ISs) with Reftek. In summer 2004, van Avendonk and Lawver made a trip to the USCG Polar Helicopter operation in Mobile, AL. We measured space in the USCG helo to determine design of the S-ISs and discussed with CDR Don Marinello our plans for the seismic refraction experiment. At the time we thought we would do the experiment during summer 2005. Unfortunately, *USCGC Healy* time in 2005 was used to support the Beringia Expedition with *Oden* and our work was delayed until summer 2006. By 2006, the USCG Polar helo operation was disbanded and helicopter support was provided by Maritime Helicopters from Homer, Alaska with flight coordination provided by Dave Kreutzer under a contract with the U.S. Department of Interior. USID regulations result in a smaller operational load on the Bell 206L LongRanger helicopters than what Maritime Helicopters shows on their website. In the end, the smaller load requirement did not pose a problem for our work.

The other key component for our cruise was provision for a seismic source system. This will be discussed in greater detail in a later chapter. We had included in our original proposal, an airgun arrangement that had worked well for Art Grantz when he collected seismic reflection data in Canada Basin and around Chukchi Borderland. The seismic source arrangement provided by Yngve Kristoffersen of Norway for HLY0503, while much smaller than our needs, worked very similar to the one Art Grantz had used. During the 2005 summer season, the only seismic operation in the Arctic was the work done on HLY0503. During 2006, there were major operations planned by Shell Oil, Conoco-Phillips, Kerr-McGee, GX Technology and our work on *Healy*. Permitting by the US Fish and Wildlife Service concerning harrassment of polar bears and walruses and by the National Marine Fisheries Services concerning harrassment of whales and seals became a major issue. In addition to the permits required, a presentation was requested at the Alaska Eskimo Whaling Commission (AEWC) at their annual meeting in March in Anchorage. Lawver attended the meeting and presented the planned track chart and work schedule as shown in Figure 1. Of the other four operations scheduled to be presented at the AEWC meeting in Anchorage, Shell gave a good presentation with five representatives present as well as legal counsel, Conoco-Philips gave a less polished presentation and indicated that they

were not familiar with a lot of the marine mammal information and data that they should have known about, Kerr-McGee did not show for their presentation and GX Technology's presentation was not well-received.

Our Incidental Harassment Assessment package was produced by LGL, Ltd., environmental research associates (see: <http://www.lgl.com/>). They consistently over-estimated our harassment potential and van Avendonk and Lawver requested that they reduce their estimates by about half. In the end, the harassment potentials were still over-estimated by about a factor of 20. Getting permits will probably only become more difficult with even more industry seismic work planned in the Arctic. It may be difficult to get IHA permits. There are some proponents of a "noise budget" for the nearshore Arctic region which would restrict total number of seismic cruises per season.

We did not know how many polar bears we might encounter in our on-ice work so we asked for an intentional harassment permit in case we needed to use the helicopter to chase a polar bear away from our S-ISs when we went to retrieve them. We were issued such a permit but did not have a need for it. On our whole expedition, we only saw 7 polar bears and none were at any time near enough to us to be a problem.

### **Cruise narrative**

Six of the student participants in HLY0602 met in Anchorage on 10 July 2006 for an eight day field trip prior to the cruise. They were joined in Fairbanks by students from the University of Alaska at Fairbanks and Gil Mull for a three day field trip along the Dalton Highway (the Haul Road) and across the Brooks Range to Deadhorse, AK. They arrived in Barrow on the evening of the 17<sup>th</sup>. *USCGC Healy* did not arrive off Barrow until the afternoon of the 18<sup>th</sup> of July since they made an unscheduled stop in Nome to pick up seismic gear and they encountered heavy ice off Barrow (see Figure 1). A request had been made by residents of Barrow that we do not conduct extensive helo ops over the region where the locals were engaged in subsistence hunting. Given the severe ice conditions, it was suggested that *USCGC Healy* hold in place north of Pt. Barrow and that our helo flights proceed to the northeast from the SAR facility at the Barrow airport,

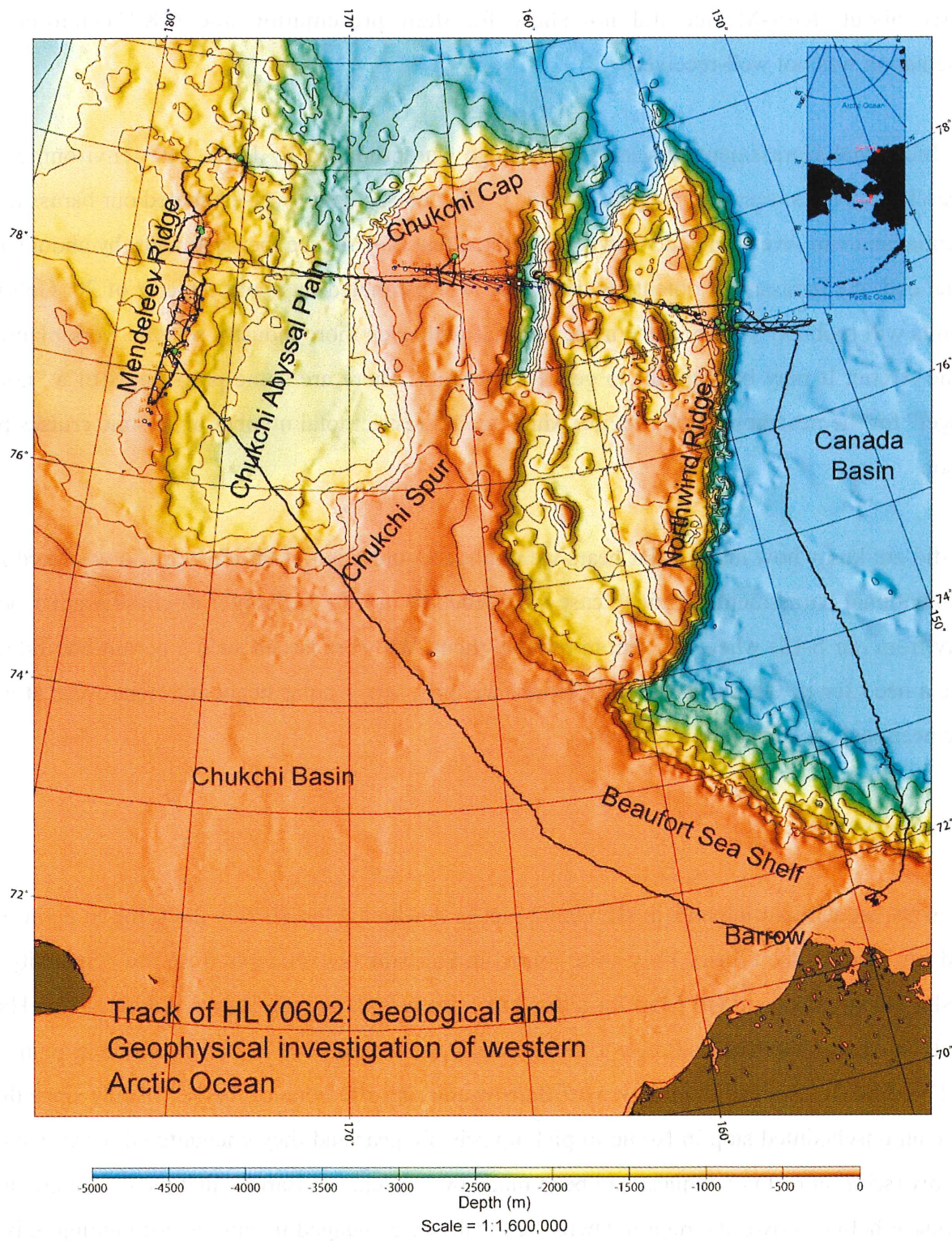


Figure 1. Cruise track of *USCGC Healy* from 19 July 2006 until 19 August 2006. Cruise HLY0602.

pass over Plover Point and then proceed to where *USCGC Healy* was stopped. Fog in the early evening ended flight operations on the 18<sup>th</sup> and the remainder of the science party did not board *USCGC Healy* until the morning of the 19<sup>th</sup>. The fact that 10 members of the science party were left overnight in Barrow after they had checked out of their accommodations in Barrow did not prove to be a problem thanks to the logistical assistance of BASC.

#### Weekly Report for 19 – 26 July 2006

Most of the scientific party arrived in Barrow, Alaska on either the 15<sup>th</sup> or 16<sup>th</sup> of July. Five students arrived on the 17<sup>th</sup> after having spent 8 days on a field trip from Seward, Alaska, through Denali National Park onto Fairbanks and up the Dalton Highway with Gil Mull to Deadhorse. They flew into Barrow from Deadhorse via Nuiqsit, somewhat surprised to find that on bush airlines there are no security checks. Healy was enroute from Seattle and encountered extraordinarily heavy ice near Wainwright. They eventually made it to north of Pt. Barrow where Healy had been requested to position itself so that the helicopter shuttle flights would not adversely impact the subsidence hunters in Barrow. In consultation with folks in Barrow, it was decided the best approach in/from the ship was from the airport to Plover Point to the ship. To our knowledge Healy's presence off Barrow was only detected by the extremely sensitive aerosol particle counter at the Barrow Environmental Observatory. No complaints were received by anyone concerning our flight operations. All inbound USCG personnel and eight of the science personnel were able to board Healy on the 18<sup>th</sup>. Those of us left in Barrow spent the evening observing snowy owls, most impressive birds that nest in the Barrow area.

The logistical support received by us and by Healy from the Barrow Arctic Science Consortium including Glenn Sheehan, Lewis Brower, Bob Bulger, Alice Brower and numerous others must be acknowledged. They were always there when needed, put our interests at the forefront and we could not have gotten aboard without their tremendous help. Bob even helped out Harm when Harm dropped his laptop, got it running again. Thanks to all of you.

Due to a delay in receiving some critical seismic parts, we knew we had to return to Barrow before the 24<sup>th</sup>. We decided we would use the time to core on a couple of sites of interest to

Larry Phillips along the Northwind Escarpment, northwest of Barrow. We attempted to head west and found that the heavy ice, far heavier than any known at this time of year even by the Elders at Barrow, made it such that full speed to the northwest resulted in no net motion of the ship over the ground. In one day we used 1.6% of our fuel in order to stay stationary. We then spent 11 hours reversing direction and drifted with the ice over the weekend. We went much farther east than we had ever gone westward. Finally we broke out of the heaviest ice, slightly to the east of Pt. Barrow. At that time we decided to practice launching the airgun cage to find that it does indeed fit through the A-frame. We then undertook to acquaint the first helo pilot with the ice. Harm and Bill went over in a small boat and jumped up and down on the ice to convince themselves that it would hold them and the helo without cracking. Then Harm, Anatoly and Peggy went with the helicopter to the same small multi-year iceflow and set up one of our stations. It worked! They did a range test with an antenna in the helo and an antenna test of the main antenna we have on the ship. Both systems worked which means we should be able to recover the seismometers as long as we have radio contact with them to give us their GPS determined position.

On the evening of the 24<sup>th</sup>, our critical seismic parts arrived and they were quickly installed by Dale Chayes and Jay Ardai. The seismic system should now operate, and Jay left Healy last night on a final helo flight to Barrow. After that we got underway and are headed roughly north to our first worksite. Ice is such that we make between 1.5 kts and 9 kts.

Weekly Report for 27 July – 2 August 2006

After we headed north from Barrow we encountered the opposite ice conditions from what we had found immediately off Barrow. Instead of extremely heavy, compressed ice, we found extremely thin annual ice. Where 2 meter thick ice would normally be expected, we found 60 cm ice. So instead of stopping at about 75°N for our seismic anisotropy experiment, we continued north to 77°N. The seismic gear was not ready when we got to the northern position for an anisotropy experiment so we went to do two Benthos gravity cores at the base of the Northwind Escarpment. Two successful cores were recovered but only found recent sediments with up to four zones of glacial and interglacial deposits. We then placed seven of our sea ice seismometers

on the ice and returned to the start of the line at 76°52'N 150°W to begin the seismic refraction shoot. Initial deployment of the seismic source cage resulted in the decision that it was not ready for operation and we headed to the top of Northwind Ridge to take some large-diameter gravity cores. As we were waiting for the seismic gear to be ready we decided to head to a coring spot found on seismic work done last season by Bernie Coakley. This time we used a larger diameter gravity core launched from the starboard A-frame. Enroute from that site to put out additional sea ice seismometers, we crossed a seamount with 1000 m of relief that is on Northwind Ridge. We deployed an additional five sea ice seismometers for a total of 12. At that time we deployed the seismic source cage and streamer and started to shoot the seismic refraction line from west to east. Not too far into that line we hit hard ice and we recovered the seismic cage for redesign and repair.

We then stopped for our first Jumbo Piston Core (JPC). Larry Phillips decided to try for a 10 meter core and recovered 9.5 meters of a bluish-grey clayey core that had a distinct hydrogen sulfide smell. He thinks it is either the ubiquitous 90 Ma volcanic tephra that is found in much of the Arctic or something no one has ever found here. We then decided to run back to where we had deployed Cooler #1 to east in the deep Canada Basin. After a further delay waiting for the seismic source to be ready, we finally got the source array in the water and were able to begin the northern seismic refraction line. We were able to collect 13 hours of seismic data. We recorded data at least out to cooler 7b, 48 n.m. (>80 km) from the start of the line.

Weekly Report for 3 – 9 August 2006

After we recovered the last of the coolers from the eastern end of our northern line, Northwind Ridge to Canada Basin, we headed west to the Chukchi Cap region. Enroute to Chukchi Cap we knew we would be crossing the Chukchi Ditch, a remarkable feature that shows prominently in both the satellite and aerogravity data as well as a depth feature on the IBCAO bathymetry at 162° W. We found a remarkable straight eastern wall to the ditch-like feature that is virtually straight for the 18 km that we surveyed. Larry Phillips took two jumbo piston cores on the steep margin. He recovered what he thinks are possibly Paleozoic meta-sediments, similar to what he found along Northwind Escarpment to the east. The Chukchi Ditch has a very nearly flat floor at

2700 meters depth, with the western side along Chukchi Cap rising to 400 meters and the eastern side stepping up to 700 meters. On the 6<sup>th</sup> of August we were visited by *USCGC Polar Sea* as they headed north to find some hard ice to crunch. Al Sutherland was hard at work leading the science efforts on *Polar Sea*. After photo ops, we headed west to deploy 13 coolers along a nearly east-west line at 78°N. As we headed west we spotted a mother polar bear and 2 or 3 cubs very close to where we had deployed cooler #25. Upon completion of deployment of the coolers we started the seismic line headed east. We were able to collect about 40 km of the seismic refraction line before the seismic gear needed a substantial refurbishment. At that point we diverted to the north where a 700+ meter deep feature is shown on the IBCAO bathymetry map. We found no bathymetric expression of the feature indicated but did find some furrows in the bottom with amplitudes of almost 30 m with wavelengths of 700 to 1000 meters. A piston core was taken on top of one of the furrows. We then returned to the seismic line and tried the seismic gear again but were only able to collect about 4 hours worth of data. We then diverted to the eastern end of our line, where two more piston cores were taken on the Chukchi Cap side of the Ditch. The first core appeared to consist of contourite deposits, deposits formed by current redeposition of sediments. The second core may have had additional meta-sediments. We then deployed the refurbished seismic gear and collected nearly 40 km of seismic refraction data from the eastern edge of Chukchi Cap to the west, leaving a 25 km gap between the two lines. We then had a day of major helicopter ops where we recovered 12 of the 13 coolers. The helicopter support that we have received on this cruise is exemplary and the pilots and the aviation staff should be commended. Unfortunately we did not recover Cooler #25. It had not been heard from since immediately after deployment so we did not have a location for it for pick-up. Since it was nearest to where the Polar Bears had been sighted it is thought that it was mangled by the bears. It was looked for by two separate helicopters and was not sighted. Since the ship was at least three hours steam from the cooler site and we had collected the coolers to either side we no longer had a handle on its drift rate. We are now headed west to the Mendeleev Ridge where we will do one last seismic refraction line, more coring and possibly some dredging if warranted.

Weekly Report for 10 - 16 August 2006

Finally a week when everything went right. After reluctantly leaving cooler #25 behind on Chukchi Cap we headed westward to Mendeleev Ridge. Enroute we passed over what might be

considered a five kilometer wide “rift valley”. It looked somewhatly like a miniature version of the Chukchi Ditch that we cored and mapped the previous week. Unfortunately we did not have time to stop and core. We crossed the Mendeleev Ridge to the south of where HLY0503 crossed and continued to the west towards the Makarov Basin. We then ran to the northeast to core a possible slump site identified on HLY0503. Ice conditions were quite heavy (9/10s to mostly 10/10s) so we took two jumbo piston cores at the slump site where very consolidated material, overlain by up to 9 m of quaternary cover was recovered. It is unclear what the consolidated layer is. We then headed south to an area that HLY0503 found numerous pockmarks and took three Benthos gravity cores in a heavily pock-marked area. Our first core nailed the center of a pockmark less than 200 meters across and approximately 30 m deep. The next two cores were taken on what appeared to be a consolidation of pockmarks that appeared to be a “blow-out” feature from the CHIRP data. In places the entire 20 to 30 meter upper section appeared vertically eliminated with perhaps only a few meter of post-explosion drape. Three cans of sediment were collected for later gas analysis. We then proceeded southward with the idea that we would start placing coolers on the ice when we found ice conditions in which we could tow our ungainly seismic source frame. That took us far enough south that the end of our last cooler wound up at 76° 30' N on Arlis Plateau. We then began the line in the south and collected the seismic refraction data northward. We had very few problems with the seismic source frame and had excellent weather and ice conditions. We passed over a number of interesting multibeam and CHIRP sites both going south and then north. One feature at the southern end near Arlis Plateau appears to have been slumped off Arlis Plateau in such a way as to compress recent sediment downslope. We also saw numerous pock marks, sometimes in very heavy concentrations. We planned to multibeam survey and CHIRP survey some of the sites, particularly the heavily pockmarked sites upon completion of the seismic refraction work. Midway along the Mendeleev Ridge line we stopped to take a “library” jumbo piston core. We wanted to take a sample of the flat lying CHIRP data. A 30 foot jumbo piston core was rigged. It over-penetrated with the core weight going into the mud. We collected almost a full 30 feet of mud plus a full trigger core. We intend to take a 40 foot jumbo piston core on the next site. After coring, things went so well that we ran the seismic refraction line northward past the northernmost cooler for a total line length of 140 km with no significant gaps. After a snowfall that left a couple of cm of snow on the deck, the day for retrieving coolers turned out to be brilliantly sunny but cold. Cooler recovery went

like clockwork. Of the 14 coolers we had on the ice, only one did not communicate with us and we had replaced it while we did the piston core. Good weather and actively communicating coolers make recovery easy. We recovered the southern eight coolers with the two helicopters flying simultaneously. We could finally say we had done what we had proposed with the three seismic refraction lines collecting the most important lines, Northwind Escarpment-Canada Basin, Chukchi Cap and Mendeleev Ridge. By this point the cruise was a success, both seismic refraction and coring wise.

Report 5 for for 17 August 2006

After the very successful week #4 we were looking forward to taking more cores and trying to collect multi-channel seismic reflection data since we had finally found ice conditions where it might be safe to tow a long (~400 m) streamer. Unfortunately on the 17<sup>th</sup> of August, tragedy struck the Healy family. There was a tragic diving accident involving two USCG divers. The diving did not involve the science party in anyway. The two divers were outgoing, interactive folk who were friends to everyone and well liked by all including the science party. Ms. Jessica Hill was the science liasion so Harm and I met with her every evening. She was a truly fine person. Needless to say, science operations ceased immediately and we are enroute to Barrow. We will be disembarking in Nome on Tuesday, 22 August 2006. It has been a difficult time for all aboard. The science party seems to be holding up well. All of us have been deeply touched by the loss of Jessica Hill and Steven Duque.

#### **Chapter 4: Seismic instrument deployment on the sea ice**

Seismic refraction is used to study the earth's crust. Seismic waves are refracted by the crustal layers at the different boundaries and records of the refracted waves requires the recording of the seismic waves at long offsets of tens of kilometers to hundreds of kilometers. The sea ice of the Arctic Ocean precludes the use of ocean bottom seismometers, the instruments of choice in ice-free regions. The constant drift of the ice adds a logistical complication to the data acquisition. Two helicopters were requested for our experiment to deploy and recover our sea-ice seismometers on the drifting ice at distances up to 80 kilometers from the ship. A typical helicopter sortie included a pilot, two scientists and between one and four seismic instrument set ups. The instruments deployed included a REFTEK 130 data logger with a GPS receiver, Freewave radio, hydrophone and geophone. The data logger and a large truck battery were packaged in a Coleman™ 40 quart cooler, and the whole instrument setup is hereafter referred to as a "cooler". The GPS receiver was secured on top of the cooler, the geophone was placed under the cooler, and the hydrophone was dropped into open water, although a couple of times that was not practical and large melt ponds were used. The antenna for the Freewave radio was placed atop a 1" in diameter PVC mast about 2 meters tall. The PVC mast was cut to fit into the luggage compartment of the Bell LongRanger helicopter. The planned cooler deployment locations were input as GPS coordinates in the helicopter navigation system and in a hand-held GPS unit used by the scientists aboard the helo. Deployment of coolers went fairly rapidly because Radio communications between the sea-ice seismometers and the ship and helicopters allowed us to track the location of the deployed instruments as they drifted over several days to a week.

#### **Canada Basin**

During HLY0602 we were able to complete three linear arrays with 12-to-15 km spacing between the instrument sites. The first of these transects extended from the western Canada collecting seismic data across the Northwind Escarpment Basin across the Northwind Escarpment. Unfortunately, heavy ice conditions prevented us from collecting seismic data across the Northwind Escarpment although we did get a few shots on the Northwind Escarpment. In addition to the long offset seismic refraction work we had hoped to collect multi-channel seismic reflection work to determine sediment thickness and velocity. It quickly became clear

that the seismic reflection streamer provided for our work, could not be towed together with the airgun cage. After the first streamer was damaged beyond



**Figure 1.** Initial deployment method using guy-lines to secure antenna mast. It was determined that guy-lines were not useful since tentpegs melted out.

repair, additional seismic reflection data was not collected when HLY0602 ended prematurely just before the planned seismic reflection work was to be attempted again. So unfortunately, seismic reflection was not collected during HLY0602. On the first E-W transect, we were able to collect seismic refraction data along the eastern portion of the transect in the deepwater Canada Basin. All 12 instruments of the first array were recovered successfully. Although there was not much sun during the first deployment of the Sea-Ice Seismometers, the amount of ice melting around the equipment was substantial. The stakes that fixed the guidewires to the ice became loose and many guidewires were slack. The wooden stakes were particularly ineffective. More importantly, on the first refraction line, none of the geophones upon recovery were found in good contact with the ice due to melting. Not surprisingly therefore, the hydrophone data from this

first transect appear to be much better than the geophone data. A couple of hydrophones were dropped in melt ponds instead of open leads, which resulted in higher noise levels on those phones. Originally we were afraid that putting the hydrophones in open leads might lead to difficulties in recovery if the leads closed while the instruments were deployed. It turned out that that was not a problem on any of the deployments.

### **Chukchi Cap**

For our second seismic refraction line, we dropped thirteen instruments from east to west across Chukchi Cap. During the seismic shoot of this second refraction line we had to pull in our seismic gear several times to make extensive repairs and changes to the airgun cage. After shooting some seismic refraction data on the western Chukchi Cap we transited to the eastern Chukchi Cap for some additional seismic refraction shooting. The shot



Figure 2. Later evolution of deployment with orange flag and without guy-lines. Note helo skids depressions in the snow to the left of the deployment.

coverage on this transect left a large gap on central Chukchi Cap, but we had made some progress. During the shooting of this seismic refraction line we noticed that some of the instruments on ice ceased to broadcast to the ship. Fortunately, the coolers drifted almost exactly in parallel, such that their position could be estimated within one kilometer once the drift of a neighboring instrument was found by radio communication. We nevertheless lost one instrument from which we lost radio contact. We searched for the instrument in two separate helicopter trips, but the instrument was not seen and it did not make radio contact with the helicopter either. The cooler and/or antenna may have been lost due to breaking and shifting ice, or it may have been destroyed by a polar bear, since we saw three bears nearby when the instrument was deployed. Due to colder weather, melting ice was not as much a problem as we had seen in our first experiment. In addition, we now buried the geophones in the ice beneath the coolers, where they were sheltered from the sun.

### **Mendeleev Ridge**

Our third seismic refraction line was oriented approximately north to south on the Mendeleev Ridge. As we were deploying 14 instruments from north to south, 20-knot winds immediately started to push the instruments several miles to the east. Fortunately, these winds subsided, and instrument drift rates were much lower by the time we started shooting refraction data. The instrument deployment was smooth, and the one instrument that failed to communicate by radio was replaced by another during the seismic refraction shoot. The seismic refraction shoot went fast, the airguns held up well, and at times the sea was as smooth as glass. After we acquired data towards the northern end of the transect we picked up the coolers while Healy steamed south again. As on our second transect, we managed to keep the geophones from thawing out by placing the sensors in the ice beneath the coolers. Due to the diving accident the Mendeleev Ridge transect was our last science operation during the Healy 0602 cruise.

### **Helicopter services**

The seismic refraction work that we conducted during Healy cruise 0602 involved fewer instrument deployments and hence fewer helicopter flights than we originally proposed. During the installation of our seismic arrays, which involved 12 to 14 instruments per line, the task of

deploying and recovering these instruments was nevertheless a considerable task. Fortunately, Maritime Helicopters, a company based in Homer (AK) that was contracted for this Healy cruise, provided us with an outstanding helicopter crew. Pilots Joseph Trudo and Bill Springer took opposite work shifts to allow helicopter operations any time of the day. Similarly, mechanics Charles Sims and Andrew Ulrich shared the task of keeping the helicopters safe and ready for our project. David Kreutzer, a federal government aviation manager, planned each flight with the science party and the Healy Operations Officer.

### **Equipment**

Sea-ice seismometers: Reftek 130 recorder, 4.5 Hz geophone, hydrophone. GPS, Freewave radio, Maxrad antenna. Chairman battery. Coleman 40-gallon ice chest. PVC antenna mast. Red-orange flag. Guy wires and stakes for the antenna mast were discontinued after first deployment.

Table 1. Flights

| Flight # | Start Date & Time | End Date & Time | Total time [hh:mm] | Weather        | Operation                                | Ship's Lat | Ship's Lon |
|----------|-------------------|-----------------|--------------------|----------------|--|------------|------------|
| 1        | 07/25/06 00:06    | 07/25/06 01:50  | 01:44              | foggy          | test flight                              | 71.5165    | 154.5279   |
| 3        | 07/29/06 15:05    | 07/29/06 16:17  | 01:12              | clear          | deploy 7,6                               | 77.0411    | 153.5593   |
| 4        | 07/29/06 16:24    | 07/29/06 18:16  | 01:52              | clear to foggy | deploy 5,4                               | 77.0075    | 153.0629   |
| 5        | 07/29/06 20:18    | 07/29/06 21:56  | 01:38              | foggy          | deploy 3,2,1                             | 76.9036    | 153.5453   |
| 6        | 08/01/06 10:59    | 08/01/06 12:37  | 01:38              | foggy          | deploy 12,11                             | 77.3329    | 156.2060   |
| 7        | 08/01/06 12:41    | 08/01/06 13:23  | 00:42              | foggy          | deploy 10                                | 77.3073    | 156.0082   |
| 8        | 08/01/06 14:36    | 08/01/06 15:10  | 00:34              | foggy          | deploy 9                                 | 77.2515    | 155.5102   |
| 9        | 08/01/06 15:15    | 08/01/06 15:39  | 00:24              | foggy          | deploy 8                                 | 77.2515    | 155.5102   |
| 10       | 08/02/06 18:30    | 08/02/06 20:21  | 01:51              | clear to foggy | 7 not found, deploy 7B                   | 77.0194    | 153.7605   |
| 11       | 08/04/06 00:37    | 08/04/06 01:48  | 01:11              | foggy          | recover 1,2                              | 76.8912    | 152.8996   |
| 12a      | 08/04/06 01:50    | 08/04/06 02:23  | 00:33              | foggy          | recover 3                                | 76.8940    | 152.9128   |
| 12b      | 08/04/06 05:36    | 08/04/06 06:00  | 00:24              | foggy          | recover 4                                | 77.0050    | 153.8616   |
| 13       | 08/04/06 08:35    | 08/04/06 08:55  | 00:20              | foggy          | recover 5                                | 77.0539    | 154.5512   |
| 14       | 08/04/06 10:23    | 08/04/06 10:39  | 00:16              | foggy          | recover 6                                | 77.1148    | 155.0900   |
| 15       | 08/04/06 11:51    | 08/04/06 12:07  | 00:16              | foggy          | recover 7B                               | 77.1693    | 155.3370   |
| 16       | 08/04/06 13:23    | 08/04/06 13:36  | 00:13              | foggy          | recover 7                                | 77.1895    | 155.7045   |
| 17       | 08/04/06 22:40    | 08/05/06 00:43  | 02:03              | foggy          | recover 9, 8 (10 not found)              | 77.3257    | 155.9492   |
| 18       | 08/05/06 04:11    | 08/05/06 04:37  | 00:26              | foggy          | recover 10                               | 77.4334    | 157.0440   |
| 19       | 08/05/06 06:01    | 08/05/06 06:18  | 00:17              | foggy          | recover 11                               | 77.4807    | 157.5615   |
| 20       | 08/05/06 07:49    | 08/05/06 08:05  | 00:16              | foggy          | recover 12                               | 77.5496    | 158.1186   |
| 21       | 08/06/06 16:19    | 08/06/06 17:43  | 01:24              | foggy          | deploy 20,21,22                          | 77.8806    | 162.6736   |
| 22a      | 08/06/06 18:13    | 08/06/06 18:59  | 00:46              | foggy to clear | deploy 23                                | 77.9123    | 163.3468   |
| 22b      | 08/06/06 19:03    | 08/06/06 20:02  | 00:59              | clear          | deploy 24,25                             | 77.9206    | 163.6126   |
| 23       | 08/06/06 22:07    | 08/06/06 23:57  | 01:50              | clear          | deploy 26,27,28                          | 77.9645    | 164.4868   |
| 24       | 08/07/06 00:15    | 08/07/06 01:27  | 01:12              | clear to foggy | deploy 29,30                             | 78.0061    | 165.3184   |
| 25       | 08/07/06 02:47    | 08/07/06 04:17  | 01:30              | clear          | deploy 31,32                             | 78.0423    | 166.3510   |
| 26       | 08/10/06 20:13    | 08/10/06 23:33  | 03:20              | clear          | recover 20,21,22,23<br>(25 not found)    | 77.9247    | 165.0083   |
| 27       | 08/10/06 20:50    | 08/10/06 22:40  | 01:50              | clear          | recover 24,26,27,28,29<br>(25 not found) | 77.9241    | 164.9983   |
| 28       | 08/11/06 00:08    | 08/11/06 01:32  | 01:24              | clear          | recover 30,31,32                         | 77.8862    | 165.2295   |
| 29       | 08/14/06 12:17    | 08/14/06 12:42  | 00:25              | foggy          | deploy 42                                | 77.9206    | 177.2722   |
| 30       | 08/14/06 14:31    | 08/14/06 15:04  | 00:33              | foggy          | deploy 43                                | 77.8108    | 177.3915   |
| 31       | 08/14/06 16:06    | 08/14/06 16:30  | 00:24              | foggy          | deploy 44                                | 77.6991    | 177.3017   |
| 32       | 08/14/06 18:15    | 08/14/06 18:54  | 00:39              | clear          | deploy 45                                | 77.6252    | 177.5240   |
| 33       | 08/14/06 19:06    | 08/14/06 19:34  | 00:28              | foggy to clear | deploy 46                                | 77.5752    | 177.6127   |
| 34       | 08/14/06 21:18    | 08/14/06 22:36  | 01:18              | foggy to clear | deploy 47,48,49                          | 77.4362    | 177.7451   |
| 35       | 08/14/06 22:55    | 08/15/06 00:08  | 01:13              | clear          | deploy 50,51                             | 77.3237    | 177.8327   |
| 36       | 08/15/06 01:59    | 08/15/06 03:59  | 02:00              | clear          | deploy 53,54,52                          | 77.0411    | 177.9229   |

|    |                |                |       |       |  |         |          |
|----|----------------|----------------|-------|-------|--|---------|----------|
| 37 | 08/15/06 04:13 | 08/15/06 04:55 | 00:42 | clear | deploy 55                                  | 76.8250 | 178.0902 |
| 38 | 08/16/06 04:55 | 08/16/06 06:13 | 01:18 | clear | recover 47 and deploy 47B in same location | 77.2057 | 177.3771 |
| 39 | 08/17/06 12:20 | 08/17/06 13:29 | 01:09 | clear | recover 42,43                              | 77.8603 | 176.4817 |
| 40 | 08/17/06 15:56 | 08/17/06 17:12 | 01:16 | foggy | recover 44,45,46,47B                       | 77.5863 | 176.6064 |
| 41 | 08/17/06 20:15 | 08/17/06 22:16 | 02:01 | clear | recover 55,54,53,52                        | 77.2852 | 177.2231 |
| 42 | 08/17/06 20:43 | 08/17/06 22:22 | 01:39 | clear | recover 51,50,49,48                        | 77.2636 | 177.3277 |

Table 2. Instrument sites.

| Station # | Cooler # | DAS # | Rate [Hz] | Start acquisition | End acquisition | Start Lat | Start Lon | End Lat | End Lon | Total time on the ice [d:hh:mm] | Radio problems                          |
|-----------|----------|-------|-----------|-------------------|-----------------|-----------|-----------|---------|---------|---------------------------------|---|
| 01        | 01       | 9629  | 1000      | 07/29/06 21:42    | 08/04/06 01:11  | 76.857    | 150.714   | 76.906  | 151.894 | 5:03:29                         |   |
| 02        | 02       | 962A  | 1000      | 07/29/06 21:11    | 08/04/06 01:33  | 76.917    | 151.251   | 76.954  | 152.613 | 5:04:22                         |   |
| 03        | 11       | 963E  | 500       | 07/29/06 20:42    | 08/04/06 02:08  | 76.975    | 151.787   | 76.983  | 153.229 | 5:05:26                         |   |
| 04        | 09       | 963C  | 500       | 07/29/06 17:57    | 08/04/06 05:46  | 77.033    | 152.329   | 77.018  | 153.894 | 5:11:49                         |   |
| 05        | 10       | 963D  | 500       | 07/29/06 17:26    | 08/04/06 08:46  | 77.090    | 152.876   | 77.068  | 154.510 | 5:15:20                         |   |
| 06        | 06       | 9639  | 250       | 07/29/06 15:57    | 08/04/06 10:29  | 77.144    | 153.428   | 77.125  | 155.101 | 5:18:32                         |   |
| 07        | 05       | 9638  | 250       | 07/29/06 15:24    | 08/04/06 13:30  | 77.199    | 153.981   | 77.188  | 155.685 | 5:22:06                         | lost radio contact after 08/01/06 16:38 |
| 07B       | 12       | 963F  | 500       | 08/02/06 19:40    | 08/04/06 11:59  | 77.081    | 154.791   | 77.171  | 155.345 | 1:16:19                         |   |
| 08        | 03       | 962B  | 500       | 08/01/06 15:24    | 08/05/06 00:26  | 77.207    | 154.825   | 77.339  | 155.838 | 3:09:02                         | lost radio contact after 08/02/06 03:07 |
| 09        | 17       | 9654  | 500       | 08/01/06 14:57    | 08/04/06 23:31  | 77.261    | 155.399   | 77.391  | 156.398 | 3:08:34                         |   |
| 10        | 04       | 962C  | 500       | 08/01/06 12:58    | 08/05/06 04:20  | 77.310    | 155.976   | 77.444  | 157.010 | 3:15:22                         |   |
| 11        | 07       | 963A  | 500       | 08/01/06 12:14    | 08/05/06 06:07  | 77.359    | 156.534   | 77.495  | 157.586 | 3:17:53                         |   |
| 12        | 08       | 963B  | 500       | 08/01/06 11:31    | 08/05/06 07:56  | 77.410    | 157.126   | 77.547  | 158.186 | 3:20:25                         |   |
| 20        | 01       | 9629  | 1000      | 08/06/06 16:34    | 08/10/06 20:54  | 77.802    | 161.944   | 77.674  | 160.477 | 2:04:20                         |   |
| 21        | 02       | 962A  | 1000      | 08/06/06 17:01    | 08/10/06 21:08  | 77.832    | 162.424   | 77.703  | 160.968 | 2:04:07                         |   |
| 22        | 04       | 962C  | 1000      | 08/06/06 17:29    | 08/10/06 21:25  | 77.859    | 162.908   | 77.728  | 161.441 | 2:03:56                         |   |
| 23        | 14       | 964C  | 1000      | 08/06/06 18:47    | 08/10/06 21:41  | 77.887    | 163.402   | 77.754  | 161.899 | 2:02:54                         |   |
| 24        | 15       | 9651  | 1000      | 08/06/06 19:19    | 08/10/06 21:18  | 77.911    | 163.904   | 77.762  | 162.403 | 2:01:59                         |   |
| 25        | 16       | 9653  | 1000      | 08/06/06 19:40    | Lost            | 77.936    | 164.403   | Lost    | Lost    | Lost                            | lost radio contact after deployment     |
| 26        | 17       | 9654  | 1000      | 08/06/06 22:27    | 08/10/06 21:52  | 77.960    | 164.889   | 77.803  | 163.390 | 1:23:25                         |   |
| 27        | 18       | 9655  | 1000      | 08/06/06 23:01    | 08/10/06 22:08  | 77.984    | 165.408   | 77.824  | 163.895 | 1:23:07                         |   |
| 28        | 19       | 9656  | 1000      | 08/06/06 23:37    | 08/10/06 22:21  | 78.005    | 165.915   | 77.848  | 164.426 | 1:22:44                         |   |
| 29        | 10       | 963D  | 1000      | 07/08/06 00:35    | 08/10/06 22:33  | 78.025    | 166.427   | 77.862  | 164.934 | 2:21:58                         | lost radio contact after deployment     |
| 30        | 09       | 963C  | 1000      | 07/08/06 01:07    | 08/11/06 01:17  | 78.048    | 166.930   | 77.887  | 165.376 | 3:00:10                         |   |
| 31        | 20       | 9657  | 1000      | 07/08/06 03:21    | 08/11/06 00:56  | 78.066    | 167.448   | 77.900  | 165.924 | 2:21:35                         |   |
| 32        | 11       | 963E  | 1000      | 07/08/06 03:51    | 08/11/06 00:37  | 78.080    | 167.958   | 77.915  | 166.432 | 2:20:46                         |   |
| 42        | 01       | 9629  | 1000      | 08/14/06 12:36    | 08/17/06 12:29  | 77.919    | 177.259   | 77.858  | 176.561 | 2:23:53                         |   |
| 43        | 02       | 962A  | 1000      | 08/14/06 14:49    | 08/17/06 12:47  | 77.794    | 177.297   | 77.731  | 176.440 | 2:21:58                         |   |
| 44        | 04       | 962C  | 1000      | 08/14/06 16:18    | 08/17/06 16:02  | 77.693    | 177.396   | 77.610  | 176.458 | 2:23:44                         |   |

|     |    |      |      |                |                |        |         |        |         |         |  |
|-----|----|------|------|----------------|----------------|--------|---------|--------|---------|---------|--|
| 45  | 07 | 963A | 1000 | 08/14/06 18:42 | 08/17/06 16:19 | 77.589 | 177.461 | 77.520 | 176.678 | 2:21:37 |  |
| 46  | 09 | 963C | 1000 | 08/14/06 19:24 | 08/17/06 16:36 | 77.479 | 177.596 | 77.440 | 176.872 | 2:21:12 |  |
| 47  | 08 | 963B | 1000 | 08/14/06 21:35 | 08/16/06 05:38 | 77.372 | 177.630 | 77.257 | 177.009 | 1:08:03 | lost radio contact<br>after deployment |
| 47B | 10 | 963D | 1000 | 08/16/06 05:51 | 08/17/06 16:54 | 77.257 | 177.009 | 77.305 | 177.039 | 1:11:03 |  |
| 48  | 11 | 963E | 1000 | 08/14/06 22:02 | 08/17/06 22:03 | 77.266 | 177.708 | 77.199 | 177.185 | 3:00:01 |  |
| 49  | 14 | 964C | 1000 | 08/14/06 22:23 | 08/17/06 21:48 | 77.157 | 177.785 | 77.094 | 177.287 | 2:23:25 |  |
| 50  | 15 | 9651 | 1000 | 08/14/06 23:31 | 08/17/06 21:28 | 77.052 | 177.866 | 76.990 | 177.320 | 2:21:57 |  |
| 51  | 17 | 9654 | 1000 | 08/14/06 23:53 | 08/17/06 21:05 | 76.941 | 177.946 | 76.941 | 177.946 | 2:21:12 |  |
| 52  | 06 | 9639 | 1000 | 08/15/06 03:51 | 08/17/06 21:43 | 76.835 | 177.981 | 76.796 | 177.531 | 2:17:52 |  |
| 53  | 18 | 9655 | 1000 | 08/15/06 02:40 | 08/17/06 21:25 | 76.732 | 178.147 | 76.716 | 177.937 | 2:18:45 |  |
| 54  | 19 | 9656 | 1000 | 08/15/06 03:16 | 08/17/06 21:05 | 76.628 | 178.167 | 76.607 | 178.009 | 2:17:49 |  |
| 55  | 20 | 9657 | 1000 | 08/15/06 04:38 | 08/17/06 20:50 | 76.520 | 178.237 | 76.493 | 178.019 | 2:16:12 |  |

## Chapter 5: Seismic Data Acquisition

### 1.1 Departure from Barrow

In our original cruise plan we were scheduled to leave Barrow on July 18<sup>th</sup> and to begin seismic work a few hours after departure when we cleared the continental shelf. Although we did have a valid NMFS permit before we arrived on board *Healy*, we were informed that we would not receive our seismic use permit from the U.S. Fish and Wildlife Service until August 24<sup>th</sup>. Permitting did not pose a large problem for our study, because we immediately switched to a plan that began with taking sediment cores at the base of the Northwind Escarpment until the FWS permit was authorized. Unfortunately, we faced three additional setbacks that delayed our departure from the Barrow area:

1) Three days of ship time were lost because of *Healy*'s slightly, delayed arrival but more importantly, our departure from Barrow was delayed due to abnormally heavy ice immediately off Barrow. In February of 2006 there had been a three-week storm that had blown an ugly mass of compressed multi-year ice into the Barrow region. On the 19<sup>th</sup> of July, when we were all finally aboard *Healy* we got underway to head west to start coring on Northwind Escarpment and spent 16 hours at full power but made no progress whatsoever. We had expended 1.6% of the total fuel capacity of *Healy* during our futile attempt to head west, so we decided to drift with the compressed pack ice for two days to get past Point Barrow since we were forced to remain in the vicinity of Barrow for the reasons explained below.

2) In Barrow we learned that Dale Chayes had not been able to hire air-gun technicians for our cruise. Jay Ardai, an experienced air-gun technician, accompanied Dale Chayes on the transit from Seattle to Barrow. The air-gun cage was put aboard in Seattle and we think that some or all of the air guns were picked up during a stop enroute in Nome, Alaska. Unfortunately Jay was only available to us until about the 25<sup>th</sup> of July, six days after we embarked and had to be disembarked at Barrow. We needed Jay's help with the air-gun assembly, so we stayed near Point Barrow even after we had passed through the heavy ice. In this first week of our cruise, Jay Ardai and Dale Chayes installed the electrical wiring to the air guns. In addition, Jay Ardai showed four University of Texas students how to build and maintain the GI and Bolt air guns, since they would have to function as airgun techs during the cruise. After a simple test

deployment of the seismic source cage, Jay Ardai departed to Barrow by helicopter on the 26<sup>th</sup> of July.

3) On arrival on board *Healy*, we found that the seismic source array and the MCS recording system had not been assembled, and that some critical parts of the air-gun array had not arrived. We then discovered that the missing equipment had yet to be manufactured in Houston, although Dale Chayes assured us that it would be shipped momentarily. We queried him daily on the missing parts and their shipping date. When Dale told us on the morning of the 21<sup>st</sup> of July that he had not received a reply to an email he sent to the company on the previous day, we decided that we needed to take matters into our own hands. We found out from our purchasing agent at UTIG that some components were not even scheduled to be manufactured until the 2<sup>nd</sup> of August, after which time they would be shipped to Barrow. We were faced with not having our seismic source until *more than two weeks* after the scheduled start of our cruise. Needless to say we are not happy with the lack of candor that Dale Chayes gave us, and we were stunned that he had not considered borrowing the equipment from other seismic data acquisition groups. Larry Phillips, retired from the USGS, and Paul Henkart of Scripps contacted people at the USGS in Menlo Park and at SIO respectively, to see if we could borrow the fire lines and jumper cables that we needed. Both organizations had the necessary equipment and they were willing to loan it to us. Dale determined from the information that we provided him that the USGS parts would complete the seismic source array. Unfortunately the weekend was approaching, and arrangements could only be made to get the necessary parts picked up on Monday morning and shipped to Barrow, arriving Monday evening on the 24<sup>th</sup>.

## **1.2 Canada Basin**

Finally on the 26<sup>th</sup> of July, eight days after we were scheduled to depart Barrow, we were able to get underway. We left the continental shelf 50 nautical miles north of Barrow and continued north into the Canada Basin. During this transit, Dale Chayes, Steffen Sastrup, Steve Stevenoski and four UT students began to install the eight air guns on the frame. The bottom four air guns (two GI guns forward, two Bolt guns aft) were hard-mounted to the frame, while the upper four were hung from chains, the more traditional method for mounting airguns. The students pulled the electric cables and air hoses from the compressors through the protective

cement hose to connect to the air guns. The shot triggering and MCS recording systems were still under construction. Mark Wiederspahn of UTIG analyzed the timing of both air-gun shooting



Figure 1. Airgun frame with initial installation of some airguns. GI guns are to the left, Bolt guns are to the right. Lower forward GI gun not yet installed.

and MCS data acquisition. Instead of using the OYO DAS provided by LDEO, Mark decided to use a Geometrics Geode from UTIG to record the MCS data. The Geode was brought from UTIG as a back-up for the OYO recording system, but the Geode turned out to be a better solution. We cleared the pack of compressed ice north of Barrow on July 27<sup>th</sup>, where we then encountered relatively thin and melting ice as we headed north.

On July 28<sup>th</sup> we reached 75°N, where we had planned a seismic anisotropy shoot. In this first experiment we planned to fire the air guns as *Healy* steamed a circular track, 75-km in diameter. The range of azimuths at which seismic shots would be recorded by the sea-ice seismometers would have given us insight into the paleo-spreading direction in the Canada Basin. Given the light ice conditions at 75°N and the fact that the airguns were not yet ready for use, we decided to move the anisotropy shoot farther to the north. However, when we reached 76°N, the air guns were still not ready for deployment even though ice conditions for landing the



Figure 2. Airgun frame from forward end showing cement pipe with airlines and firing lines. All four GI guns are installed. Central tow point at center-top of frame.

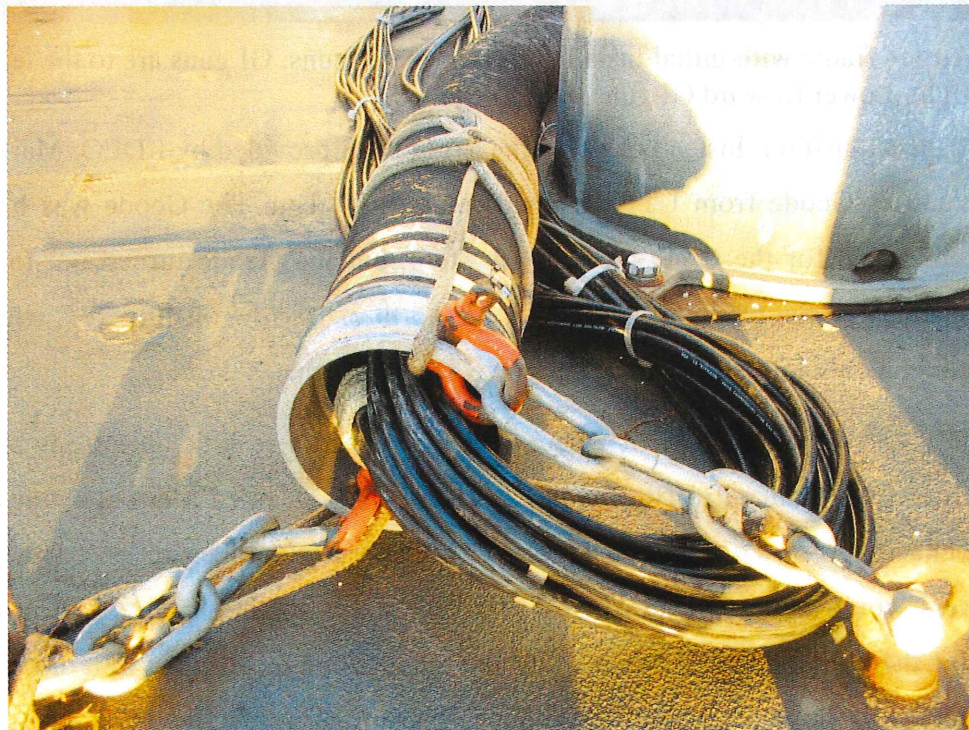


Figure 3. Air lines and firing lines emerging from cement pipe at end chained to deck. From this point air lines connect to compressors, firing lines connect to aft science.diameter.

helicopter on the ice were satisfactory. Since all of our contingency time for the cruise had been used up, we abandoned the anisotropy experiment.

### 1.3 Northwind Ridge

Since the seismic gear was still not ready for use, we took two gravity cores (01GC and 02GC) along the Northwind Escarpment (July 29<sup>th</sup>). Later that day we made plans for a seismic refraction line from the Canada Basin to the Northwind Ridge at 77°N. As we steamed eastward from the Northwind Escarpment into the Canada Basin, we deployed the first 7 coolers on the ice along the planned transect prior to starting seismic data acquisition. When we were ready to deploy the seismic source array, we found out that some air guns would not seal properly, and it became clear that the seismic source cage did not tow well behind the ship. The poor hydrodynamics and its narrow width made it difficult to find a good towing arrangement. We spent all of July 30<sup>th</sup> and much of July 31<sup>st</sup> trying to improve the tow points of the air-gun cage. We added more tow lines and tag lines to stabilize the rectangular cage, but the instability of the cage continued to limit *Healy*'s ability to maneuver through the ice. Later on July 31<sup>st</sup> we found that further adjustments to the air-gun cage required considerable time, so we went back to Northwind Escarpment to acquire two more cores (03BB and 04BB). While the coring team from OSU was working, Dale Chayes, Mark Wiederspahn, Steffen Saustrup, Steve Stevenoski, the Coast Guard marine science technicians, and four UT students worked on more improvements to the air-gun cage. Other members of the science party prepared five additional seismometers for deployment on ice along the western portion of the first transect.

On August 1<sup>st</sup>, we finally launched the multichannel seismic (MCS) streamer and seismic source on Northwind Ridge, just west of our linear array of 12 sea-ice seismometers. Our plan was to acquire seismic reflection and refraction data from west to east along the array. This first attempt to collect seismic data was not very successful. The cage was still not stable when towed, and the arrangement for the streamer made it impossible to acquire MCS data without damaging the streamer cable. The 300-meter-long streamer was towed off the edge of the fantail, originally tied to the seismic source cage after the streamer was deployed. When that proved hazardous to the streamer, it was deployed through two U-bolts at the forward and aft ends of the top of the air-gun cage with the idea that the streamer could be deployed and retrieved after the cage was in the water. Unfortunately, this arrangement resulted in the streamer cable being bent in two 90° angles, first where it ran downward over the edge of the ship, and secondly when it passed through the first U-bolt. To make matters worse, the cage would often pivot sideways,



Figure 4. View of seismic source frame from above. Frame towed by main trawl wire.

particularly when the ship's rudder was turned, or when differential power was applied to the two screws of the ship. As a result, the streamer was periodically dragged sideways by the two U-bolts on the air-gun cage, which caused even larger stresses on the cable at the contact points. The first seismic deployment on the Northwind Ridge was short-lived. The ramp up protocol with regards to marine mammals was followed, starting with firing a single GI gun. After the first phase of ramp-up, we were able to fire 44 shots with all four GI guns in just over 30 minutes. However, before we started to fire any of the Bolt air guns, the cage rotated so much that it overstretched the streamer. Upon recovery of the cage and the damaged streamer, we moved east to take two more cores on Northwind Ridge (05BB and 06JPC) pending redesign of the seismic system.

After we recovered the Jumbo Piston core on Northwind Ridge (August 2<sup>nd</sup>), we returned to the east end of our seismometer array in the deepwater Canada Basin to try to acquire only seismic refraction data. Since the first MCS streamer was damaged due to poor towing design, we felt that there was no point in deploying a second streamer as it would not last very long. On August 3<sup>rd</sup> and August 4<sup>th</sup>, we managed to cover a distance of 10 nautical miles in the Canada Basin over

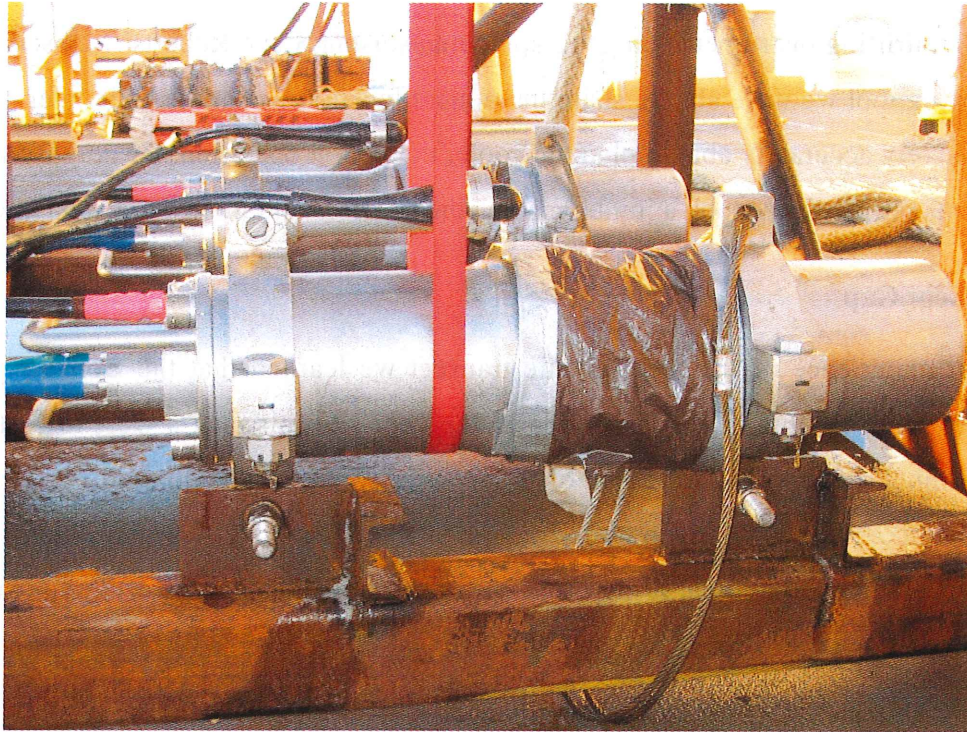


Figure 5. Bolt guns hard-mounted to the frame prior to loss of nearest one shown above.

10 hours, using 4 GI guns and one Bolt air gun. We could not engage more Bolt air guns at any time, because the air hoses regularly detached from two of the Bolt air guns, often after just a few shots. The stability of the cage continued to be a problem and one shot was fired while part of the cage was lifted out of the water by the sea ice. When we brought the seismic source cage back on deck we immediately noticed that one Bolt air gun had disappeared entirely and the other lower Bolt air gun was loose but still attached to the frame. Both of these guns were the lower ones that had been hard-mounted to the steel frame. Clearly, the decision to hard-mount the Bolt airguns to the seismic cage misjudged whether the larger Bolt airguns could withstand the vibrations.

The sea-ice seismometers drifted by as much as 20 nautical miles during their first deployment which lasted for 5 or 6 days. Originally, we did not plan for them to be deployed for so long but we were able to get regular updates on their positions through the Freewave radio communication between the instruments and either the helicopter or the ship. GPS positions and other data were only obtained when the coolers were in radio range, which was up to 11 nautical miles. Communications with two of the instruments failed during the first deployment, however, the instrument drifts were consistent with neighboring instruments, so we were able to accurately predict the location of each instrument in the 90 n.m. long array. We displayed the locations of

the nearby, drifting instruments on geographic maps using Steve Roberts' Mapserver. Thanks to this mapping tool we were able to share instrument locations, with the helicopter operations and were relatively accurately able to plan the cooler collection operation. By August 4<sup>th</sup>, with all 12 instruments retrieved, we took a jumbo piston core (07JPC) and moved to Chukchi Cap.

#### **1.4 Chukchi Cap**

From our experience of the first seismic transect we learned that the Bolt air guns must be suspended from chains, rather than fixed to the cage. We planned a west to east seismic line across Chukchi Cap. Prior to the start of the seismic work we acquired two sediment cores (08JPC and 09JPC) on the steep eastern slope of the Chukchi Trough on August 6<sup>th</sup>. Over the next day we deployed a linear array of 13 instruments with a spacing of 7 nautical miles, from east to west across Chukchi Cap. Due to often foggy conditions we could not deploy or recover instruments over large distances, as we had originally planned. We nevertheless made good progress during deployment, and by August 7<sup>th</sup> we started firing the air guns while *Healy* steamed east at a speed of 2 knots. We had to interrupt the seismic data acquisition several times for extensive maintenance on the air guns. To avoid further major damage to the equipment we scheduled inspections of the air-gun cage every 4 hours during seismic operations. When the air-gun cage was on deck for maintenance, we gathered more bathymetric data and sediment cores (10JPC, 11JPC and 12JPC). By August 10<sup>th</sup>, we had finished shooting the Chukchi Cap seismic refraction transect. Recovery was reasonably fast, but unfortunately, one of the 13 instruments on this line, cooler #25, was not found. Possibly, the ice failed where the instrument was deployed, or most likely, a polar bear may have destroyed the instrument since a mother bear and two cubs were seen within 2 km of the cooler shortly after it was deployed.

#### **1.5 Mendeleev Ridge**

We reached the crest of Mendeleev Ridge on August 12<sup>th</sup>. After bathymetric mapping and coring we reached the north end of our third seismic transect on August 14<sup>th</sup>. We deployed 14 instruments from north to south along Mendeleev Ridge. Two additional modifications to the air-gun cage made this last seismic refraction line more successful than the two previous transects. First, we used a few extra steel cables to keep the air guns in place. We had noticed on the previous seismic transect that the air guns had collided with the steel frame of the cage, potentially causing damage. Secondly, we applied less torque to fittings between the air guns and

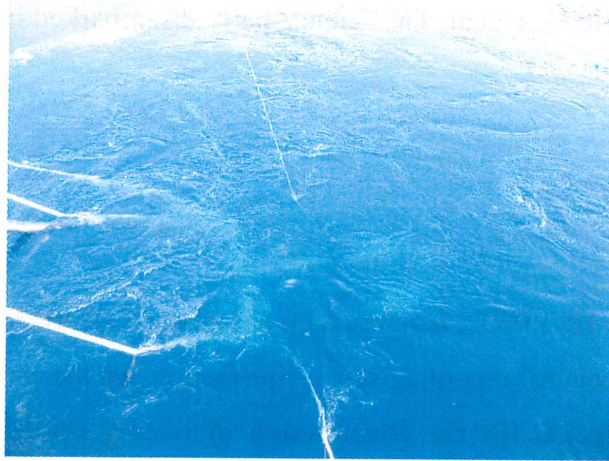


Figure 6. Seismic source frame deployed. Tag lines can be seen in photo above and photo on the right. Typical ice conditions on Chukchi and Mendeleev ridge profiles. Ice conditions on Northwind Ridge were much worse.



air hoses. By applying the air hoses with some flexibility, we were able to avoid leakage of the air guns during seismic shooting. As we were shooting the last seismic transect, the air compressors started to wear out. We had maintained the diesel compressors as well as possible, but the output air pressure became unreliable and was significantly lower than in the weeks before. In order to keep the pressure up at 2000 psi, we occasionally operated just one or two of the three Bolt air guns. We were nevertheless able to complete much of the 100 n.m. seismic transect with 7 active air guns. We finished the seismic shoot early in the morning of August 17<sup>th</sup>. Since the weather was now very clear, we retrieved all 14 instruments by helicopter in just half a day.

After we finished three seismic transects, we still had one week of ship time left on our project. However, on the evening of August 17<sup>th</sup> a tragic accident unrelated to our science project cost the lives of two Coast Guardsmen. We immediately ceased science operations, and set

course for Barrow to allow a full investigation of the accident. The science party disembarked in Nome on August 22<sup>nd</sup>.

## **2. Evaluation of seismic data acquisition**

### **2.1 Design and assembly of seismic equipment**

The seismic experiment that we planned for HLY0602, required a large logistical effort. At the University of Texas we assembled the equipment for recording seismic refractions on the sea ice. In the proposal for this project, we budgeted for the construction of twenty sea-ice seismometers. Well before the start of the cruise we had seismometers ready that utilized a REFTEK 130 data logger integrated with a GPS receiver, a Freewave™ radio, a hydrophone and a geophone. Each REFTEK 130 data logger, Freewave™ radio, and a large truck battery were contained in a Coleman™ 40 quart cooler. These seismometers had the unique capability to communicate their position to *Healy*, even after they had been drifting with the sea ice for a week. The sea-ice seismometers and the other equipment from UTIG were loaded on *Healy* on June 13<sup>th</sup> before the ship left Seattle.

In an appendix to our original NSF-OPP proposal, we described a configuration for the air-gun source and MCS streamer that was used by the USGS for reflection studies in the Arctic Ocean in the 1980s and 1990s. It was a design developed by Art Grantz and people at the USGS marine facility that had been successfully used by Art on a number of USCG polar class icebreakers. Art's design is very similar to the design used by Yngve Kristoffersen on HLY0503. We are not sure why such a design was not used for our cruise. In Art's design, six air guns were held in position by a triangular steel frame that was held well below any ice by the weight (~one ton) of a heavy steel ball. Both the air hoses and streamer cable of the USGS setup were protected from the sea ice by a large reinforced tube that extended from the fantail to the air gun frame. Since we wanted to record seismic refractions over about 100 kilometers, the volume of the air-gun array, and hence the size of the air-gun frame, needed to be larger than the structure used by USGS. This adjustment could still have resulted in a USGS-type design for HLY0602. In the appendix of our proposal we also provided a budget for the rental of air compressors and for the purchase of an air gun and streamer system. We felt that the purchase and maintenance of air guns and seismic streamer should be handled by a support group that would maintain the

equipment for *Healy*. Our sea-ice seismometers have been requested for use by a UCSB group for work in Antarctica which we entertained favorably.

An aviation team from Maritime Helicopters, a company based in Homer, Alaska, retrieved and deployed our instruments from on the ice. Using two helicopters and two pilots, they carried out up to 8 sorties in one day. The crew from Maritime Helicopters, who were assisted by a federal aviation manager, did a stellar job during the cruise. They embarked and disembarked people from *Healy*, they carried out the sorties for our seismic study perfectly, and they supported reconnaissance flights when we were looking for better ice conditions. All these flights were safe, fast, and well planned. Maritime Helicopters proved invaluable when we had to return unexpectedly to Barrow in August.

## **2.2 Science planning and operation**

The planning of our science on HLY0602 was a large challenge. We now realize that we needed a number of separate things to go very well if we were going to collect the amount of data that we had proposed. As mentioned above, we needed good weather, thin but mechanically stable sea-ice, willing and able helicopter support, and a seismic system that worked. The support that we received from both the USCG crew, particularly the marine science technicians and Maritime Helicopter were very good. The weak link in our science operation turned out to be the seismic source as detailed above.

The seismic source array designed for use on HLY0602 could not be towed at a speed greater than 2.5 kts. This produced a serious problem because even minor pressure ridges slowed the momentum of *Healy* such that she could not make it through without “backing and ramming” which necessitated pulling in the seismic source array cage, backing and ramming and then redeploying the cage. In addition, the seismic source array when finally operational was found to ungainly and did not tow well. In our proposal, we included a design for towing airguns in ice-covered regions that had been used by Art Grantz formerly of the U.S.G.S. working off the Polar Class Coast Guard icebreakers and was similar but much larger than the system successfully by Yngve Kristoffersen on HLY0503. In addition to the mentioned deterioration of the rented seismic compressors, they also produced an unacceptable level of exhaust fumes that produced numerous problems with air circulation in the aft part of *Healy*. It is hoped that air compressors

can be incorporated into the engineering department of *Healy* such that they are joint use by the engineering department and the science party. That would solve both the maintenance concerns and the airhandling concerns.

In addition to the seismic source problems, the science party had difficulties with Dale Chayes. Chayes was less than candid with us about the seismic source and MCS recording problems at the beginning of HLY0602. He also did not seem to have followed up on finding the airgun technicians that were needed for our project. The work that we planned for HLY0602 was known at least 2 years in advance, so it is difficult to understand why these tasks were left to the last few months before departure. Also, there were numerous occasions where Chayes interfered with science operations that were not within the scope of Chayes' responsibilities. One of many examples was an incident that occurred during a coring operation on Chukchi Cap. While the airguns were on board for 12 hours for maintenance, Harm Van Avendonk and Larry Phillips decided to use this time to sample the seafloor. While the PI's thought that Dale Chayes would remain focused on the ongoing maintenance of the airguns, Chayes demanded to know why he was not consulted in the decision to take a sediment core. It is clear that Chayes felt that he should be the liaison between the science party and the Coast Guard and as such, he often frustrated efforts by the science party to make the best of a cruise that had a very late and difficult start. It would have been better for the cruise HLY0602 if Chayes had been more focused on the shipboard seismic operation since there were no significant communication problems between the Coast Guard and the science party.

### **3. Conclusions**

The acquisition of seismic reflection and refraction data was the most important objective of cruise HLY0602. The goals of the study could not be met due to problems with the shipboard seismic gear. We summarize the principal problems encountered before and during the cruise:

- 1) The seismic source array was not ready at the beginning of our cruise. Some parts were not yet on board ship, and the airguns and the shot-triggering system had not been built. Both the air-gun mounts on the steel frame and the air-hose connections to the airguns were poorly designed. A large portion of ship time was used to build and improve the airgun array. A better design of the airgun source was developed during the cruise by trial-and-error.

- 2) An adequate MCS system was not provided, even though reflection seismology was one of the key activities planned for cruise HLY0602. Due to poor design of the towing points, the streamer cable was damaged by the rotating airgun cage.
- 3) No airgun technicians were provided for the cruise. The lack of expertise exacerbated the above problems.
- 4) Poor design of the airgun cage limited the maximum speed of Healy to 2-2.5 knots during seismic data acquisition. This speed was too low to break through thicker ice without backing up, which slowed our progress during seismic shooting.
- 5) The diesel air compressors worked fine at the start of the cruise but they started to fail in the last week of seismic data acquisition. Ship time was lost due to maintenance of the compressors, and the air-gun shots were fired at pressures lower than the desired level of 2000 psi.
- 6) The range of geophysical and coring activities and the repair and maintenance of the on-board seismic gear during cruise HLY0602 required a clear chain of command among both the Coast Guard and the science party. The communication between the Coast Guard and science party went well, but the poorly defined role of Dale Chayes sometimes made it difficult to coordinate the construction of the seismic source with other activities on board Healy during the cruise.

## Chapter 6: Coring on HLY0602

Support for the coring operation from the Oregon State Coring group was excellent. Lead by Chris Moser and Dale Hubbard, Paul Walczak was an apprentice who learned quickly. Eighteen cores, nine gravity and nine piston cores, have been obtained from the western Canada Basin, Chukchi Borderland, and Mendeleev Ridge during this cruise. Nine cores contain Quaternary glacial-interglacial depositional cycles with a few cores penetrating into Unit A of Clark and others (1980), whereas, the other nine cores apparently bottomed in overconsolidated sediment representing pre-Quaternary “bedrock”. Due to the damage of the trigger core frame by ice, which required building of a new trigger core holder, gravity cores were used until the trigger core frame was replaced.

Four gravity cores were initially obtained along the flank of Northwind Ridge between 77°00” and 77°13” W and water depths of 3300 to 3600 m. The four gravity cores record over five Quaternary glacial-interglacial cycles. Another gravity core from the crest of the Northwind Ridge at 1147 m hit hard substrate, either bedrock or a thick erosional gravel lag resulting in only 47 cm of sediment retained within the core barrel. A piston core from the Northwind Ridge crest at 1243 m records a condensed Quaternary section of less than 2 m thick overlying 6 m of overconsolidated light grayish blue mud. The blue mud apparently post dates glacial ice rafting within this part of the Arctic Ocean and would be expected to be greater than 3 Ma.

Four cores, one gravity and three piston cores apparently bottomed in hard substrate in the eastern and western flank of the Chukchi Cap Trough. On the eastern flank a gravity core recovered 12 cm of muddy gravel containing angular clast of metasediment. A piston core near the base of the eastern flank of the trough also bottomed in metasediments. Cores on the western flank of the trough contain thick Quaternary sections overlying overconsolidated brown sediment of possible Cretaceous age. To the west, a core on the ice gouged Chukchi Cap crest at 451 m depth cored overconsolidated sediment either representing ice override strata or ice eroded laminated bedrock.

Cores on the east flank of Mendeleev Ridge between depths of 1800 and 2000 m record Quaternary strata overlying orange altered tephra. Core 13 altered tephra contains relatively abundant siliceous microfossils consisting of over at least 3 species of radiolaria, siliceous spheres, and a possible large diatom? Three gravity cores were obtained from the crest of Mendeleev Ridge in gas pock marked zones between depths of 808 to 818 m. Four samples

were obtained for gas analysis. The last core, core 18, taken at 1400 m depth on the south central crest of Mendeleev Ridge contains Quaternary glacial-interglacial cycles to Unit A of Clark and others (1980).

A major difficulty encountered in piston coring was the lack of retention of sediment within the core barrel below the core retention fingers. In previous coring cruises retention of these samples were critical in defining the composition of bedrock penetrated.

### **Core Summary**

**GC**-Gravity core, usually 10' barrel

**BB**-Gravity core, large diameter 10' barrel

**JPC**-Piston core, large diameter, up to 10 meters

**TC**-Trigger core, usually 1 meter barrel length

#### **1. HLY0602-01GC**

Date and time: **210 – 29 July 2006 – 0949:20**

Location: **77°01.0162' 153°34.935'** East side Northwind Ridge flank

Depth: **3600 m**

Core length: Sec. 1 0-149 cm

Description Quaternary glacial-interglacial cycles, up to 5

#### **2. HLY0602-02GC**

Date and time: **210 – 29 July 2006 – 1235**

Location: **77°00.783' 153°38.071'** East side Northwind Ridge flank

Depth: **3363 m**

Core length: Sec. 1 0-155 cm

Description: Quaternary glacial-interglacial cycles, up to 5

#### **3. HLY0602-03BB**

Date and time: **212 – 31 July 2006 – 2332**

Location: **77°13.436' 153°20.439'** East side Northwind Ridge flank

Depth: **3534 m**

Core description:      Sec. 1            0-85 cm  
   Sec. 2            85-234.5 cm  
   Sec. 3            234.5-357.5 cm

Description: Quaternary glacial-interglacial cycles

#### **4. HLY0602-04BB**

Date and time: **213 – 1 August 2006 - 0259**

Location: **77°13.03' 153°22.480'** East side Northwind Ridge flank

Depth: **3543 m**

Core description:      Sec. 1            0-20 cm  
   Sec. 2            20-170 cm

Sec.3 170-314.5 cm  
Description: Quaternary glacial-interglacial cycles

**5. HLY0602-05BB**

Date and time: 214 – 2 August 2006 - 0442  
Location: 77°06.036' 154°21.896' Crest Northwind Ridge  
Depth: 1147 m  
Core description: Sec. 1 0-47 cm  
Description: May have hit erosional gravel lag or overconsolidated sediment.

**6. HLY0602-06JPC**

Date and time: 214 – 2 August 2006 - 1517  
Location: 77°02.539' 154°13.487' East crest of Northwind Ridge  
Depth: 1243 m  
Core description: Sec. 1 0-75 cm  
Sec. 2 75-226 cm  
Sec. 3 226-377 cm  
Sec. 4 377-528 cm  
Sec. 5 528-679 cm  
Sec. 6 679-801 cm

Description: Light grayish blue overconsolidated mud starts in sec. 2 and continues to base of core. Unit represents deposition prior to glacial ice rafting (>3.2 ma) and may represent altered Cretaceous tephra (90 Ma). Quaternary section condensed or eroded in sec. 1 and 2.  
10,020 lbs. pull out

**HLY0602-06TC** Sec. 1 0- 75 cm

**7. HLY0602-07JPC**

Date and time: 216 – 4 August 2006 – 2100?  
Location: 77°19.366' 155°55.821' Central crest Northwind Ridge  
Depth: 1295 m  
Core description: Sec. 1 0-95 cm  
Sec. 2 95-242.5 cm  
Sec. 3 242.5-392.5 cm  
Sec. 4 392.5-545 cm  
Sec. 5 545-695 cm  
Sec. 6 695-823.5 cm

Description: 9,110 lbs. pull out. Quaternary glacial-interglacial cycles

**HLY0602-07TC** Sec. 1 0-17 cm  
Sec. 2 17-167 cm

**8. HLY0602-08GC**

Date and time: 218 – 6 August 2006 – 0136?  
Location: 77°851.103' 161°22.707' East flank of Chukchi Cap trough-steep slope.  
Depth: 2225 m

Core description: 12 cm mud/gravel (did not keep).

Description: Pull out 1,640 lbs. Washed sample contains abundant angular metasediment clasts.

#### 9. HLY0602-09JPC

Date and time: **218 – 6 August 2006 – 0718**

Location: **77°50.766' 161°23.118'** East flank Chukchi Cap trough.

Depth: **2630 m**

|                   |        |            |
|-------------------|--------|------------|
| Core description: | Sec. 1 | 0-145 cm   |
|                   | Sec. 2 | 145-296 cm |
|                   | Sec. 3 | 296-391 cm |
|                   | Sec. 4 | 391-419 cm |

Description: 9,400 lbs. pull out. Muddy gravel in sec. 4 contains clasts of metamorphic coarse-grain sandstone of possible Paleozoic age. Bit chewed up.

|                     |        |         |
|---------------------|--------|---------|
| <b>HLY0602-09TC</b> | Sec. 1 | 0-48 cm |
|---------------------|--------|---------|

#### 10. HLY0602-10JPC

Date and time: **220 – 8 August 2006 – 1011:40**

Location: **78°09.727' 165°10.675'** Center of Chukchi Cap in ice-gouged sea floor.

Depth: **451 m**

|                   |        |                |
|-------------------|--------|----------------|
| Core description: | Sec. 1 | 0-53.5 cm      |
|                   | Sec. 2 | 53.5-156.5 cm  |
|                   | Sec. 3 | 156.5-285.5 cm |

Description: 15,200 lbs. pull out. Quaternary overconsolidated bioturbated brown mud found in sections 2 and 3 caused either by ice override or in section may represent over-consolidated Cretaceous strata.

|                     |       |         |
|---------------------|-------|---------|
| <b>HLY0602-10TC</b> | Sec 1 | 0-76 cm |
|---------------------|-------|---------|

#### 11. HLY0602-11JPC

Date and time: **221 – 9 August 2006 – 1045**

Location: **77°54.073' 162°20.995'** West flank of Chukchi Cap trough.

Depth: **2395 m**

|                   |        |                |
|-------------------|--------|----------------|
| Core description: | Sec. 1 | 0-119.5 cm     |
|                   | Sec. 2 | 119.5-268.5 cm |
|                   | Sec. 3 | 268.5-420.5 cm |
|                   | Sec. 4 | 420.5-571.5 cm |
|                   | Sec. 5 | 571.5-706 cm   |

Description: 11,800 lbs. pull out. Quaternary brown mud to Unit A of Clark and others, 1980, to possible consolidated Cretaceous strata in section 5.

|                     |        |             |
|---------------------|--------|-------------|
| <b>HLY0602-11TC</b> | Sec. 1 | 0-56.5 cm   |
|                     | Sec. 2 | 56.5-197 cm |

#### 12. HLY0602-12JPC

Date and time: **221 – 9 August 2006 – 1655**

Location: **77°54.450' 162°21.066'** West flank of Chukchi Cap trough.

Depth: **2301 m**

|                   |        |         |
|-------------------|--------|---------|
| Core description: | Sec. 1 | 0-55 cm |
|-------------------|--------|---------|

|        |                |
|--------|----------------|
| Sec. 2 | 55-205.5 cm    |
| Sec. 3 | 205.5-287.5 cm |
| Sec. 4 | 287.5-307.5 cm |

Description: 11,900 lbs. pull out. Cored overconsolidated brown mud. Age unknown, may represent Cretaceous strata.

**HLY0602-12TC** Sec. 1 19 cm

### 13. HLY0602-13JPC

Date and time: **225 – 13 August 2006 – 0055**

Location: **79°03.666' 175°24.714'** East flank of Mendeleev Ridge.

Depth:**2301 m**

|                   |        |                |
|-------------------|--------|----------------|
| Core description: | Sec. 1 | 0-150.5 cm     |
|                   | Sec. 2 | 150.5-300.5 cm |

Description: 17,200 lbs. pull out. Both core sections contain overconsolidated orange, yellow, to brown mud. Strata apparently represent altered siliceous volcanic sediments. Sediment contains at least 3 species of radiolarians, siliceous spheres, and a large diatom(?)

|                     |        |           |
|---------------------|--------|-----------|
| <b>HLY0602-13TC</b> | Sec. 1 | 0-49 cm   |
|                     | Sec. 2 | 49-199 cm |

### 14. HLY0602-14JPC

Date and time: **225 – 13 August 2006 – 0355**

Location: **79°04.156' 175°21.433'** East flank of Mendeleev Ridge.

Depth:**1998 m**

|                   |        |            |
|-------------------|--------|------------|
| Core description: | Sec. 1 | 0-42 cm    |
|                   | Sec. 2 | 42-192 cm  |
|                   | Sec. 3 | 192-322 cm |
|                   | Sec. 4 | 322-472 cm |
|                   | Sec. 5 | 472-622 cm |
|                   | Sec. 6 | 622-724 cm |

Description: 10,740 lbs. pull out. Sections 1 into 6 contain Quaternary glacial-interglacial cycles into Unit A. Base contains orange & brown clasts, to 3 cm diameter, of overconsolidated tephra representing possible slump deposit of strata in core 13.

|                     |        |           |
|---------------------|--------|-----------|
| <b>HLY0602-14TC</b> | Sec. 1 | 0-41 cm   |
|                     | Sec. 2 | 41-191 cm |

### 15. HLY0602-15GC

Date and time: **23:12 UTC, 08/13/2006 (JD 225)**

Location: **78°22.233' 176°56.579'** Crest of Mendeleev Ridge.

Depth:**813.4 m**

|                   |        |          |
|-------------------|--------|----------|
| Core description: | Sec. 1 | 0-8 cm   |
|                   | Sec. 2 | 8-171 cm |

Description: Core in large gas pock mark. Quaternary strata, gas sample taken from core base.

### 16. HLY0602-16GC

Date and time: **01:14 UTC, 08/14/2006 (JD 226)**

Location: **78°20.334' 176°51.048'** Crest of Mendeleev Ridge.

Depth: **808 m**

Core description:    Sec. 1            0-25 cm  
                          Sec. 2            25-35 cm gas sample  
                          Sec. 3            35-175 cm  
                          Sec. 4            175-181 cm gas sample

Description: Core in large gas pock mark. Quaternary strata, gas sample taken from 35 cm depth and at core base.

#### 17. HLY0602-17GC

Date and time: **02:04 UTC, 08/14/2006 (JD 226)**

Location: **78°20.676' 176°50.752'** Crest of Mendeleev Ridge.

Depth: **818 m**

Core description:    Sec. 1            0-28 cm  
                          Sec. 2            28-178 cm  
                          Sec. 3            178-186.5 cm gas sample

Description: Core in large gas pock mark.

#### 18. HLY0602-18JPC

Date and time: **05:02 UTC, 08/16/2006 (JD 228)**

Location: **77°12.330' 177°22.600'** South crest of Mendeleev Ridge.

Depth: **1395 m**

Core description:    Sec. 1            0-78.5 cm  
                          Sec. 2            78.5-228.5 cm  
                          Sec. 3            228.5-378.5 cm  
                          Sec. 4            378.5-528.5 cm  
                          Sec. 5            528.5-616.5 cm  
                          Sec. 6            616.5-766.5 cm

Description: 8,990 lbs. pull out

**HLY0602-18TC**    Sec. 1            0-5 cm   Sampled for biology, no core section retained  
                          Sec. 2            5-58 cm  
                          Sec. 3            58-209 cm

**CORE DETAILS for Cores 15-18: MOST SHELLS ARE DOCUMENTED WITH PHOTOS AND SAVED IN CONTAINERS**

Note: for cores 15,16,17, gas analysis samples were obtained and will be shipped off by Larry Phillips for analysis. All three cores were taken in pockmarks—16 and 17 taken in very large pockmark feature, 15 in a smaller pockmark structure. Of these cores, my impression is that Core 16 provided the most exciting set of shells, however, this was the first core analyzed, and was not studied in the most detailed manner. Core 17, though it contained fewer shells, was studied more extensively. Furthermore, both Cores 15 and 17 contained what appear to be larger (dime sized) Bivalve shell fragments that looked promising, and we did not find this type of shell in the upper few cm of core 16. Besides shells, cores 15,16 and 17 contained what appeared to be dolomite nodules. Core 18 had no dolomite, and significantly less shell numbers or shell diversity per cm depth, despite being a much wider diameter core.

**Core 15**

**Lat:** 78 degrees 22.253 min

**Lon:** 176 degrees 56.5799 min

**Depth:** 813.4 m

**Time:** 23:12 UTC, 08/13/2006 (JD 225).

Type: Gravity Core, barrel 2.5 inches in diameter—length, ~2 meters (?).

Some details of gravity Core 15: Only looked quickly at upper 5 cm all together sieved. Also saw a black tube worm and other strange biological things. Shell 15, found in top centimeter, #1: a couple of our largest shell fragments that look as if they originate from a bivalve, about the size of a dime. They are clear and see-through. I have a photo of them on a spatula, sent to Cindy. See Core15shells1.jpg



**Core 16**

**Lat:** 78 degrees 20.6899 minN

**Lon:** 176 degrees 51.0486 min W

**Depth:** 808 m

**Time:** 01:14 UTC, 08/14/2006 (JD 226).

Type: Gravity core (core barrel diameter 2.5 inches).

notes—upper few cm of sediment were analyzed quickly, and not in nearly as much detail as core 17, since I we weren't sure what I we were looking for, or the correct way to proceed. Some details of Gravity Core 16 analysis: We only looked at approximately the top 5 cm sieved all together at 2mm hole size. Besides the shells, we saw tube worms brachiopods as well as other strange (unidentified) things that are photographed.

Shell 16, number1: found right on surface when we opened the core! Appears as a pecten shell with bumps running radial out from 1 side. See Core16shell1.jpg

Shell 16, number2: another pecten shell, also has radial bumps on one side.

Shell 16, number3: pecten shell, clear, no bumps. See Core16shell3.jpg

Shell 16, number4: pecten shell, bumps all over, it broke while trying to wrap it up, after we photographed it though. Very small and delicate. We had two of these, both unfortunately broke-up. We still have some fragments though. See Core16shell4.jpg Core16shell5.jpg

Shell 16,number5&6: wrapped together. Two pecten shells, clear/white. No bumps.

Shell 16, number 7: shells, tubeworm, 0.25 cm sieve etc. See Core16shells6.jpg and Core16tube1.jpg

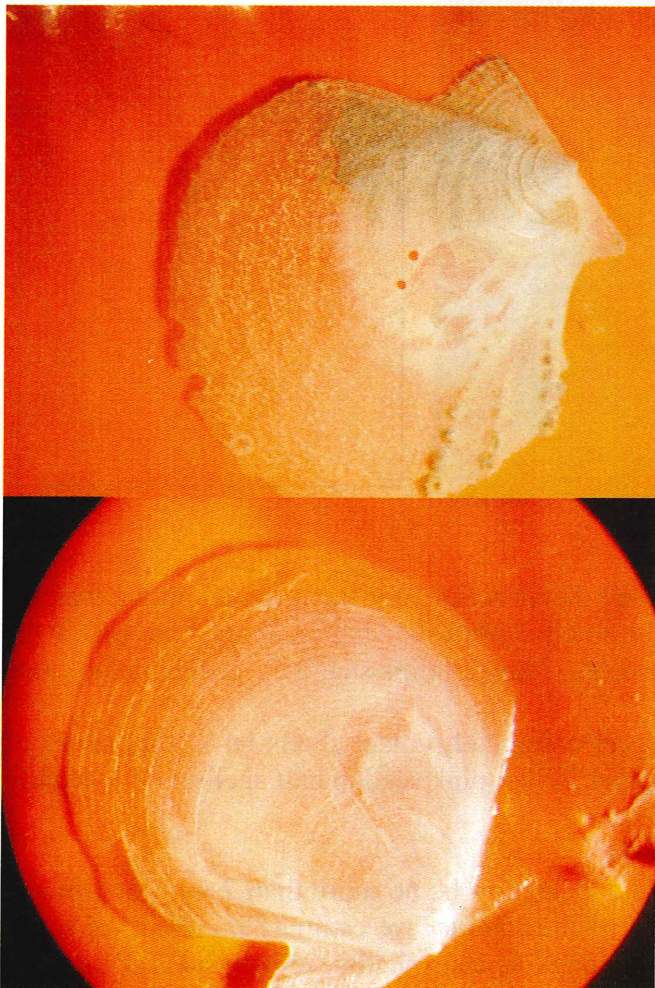
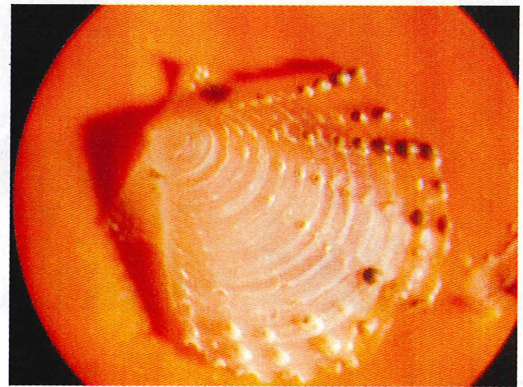


Figure 2. Shells from Core 16. Upper shell on left was found on surface of core. Shell below broke because it was so delicate. Tubeworm found in 0.25 cm sieve.



**Core 17**

**Lat: 78 degrees 20.676 min**

**Lon: 176 degrees 50.752 min**

**Depth: 815.8 m**

**Time: 02:04 UTC, 08/14/2006 (JD 226).**

Type: Gravity core (core barrel diameter 2.5 inches).

Detailed Look at the Top 28 cm of Gravity Core #17

Shipboard analysis of this core included the top 28 cm, and showed signs of being bioturbated to this depth (looking at the core cut, there were little holes passing through it. (core diameter is 2.5 inches (~7cm)). Looking at the contents 1 cm at a time:

Each cm of material is filtered through two sieves: the first is 2 mm, the second is 0.25 mm.

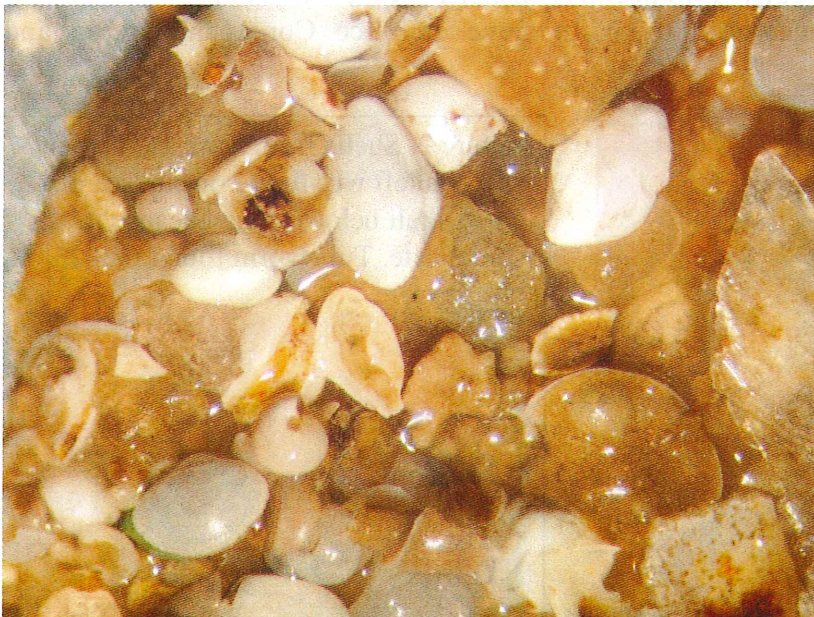


Figure 3. Core 17, top of core shows shell hash.

**0 – 1 cm:**

Description: upper most layer appears as relatively nondescript very fine-grained brown watery-mud, with a few small white flecks. Many of the shells started showing up about 1 cm below the seafloor, however, the sediment is fairly bioturbated. Larry Philips suggest a sedimentation rate of 1cm/1000 years.

Results from 2mm sieve: Shell size—the largest completely intact shells have a diameter of about half the size of a dime. In this layer we found 2 clear/pink scallop half shells, and 1 slightly larger white half shell.

Results from 0.25 mm sieves: the intact shells appeared to be no more than 2 mm long in any given direction. from quick statistical analysis of the sample, we estimate hundreds of shells above the sieve size. This group included several complete clam shells—ie both sides of the clam were intact and appear sealed (I have a picture on my camera). Upon opening some of these, we found them full of sand.

Claudio Photos from the 0-1 cm layer, Core 17:

1.jpg – Top of core 17

2.jpg – small shell, ~2 mm radius(?), in layer 0-1 cm depth.

1(2).jpg – scallop, other shell, and drop stones, found ~1/2 cm below seafloor using 2 mm sieve.

1(3).jpg – scallop half shell. Photo of inside part of shell.

1(4).jpg, 1(6).jpg – scallop half shell. Photo of outside part of shell. Second photo shot on orange background.

1(7).jpg 1(8).jpg – inside and outside of other white bivalve half shell, found in the upper 0-1 cm at core site 17.

### **1-2 cm:**

Same nondescript fine-grained brown mud.

Results from 2 mm sieve: Only one intact shell found in this sieve above the 2mm size, one other partial piece of shell was also found.

Results from 0.25 mm sieve: Less shells than in the layer above. Part of a Box echonoid(?)—a type of sea urchin identified by Larry P. Some closed shells also found, all appear to have sand in them. New type of shell we haven't seen before—looks like a bivalve. It is wider and pinches out narrowly on one side. Photo number 4 on my camera. Length of the shell is between 1-2 mm.

### **2-3 cm:**

Results from 2mm sieve: not much in it. Two pieces of shells, nothing whole. There was a new observation however. We saw white nodules in many of the other 0.25 mm sieve units—these white material looked somewhat like baby coral. Large pieces (greater than 2mm) were found in this section, and applying HCL resulted in bubbling (I have video of this, as well as a photo). Larry Philips felt that what we were looking at was Dolomite (not calcium carbonate) because it bubbled moderately. There were what appear to be magnesium grains imbedded into the calcium, similar to what you would expect when limestone is chemically altered to dolomite.

Results from 0.25 mm sieve: again much less than the previous (~20 percent of what we found in the very top layer. Still sea urchins seen in this materials, and some gastropods. Appear to be pieces of broken pecten shells—very fragile and weathered--but the foraminifera appear fully intact—maybe more silica in them?

### **3-4 cm:**

Description note: sediments are definitely getting more consolidated—takes much more water to break down the clay and wash it away. An also strange phenomena—there seems to be progressively less “dropstone” pebbles in the core as we have gone down, although this may not be statistically robust to say, since we only saw a few at the top to begin with, and haven't seen any of notable size since the first two layers.

Results from 2 mm sieve: No observed shells or shell fragments.

Results from 0.25 mm sieve: We see shells at this smaller scale still, but again much less. Lots of forams, but not many shells at all. I would argue that what we have observed progressively with

depth is something similar to an exponential decay in shell quantity with depth. There is something new in this material that we observed: something long and relatively soft and thin that is mainly clear, and almost transparent, but also a little iridescent. I took a picture as well of it.

**Sieving cm 4 – 28 using the 2mm sieve only:** Only a few items found, however, these included 2 halves of a bivalve, a tube worm, a large bivalve fragment identical in nature to what was found at site 15, and calcium (dolomite?) nodule a couple millimeters in diameter.

### **Core 18**

**Lat: 77 degrees 12.1331 min**

**Lon: 177 degrees 22.600 min**

**Depth: 1395 m**

**Time: 05:02 UTC, 08/16/2006 (JD 228).**

Type: Jumbo Piston Core (core barrel diameter 4 inches).

Details: this core was taken on the South Mendeleev ridge, not in a pockmark. It was a piston core, however, we only looked at the upper 5-7 cm of the trigger core component. We originally sieved from 0-1 cm, and then 1-2 cm, but found no signs of any pecten-type shells in the sieve using either the 2mm or 0.25mm sieves. We did however see some unidentifiable shell fragments, as well as a shell of a krill. The 0.25 mm sieve had only one small bivalve in them—very small relatively non-descript white one, for which I have photos, however, there were only a very few in the core, and these were vastly outnumbered by the forams and urchins. Note that the Trigger core is 4 inches in diameter and therefore contains much more sediment per cm of depth than the gravity core. Despite this, only few shells were found, and less were found in the trigger than in cores 15, 16, and 17. After looking through the first two cm in great detail, we sieved the next 5 cm of the core using only the 2mm sieve, and found only two shell fragments of unclear origin. They did not look like bivalve shells however. We did however find several drop stones, one of which is a well-preserved pink-red granite with nice crystals that Larry and Kelly believe originated in Canada. Rereading notes indicate that after 0.25 mm sieve only one bivalve was found, and also unlike cores 15,16,17 no clear indications of dolomite.



Figure 4.  
Note conspicuous absence of shells. Only one bivalve found in the 0.25 mm sieve.

## **Chapter 7: HLY0602 Multibeam Cruise Report**

**Prepared by Marcy Davis and Lawrence Lawver**

### **Description of Work**

The HLY0602 cruise departed offshore Barrow, Alaska, on 18 July 2006 and ended prematurely on 22 August 2006 in Nome, Alaska. SeaBeam 2112 multibeam data were collected from 1800 UTC (Universal Time Coordinated, formerly referred to as GMT) on the 18<sup>th</sup> of July (Julian Day = JD 199) until 0500 UTC on the 20<sup>th</sup> of August (JD 232). Data recording was suspended for approximately 25 minutes and then resumed as transit data from 0525 JD 232 until 2100 JD 233 between Barrow and Nome. Steve Roberts (University Corporation for Atmospheric Research (UCAR), Boulder, Colorado) was responsible for the multibeam data acquisition system. Marcy Davis was responsible for initial processing and ping editing quality control. Mark Wiederspahn archived the data. The science party stood a 24-hour watch and noted changes in multibeam acquisition in the underway log when appropriate. Track coverage is shown in Figure 1.

Raw multibeam data were logged in standard one hour-length files in SeaBeam file format: .mb41. The raw data files are named sb2006dddhhhh.mb41 where ddd is the Julian Day and hhhh is the hour. All data were recorded in UTC.

Once the one hour files were completed, the closed multibeam files were copied from Healy's data acquisition computer (part of the ship's science network) to a storage area (also on the ship's science network, but accessible by the science party network) at the completion of each UTC day. The raw hourly files were converted from MB-System file format, .mb41, to MB-System file format, .mb43, using mbcopy and were then available for manual editing. Format .mb43 files are smaller in size and therefore help expedite file manipulation. The only change in the naming format, is the file extension which denotes the new format (i.e. sb20062021400.mb43 instead of sb20062021400.mb41). Plots of the hourly raw data files in the new .mb43 format were then plotted. The raw files for the transit from Barrow to Nome were not plotted.

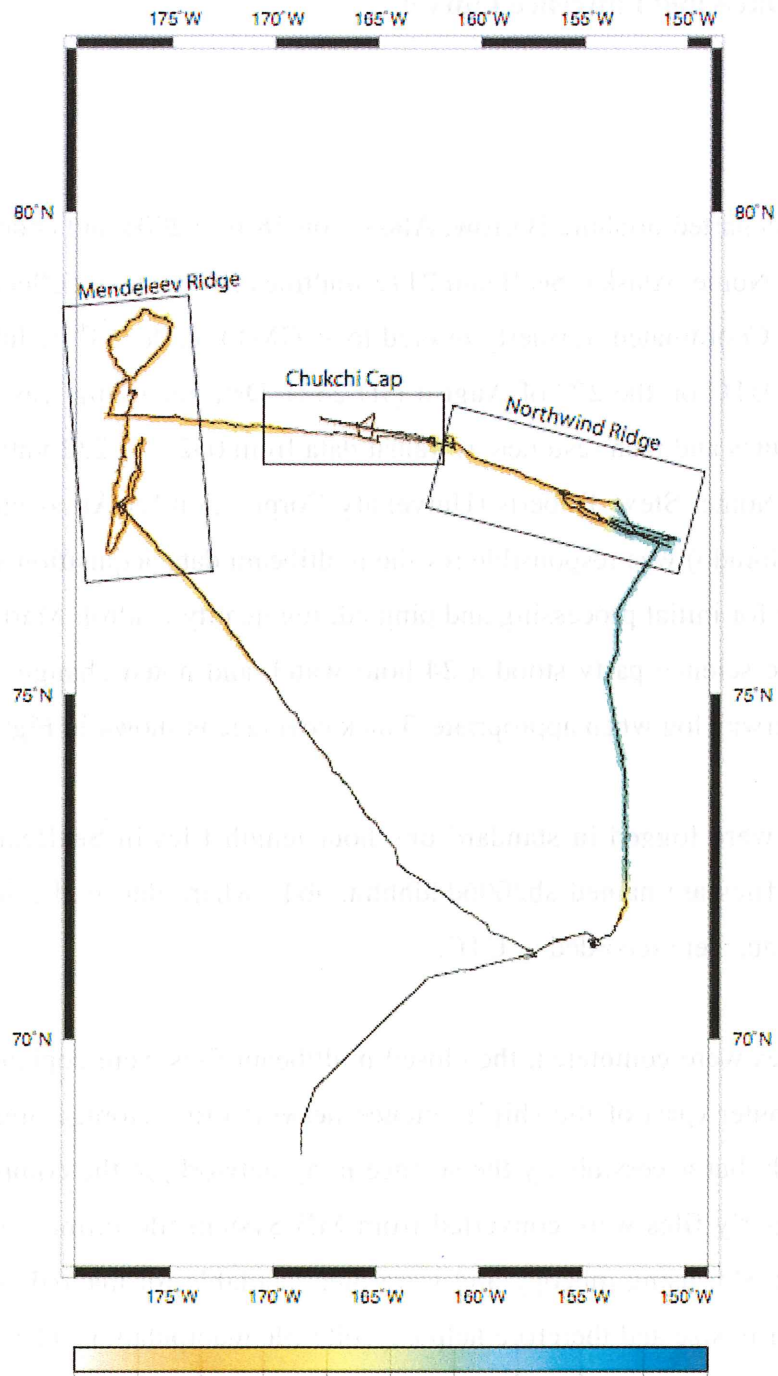


Figure 1. Multibeam track coverage for HLY0602. Individual surveys are shown in Figures 2 through 4.

The science party was responsible for using mbedit to remove bad data points from multibeam files. Due to network and software difficulties throughout the cruise, however, only days 203,

204, 226, 227 were edited along with a few high priority locations such as coring sites. Seismic acquisition was the top priority so multibeam processing often went unchecked for several days at a time. A computer issue that impacted the processing of the raw multibeam data concerned initial difficulties in setting up network connections between the ship's science network and the processing/archiving network set up by the science party.

MB-System Version 5.0.2 was installed on the science party network prior to embarkation but, once on board, we installed MB-System version 5.0.9. MB-System 5.0.2 uses GMT (Generic Mapping Tools) Version 3.4.1, but this particular version of GMT proved to be a problem for other shipboard cartographic endeavors with scripting syntax that required GMT Version 4.0 or higher. To solve this problem Mark Wiederspahn recompiled MB-System 5.0.9 which uses GMT Version 4.1. Unfortunately, there is a bug in MB-System 5.0.9 which causes the software to crash when dealing with .mb43-formatted multibeam files. In the end, we went back to using MB-System 5.0.2 for processing and editing multibeam files and sourced GMT Version 4.1 when we needed it for other applications. This was only sorted out during the last few days of the cruise so there was not a great deal of time left for any meaningful shipboard multibeam editing. High priority locations are being edited in the lab at UTIG.

XBT's (Expendable Bathythermographs) were taken every morning to determine the water temperature profile in the upper 300 meters of the water column. The water velocity profile calculated from the temperature profile was then applied directly to the SeaBeam 2112 acquisition system data. Corrections for roll and pitch biases for the multibeam system were automatic. To date, the mb-edit system is reported to not need any navigational corrections, so no navigational corrections have been applied.

Multibeam data quality was affected largely by the presence of ice, especially near the beginning of HLY0602 near Barrow where thick, heavily compacted multiyear ice brought *Healy* to a virtual stop during Julian Days (JD) 199 to 207 except for the period JD 202 0300 to JD 204 0600 when *Healy* was hove to and drifting with the ice. When backing and ramming, the multibeam showed a characteristic pattern. During the ramming phase, the data quality is exceptionally poor. Daily plots look like pipe cleaners. Data recorded while *Healy* is backing is

better because the ship was moving backward through a relatively clear channel. Even so, the data still require substantial cleaning. From JD 207-209 *Healy* was in transit to the survey area. Data recorded during this period is also poor due to a combination of ice conditions and high speed. This is also true of the data recorded en route from the Mendeleev Ridge back to Barrow. For the transit from Barrow to Nome, JD 230-232, ship speed was often up to 18 nm/hr, again resulting in poor data quality. In general, data quality varies throughout the survey depending on ice conditions and ship speed. Data quality showed marked improvement with ship speeds of less than 4 nm/hr and in locations with good leads. Multibeam data quality improved during coring operations and during most periods of seismic refraction acquisition and instrument deployment.

### **Multibeam data during seismic refraction experiments**

The first survey shown in Figure 2 covers the Canada Basin to the Northwind Ridge region. Figure 2a is a plot of the multibeam bathymetric data acquired on HLY0602 plotted on a polar stereographic plot with north to the north-northwest of the area shown. In figure 2b, mapserver is used to show the new multibeam data along with the older multibeam data in the same general area also plotted on a polar stereographic plot but with due north at 155°W near the center of the figure. The mapserver version, Figure 2b has a subdued background “bathymetry” taken from the International Bathymetric Chart of the Arctic Ocean (IBCAO) dataset of Arctic bathymetry (Jakobsson, Cherkis, et al., 2001). Much of the IBCAO “bathymetry” is based on satellite and aerogravity data collected by the Naval Research Lab. As such, major features such as the Northwind Escarpment between 154°W and 153°W on Figure 2a are well located as shown on Figure 2b but the magnitude and depth of features on Northwind Ridge itself are not imaged well on Figure 2b. In the vicinity of 154°W there is as much as a 600 m difference between the recorded multibeam depth and the calculated IBCAO depth (1125 m versus 1726 m).

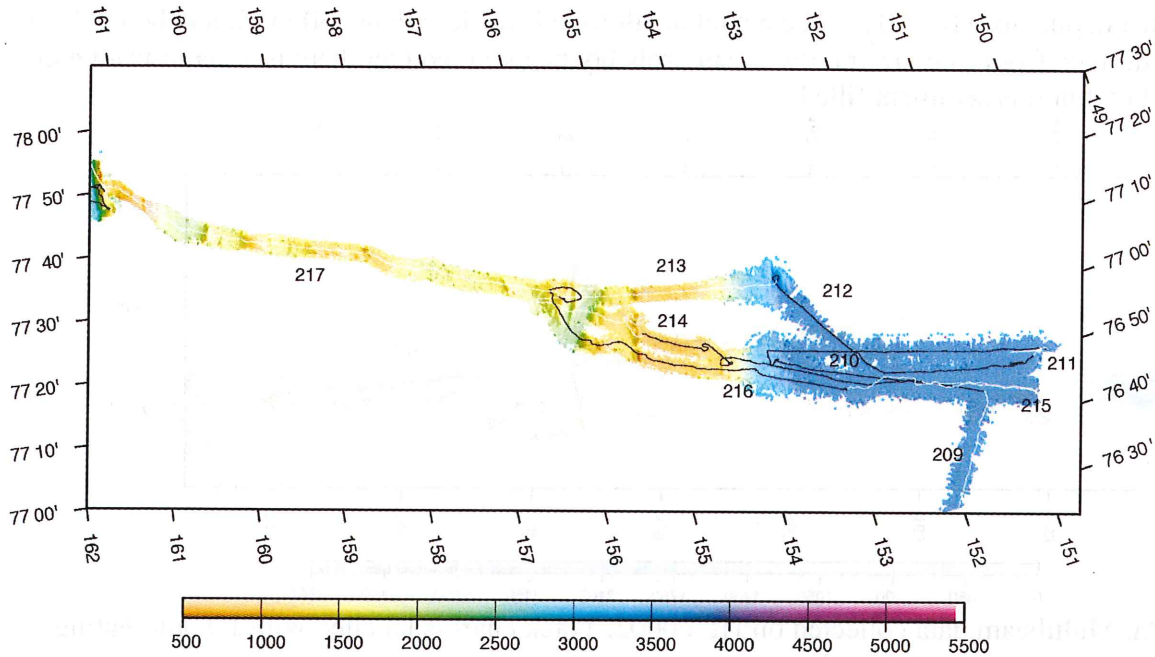


Figure 2a. Northwind Ridge multibeam data collected on HLY0602 using a polar stereographic projection with a different origin and orientation than the Mapsurfer data shown below.

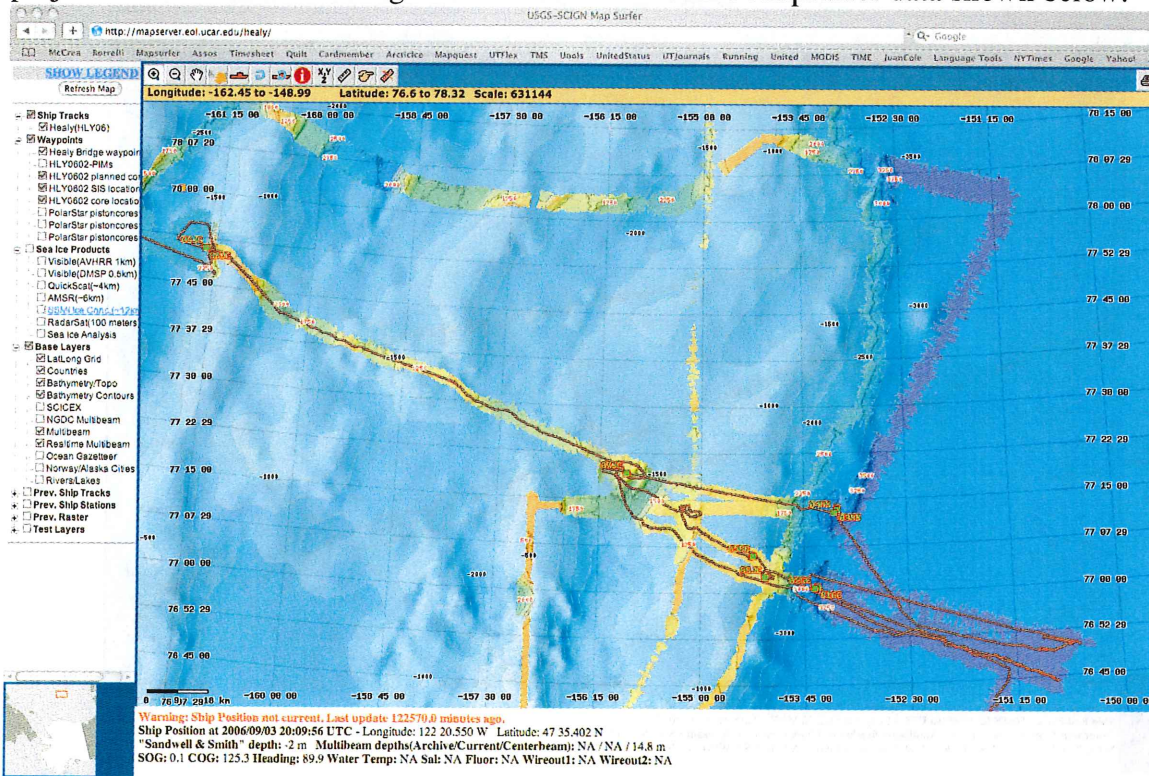


Figure 2b. Healy archived multibeam data with new HLY0602 data shown with tracklines, older data shown without tracklines. Mapsurfer data has polar stereographic latitude of origin of 67.5°N, central meridian of 155°W.

The multibeam bathymetry for Chukchi Cap is shown in Figure 3. The northern most point at 78°10'N was the location of core 10JPC. The IBCAO data indicated a trough on the Chukchi

Cap with a depth close to 700 m. The actual depth found was less than 460 m. Since the IBCAO depth is derived from free-air gravity, it can probably be assumed that there is a major trough at this location but it is sediment filled.

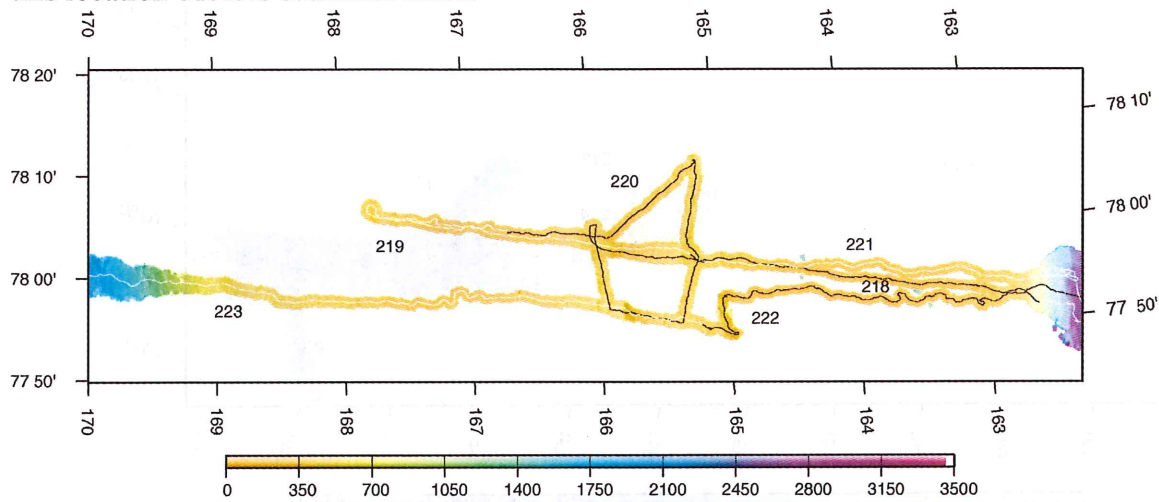


Figure 3a. Multibeam data collected on HLY0602. Track chart is labelled with JD, alternating black and white track per Julian day.

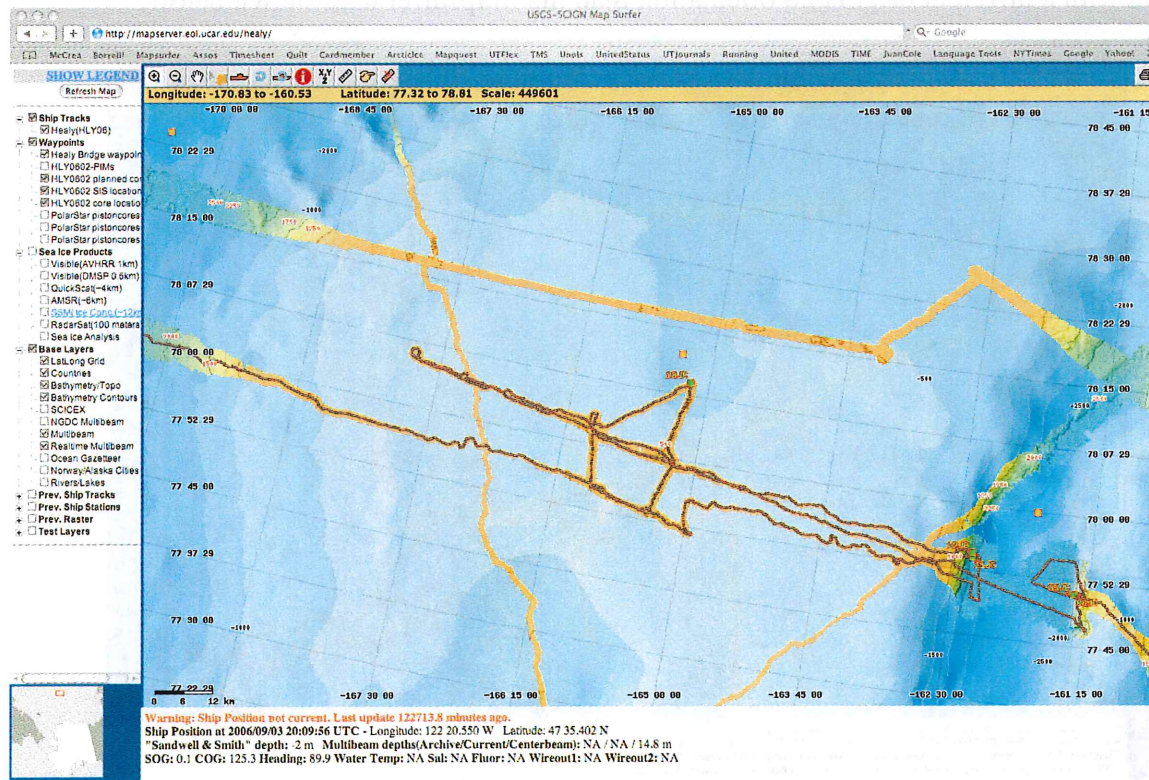


Figure 3b. Healy archived multibeam data with new HLY0602 data shown with tracklines, older data shown without tracklines. At the base of Figure 3b, the maximum discrepancy between the IBCAO data and the multibeam data is less than 200 m.

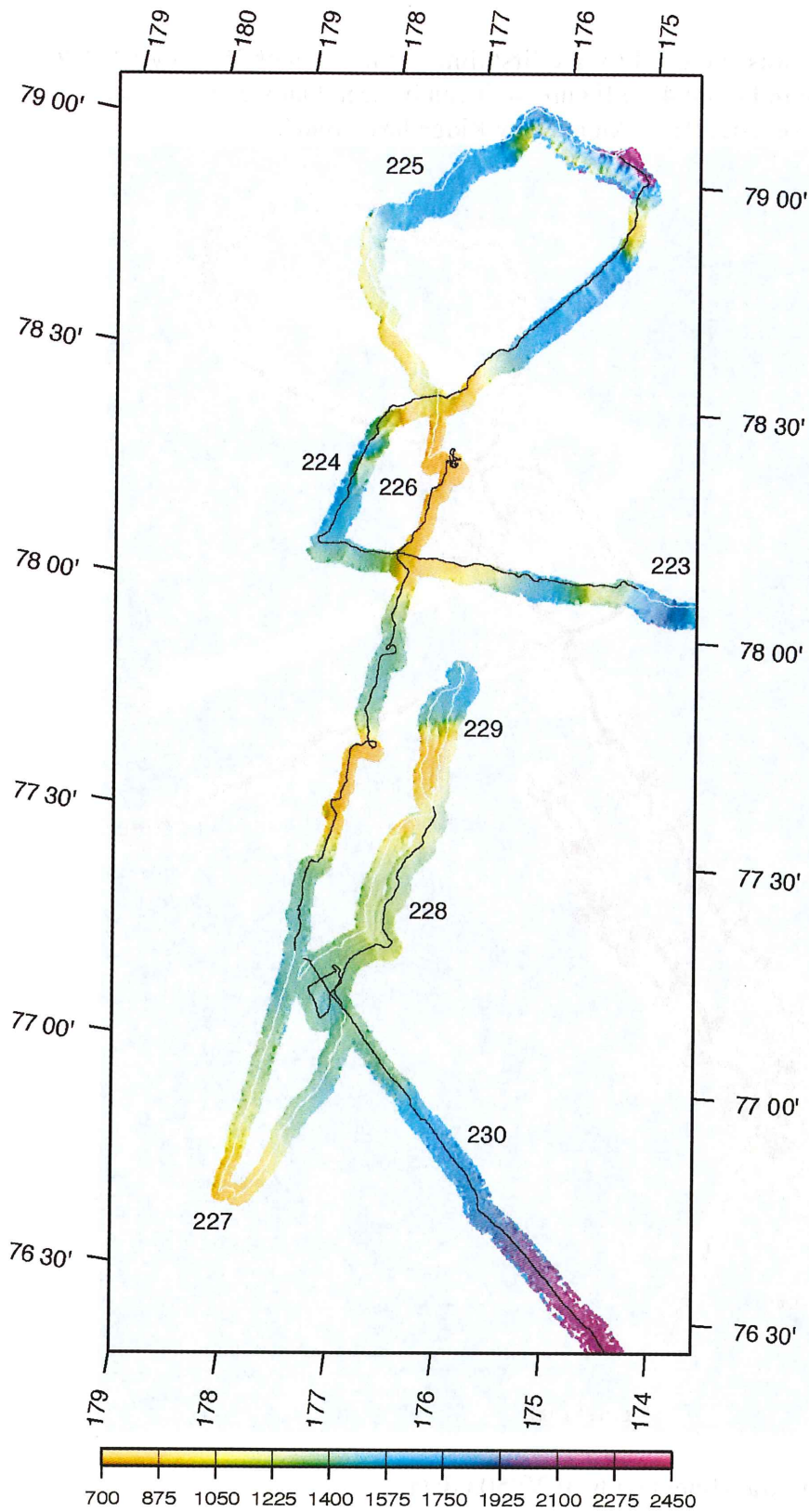


Figure 4a. HLY0602 multibeam data from Mendeleev Ridge. Bathymetric variations are obvious on Mendeleev Ridge as opposed to the fairly flat Chukchi Cap.

The southern Mendeleev Ridge was surveyed for the first time to the south of 78°N by *USCGC Healy* during HLY0602 as seen in Figure 4. In Figure 4b it can be seen that we cored a scarp mapped by Coakley and others on HLY0503. Mendeleev Ridge has a much

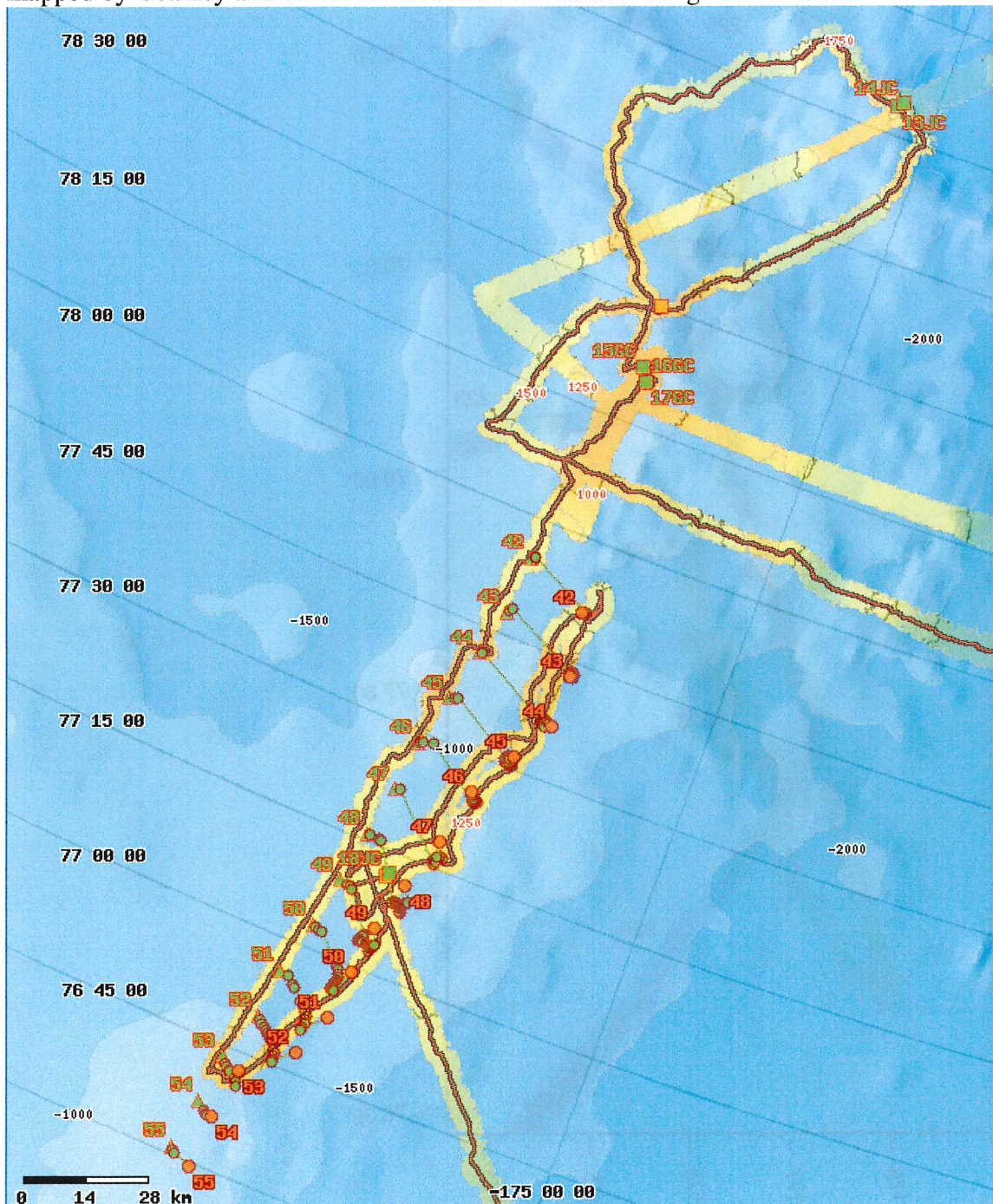


Figure 4b. HLY0602 data (with tracklines) with HLY0503 data.

different morphology than either Chukchi Cap or the Northwind Ridge region. We had just discovered some very exciting bathymetry when HLY0602 ended prematurely.

## **Chapter 8: Knudsen 320 Sub-bottom profiler**

The Knudsen 320 sub-bottom profiler generally penetrated the upper 0.06 second of sediment and in a few places with flat lying sediments and a strong reflector may have returned as much as 0.08 seconds or well over 50 meters of penetration. In areas of steep bottom slopes or what may have been bare rock, the sub-bottom penetration was none or much less. The Knudsen 320 or CHIRP system worked nearly flawlessly with virtually no down time. It is an excellent system and highly recommended as a valuable science tool. HLY0602 was very fortunate to have both Steve Roberts and Paul Henkart on board to watch over the system and to process the raw data. Paul has developed some new processing algorithms that are described below. Figure 1 shows the standard sub-bottom depth along track with pings based on time. In Figure 2, Paul Henkart has changed the processing algorithm such that the pings are plotted with respect to distance. The processed-for-distance section shows that the slope was actually steeper above the scarp than below it, making the central feature much more morphologically similar to a headwall scarp at the top of a slump. The reflector dipping to the right in the center of Figure 2 would be side reflector rather than a reflector at depth as it might be misinterpreted from Figure 1.

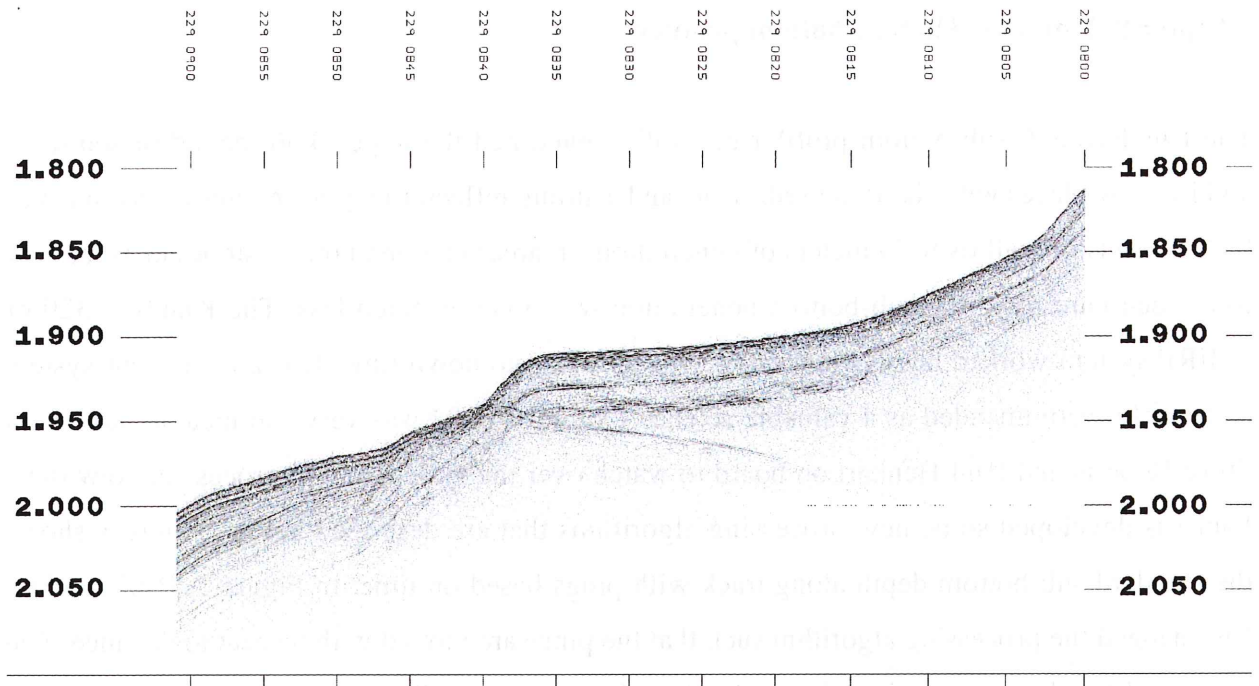
### **Data processing**

Two significant enhancements were made to the post-processing of the Knudsen chirp sub-bottom profiler:

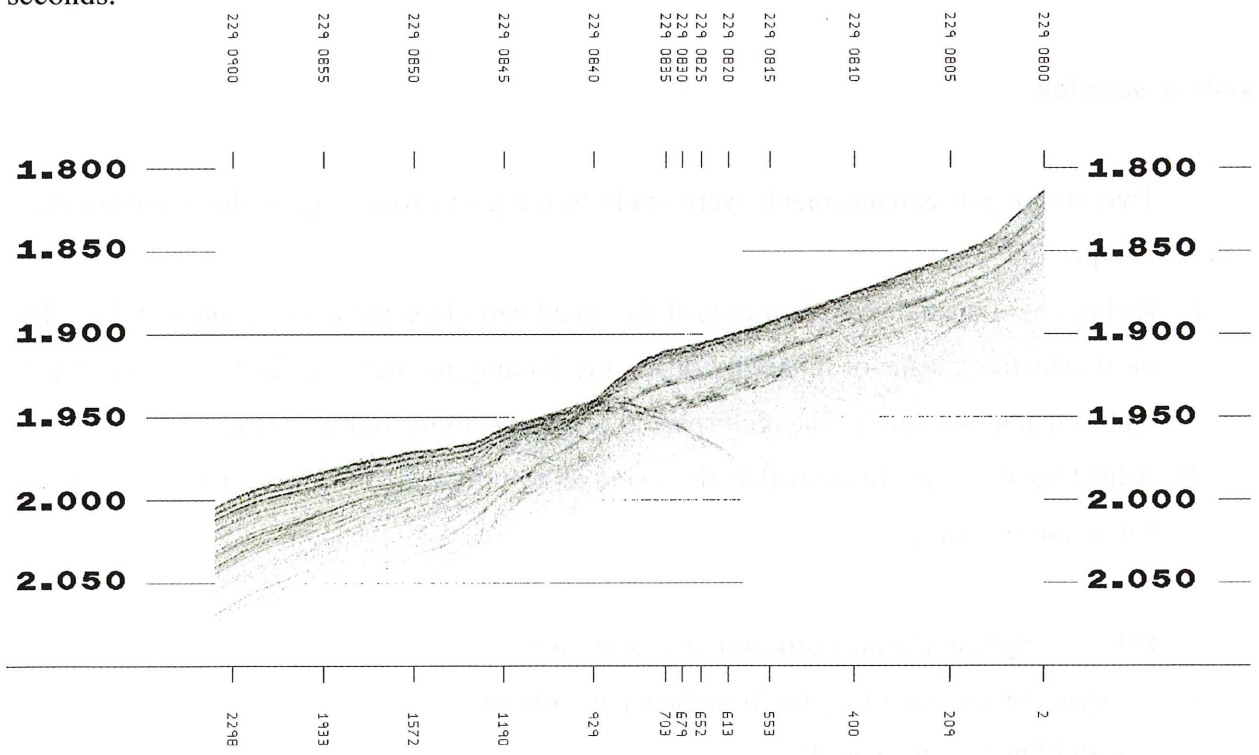
- 1) Reduction of spatial distortion caused the speed variations while going through ice. The most effective means of removing this is my binning the data similar to what is done in multi-channel seismics. The ping spacing on plots is more uniform now.
- 2) Adjusting the amplitude so that the average amplitude is uniform on every ping just below the seafloor.

Other changes to the post-processing scheme are:

- 1) Applying an exponential gain from the water bottom.
- 2) An additional frequency filter.
- 3) A two trace running mix that reduces random noise.



**Figure 1.** Raw CHIRP data plotted as time along track. Vertical axis is two way travel time in seconds.



**Figure 2.** CHIRP data plotted with distance along track. Note difference in morphology, particularly change in slope above the head of the scarp before and after processing.

A new option to SIOSEIS was added on HLY0602 to compute the distance along the ship track using the first trace entered into SIOSEIS as the origin. This distance is then inserted into the SEG-Y trace header word 10, the range. SIOSEIS can “plot according to range” where the horizontal plot axis is a constant increment whereas it is normally constant trace spacing.

This new feature also “bins” the data so that traces close to each other can be summed or stacked rather than plotted on top of each other.

Stacking and plotting by range eliminates “back and ram” distortions in plotting and other variable ship speed distortions.

Steve Roberts now knows enough seismic processing to create chirp plots and he has begun integrating this into his Map Surfer.

### **Errors and incomplete data sections for HLY0602 cruise**

- 1) On July 29, ~0748 the Knudsen was down for several hours while trying to get it into pinger mode for coring.
- 2) During August 4, the Ashtech GPS receiver failed to send the lat/long to the Knudsen, thus preventing plotting by range.
- 3) On August 5 the unit “froze” for ~30 minutes. Started by turning off then on via display pull down.
- 4) On August 14 the unit “froze” for ~20 minutes before restarting as above.
- 5) A significant “bug” was discovered in the SEG-Y data whenever there are more than 16232 samples in the trace. This occurs whenever the data range is set to 1000m, or 500m with the 12ms or less (6, 3, 1.5). We did not determine the threshold for the 200m range window. The error results

### **New scripts for processing Knudsen 320 sub-bottom profiler data**

#### **Comments on Script 1:**

- 1) Process header is used to save the number of samples in trace in a different word in the SEG-Y trace header because the FFTs in T2F will expand the trace to the next larger power of two. Sort integer word 58 contains the number of samples, so  $i120 = i58$  means save the contents of header word 58 in word 120. e.g. If there are 11111 samples, the next larger power of two is

16384.

Without using the header scheme, the output would be 16384 samples.

- 2) t2f creates the analytic signal and then gains does the complex modulus to create the envelope.
- 3) The SEG-Y standard uses a 16bit integer for the number of samples. SIOSEIS uses a 16 bit unsigned integer under the rationalization that the number of samples can not be negative. t2f creates complex numbers, so it creates twice the number of samples. The Knudsen often creates traces with 22222 sample, which means the fft makes it 32768 complex samples or 65536 words, which sioseis can deal with.

### **Comments on Script 2:**

- 1) Process GEOM type 17 computes the distance along the ship track line of every trace. DBRPS 3 uses a 3m bin spacing so that traces within 3 meters will be flagged as being in the same position. o that process stack can sum them. Process GEOM also sets the distance from the first trace of the job into the SEG-Y header "range" location.
- 2) There are two distinct processing sequences described. The first set assumes the water bottom depth picked by Knudsen is valid most of the time. Process wbt converts depth to time and save the time in SEG-Y header word 50, which other processes such as gains recognizes. When a zero depth is encountered, which Knudsen uses to indicate no pick, WBT uses the last good depth.

The second set of examples does not require water depths.

- 3) Both sets of examples use some type of trace equalization. Trace equalization is needed because the trace to trace amplitudes vary when the Knudsen pulse length changes or when the transducer transmit or receive power is changed. The avenor method equalizes the traces based on the average amplitude within .1 seconds of the Knudsen picked water bottom. The other method uses AGC which equalizes in time and space.
- 4) The plots don't show much difference with a two trace running mix, but remember that random noise is cancelled by the square root of the number of things added. SQRT(2) helps and a two trace mix is fine with deep dip.
- 5) The gain used in process gains is  $e^{-(5*t)}$ , hung from the water bottom ( $t_0$  = water bottom).

**Script #1: Make envelopes from Knudsen correlates**

```
#!/bin/csh -f
if( $#argv != 1 ) then
    echo "Usage: mkenv filename (without .sgy suffix)"
    exit 1
endif
set FILE = $1
sioseis << eof
procs diskin header t2f f2t gains header2 prout diskoa end
diskin
    ipath /Volumes/Data/Raw/knudsenraw/$FILE.sgy
end
end
header
    i120 = i58      ! save the original trace length
    fno 0 lno 9999999 ftr 0 ltr 999 end
end
header2
    i58 = i120     ! restore the original trace length
    fno 0 lno 9999999 ftr 0 ltr 999 end
end
prout
    info 1          ! print plotting info
    fno 0 lno 999999 noinc 50 end      ! print every 50th trace
end
gains
    type 7 end     ! complex modulus - make envelope from analytic
end
t2f
    end           ! number of sample is the next power of two larger
than the input
end
f2t
    type analytic end    ! create the complex trace
end
diskoa
    opath env-$FILE.sgy end
end
end
eof
#chmod 444 /Users/seismic/Data/Chirp/envelope/env-$FILE.sgy
#lsh /Users/seismic/Data/Chirp/envelope/env-$FILE.sgy >> info
#sort +2 -5 info > info-sorted
```

**Script #2: Make a plot from Knudsen envelopes**

```
#!/bin/csh -f
rm sunfil.ras
sioseis << eof
```

```

procs diskin prout geom stack wbt avenor filter mix gains plot
end
diskin
    fgmt 0300 lgmt 320
    ipath env-2006_226_0158_LF_028.sgy
end
end
geom
    type 17 dbrps 3 end
end
gains
    subwb yes type 5 alpha 5 end
end
avenor
    sets 0 .1 addwb yes end
end
wbt
    vel 1475 end
end
mix
    weight 1 1 end
end
filter
    ftype 0 pass 2 500 dbdrop 48 end
end
prout
    fno 0 lno 9999999 noinc 100 end
end
plot
    hscale 9000 stime 1 dir ltr
    nsecs .2 dptr 1 tlines .1 .5
    colors gray opath siofil wiggle 0 ann gmtint anninc 5 ann2
range
    trpin 300 def .01 tlines .05 nibs 2859 vscale 5 end
end
end
eof
sio2sun siofil sunfil.ras
#convert -rotate 90 sunfil.ras $FILE.png
display -rotate 90 sunfil.ras &

```

## **Chapter 9: Student and other participation on HLY0602**

We were fortunate to have participation of one high school student, three undergraduate students and five graduate students on HLY0602. Clark Wilson, chair of the University of Texas at Austin department of Geological Sciences (UT-DGS) agreed to turn participation in HLY0602 into an alternative field experience. As part of both undergraduate and graduate degree requirements at UT, students are required to have completed a field experience course. For most undergraduates, their required summer field geology course fits that criteria. In some cases, graduate students at UT-DGS, particularly those in geophysics may come into the graduate program from physics or engineering and consequently need a field experience course to satisfy graduation requirements. In the case of the one UT-DGS undergraduate, he had missed his normal field geology course so needed a replacement. In order to further the experience as a field experience, UT-DGS agreed to finance an 8-day field trip from Anchorage to Seward to Deadhorse, Alaska which five of the six UT students participated in. The land field experience included a three day trip with Gil Mull, the recognized expert on Brooks Range geology who lead the trip from Fairbanks to Deadhorse. The NSF project budget paid for the plane tickets for the students to join the ship so there was little extra expense required for the student travel costs since the price of the Deadhorse – Barrow plane ticket was not significantly different from the cost of an Anchorage – Barrow plane ticket. The sixth UT student joined the field trip in Denali. One, soon-to-be University of Alaska graduate student participated in HLY0602 at the request of Prof. Bernie Coakley of the University of Alaska. One undergraduate from Moscow State University participated in the cruise for which the project budget included his airfare only within Alaska. The high school student, Max Henkart participated for the experience and worked as an unpaid watchstander. The final undergraduate student was unknown to the science party until she arrived in Barrow. She was apparently an intern from California Polytechnic State University, San Luis Obispo hired by Dave Forcucci. She entered science log information.

In addition to the student participation, Jimmy Jones Olemuan joined the ship as a local observer. Jimmy is an excellent hunter and proved to be invaluable at spotting wildlife during HLY0602. He generally worked as a marine mammal observer under the auspices of Beth Haley of LGL, Anchorage, AK.

## **BASC support and lack of support in Nome**

We received extraordinary support from the people at the Barrow Arctic Science Consortium (BASC). Glenn Sheehan, Alice Brower, Lewis Brower, Robert Bulger and all the others involved with BASC made things go as smoothly as possible for us. Initially there were some serious problems with Alaska Airlines completely changing their flight schedules into Barrow after we had made plane reservations. Without the local information we received from BASC, we would not have known what was happening. At one point, the Alaska Airlines reservation people were ignorant of the changes and we had to refer them to their own employee newsletters that explained the situation. We were extremely fortunate that when *Healy* was delayed arriving in Barrow and consequently delayed in leaving, BASC was able to arrange for lodging for the extra time. BASC was always at the airport to meet the arriving scientists and others boarding *Healy*. BASC was able to provide us with internet connections and lab space so we could work while waiting for *Healy* to arrive. From prior experience, it is difficult to plan on arriving at a port in Alaska immediately prior to boarding a ship so it is very good to have a place to be able to work and communicate for the day or two that we waited. Dutch Harbor is a very difficult port to access by commercial plane. BASC made a special effort to retrieve a late-incoming airfreight shipment that Northern Air Cargo wanted to simply put off until the next morning. Without the intervention of Lewis Brouwer and Glenn Sheehan, it would have meant an extra 10 hour wait for the cargo.

As most people now know, our cruise was cut short by the tragic deaths of Lt. Jessica Hill and Steven Duque in a diving accident on 17 August 2006. Our science ended prematurely and *Healy* got underway to return to Barrow. Our disembarkation port was to be Nome, Alaska on the 28<sup>th</sup> of August but we stopped in Barrow with virtually no prior notice to BASC on the 19<sup>th</sup> of August. To the very great credit of Glenn Sheehan and the others at BASC, they all provided logistical support way above the call of duty. We hope that they can be commended for their extraordinary effort.

As a consequence of the diving accident, our arrival at Nome was shifted from the 28<sup>th</sup> of August to the 22<sup>nd</sup> of August. The scientific party was left with the problem of trying to rebook airline flights and hotels during one of the very busiest parts of the Alaska summer tourist season. By the time email service was restored to us on *Healy*, it was too late on a Friday

afternoon to get travel support from people at the University of Texas. As a consequence we had to rely on the emergency number for the UT travel provider. While that worked better for some than others, we at least were able to make a start on getting rebooked. Others in the scientific party such as the coring group from Oregon State found that their travel agent's emergency number only worked between 0900 and 1700, Monday through Friday, so was not of much use when they needed it. When the Aurora Inn in Nome was contacted to change hotel reservations from the 28<sup>th</sup> to the 22<sup>nd</sup> of August, it was found that they were full for the 22<sup>nd</sup>. Luckily the Nugget Inn in Nome took care of us and should be commended for coming through in an emergency. Initially they said that they did not have enough beds for us but when they understood the nature of the emergency, they immediately said 'not to worry, they would take care of it for us'. It would have been much easier for all concerned if there was a contact in Nome. It is unlikely it would ever be similar to the BASC operation in Barrow. It would have been far easier on us if we could have made one phone call and that representative could have organized both hotel rooms and new plane reservations as the ship's agent in any port does routinely for UNOLS ship support.

