

Overview of Seabed Characterization Experiment Survey Cruise 2015

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Executive Summary: A survey cruise was conducted in July and August of 2015 in the New England Mud Patch, in about 75 m of water, located about 90 km south of Martha's Vineyard, Massachusetts, in preparation for a full acoustic experiment in 2017. During the first leg of the survey (July 22 – August 2), a CHIRP sub-bottom profiler was used to study the seabed stratigraphy, and a multibeam sonar obtained a detailed map of the bottom at the experimental site. These measurements were made along 41 east-west tracks, six north-south tracks, and four diagonal tracks within the experimental site, which was a rectangle about 30 km x 10 km in the east-west direction and north-south directions, respectively. A hydrophone and oceanographic mooring was deployed at mid-depth in the center of the site (40.47738 degrees N, 070.60397 degrees W), recording acoustic and oceanographic data from July 24 through August 1. Combustive sound source signals were generated at positions on the east and west ends, and at the north and south ends of the operational area. About 20 CTD casts were obtained at various locations throughout the site during the first leg. The second leg of the survey (August 3 - 14) was dedicated to coring operations at about 30 locations within the experimental site. Thirty-three gravity cores, five multi-cores, and eight box cores were obtained. At each coring site and at several additional sites, CTD measurements were obtained. Also, 36 liters of bottom water were collected. Both GPS and ADCP measurements were made continuously during both legs. Vibra-coring was attempted, but both the primary and the backup vibra-coring systems failed and no cores that penetrated into the sand layer (believed to underlie the mud) were obtained. Both a vertical and a horizontal core logger failed early during the second leg, so core logging was conducted *a posteriori*. This document contains location maps of the various operations along with tables that summarize the measurements. A log of daily operations is also archived, and a website is under development that will ultimately host a similar overview and house and dispense all of the data.

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SECTION I. Survey Overview

A survey cruise was conducted onboard the R/V Hugh R. Sharp in July and August of 2015 in the New England Mud Patch, in about 75 m of water, about 90 km south of Martha's Vineyard, Massachusetts. The purpose of the survey was to prepare for a full experiment in the spring of 2017. The approximate geographical center position of the area of operations was 40.47748 degrees N, 070.60397 degrees W, and is shown in Figure 1.

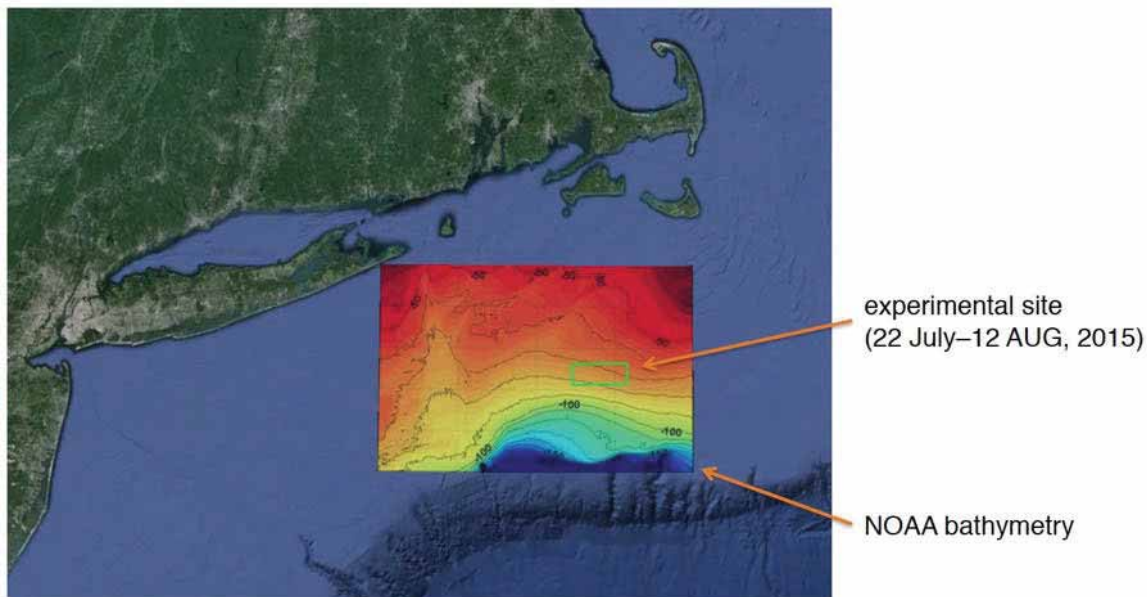


Figure 1: The green rectangle is the location of the experimental site. A color map of the bathymetry using NOAA data is also shown. The bathymetry contours represent 10 m depth changes. The depth of the site varies between approximately 70 m and 80 m.

Table 1 lists the science crew names, affiliations, and their function, for both legs of the cruise. David Knobles was the chief scientist for Leg 1, during which an EdgeTech 3200 sub-bottom profiling system was used to infer the seabed stratigraphy, and a Reson/Teledyne SeaBat multibeam sonar was employed to obtain a detailed map of the bottom at the experimental site. The Principal Investigator (PI) for the sub-bottom profiling operation was John Goff, and the PI for the multibeam mapping operation was Christian de Moustier. These measurements were obtained along 41 east-west (E-W) tracks, six north-south (N-S) tracks, and four diagonal tracks within the experimental site, a rectangle about 30 km x 10 km in the east-west direction and north-south directions, respectively. Nineteen Conductivity, Temperature, Depth (CTD) casts were obtained at various locations throughout the site during the first leg.

In addition to the main priority of Leg 1, a small acoustic experiment of opportunity was included in an auxiliary mode. A hydrophone and oceanographic mooring was deployed at mid-depth in the center of the site, which recorded acoustic and oceanographic data from July 22 through August 1. Mohsen Badiy and Ying-Tsong Lin (Lin) were PIs for the mooring. Combustive sound source (CSS) signals were generated at the east and west ends, and at the north and south ends of the site. Knobles and Preston Wilson were PIs for deployment of the CSS.

Wilson was chief scientist for the Leg 2, which was dedicated to coring operations at about 30 locations within the experimental site. Allen Reed was the PI for the coring operations. Thirty-three gravity cores, five multi-cores, and eight box cores were obtained. At each coring site and at several additional sites, CTD measurements were obtained. Thirty-six liters of bottom water was collected. Both GPS and ADCP measurements were made continuously while underway during both legs. Vibra-coring was attempted but both the primary and the backup vibra-coring systems failed, and no cores that penetrated into the sand layer believed to underlie the mud were obtained. Both a vertical and a horizontal core logger failed early during Leg 2, so core logging was conducted *a posteriori*.

Table 1: Science crewmember names, affiliations, and scientific function.

Leg 1 7/22–8/2		
	Name	Affiliation (function)
1	David Knobles	ARL:UT (Res. Sci., CSS co-PI, Chief Sci.)
2	Jason Sagers	ARL:UT (Res. Associate, CSS engineer)
3	Lin Wan	Univ. Del (grad student)
4	Mohsen Badiey	Univ. Del (Res. Sci., mooring lead)
5	John Goff	UT Austin (Res. Sci., CHIRP survey PI)
6	Steffen Saustруп	UT Austin (CHIRP survey tech)
7	Chris de Moustier	10dBx LLC (Res. Sci., multibeam PI)
8	Barbara Kraft	10dBx LLC (Res. Associate, multibeam processing)
9	Gopu Potty	Univ. Rhode Island (Res. Sci.)
10	Ying-Tsong Lin	WHOI (Res. Sci., mooring lead)

Leg 2 8/2–8/14		
	Name	Affiliation (function)
1	Preston Wilson	ARL:UT (Res. Sci., CSS co-PI, Chief Sci.)
2	Gabe Venegas	UT (graduate student)
3	Allen Reed	NRL (coring PI)
4	Bill Sanders	NRL (parametric sub-bottom profiler)
5	Joe Smith	USNA (coring team lead)
6	Daniel Ecker	USNA MIDN (coring)
7	Kyle Fringer	USNA MIDN (coring)
8	Chuck Dill	Alpine Ocean (coring)
9	Matt James	Alpine Ocean (coring)
10	Ellen Roosen	WHOI (MC-800 tech)
11	Megan Ballard	ARL:UT (Res. Associate, shear wave)
12	Kevin Lee	ARL:UT (Res. Associate, shear wave)
13	John Goff	UT Austin (CHIRP survey PI)

The R/V Sharp is shown in Figure 2. Both Legs departed from and returned to the R/V Sharp's home port, Lewes, Delaware. On August 9, during Leg 2, the R/V Sharp spent about 24 hours at the NOAA dock in Woods Hole, Massachusetts, to retrieve supplies and weather a storm. Photos of the science crews are shown in Figures 3 and 4.



Figure 2: The R/V Hugh R. Sharp.



Figure 3: Science crew on Leg 1. Left to right: Christian de Mousier, David Knobles, Jason Sagers, Ying-Tsong Lin, Barbara Kraft, Gopu Potty, Mohsen Badiey, John Goff, Steffen Sastrup, and Lin Wan.



Figure 4: Science crew on Leg 2. Back row, left to right: Bill Sanders, Dan Eckart, Kyle Fringer, Joe Smith, Kevin Lee. Front row, left to right: Preston Wilson, Matt James, Ellen Roosen, John Goff, Megan Ballard, Gabe Venegas, Chuck Dill.

SECTION II. Leg 1: Results

Details of the various operations during Leg 1 are provided in SECTION IV. Leg 1: Daily Operations Log.. Figure 5 shows the Leg 1 tow tracks, mud thickness estimate, locations of the CTD casts, CSS shots, and acoustic-oceanographic mooring. The position of the UD/WHOI mooring is 40.476136 degrees N, 70.780961 degrees W. Coordinates of the CTD casts are presented in Table 2 and the coordinates for the CSS shots are presented in Table 3.

The CTD casts served the primary role of providing de Mousier sound speed profile (SSP) data that are used to calibrate the processing of the multibeam sonar data for bottom bathymetry. At the time of this writing, the bottom bathymetry data from the multibeam sonar is yet to be completed.

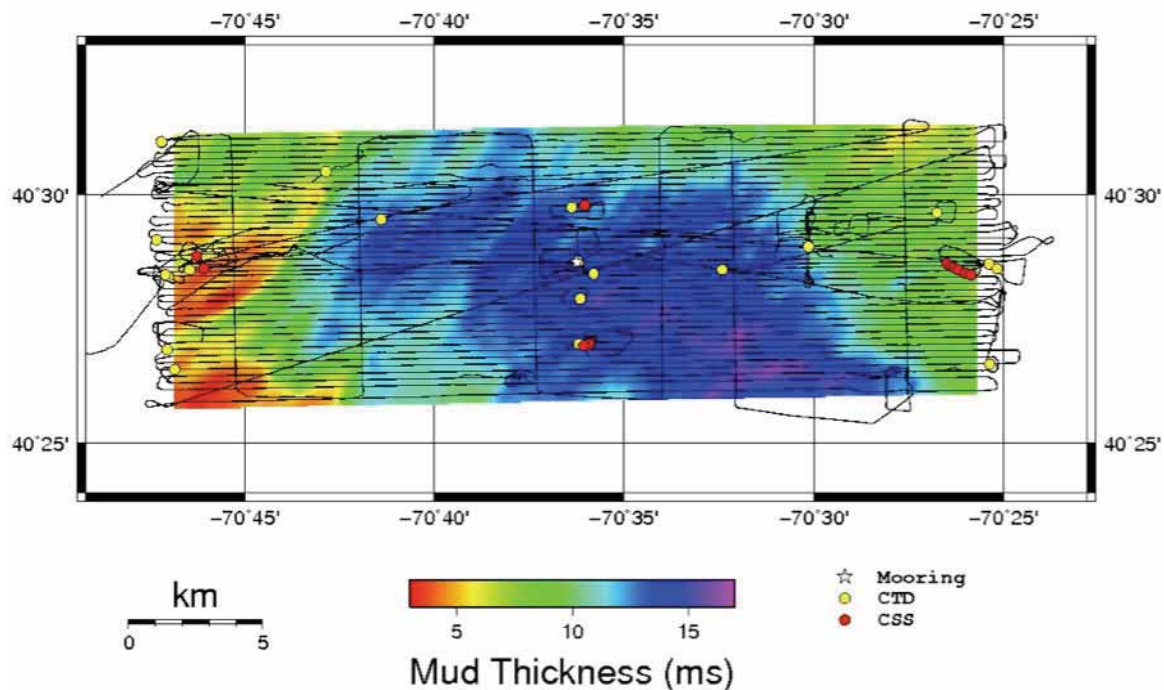


Figure 5: Leg 1 tow tracks for cruise DK10-15, CHIRP-derived mud thickness estimate color map, the locations of the CTD casts, the CSS event positions, and the UD/WHOI mooring position. Mud thickness is expressed in two-way travel time t_{2w} in units of milliseconds.

To convert two-way travel time t_{2w} in units of milliseconds into approximate thickness T in units of meters, one can use $T = (t_{2w} / 2000) / 1500 = 0.75 t_{2w}$. For example, the thickest area is in the southeast (purple color) at 17 ms and $T = 12.75$ m whereas the thinnest portion is about 2 m (red color). The largest section (blue color) is about 10 m thick. The black lines are the survey tracks of 41 E-W lines and 6 N-S lines. The E-W lines were about 30 km long and the N-S lines about 11 km long. There are some additional tracks that were selected for deployment, recovery, high-speed transits, duplicate transects for the multibeam, etc. Some of the lines have deviations from straight-line paths, caused in part by CHIRP fish becoming entangled in fishing gear or the R/V Sharp attempting to avoid surface expressions of the fishing gear. Overall the Captain did a good job avoiding the fishing lines, once it came to his attention that some of the crew were using close encounters with the lobster pods to enhance fishing from lines secured on the back deck. To a significant degree the sediment thickness map (Figure 5, and subsequent versions) derived from the

CHIRP survey is the main result of Leg 1 and may be viewed as an upgrade to the map reported by [Twichell](#).¹ Additional data products such as seabed stratigraphy can be derived from the CHIRP data. Two examples are given in Figure 6 and Figure 7. Additional examples of bottom layering derived from the CHIRP survey are presented in SECTION IV. Leg 1: Daily Operations Log. to provide insight into selection of core sites.

In summary the area consists of a mud pond filled with fine-grained sediments and a thickness ranging from 2 to 12 m. The fine-grained sediments were deposited within a depression formed first by erosion of Pleistocene sediments of unknown composition, followed by a mantling of Holocene sands organized into an oblique sand-ridge morphology. The mud is seismically laminated, i.e., has increasing impedance contrasts with increasing age (depth of deposition).

Table 2: Coordinates of CTD casts deployed during Leg 1.

Lat (Deg N)	Long (DEG W)	Date	Time
40.473167	70.785667	7/23/15	19:21:50
40.475167	70.419167	7/24/15	0:03:10
40.474500	70.599167	7/24/15	16:30:37
40.484833	70.788500	7/25/15	8:35:13
40.495667	70.606000	7/25/15	22:34:59
40.476667	70.421833	7/26/15	13:34:04
40.464667	70.602167	7/27/15	4:35:11
40.450500	70.602833	7/27/15	16:48:13
40.447000	70.784500	7/27/15	20:25:05
40.482833	70.502667	7/28/15	17:23:37
40.517333	70.786500	7/29/15	14:44:12
40.476167	70.776000	7/30/15	4:24:44
40.477500	70.602833	7/30/15	17:03:41
40.441500	70.780667	7/31/15	16:04:59
40.443333	70.422333	7/31/15	18:57:38
40.475000	70.539167	7/31/15	20:19:24
40.493167	70.445000	7/31/15	21:19:01
40.492000	70.689500	8/1/15	0:44:06
40.507500	70.714667	8/1/15	18:02:01

Table 3: CSS events during Leg 1.

Way point	Latitude (DEG N)	Longitude (DEG W)	JD Time (UTC)	Source depth (m)	Range to UD/WH OI mooring (km)	Gas flow duration (sec)	Peak spectral level (dB re 1uPa ² /Hz @ 1m)	Peak pressure level (dB rel @ 1m)
015	40.496	70.600	206	5	2.2	58	170.0	

			23:07					
016	40.49618	70.6002	206 23:17	10	2.2	114	174.0 @ 33 Hz	216.2
019	40.47326	70.43105	207 14:08: 34	20	14.2	300	clipped	clipped
020	40.47377	70.43330	207 14:18: 38	20	14.2	480	clipped	clipped
021	40.47482	70.43632	207 14:32: 12	20	14.2	720	clipped	clipped
022	40.47561	70.43800	207 14:38: 47	10	14.2	240	169.5 @ 52 Hz	228.0
023	40.47601	70.43927	207 14:44: 52	10	14.2	240	167.4 @ 53 Hz	222.80
024	40.47697	70.44139	207 14:53: 57	10	14.2	480	171.8 @45 Hz	222.8
025			208	10		?	Misfire	Misfire
026				10		?	Misfire	Misfire
027	40.44930	70.6008	208 17:27	10	3.0	240	170	232.4
028	40.44930	70.5452	208 17:39: 32	20	3.0	600	171.3	232.0
029	40.44996	70.59856	208 17:48: 30	20	3.0	720	172.6	240.7
030	40.45031	70.59815	208 17:56: 21	20	3.0	390	170.6	235.9
031	40.45064	70.59794	208	10		?	Misfire	Misfire
032	40.45064	70.59794	208 18:08: 56	10	3.0	?	173.0	236.7
038			211 05:12: 07				Misfire	Misfire
039	40.47623	70.7681	211 05:12: ?	20	14.7	?	179.4 @ 12 Hz	232.6
040	40.47944	70.77097	211	20	14.7	?	171.7	232.3

			05:54: 49					
041			211 07:11: 08	12		?	Misfire	Misfire

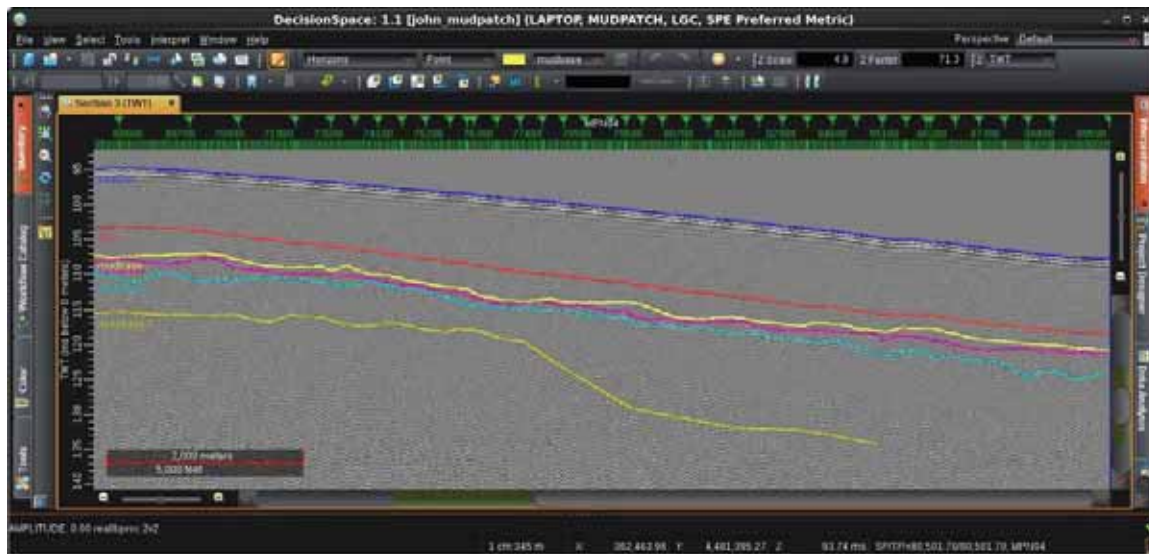


Figure 6: Example of seabed stratigraphy derived from processing of CHIRP data. The sediment between the blue and red lines is mud. The red line defines a sand base, but there is not a single line that defines an interface between the two sediment types.

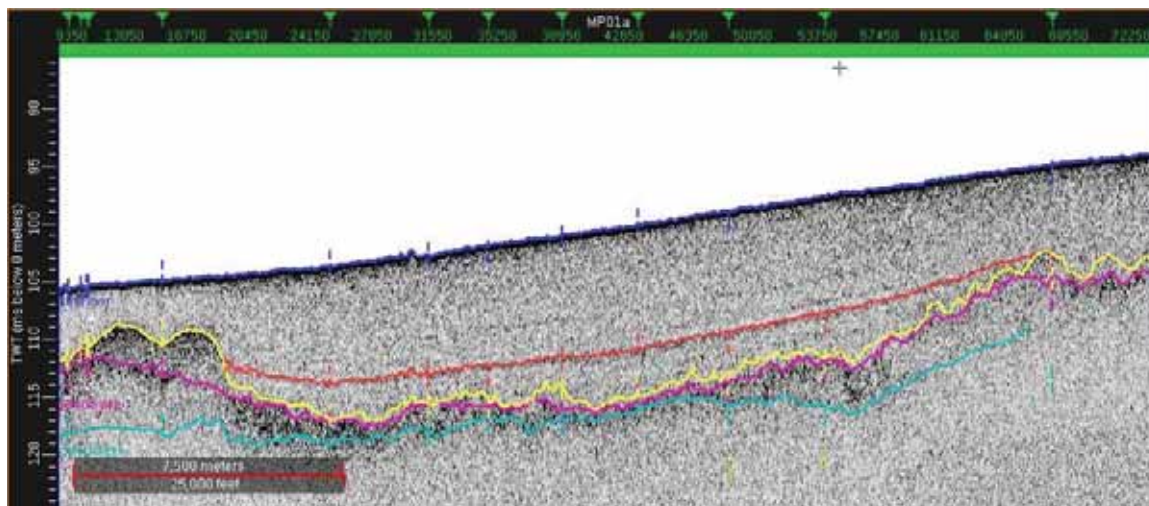


Figure 7: Example of seabed stratigraphy derived from processing of CHIRP data. The sediment between the blue and red lines is mud. The red line defines a sand base, but the details of the transition from mud to sand appear to indicate additional structure including roughness.

The UD/WHOI mooring was successfully deployed and recovered. Both Lin and Mohsen Badiey did some basic processing and analyses of the received pressure time series on the ship for the CSS events (see Figure 8).

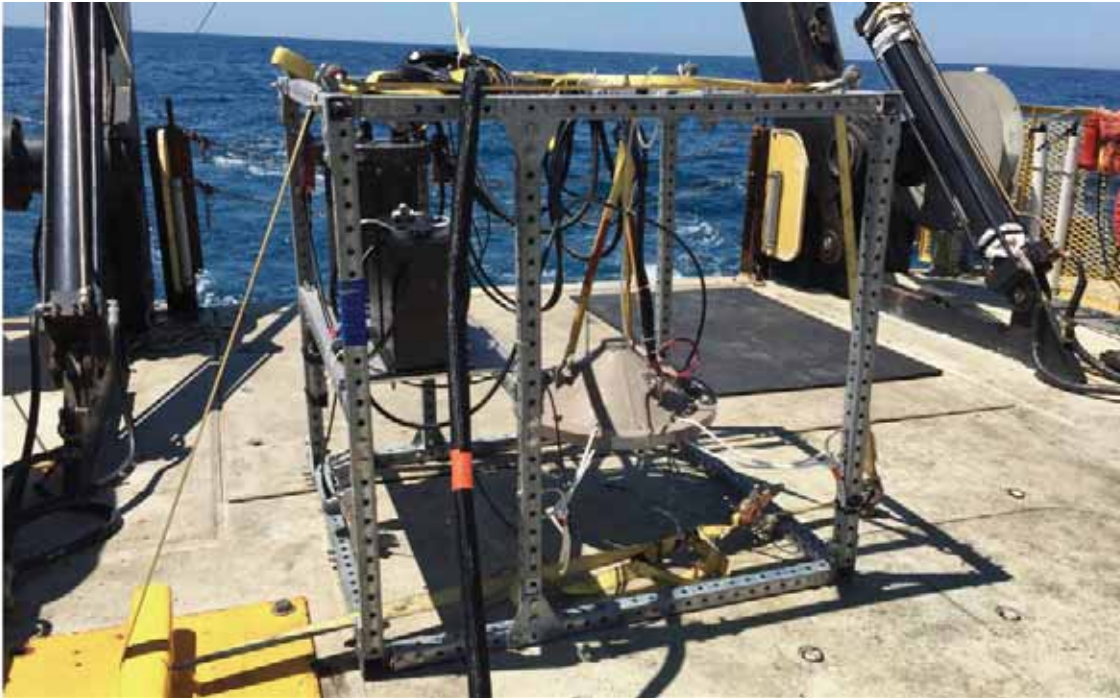


Figure 8: The CSS apparatus on the stern deck of the R/V Sharp (Source: Mohsen Badiey).

Figure 9 and Figure 10 show two received time series cases: short range with the mud layer having an approximately range-independent sediment thickness and long range with the mud layer having a range-dependent thickness. For the short-range case, the time spread of the time series is on the order of 200 ms, with the majority of the energy arriving at the lower frequencies; however, at this range a significant amount of energy is arriving at the higher frequencies, up to about 3.5 kHz. For the long range CSS event, the time spread has increased significantly to about 800 ms, with the majority of the arrivals characterized by frequencies less than 500 Hz. Because the waveguide admits significant time spreads for such a shallow waveguide depth (~ 75 m), along with the observation that arrivals are observed over the full 5 kHz band, one might hypothesize the mud is characterized by a low attenuation.

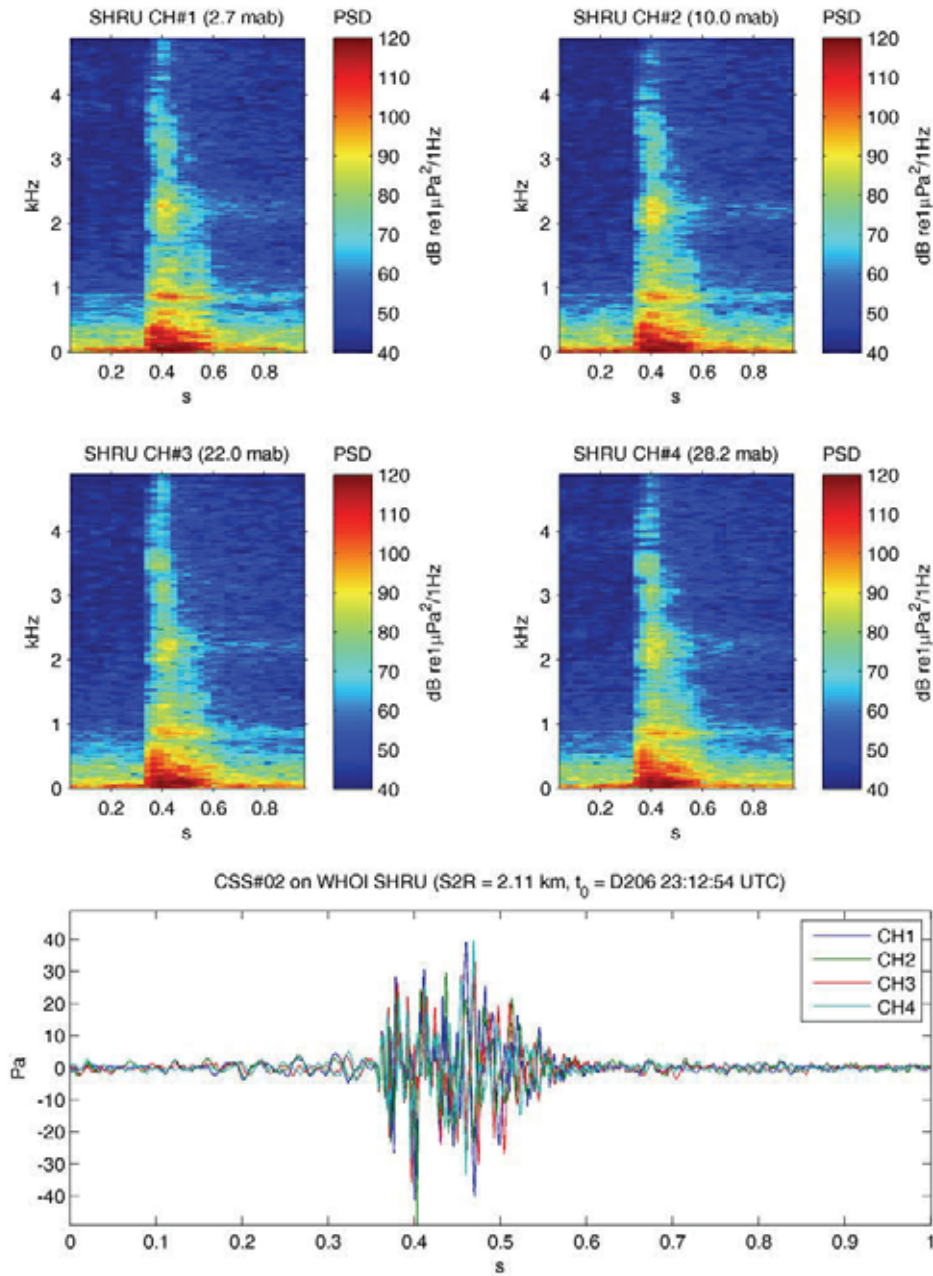


Figure 9: Measured pressure time series recorded on the UD/WHOI mooring and spectrograms for CSS event 1. The source receiver range was 2.11 km. The propagation track ran along a N-S line where the sediment thickness was approximately range-independent with a depth of 10 m. (Source: Ying-Tsong Lin.)

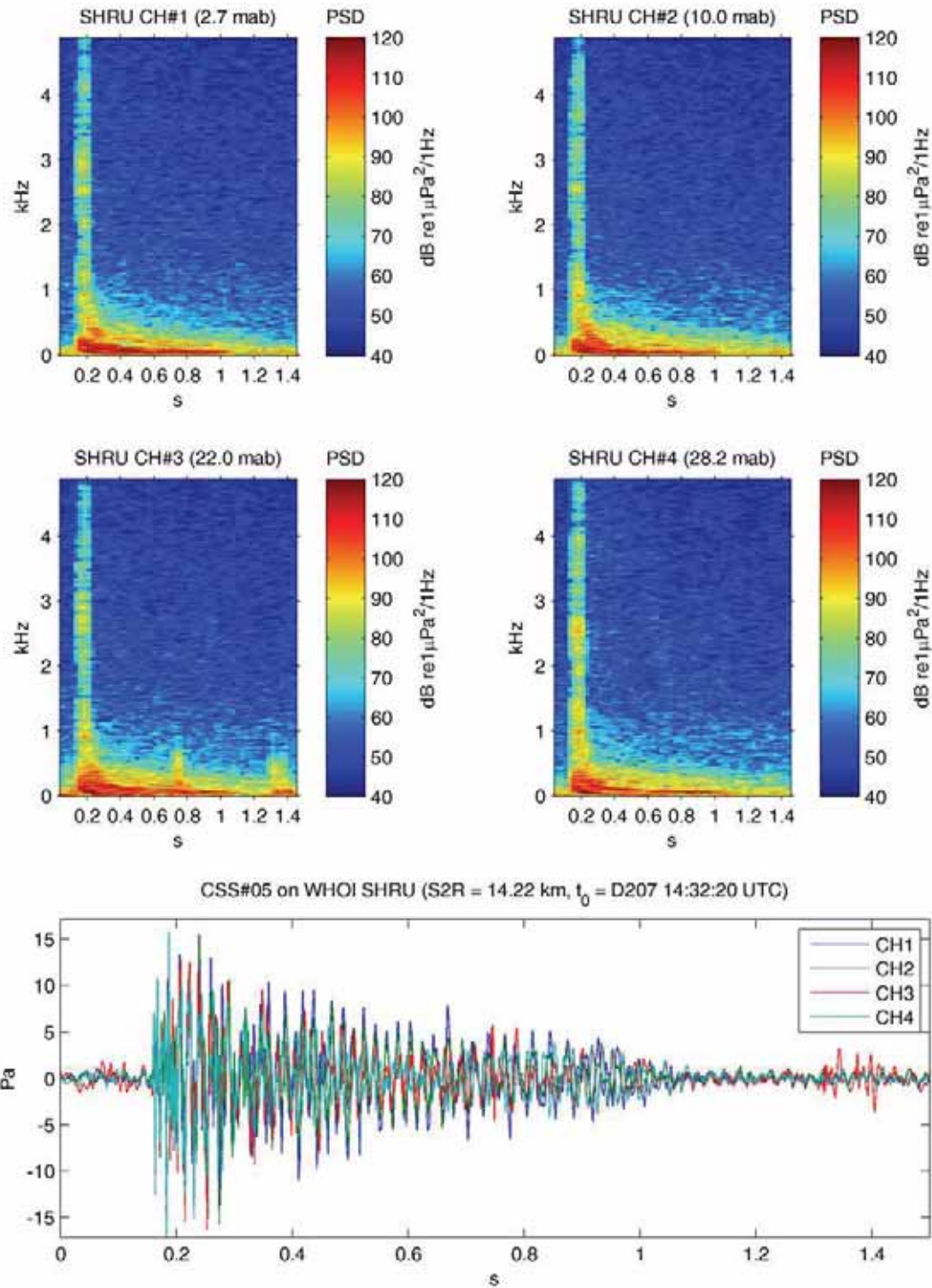


Figure 10: Measured pressure time series recorded on the UD/WHOI mooring and spectrograms for CSS event 1. The source receiver range was 14.22 km. The propagation track ran along a E-W track where the sediment thickness was started with a depth of about 3 m at the source and ended with a depth of about 10 m at the receiver (Source: Ying-Tsong Lin).

There is a discernable difference in the attenuation for two of the long-range shots, one with the source in the eastern sector and one in the western sector. Both shots were about 15 km from the mooring.

The source signature of each CSS event was measured on a hydrophone attached to the CSS apparatus. Starting about two hours prior to the CSS deployment, Knobles would scan the surrounding area for signs of marine mammals and asked the bridge to notify him of marine mammal sightings. The first CSS test (waypoint 015) started with a source depth of 5 m, and the second shot at waypoint 16 was at a depth of 10 m. Jason Sagers and Knobles were preparing for another firing at a deeper depth (20 m) when ship crew and scientists noticed a large group of dolphins (as many as 100) in the area. After about 15-20 minutes, there were still dolphins present in the operation area and CSS testing was suspended for the rest of the day. It is noted that in the other three CSS deployments no dolphins were sighted; however, dolphin sightings were made on numerous other occasions throughout Leg 1, often riding the bow wave of the ship.

There is some speculation why so many dolphins appeared after the second CSS shot. Badiey observed an internal wave (IW) during this period and suggested the small fish that like to stay in front of the IW attracted the large numbers of dolphins. There was another time an IW was observed and a dolphin feeding frenzy followed. One might hypothesize the dolphins visit to the ship after the second CSS firing was not coincidental and may have been correlated with the presence of internal waves. Further detailed scientific studies are needed to verify the correlation. It is interesting to note no dolphin sightings were made in Leg 2.

As shown in Table 3: CSS events during Leg 1., the CSS peak spectral level stayed below 186 dB Pa²/Hz @ 1 m. This observation is important because the Office of Naval Research previously determined this value should be an upper limit of emitted sound levels for this area. A future study of these arrival time series (shown in Figure 9 and Figure 10), for example an inversion analyses, might provide preliminary geoacoustic parameters that could be useful for planning purposes for the 2017 main experiment.

The CTD measurements from Leg 1 are presented in Figure 11a and Figure 11b. Some of the measurements show the presence of the warm saline water from the Gulf Stream intruding onto the shelf into the survey area. Figure 11b clearly shows the variability of the SSP, which in some cases reveal the presence of additional layers of warmer water below the thermocline, which, in turn, create sound channels that could be of interest at the mid frequencies for SBC 2017. This variability had adverse effects on the bathymetry processing of the multibeam sonar.

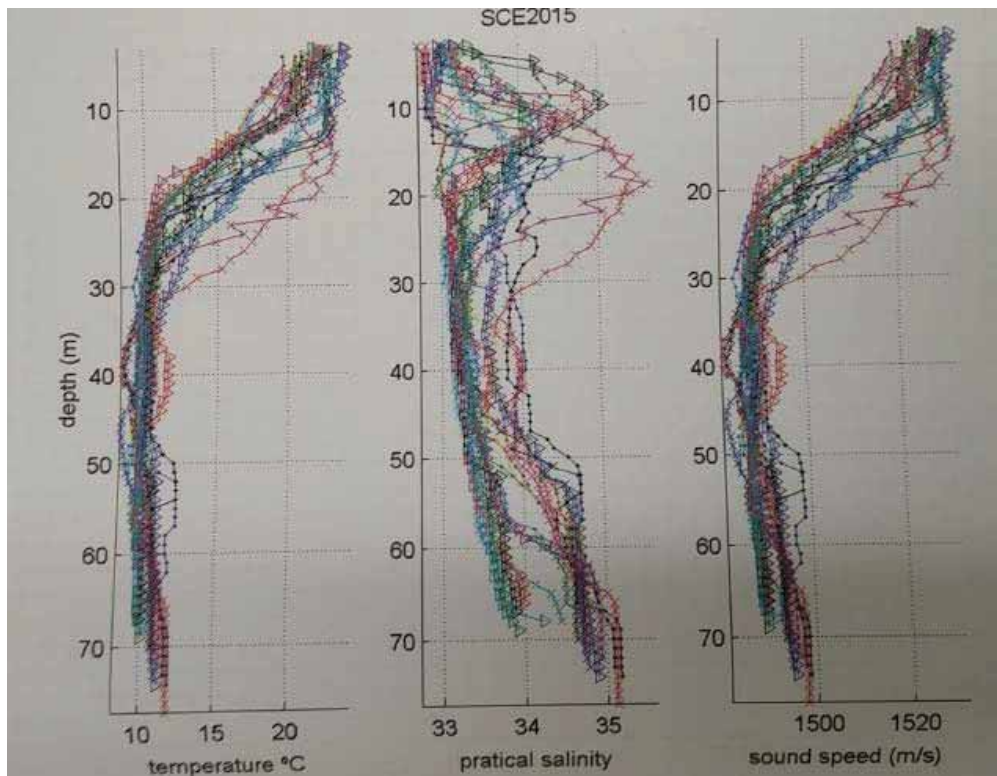


Figure 11 a: Temperature, salinity, and sound speed measurements derived from Leg 1 CTD data.

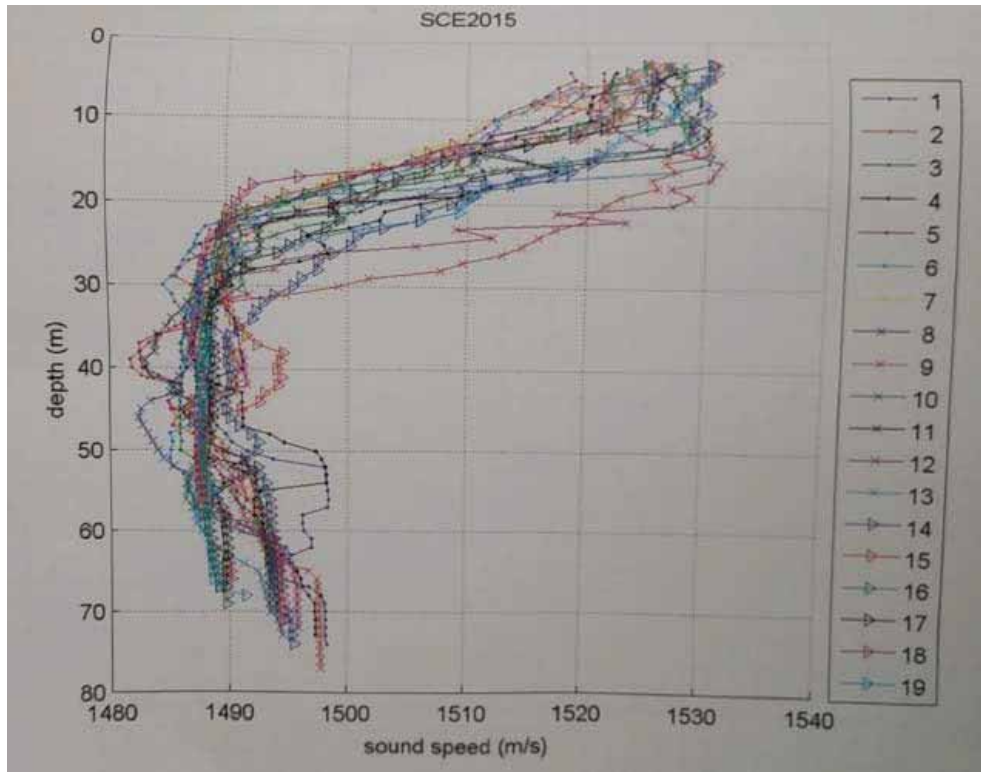


Figure 11b: Enhanced view of the SSP data from Leg 1 CTD measurements.

SECTION III. Leg 2: Results.

Details of the various operations during Leg 2 are provided in SECTION V. Leg 2: Daily Operations Log.. Figure 12 shows the Leg 2 coring locations, which also included CTD casts at each location, and bottom water collection at a subset of the locations, as well as a revised mud thickness color map. Specific coordinates of the coring and CTD locations and the type of cores that were collected are shown in Table 4.

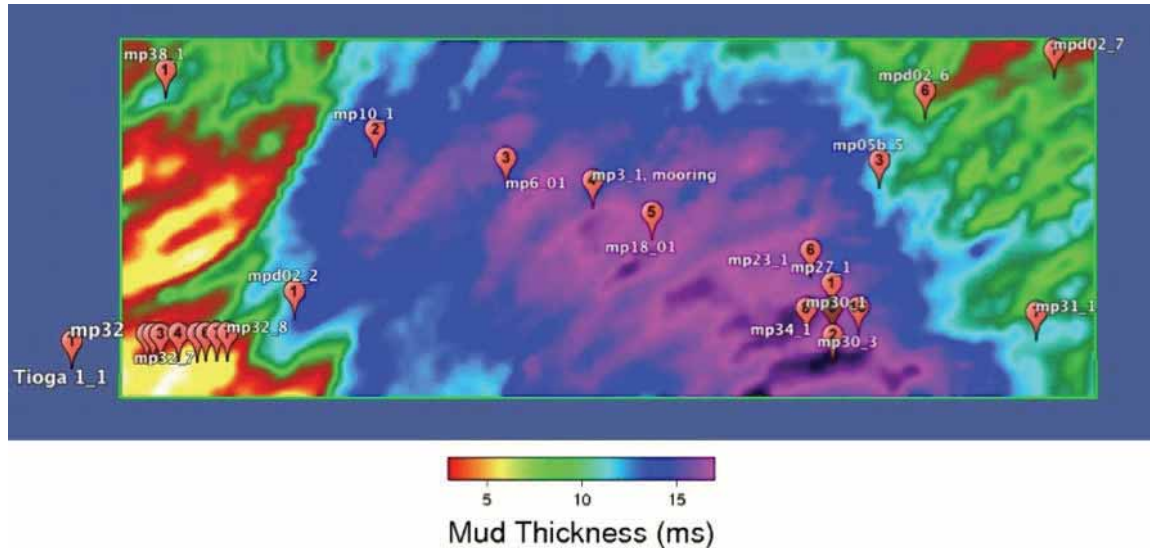


Figure 12: Revised color map for mud thickness. The map pins show the locations of all of the coring operations.

General Purpose Shipboard Data Collection

A number of systems collected data either autonomously or were operated by the ships' crew in conjunction with the science crew. These data are described in this section, and include GPS navigation data, water column sampling for CTD data and bottom water collection, the ship's surface measurement system, and an acoustic Doppler current profiler.

GPS Data

GPS ship track data were recorded continuously, once-a-second, from two different GPS antennae locations during Leg 1 and Leg 2, as shown in Figure 13. These GPS records include date, time, and latitude-longitude (lat-long) coordinates and are archived in folders labeled "POS" and "GPS," accordingly. During the time of the cruise, the computer recording this information used a 12-hour clock rather than a 24-hour clock for file-naming conventions. Data from hours 13 through 24 of a given day are appended to the data files for hours 1 through 12 of the same day, in both the "POS" and "GPS" data folders. (Marine Operations personnel at the University of Delaware are working to correct this at present). A second copy of the "GPS folder" data was stored at 1/10th the time resolution (once every 10 seconds) and archived using the Surface Measurement System (SMS). The file naming system is correct for the data recorded on the SMS system, and there is unambiguous

GPS data for every hour of every day in the SMS folder, but the computer clock that recorded these data was set to local time and was several minutes offset from GMT.

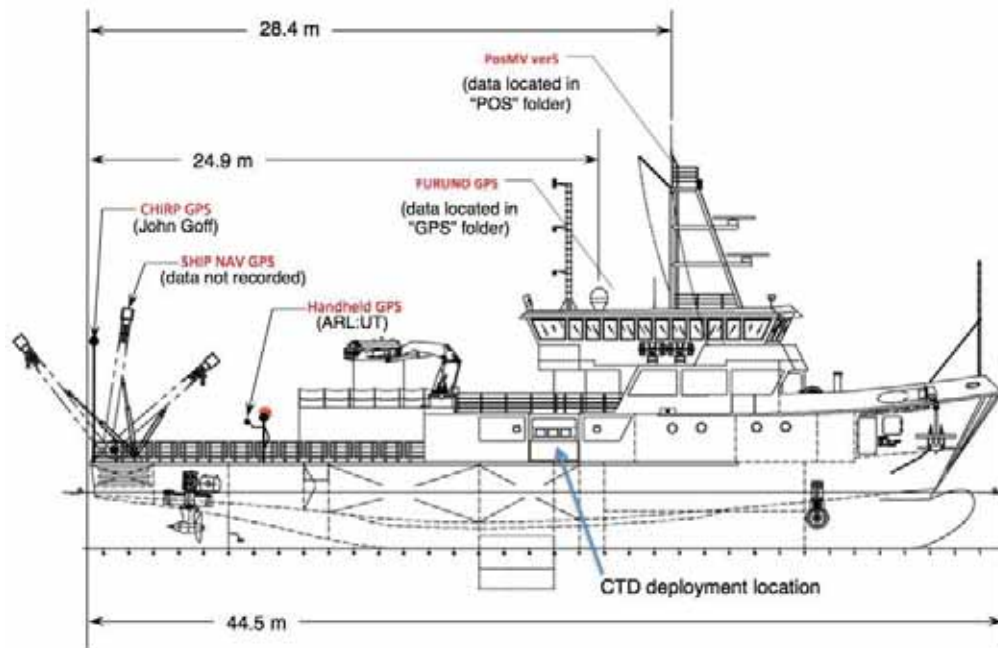


Figure 13: Locations of the five GPS antennae. The FURUNO GPS is the most closely located to the location of the CTD casts, which were deployed about 2 m sternward from the FURUNO antenna.

A GPS antenna was deployed, as shown in Figure 13, from the railing at the stern, just aft of the A-frame pivot. This location was recorded on the CHIRP sub-bottom profiling computer, and these data have been used to process the CHIRP data. Goff administered this GPS record. A handheld GPS system, Garmin Model Oregon 600, was used by ARL:UT personnel on the fantail of the R/V Sharp during CSS operations and coring operations, to make another independent record of the deployment locations. ARL:UT administered this GPS record.

All ship's navigation and station keeping was conducted through a different GPS antennae located on the top of the A-frame, from which most of the scientific equipment was deployed, also shown in Figure 13, but this GPS signal was not recorded. Waypoints and stations given to the Captain during operations were achieved via this A-frame mounted GPS antennae, but ship tracks plotted with the FURUNO or PosMV data will show the offset between the various antennae locations. This is illustrated in Figure 14, where the offset between pin 3 (desired location of the stern of the ship) and the red track (actual location of FURUNO GPS antenna) can be seen. It will ultimately be possible to use the recorded GPS data from the two antennae, and their relative locations on the ship, to reconstruct tracks coinciding with the location of the stern of the ship. Until that time, one can simply keep in mind the approximately 25 m offset between the existing recorded GPS data, and the actual coring locations.

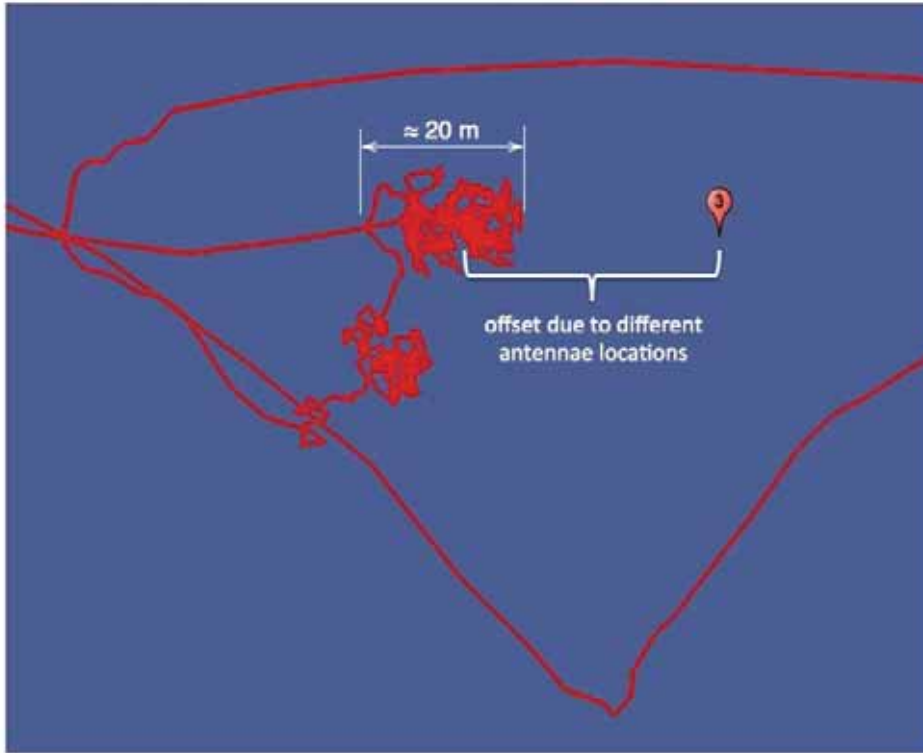


Figure 14: Ship track data from the FURUNO GPS (GPS folder), plotted with the red line. The “3” map pin shows the desired location of the stern of the ship (the station keeping coordinate), and the cloud of red tracks (about 20 m in extent) shows the actual location of the FURUNO antenna, during a coring operation.

Finally, Figure 14 also shows the ship's station keeping efficacy, which for the sea state shown here is ± 10 m. The actual station keeping accuracy and precision for particular events depended on the weather and sea state during the event. The example shown here is for a nominal sea state value.

CTD Data

As described previously, CTD casts were obtained at many locations during Leg 1 and Leg 2. The R/V Sharp deployed a Seabird system, and users can freely download software to process the CTD data from the following site: <http://www.seabird.com/software/sbe-data-processing>. An example of CTD data from Leg 2 is shown in Figure 15. Three CTD casts from different days are shown as examples. Sound speed versus depth is shown here, but the user can access and plot all the data that were recorded on the CTD. The software at the above site can be used to make plots, to export the data, and to do a fair amount of analysis. The recorded or calculated data is conductivity, temperature, pressure/depth, fluorescence, oxygen concentration, salinity, sound velocity, turbidity and altimeter (height above bottom). The location of the CTD instrument relative to GPS data is shown in Figure 13. The CTD data are available on the SCE2017 website. Ship roll likely affected the CTD casts, as shown in Figure 16. Christian DeMoustier has spent significant effort to improve the CTD data. Contact him directly for more information.

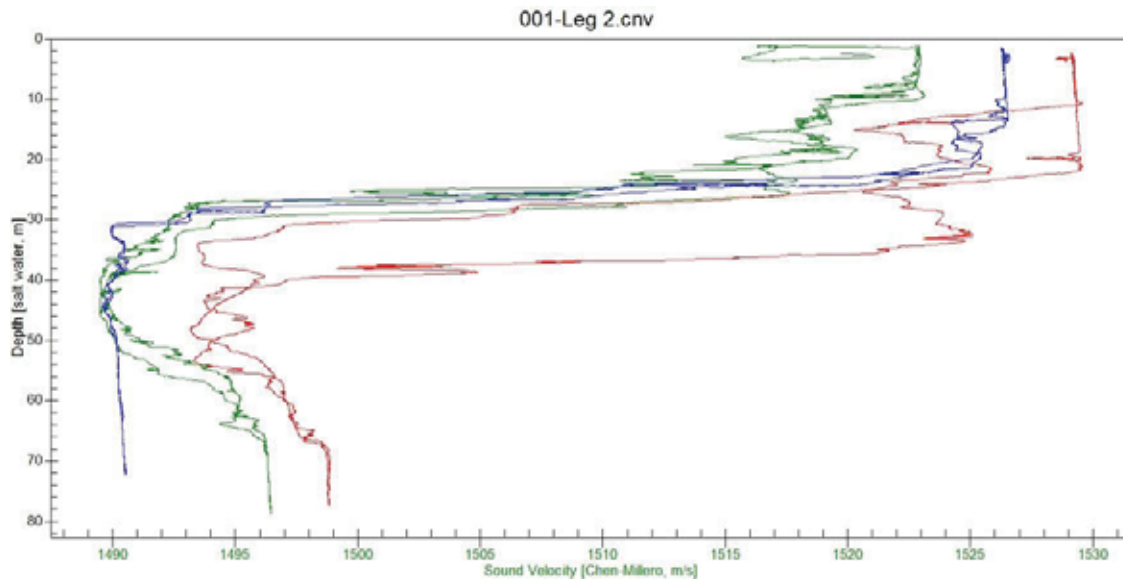


Figure 15: CTD data example. Sound speed versus depth for both up and down casts at three sites (red, green, blue) from Leg 2.

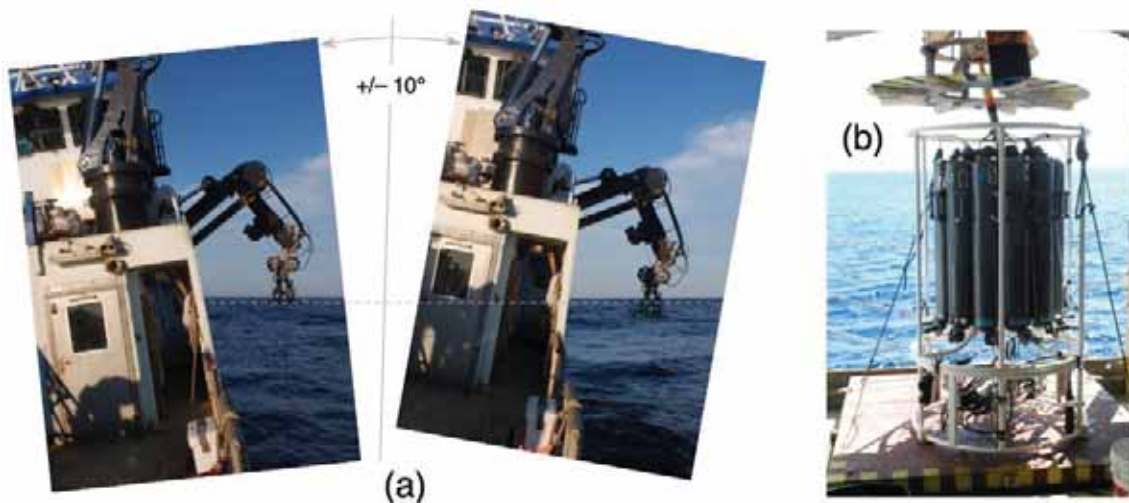


Figure 16: The R/V Sharp's CTD and Niskin bottle rosette is shown in (b). It is deployed from the starboard amidships using the knuckleboom crane shown in (a). The view in (b) is looking forward, hence ship roll can be seen. The example shown in (a) was fairly typical for the leg 2 cruise, about $\pm 10^\circ$ roll. Pitch is also evident in (b).

In addition to the CTD instrument, a rosette of Niskin bottles was available for collection of water samples as a function of depth. Water samples were only collected during Leg 2. In all cases, only bottom water was collected, filled at the lowest depth of the CTD cast. The height above the bottom is available in the CTD altimeter data. The sites for bottom water collection are indicated in Table 4. The water samples are under the care of either Allen Reed at NRL:SSC or Preston Wilson at ARL:UT.

Surface Measurement System Data

The R/V Sharp collected data continuously using its Surface Measurement System (SMS), which logged the following measurements every 10 seconds of the cruise, for both Leg 1 and Leg 2: date, time, geographical position, compass bearing of course over ground, speed over ground, water depth, relative and true wind speed, air temperature, humidity, barometric pressure, surface water temperature, surface salinity, and the surface fluorescence. Files are named with year-month-day-hour.txt convention. As an example, the surface water temperature is shown in Figure 17.

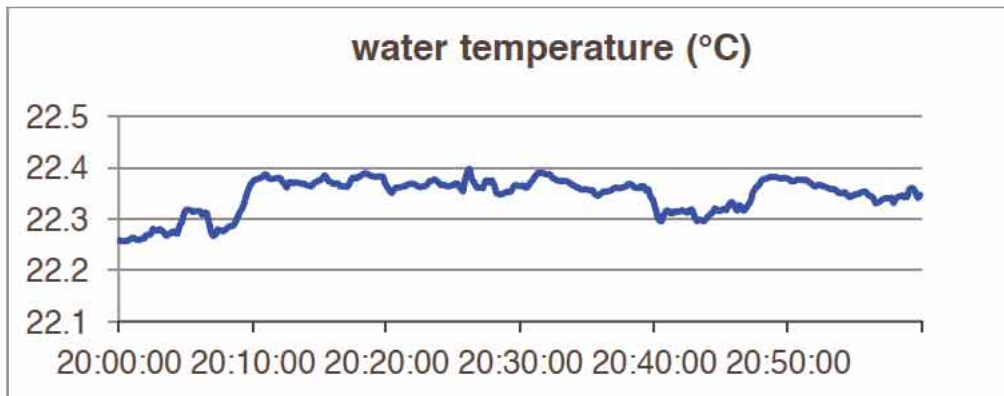


Figure 17: Water surface temperature measured by the R/V Sharp's SMS for the 20th hour of August 6, 2015, GMT.

Acoustic Doppler Current Profiler Data

The R/V Sharp collected Acoustic Doppler Current Profiler (ADCP) data continuously using its Teledyne RD Instruments Workhorse 600 system. These records are archived on the SCE website in folder ADCP. A cartoon example of ADCP measurement results is shown in Figure 18. Software to access and process these data is available from the instrument manufacturer located at <https://hydroacoustics.usgs.gov/movingboat/VMT/VMT.shtml>

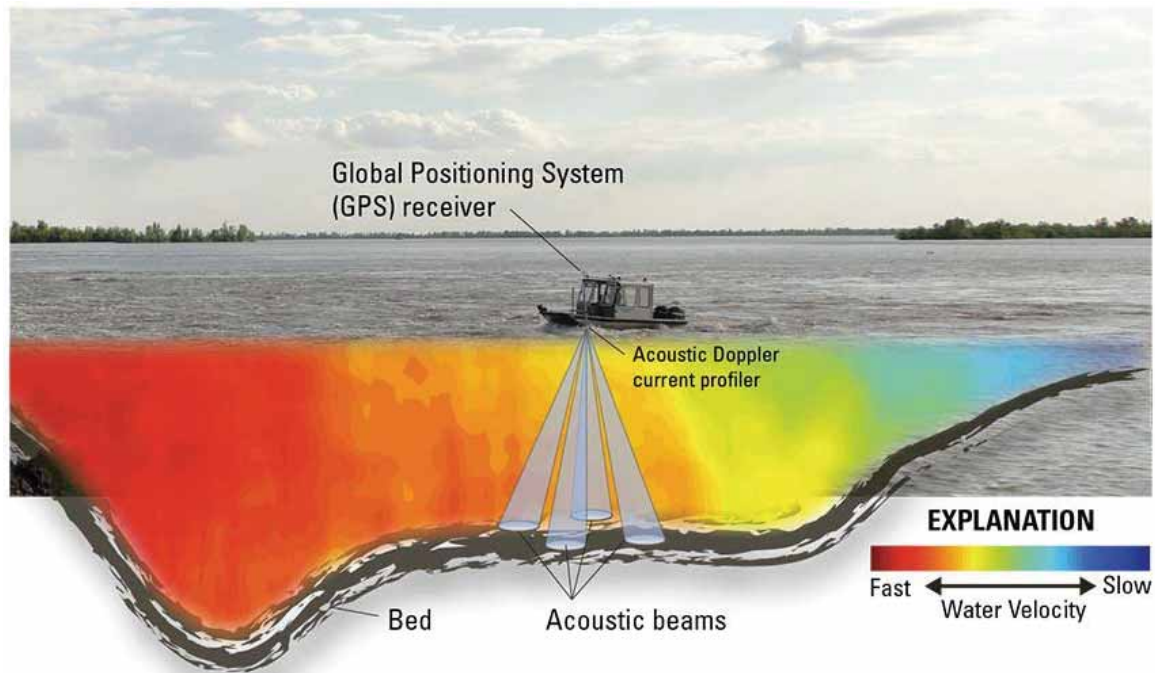


Figure 18: Example of water velocity in a 2-D slice measured by ADCP. [<http://www.mathworks.com/company/newsletters/articles/analyzing-and-visualizing-flows-in-rivers-and-lakes-with-matlab.html>.]

Coring Equipment

Four types of coring systems were brought onboard Leg 2 of the cruise: a box corer, a gravity corer (w/ 10-ft and 15-ft core tubes), a multi-corer (MC-800) equipped with a bottom-imaging camera and an altimeter, and a vibra-corer. The vibra-corer was intended to be our primary coring tool, which would have been able to penetrate into the sandy layer believed to underlie the surface mud layer. Extensive effort and time was expended on trying to deploy and operate the vibra-corer, but it was never successfully deployed and is not further described in this document. The remaining three coring tools are described below.

Box Core

An Ocean Instruments Gomex Box Corer was used to obtain all “box cores” on this cruise. The instrument is described here: <http://oceaninstruments.com/products/box-corers/gomex-box-corer/>

The sample box measures 25 x 25 x 50 cm (inside dimensions). A typical sample, just after being transferred from the corer to the sample receiver box, is shown in Figure 19.

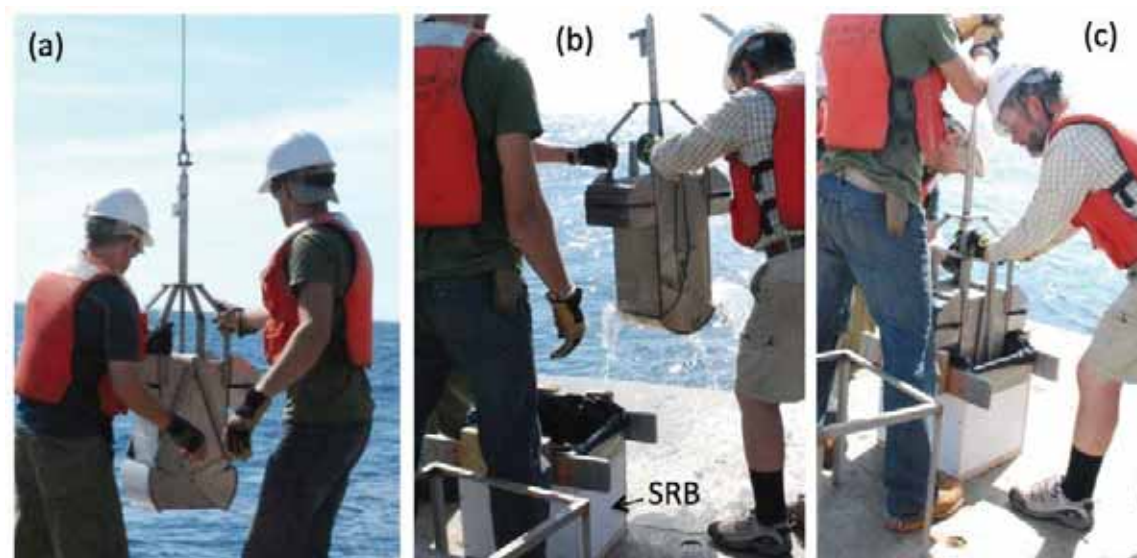


Figure 19: A sequence of photos showing a typical box core deployment. Joe Smith and Dan Ecker (USNA) deploying the box corer (a) with the spades in open position. Dan Ecker and Allen Reed (NRL-SSC) right after return from bottom (b) with water spilling out of sampler, spades closed. Also shown in (b) is the sediment receiver box (SRB), with a black plastic bag inside it. Photo (c) shows the corer being set into the SRB.

Samples from the box core were transferred into other containers, such as the box shown in Figure 20, for further shipboard analysis, or subsamples were taken for infauna analyses, which were then sieved, fixed, bagged and stored for future taxonomy analysis by Kelly Dorgan at Dauphine Island Marine Lab. The infauna samples were shipped the day the R/V Sharp arrived in port at the end of Leg 2, which was August 14.



Figure 20: A sample of mud collected with the box corer, as it sits within the sediment receiver box shortly after recovery. The photo is included here to give readers an idea of sediment disruption when using this sampling technique.

Gravity Core

The authors did not know the manufacturer of the gravity corer at the time of this writing. A schematic diagram and a photo of the gravity corer are shown in Figure 21. Most of the gravity cores collected on this cruise were with 10-foot-lengths of 3-inch schedule 40 PVC pipe serving as both the core barrel and the core liner. Two 15-foot-length cores were also collected near the end of the cruise. Upon retrieval from the ocean, the core pipes were disconnected from the core head and the core was brought on deck in a vertical orientation. The core was fixed to a vertical support to keep it vertical for the initial processing, which included measuring the depth of the sediment within the core, cutting the unused length of PVC pipe, capping the top and bottom of the sediment-filled part of the core with a core cap and tape, and marking the core with a unique identifying name. Long cores were later cut into 1-m-long sections and capped and taped. The sectioning was done with the cores horizontal. Cores were transferred in a vertical orientation into the NRL CONEX box which served as the core logging laboratory. Cores were stored vertically within the CONEX box, which was air-conditioned to room temperature. Core processing is shown in Figure 22.

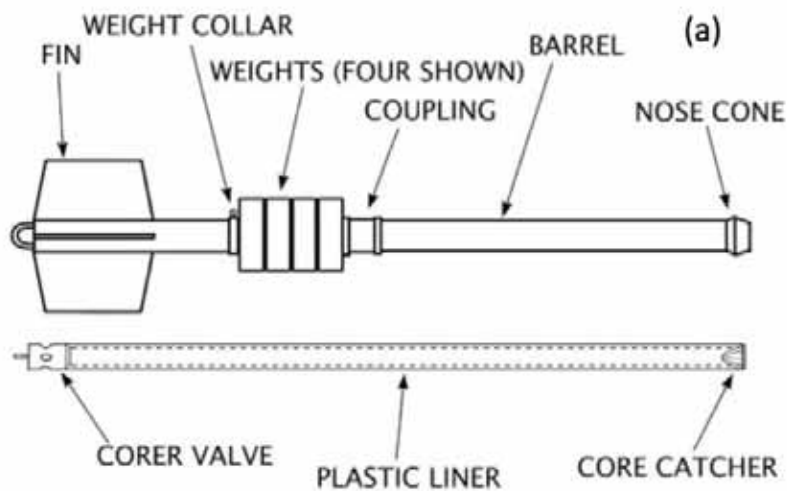


Figure 21: A schematic diagram of the gravity corer (a). Gravity core during use (b). Most of the elements of the corer used on this cruise are shown accurately in (a) except our apparatus used PVC pipe instead of a core barrel. The corer cutter [nose cone in (a)] and the core catcher were both affixed to the end of the PVC pipe. The corer valve, which allows water to flow out of the top as the core is penetrating the sediment, was built into the coupling shown in (a).

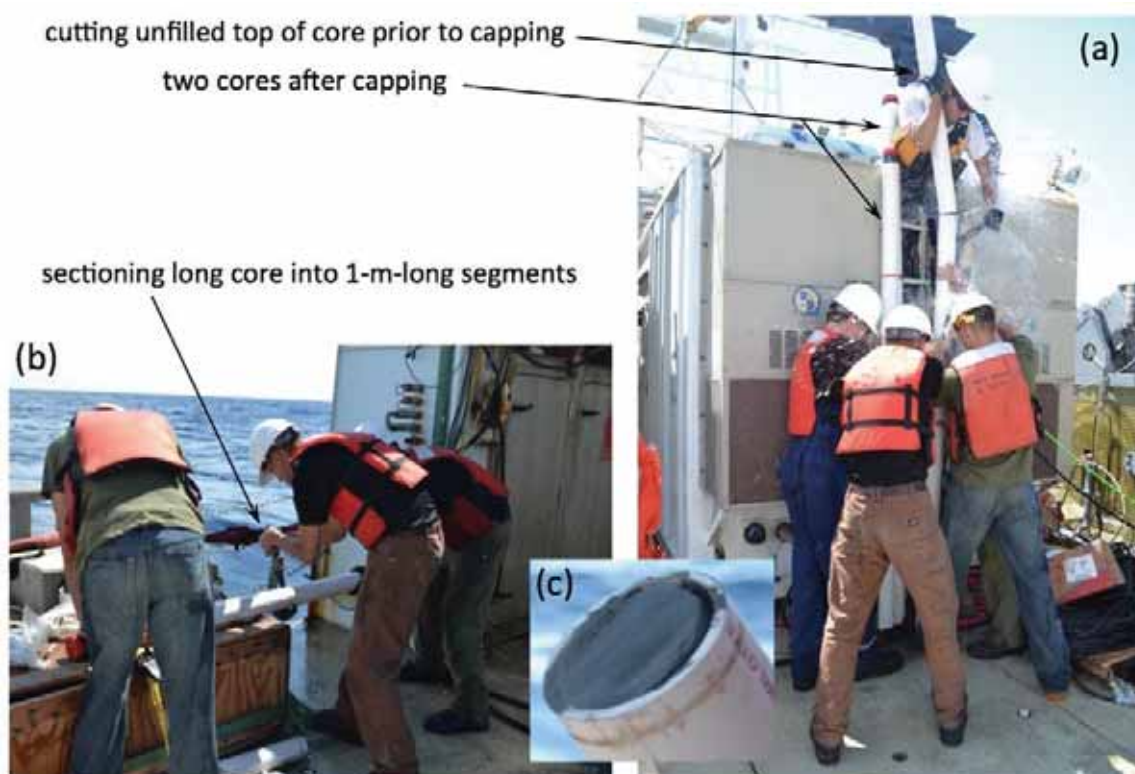


Figure 22: (a) Gabe Venegas (ARL:UT) cutting and capping a full-length core with Kevin Lee (ARL:UT), Kyle Fringer and Dan Ecker (USNA). (b) Dan Ecker, Kyle Fringer, and Joe Smith (USNA) sectioning a full-length core. The condition of a typical core at the section cut, after the sectioning was complete (c). Note the gap between the PVC pipe and the sediment material.

Multi-Core MC-800

An Ocean Instruments MC-800 multicorer was used to collect 8 short cores (10 cm diameter x 70 cm length) from a single cast. The instrument is described here: <http://oceaninstruments.com/products/multi-corers/mc-800-multi-corer/>

A bottom-imaging digital camera with a dedicated strobe light was used to take photographs during the deployment. Once initiated, this camera took a photograph every ten seconds, providing photos going from on-deck, into the water, all the way down, at the bottom, then back again. There was also an altimeter on the MC-800 that used acoustic pulses to measure the round-trip travel time from the MC-800 to the bottom and back. This data can be correlated with the time stamped photographs to determine the height above the bottom for each photograph. A photograph of the MC-800 being deployed during this cruise is shown in Figure 23. MC-800 camera and altimeter data will be archived on the SCE website.



Figure 23: (a) Ellen Roosen (WHOI) and Chuck Dill (Alpine) deploying the MC-800 during the cruise. Also visible is the altimeter and the cores. (b) Alternative view showing the location of the bottom-imaging camera and the strobe. The strobe is also partially visible in (a) but the camera is mostly obscured in (a).

Once back on deck, the cores were removed from the MC-800, hand carried about 30 feet, and placed on a processing rack in a vertical orientation, as shown in Figure 24. Some of the cores were transferred using a core extruder into core liners for future core logging by NRL:SSC. Other cores were subsampled for infauna by ARL:UT. Some cores supplied sediment material via extrusion for use in a low frequency resonator by ARL:UT.

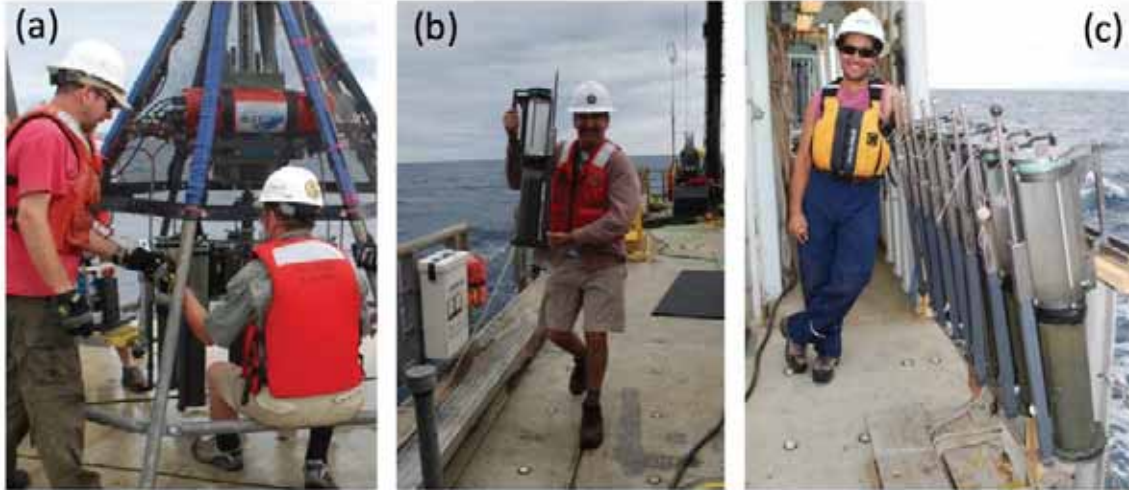


Figure 24: (a) Joe Smith (USNA) and Allen Reed (NRL-SSC) removing cores. (b) Preston Wilson (ARL:UT) carrying a core to the processing station. (c) Gabe Venegas (ARL:UT) standing behind cores ready for further processing.

SECTION IV. Leg 1: Daily Operations Log.

Knobles and Sagers arrived in Lewes around 2:00 pm on July 20, 2015. Jason was filling in for Andrew McNeese, the mechanical engineer responsible for designing and deploying the CSS. The remainder of the day and the following day (July 21, 2015) were spent with mobilization.

On July 22, 2015, around 12:00 EST the Captain requested the science party be accounted for so the ship R/V Sharp could depart. Knobles made a check and confirmed the following science team members were on board: Gopu Potty, Jason Sagers, Steffen Sastrup, John Goff, Christian de Moustier, Barbara Kraft, Lin Wan, Ying-Tsong Lin, and Mohsen Badiey. Knobles then signaled the bridge that all science team members were on the ship, and at 11:54 EST the R/V Sharp departed Lewes port. de Mousier and Knobles presented to the Captain the geographical coordinates of the destination, 40.472664 degrees N 70.780961 degrees W. With a ship speed of 9 knots, the expected time of arrival was estimated to be 14:00 EST on July 23, 2015.

On July 22, 2015, at 1300 hours (local) the Captain called a safety meeting followed by a drill. The muster station was designated to be the dry lab. Knobles had the responsibility to count and verify all science members were present and have their safety equipment on in the event of an emergency. Interesting enough, during Leg 1 such an event occurred where there was a small fire in the kitchen that set off the emergency procedure. During this emergency, as directed, all scientific team members assembled, put on their emergency gear, and awaited further instructions from the bridge. Once the fire was neutralized by ship's crew the scientific party returned to their duties.

Note on plan for survey: Overlap of the multibeam varies with changes in the water depth. Further, the coverage depends on the amount of refraction of the SSP. The planned nominal distance between the track lines was about 230 m. The SSPs derived from ship CTD's are important because they act to account for the refractive effects of the water column in the data processing. The basic scientific plan was to tow the CHIRP tow body at about 4.5 kts along planned paths. The Captain made it clear to Knobles he did not want to cross in and out of the two shipping lanes, and thus this constraint influenced the details of the N-S tracks and the E-W tracks nearest the shipping lanes.

Aside comment concerning interacting with the ship's crew: Knobles noted that generally the crew were very nice and went out of their way to be helpful. The Captain was professional and always ready to assist the scientific party in any way possible. The cook was excellent. Max was the most experienced person on the back deck of the stern.

The survey commenced on July 23, 2015, at 2:00 pm EST where a CTD cast was performed at position 1 (40.472664 degrees N 70.780961 degrees W). At 17:32 UCT the R/V Sharp was about 14 nm from position 1. At 19:11:32 UCT the R/V Sharp was 1 nm from position 1. At 19:20 UCT the R/V Sharp was at position 1 (40.47329 degrees N 70.78495 degrees W at 19:23). Figure 25 shows a sketch that was presented to the Captain by Knobles. These "mini experimental plans" were hand-delivered to the bridge about 6-12 hours prior to the start of the measurements. The data from the CTD showed a thermocline that started around 10 m, and the water depth was measured to be 77 m. After the deployment of the CTD, the yellow CHIRP fish was deployed at position 1 with the

R/V Sharp proceeding to position 2 (40.476831 degrees N, 70.426331 degrees W) with a heading of 089 degrees at 4.5 knots. A second CTD was measured at 40.47512 degrees N, 70.41913 degrees W.

Some immediate observations from the multibeam and CHIRP data:

1. The seafloor is very flat over a large spatial wavenumber scale.
2. The mud layer is presenting itself very nicely. Clearly one can see 12 m pond of mud in center of patch.
3. Not surprisingly, SSP is strongly downward refracting.
4. There exist interesting features in the CHIRP data - strong reflectors imbedded in the mud and an underlying sand layer that does not appear to be uniform. Also there are features or reflectors within the mud layer.
5. Small scale layering is more evident on the western side of the survey box.
6. The slowly varying thickness of the mud appears to eliminate the possibility of mode coupling and thus likely an adiabatic method can describe the low spatial wavenumber variability. This is not necessarily the case for the mud-sand interface, however.

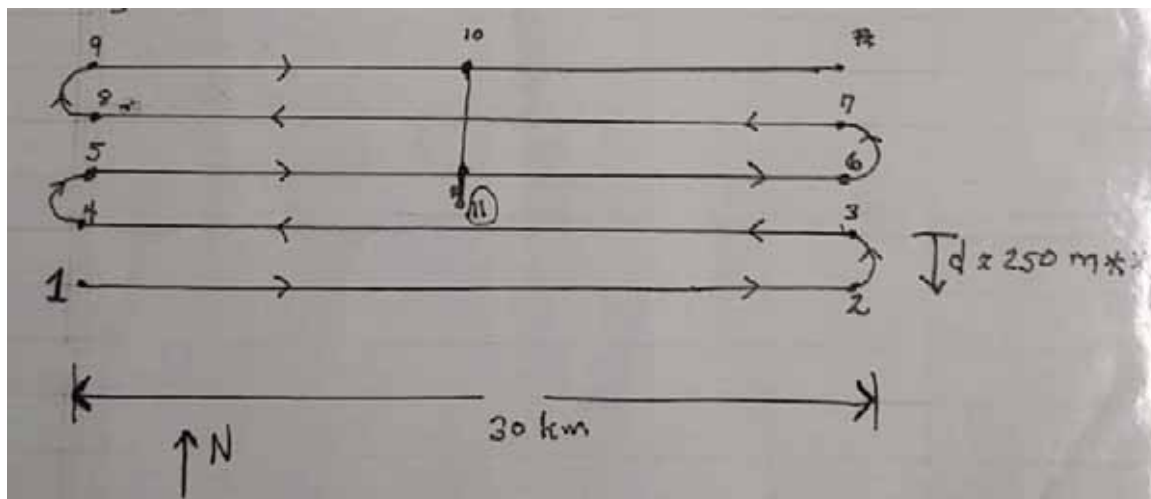


Figure 25: Initial set of survey tracks during Leg 1. The position of the UD/WHOI mooring is indicated by position 11. The position of the mooring was designed to be in the middle of the 30 km x 11 km² survey box.

Getting back to some of the details of the initial E-W CHIRP and multibeam survey lines, a 180-degree turn was executed to proceed to position 3, at which a CTD measurement was made. Then the R/V Sharp proceeded to position 4, etc. Once the R/V Sharp reached position 10, the R/V Sharp made a hard turn due south and proceeded to position 11 (40.476136 degrees N, 70.780961 degrees W) where the University of Delaware/WHOI mooring was then deployed. After deployment, it was decided to increase the distance between the E-W survey lines to 500 m, with the understanding that time permitting we would later fill in the gaps. Later in this document one will observe that all planned E-W lines were indeed completed.

Figure 25 was the first set of tracks presented to the Captain on the bridge by Knobles. One to two times per day, on the basis of work completed and consultation with John Goff and Christian de Mousier, Knobles would construct a set of tracks for the R/V Sharp to follow. The protocol is that

Knobles first went to the tech station next to the dry lab. There he would consult and go through the plan with the tech on duty and would then leave a copy with the tech so they could program the track into the ship's navigation system. Then, Knobles would take a copy to the bridge and go through the plans, most of the time with the Captain and sometimes with the First Mate. Often the plans would change during the day for a variety of reasons, but usually these changes were minor and could be changed rather easily at the tech station. As an aside, during evening hours the bridge is always "pitch dark" so the crew can see markers at sea. This made an interesting walk up the flight of stairs leading to the bridge. Figure 26 show survey track drawings/plans submitted by Knobles to the Captain over the course of the Leg 1 survey.

The naming convention of the survey lines is somewhat unorthodox. Part of the rationale for the naming convention is that the survey first started on E-W lines, moving systematically northward. Then the survey shifted to the south. For a while the distance between lines, as previously noted, was set to about 220 m. de Mousier agreed to change to 500 m distance between lines because early indications were the seabed was flat out to a high spatial wavenumber. This allowed a greater amount of area to be surveyed in a shorter time. The idea is that once the coarser survey was completed, we could return and survey those lines that were skipped; however, the approach did cause some difficulties for the multibeam survey. As an example, a measured SSP is needed to take into account refraction in the water column. By skipping back and forth the potential to degrade the data analyses of the multibeam data is increased. Also, this skipping is in part why the naming convention appears odd. Towards the end of the experiment, gaps in the multibeam coverage were systematically covered. Also, there were gaps in the tracks spread randomly over the survey area because the ship had to divert from a planned track to avoid fishing gear in the water. By the time the R/V Sharp returned to a track, a multibeam gap was created. Nevertheless we were able to pick up the vast majority of the multibeam data gaps prior to departure ~ 3:00 pm EST Saturday, August 1. Thus, when examining the tracks of the ship, it will appear that there is an element of a random walk problem being tested.

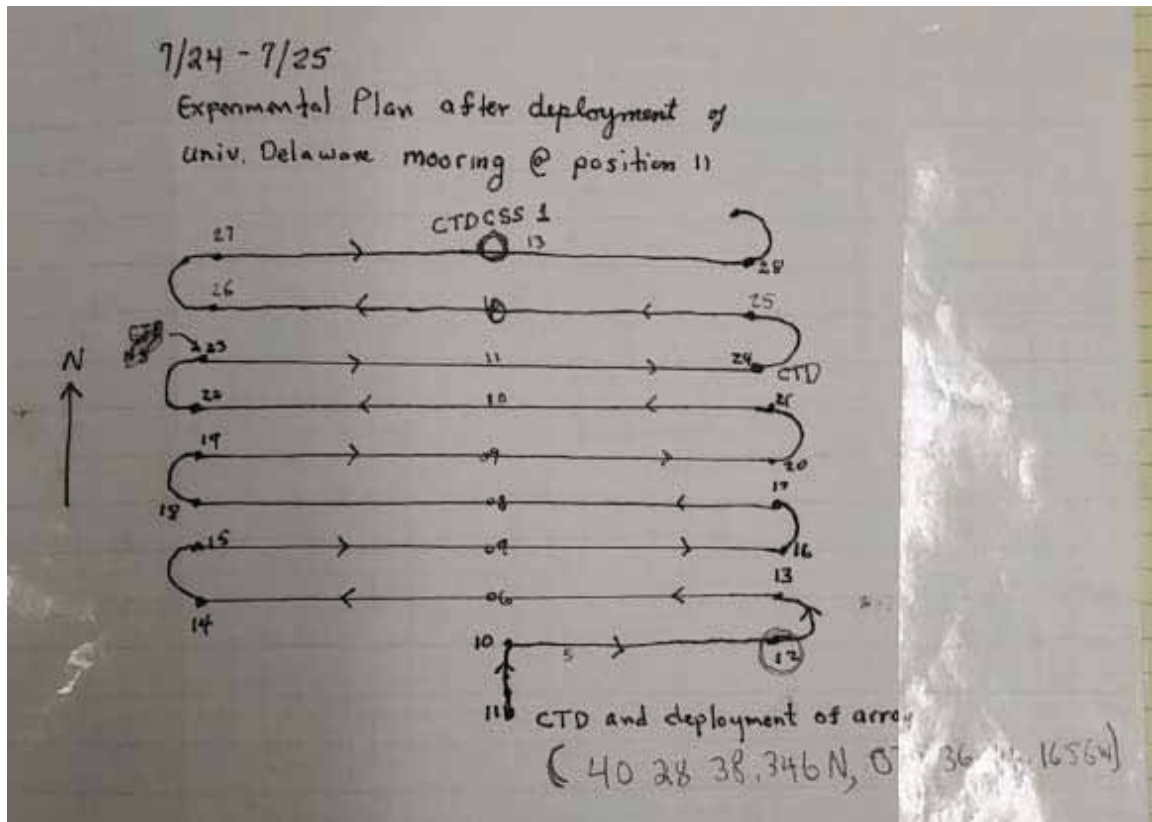


Figure 26a: A daily test plan presented to the Captain by Knobles that shows the R/V Sharp proceeding from the mooring location and creating E-W survey lines and moving to the north.

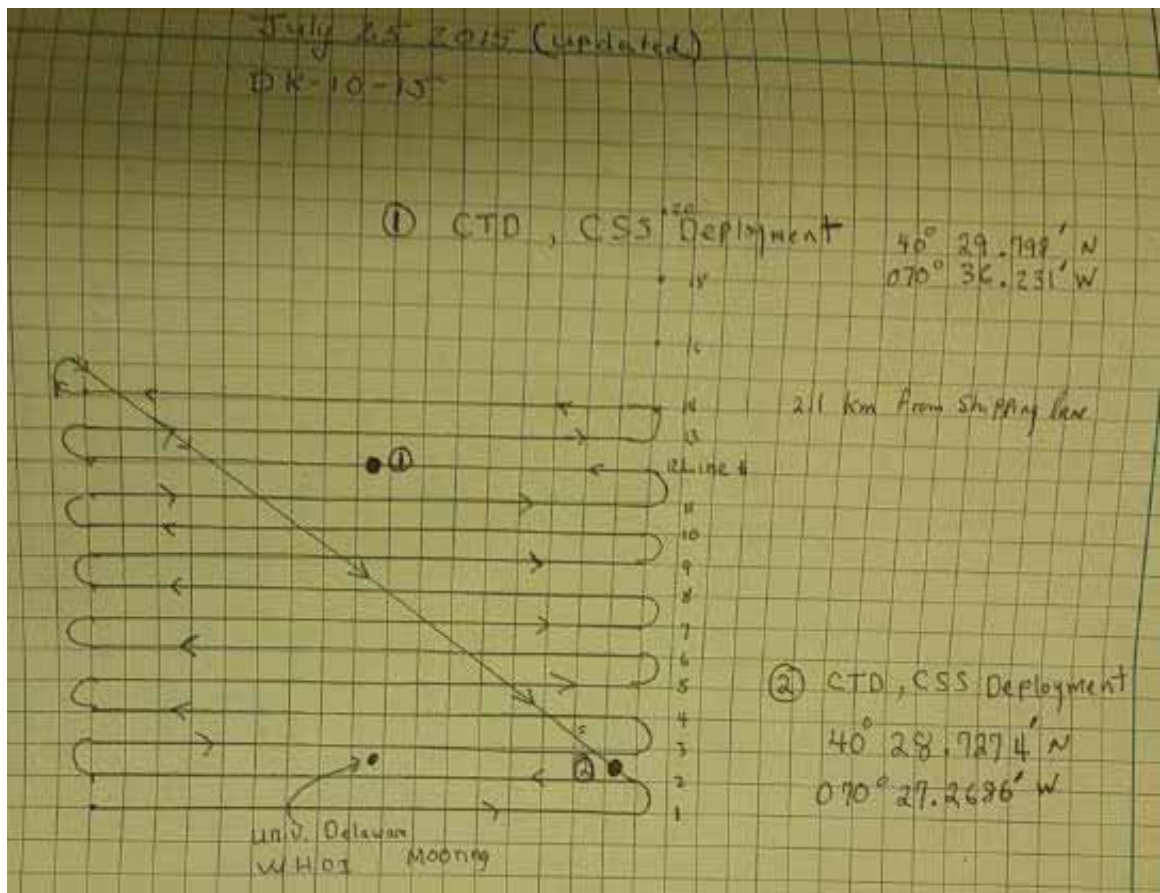


Figure 26b: Example of an updated plan presented to the Captain on July 25, 2015.

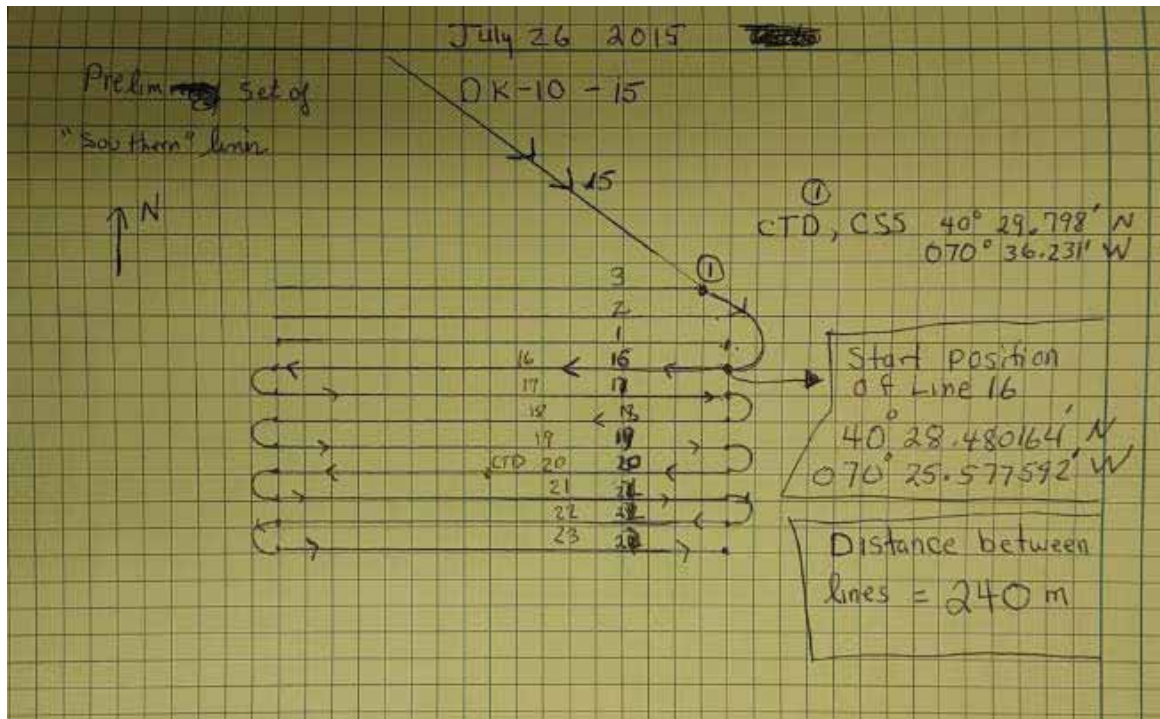


Figure 26c: Plan presented to the Captain on July 26, 2015.

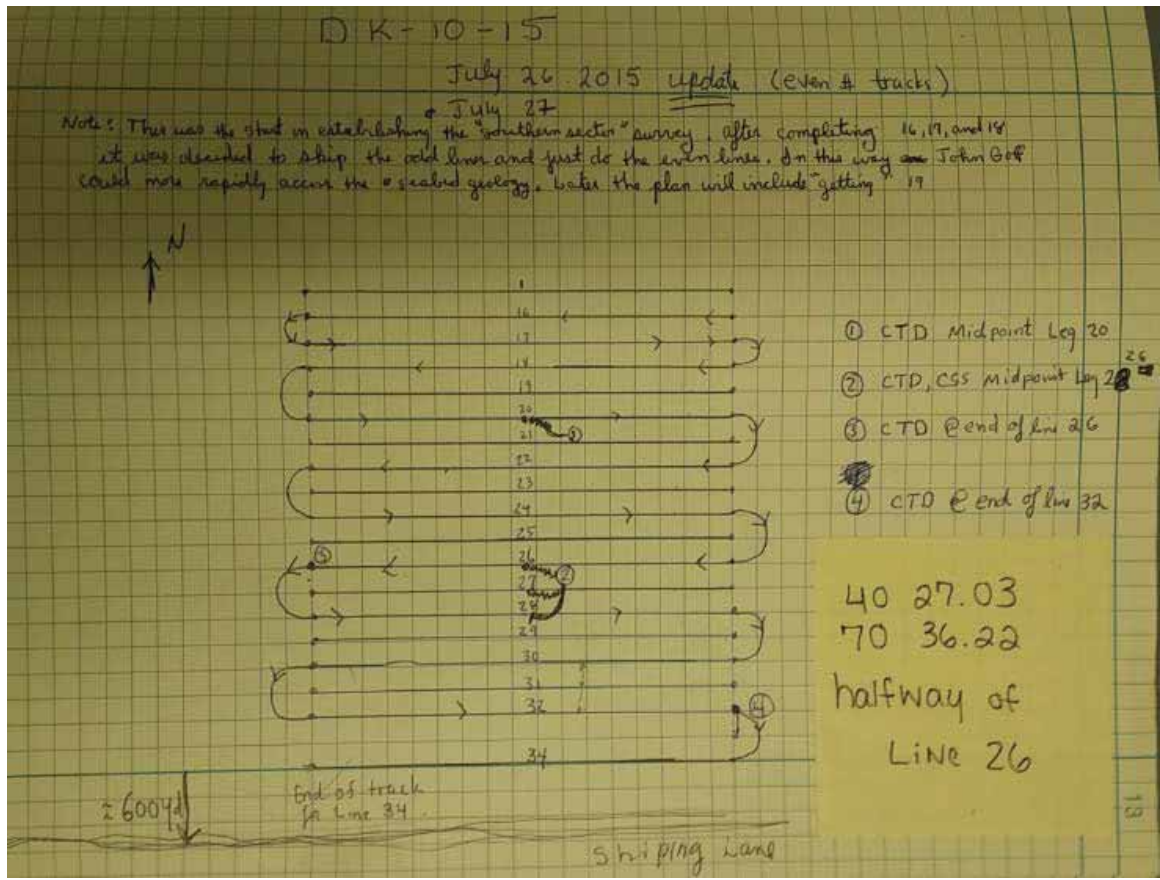


Figure 26d: Updated plan presented to the Captain on July 26, 2015.

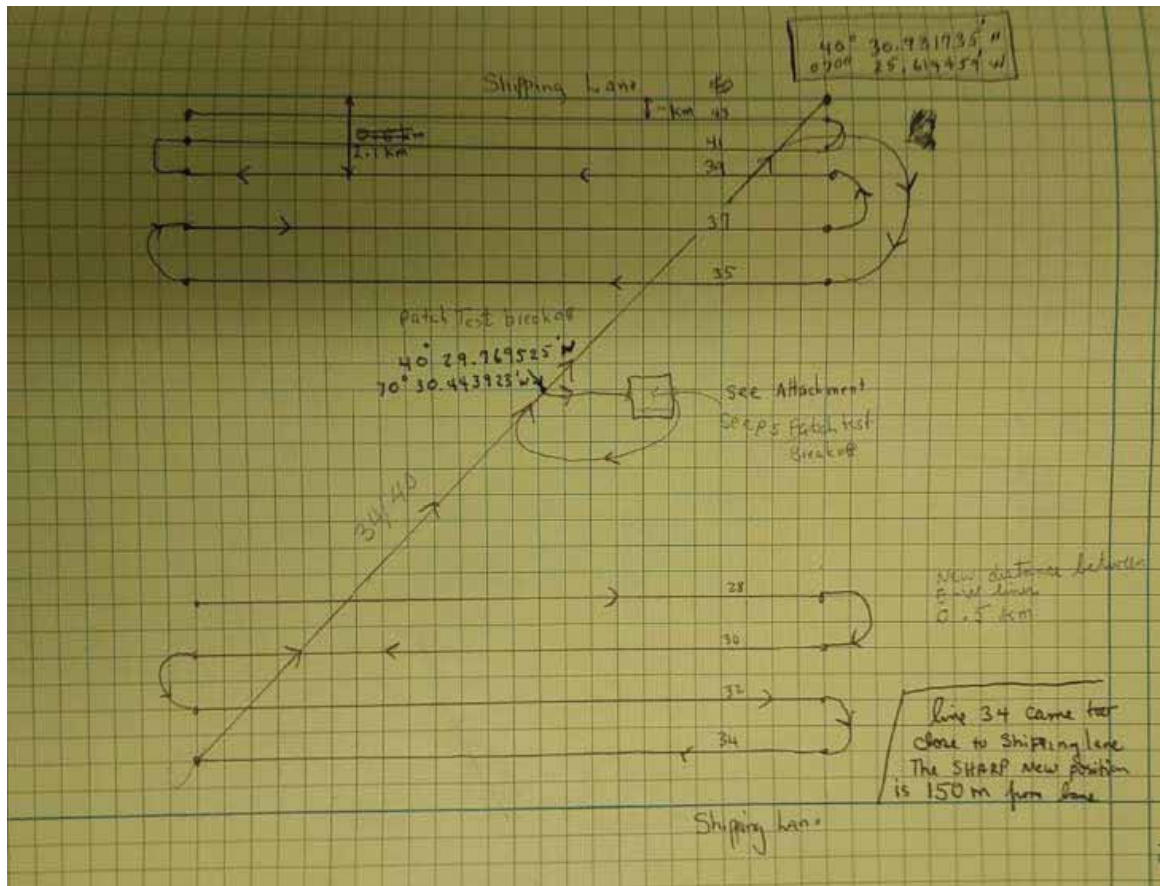


Figure 26e: Plan presented to the Captain that transitioned from the southern E-W lines back to the northern lines. Also, a patch test was performed that the request of the multibeam sonar crew.

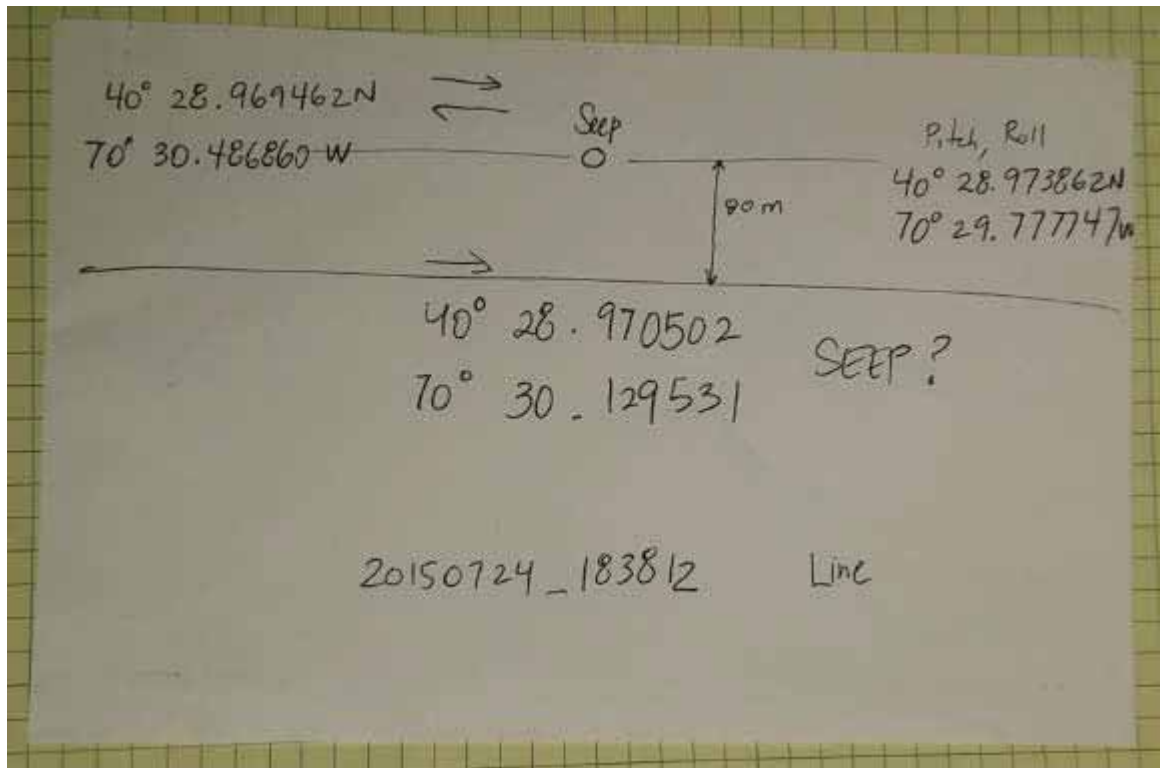


Figure 26f: Patch test plan programed into navigation system.

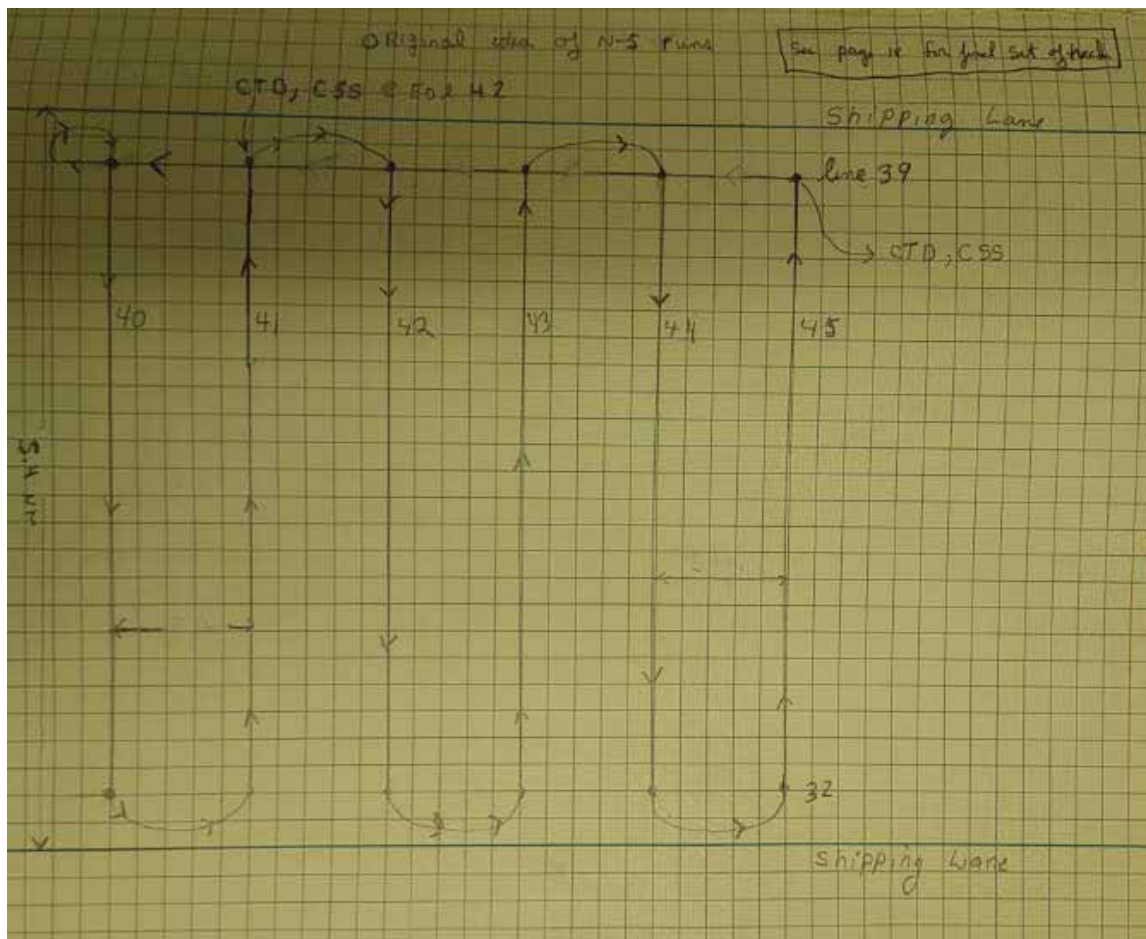


Figure 26g: Initial drawing of N-S survey lines.

The UD/WHOI mooring was deployed successfully at 40.47738 degrees N 070.60397 degrees W. On July 25, at 08:30 UCT the fourth CTD was deployed. Dolphins were previously observed at 06:59 UCT. As the ship made E-W traversals, we kept an eye out for the UD/WHOI buoy. On July 25 at 10:42:00 Z we made a CPA with the buoy. At that time we observed a very large merchant ship to the south and it was identified as the HAPPY Lloyd by Knobles with his field glasses. Knobles noted that if the AIS can be obtained for the HAPPY Lloyd then there is a chance to do ship of opportunity geacoustic inversion with a large CPA range.

Notes on CSS: Just after the CSS event 016, about 100 dolphins appeared around the ship. Knobles suspended all CSS deployments immediately. We waited about 20 min and still the dolphins were present, and Knobles decided to suspend the CSS deployments and resume Goff's and de Mousier's survey. The following day Knobles and Sagers resumed CSS testing and were able to do seven events. The 20 m source depth events were clipped on the monitoring hydrophone positioned 1 m from the source. Nevertheless they produced good received signals on the UD/WHOI mooring. Starting with events associated with waypoint 25, we began to have issues with the current. The currents would prevent the gas bubbles from rising into the combustion chamber and after a time the chamber would have sideways motion to the degree that the gas in the chamber would be lost. Then, we would have to start the process of filling the chamber. Starting with waypoint 28, we lowered the source depth to 20 m to mitigate the effects of the current and

were able to generate three successful events; however, we were unable to have a consistent gas flow time, which causes an issue with repeatability. On waypoint 031 we decreased the source depth to 10 m, and had a misfire, again associated with currents. We were able to have one additional successful event for the day (waypoint 032).

July 30, 2015 4 am (local)

A lesson learned from the previous CSS deployment is that the ropes that secure the chamber need to be tight, otherwise the up and down motion of the back of the stern causes the effective flow rate to decrease and, in some cases, the loss of the gas. Likely stiff springs would be a better solution. Sagers thought of a skirt, but such a change was not easy to make at sea and the tighter rope solution remained the principle solution.

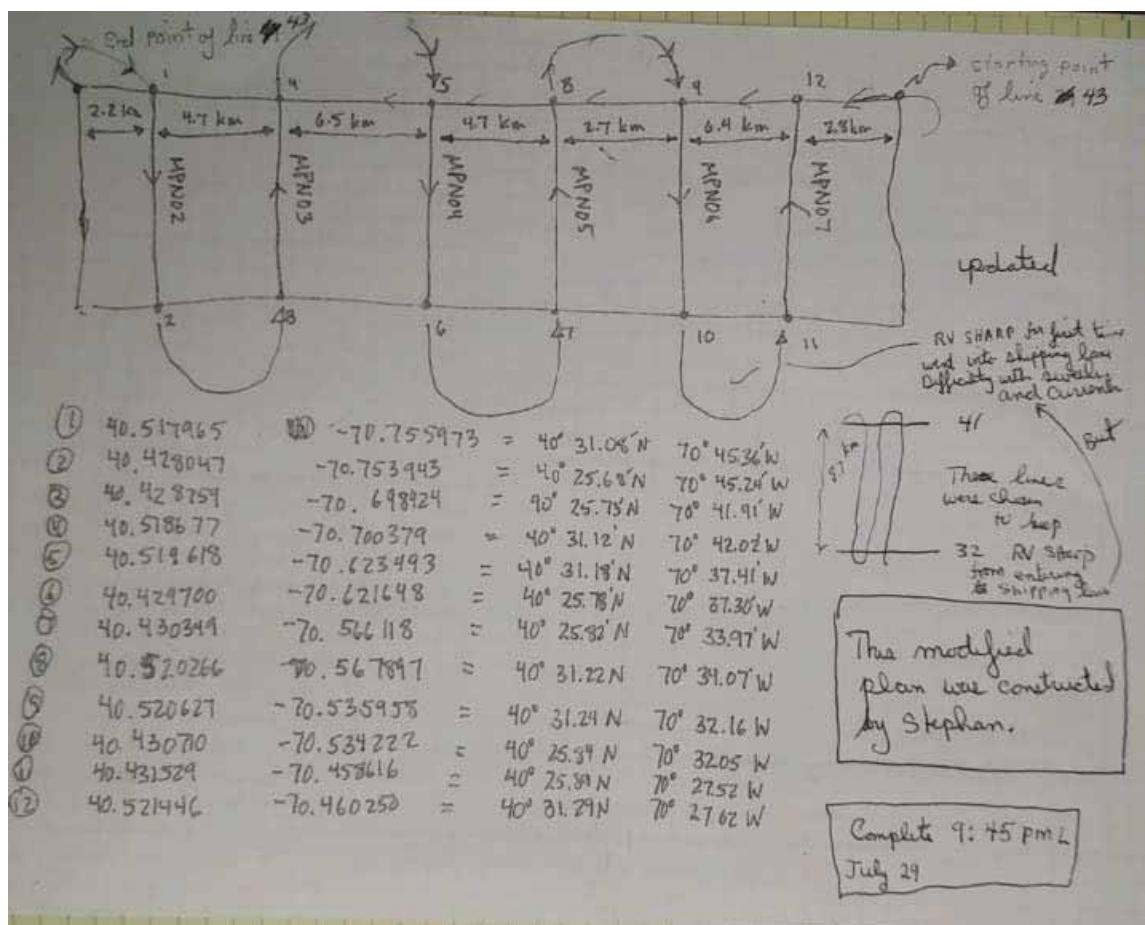


Figure 26h: Final drawings of the N-S lines. Steffen assisted with this task, carefully providing lats - longs that went into the navigation system. The plan was to complete these lines around 10 pm local time on July 29, 2015. This was the version that was presented to the bridge by Knobles.

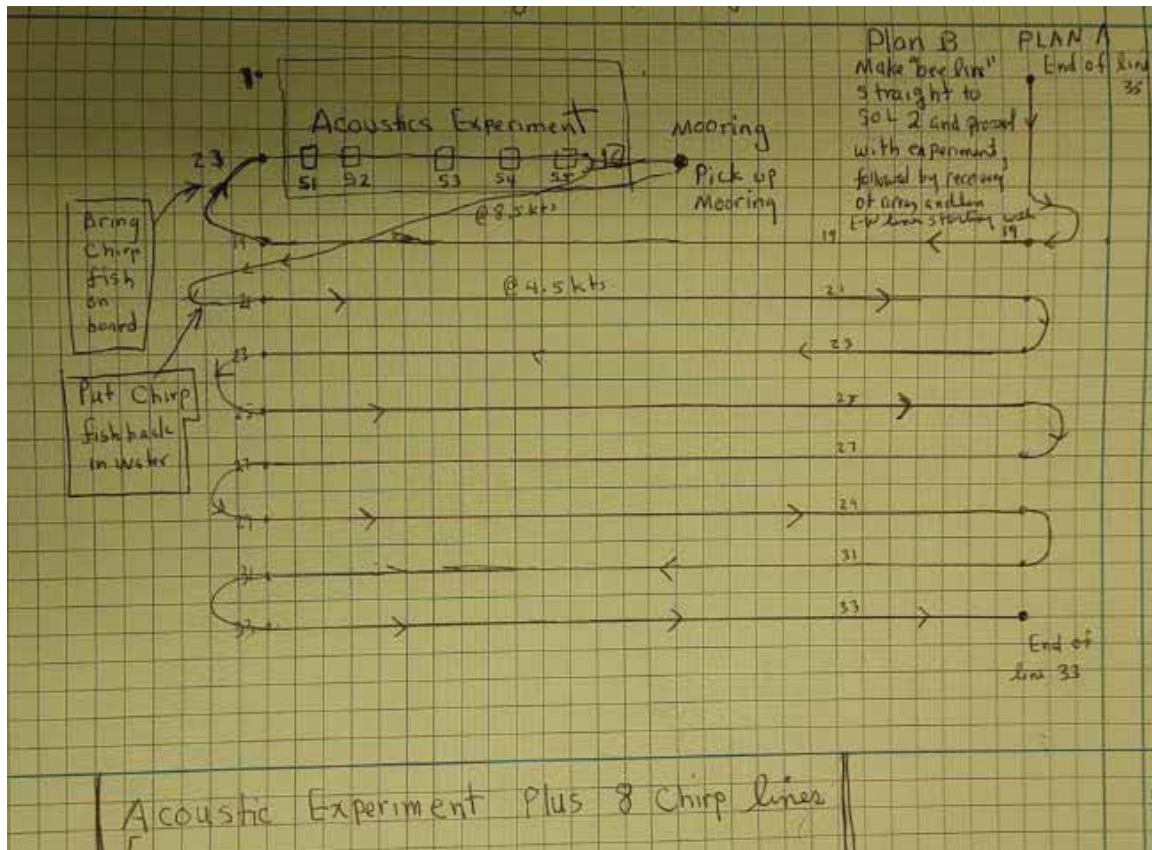


Figure 26i: Plan for an acoustic experiment with CSS plus 8 E-W survey lines. The coordinates were programmed into the navigation system and the plan was presented to the bridge by Knobles.

Planned Acoustic Experiment for Day 211 July 30: The experiment is shown in Figure 27. Sagers designed an impromptu skirt for the bottom part of the chamber out of rope. Knobles designed a test plan to deploy six CSS events along a range-dependent track (see Figure 26 and Figure 27). There were six planned positions:

S1	40.0 deg.	28.5460' N	70 deg.	46.6234' W
S2	40.0 deg.	28.5699' N	70 deg.	44.6038' W
S3	40.0 deg.	28.5858' N	70 deg.	43.3062' W
S4	40.0 deg.	28.6017' N	70 deg.	41.6110' W
S5	40.0 deg.	28.6256' N	70 deg.	39.4134' W
S6	40.0 deg.	28.6654' N	70 deg.	38.0058' W

For each station, the plan is to deploy the CSS at 10 and 20 m depths and use both ship and hand held CTD (Lin Wan of UD had this device). The conditions were night, around 12:00 am EST. The seas had been building throughout the day (not a good sign). The wind was 10-15 knots 242 degrees. All systems checked positively. Ropes and bungee cords were added to keep chamber stationary. The moon was out, giving some visibility for dolphin watch. The measured SSP suggested a strong well-developed propagation channel. The current was very high, causing considerable motion of the CSS frame and gas loss. We decided to place the CSS at 20 m to mitigate the coupling with surface wave motion, but the current became even stronger and the

effective flow rate into the chamber was seriously eroded. We recovered and placed the skirt on the CSS and redeployed.

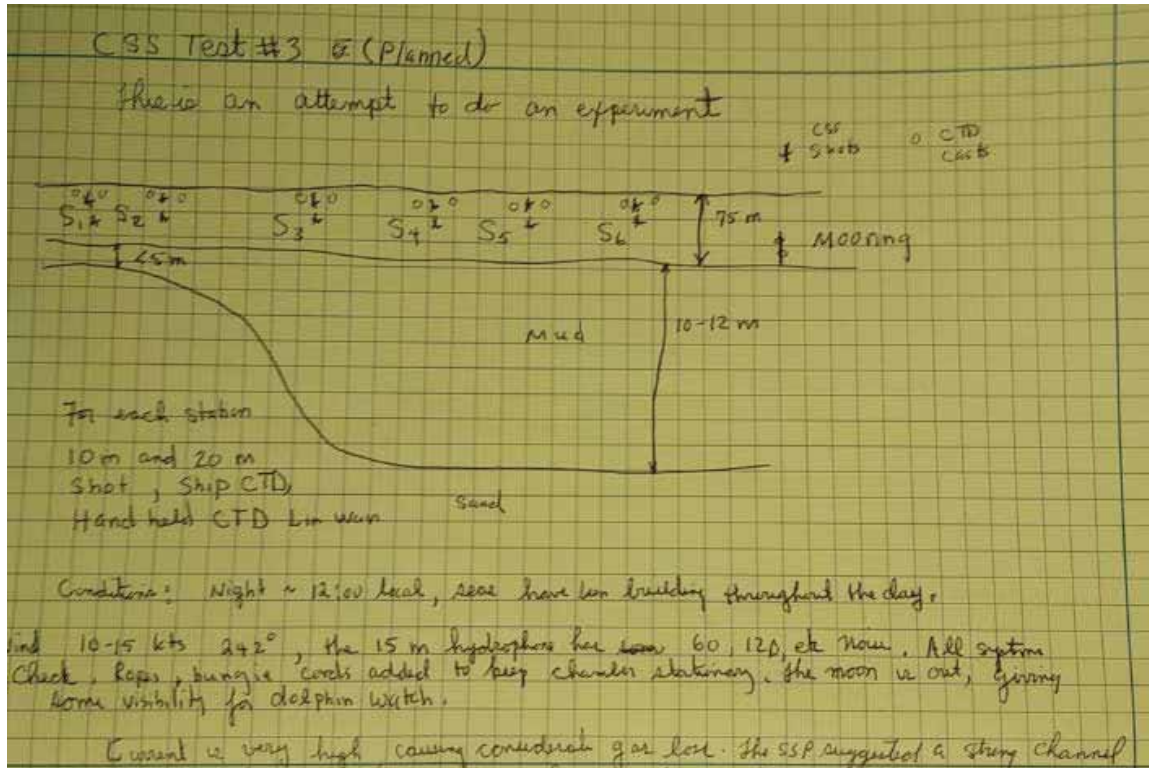


Figure 27: Sketch of a test plan for the CSS deployed along a range-dependent track (variable mud thickness). The test did not occur because of a combination of a catastrophic failure of the CSS and weather forecasts predicting increasing sea states.

Knobles and Sagers were able to fire the CSS at waypoint 040 (S1) a few times at about 05:15 UTC, but then, while filling the chamber for event at waypoint 041, it was observed there was something seriously wrong with the CSS gas flow. We recovered the CSS and immediately noticed (Lin was the first to observe the specific problem) that one of the gas valves had been stripped from the top of the gas flow mechanism, apparently from the conduit of hoses and cables at the top of the device. Sagers replaced the valve and the CSS was ready to resume deployment, but the weather forecast was predicting higher sea states and UD expressed concern for their mooring. On the basis of the forecasts and the observed deteriorating seas, it was decided to go ahead and recover the UD/WHOI mooring before the sea states increased. As such Knobles decided no additional CSS measurements would be made. [Comment in Knobles notebook: At 8:20 am local or 211 12:20:50 -- If there is a chance later in the experiment we (Knobles and Sagers) will try the experiment again, but for now the priority is the nine odd numbered E-W lines in the southern sector of the survey area, and to recover the UD/WHOI mooring. The seas have become rough, with wind speeds ~ 17-20 knots, with increasing white capping and large swells (5-8 foot seas). Looks like we need to recover the UD/WHOI mooring now.]

A summary of lessons learned with the CSS:

1. Even though great care was taken on testing at ARL:UT and the large amount of thought in deployment and recovery, the system had flaws.

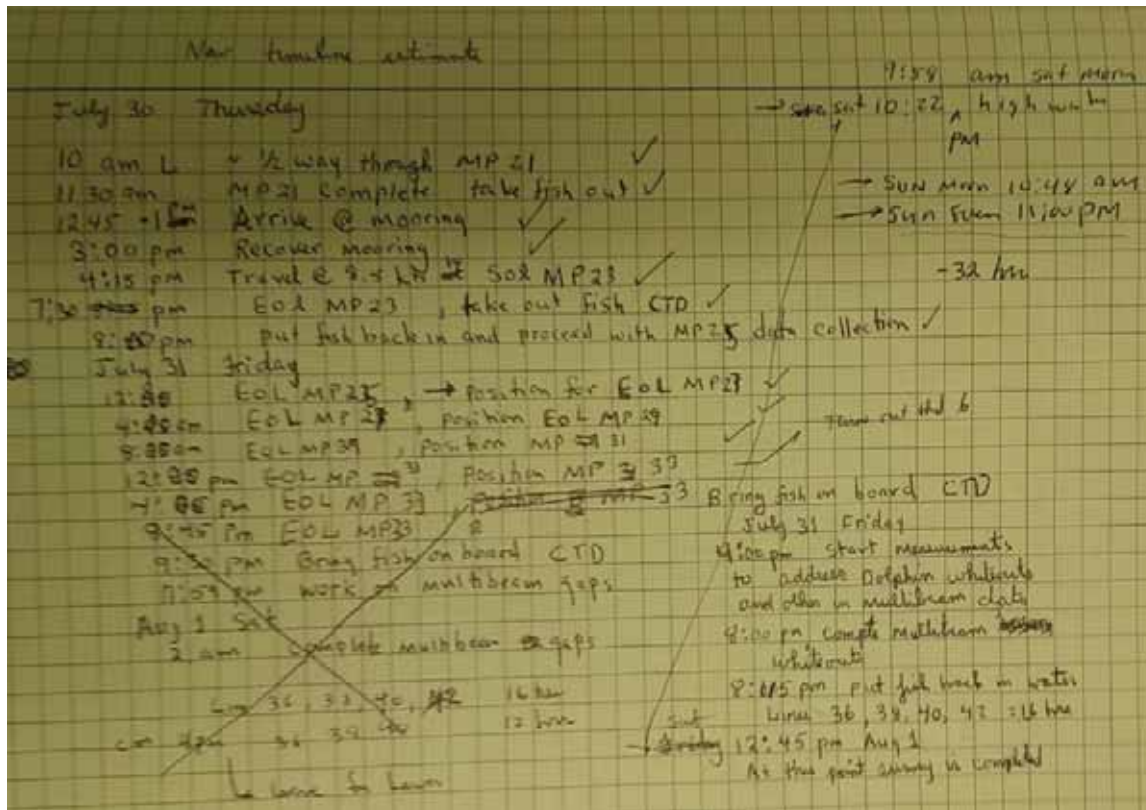


Figure 28b: Estimates of departure plans taken from Knobles' notebook.

Watchstander Log

(R/V Sharp Cruise DK10-15, "Mudpatch," July 22, 2015 – August 3, 2015)

The following is a daily log that was kept by the watch crews. There were three two-person watch crews with an eight-hour shift for each crew. Knobles and Sagers were responsible for 6 am – 2 pm, Badiy and Wan 2 pm – 10 pm, and Potty and Lin 10 pm – 6 am. Overall these pairings seemed to work well and they contributed significantly to the log below. One important point is that at any given time one member of the pair could see if there is a problem with the CHIRP tow body. Problems included becoming entangled in fishing gear. This is going to be an issue for the main experiment. It appears that fishing gear may be a much more significant problem as compared to shipping noise. These crews were necessary to keep constant vigilance on the unprocessed tow beam data. Sometimes problems occurred, such as entanglement of the tow body in fishing gear, and it was important that in such cases immediate communication could be made with the bridge to mitigate the chances of damage or loss of the tow fish. Early on, we had problems with the crew of the R/V Sharp wanting to get close to lobster pods in the track transits because they were fishing off the back of the stern. This caused the probability of entanglement of the tow fish with the mooring lines of the lobster pods. This placed the tow fish in jeopardy of being lost or damaged. A discussion with the Captain occurred and this seemed to put a stop to positioning the ship too close to the lobster pods and thus decreased the rate of entanglement. SOL stands for "Start of Line" and EOL stands for "End of Line".

All times are in UTC unless otherwise noted.

Configuration: Layback to top of deployed A-frame computed to be ~25 m from ship's GPS, or ~4 m from ship's stern. Altitude from top of A-frame when deployed is ~7 m above water line. Fish layback is distance from GPS to top of A-frame, plus $\sqrt{(\text{LO}+7)^2 + (\text{FD}+7)^2}$, where LO is line out after zeroing at water line, and FD is fish depth below water line.

22 JULY: 1600Z leave dock; heading to 40.472664 N 70.780961W for start of survey/deployment of CHIRP

23 JULY:

- 0130Z Still transiting to site at 8.5 kts.; ETA on site 1430L. End point of line 1 calculated to be 40.476831 N 70.426331 W (30 km at 89 deg from first waypoint).
- 1200Z Still transiting NE, 8.2 kts, 062 heading. ETA on site is now 1940Z, 1540L
- 1249Z Changed Fugawi GPS from ship's science splitter to portable UTIG antenna. This antenna, "GPS2", is located at the stern of the vessel, 3.3m to port of the center line. The block towing the CHIRP fish is located on the A-frame 1.4 m to the port of vessel's center line.
- 1913Z Start depth sensor test T4_mp01.
- 1920Z On station for CTD#1; 40 deg 28.3859' N, 70 deg 47.1372' W.
- 1922Z CTD in the water. Fugawi waypoint MPCTD1
- 1923Z CTD coming back up
- 1935Z CTD on surface. Fugawi waypoint MPCTD1A
- 1953Z SOL mp01, heading east; WD ~77 m; fish altitude ~64 m, wire angle ~40deg.; good bottom return; Operating with 20 ms pulse, 0.5-12 kHz.
- 1955Z Turn off ADCP. No difference to record – still numerous transients (note: this issue appears to have been fixed soon after this note, but not recorded in log).
- 2005Z EOL mp01. Looping back to restart line because multibeam wasn't ready.
- 2012Z Line meter not working. Paying out another ~5 m on top of previous 15 m as estimated by Steffen.
- 2015Z Another ~5 m out. Making turn back on line. Black tape placed at current location for ensuring consistency with line out.

- 2017Z SOL mp01a, heading east; fish altitude ~61 m, so depth ~16 m.
- 2107Z Interesting feature ~65 m.
- 2302Z Water multiple observed indicating water depth of 72 m and fish depth of ~19 m. Speed ~4.3 kts
- 2352Z EOL mp01a

24 JULY:

- 0004Z Fish on deck. CTD2 down, Waypoint MPCTD2
- 0021Z Pressure depth data and jsf files for mp01 and mp01a downloaded. Record length reduced from 120m to 100m. Base level for mp01 depth file is ~10.32 m.
- 0035Z Fish in water
- 0040Z Cable out to previous spot as marked by Steffen's black tape. Better estimate for cable out is 32m (confirmed by later depth record when fish was hanging straight down). Subsequent calculation of layback results in ~34 m behind stern GPS. This value will be used for processing.
- 0048Z SOL mp02
- 0435Z EOL mp02
- 0444Z SOL mp03
- 0752Z Vertical stripes (noise?) seen in CHIRP data. Maybe something hit the sonar.
- 0826Z EOL mp03
- 0832Z At the end of line mp03 we noticed a problem with the multibeam computer. All distances measured were shown as greater than actual by 25%. Both the multibeam computer and bridge navigations systems were rebooted. During this time, the ship was slowed to ~1.5 kts, the CHIRP fish was shallowed by ~15 m, and the ship was manually steered to the NE. The problems were corrected by 0900Z and we began to get back on course for mp04. The result is that lines mp01, mp02 and mp03 are separated by ~170m rather than the expected ~250m.
- 0900Z CHIRP fish returned to 32 m depth.
- 0911Z SOL mp04; two time errors have been discovered in CHIRP records: (1) day is off by 20 (July 4 rather than July 24), and (2) hour is off by 1 less than UTC time. The hour issue

seems to be that the time zone is set to GMT DST and topside shifts to what it things is GMT standard (?). Will fix both issues at turn.

- 1210Z Strong acoustic reflector observed on record. Base of mud layer ~10 m.
- 1218Z Abrupt apparent change in layer depth.
- 1224Z Reflection west end of this line is still very strong and about 3 m thick.
- 1236Z Deviating course to avoid fishing gear.
- 1239Z Record went to crap –snagged fishing gear
- 1241Z CHIRP looking better, but will pull it up to inspect (turned out to still be snagged)
- 1246Z EOL mp04
- 1252Z Sonar turned off
- 1305Z Fishing gear untangled from CHIRP and returned to water
- 1311Z redeploy CHIRP
- 1317Z turn initiated to restart the track where we snagged the gear
- 1320Z Steffen adjusts topside clock to be correct date and time; seconds synched
- 1335Z SOL mp04a
- 1340Z Deviation to avoid fishing gear.
- 1348Z EOL mp04a
- 1354Z SOL mp05
- 1414Z Raising CHIRP fish to avoid fishing gear; new SOP will be to change the depth of the tow in the vicinity of fishing gear to avoid future entanglements (note – this was only done once more as the crew became more adept at avoiding the gear).
- 1416Z Lowering fish to resume line
- 1419Z Deviating courses to avoid gear
- 1429Z Subbottom changed thickness again; marked as waypoint on Fugawi.

- 1518Z Observing 2 strong reflectors; sediment thickness ~10 m
- 1544Z EOL mp05; deploying mooring
- 1826Z Fish returned to water. Sonar resumed; mooring waypoint designated in Fugawi as 40 deg 28.6428' N, 70 deg 36.2382' W
- 1832Z SOL mpn01 – due north from mooring site to reconnect with mp05
- 1837Z EOL mpn01
- 1838Z SOL mp05a; time stamp on CHIRP appears to be correct now – likely needed to reboot after changing time on computer.
- 1933Z Strong reflector shows some variations
- 1940Z Hooked fishing gear. Stop recording. EOL mp05a
- 1951Z Fish untangled from fishing gear without bringing it back on board. Looks undamaged.
- 2011Z SOL mp05b
- 2058Z EOL mp05b
- 2119Z SOL mp06 heading west; pressure depth sensor had a big excursion that took a long time to recover from

25 JULY:

- 0010Z Deviating course to north to avoid fishing gear
- 0048Z EOL mp06
- 0058Z SOL mp07, heading east
- 03228Z deviating to north to avoid fishing gear
- 0337Z returning to line
- 0420Z EOL mp07
- 0427Z Testing several different pulses. Going to record line mp08 using 0.5-7.2 kHz, 30ms
- 0433Z SOL mp08

- 0651Z Slowing down, fish is sinking
- 0659Z Dolphins are swimming on the side of the ship messing up the multibeam. Chirp sonar is seeing signals in the water column.
- 0741Z Sediment layer changing rapidly. Marked on Fugawi.
- 0813Z EOL mp08; pulling fish out to do CTD
- 0830Z Fish back on deck
- 0835Z Chirp topside rebooted.
- 0840Z Wavelet changed back to 0.5-12 kHz, 20 ms
- 0845Z Chirp back in water
- 0855Z SOL mp09
- 0918Z Seas are very calm
- 0935Z Mud becoming thicker
- 1013Z High amplitude reflector of short duration
- 1150Z After processing last downloaded lines and comparing mp07 and mp08 real records, decision made to switch to 0.5-7.2 kHz, 30ms pulse for remainder of survey. Same features can be seen in each, but better definition in the lower frequency, longer pulse.
- 1159Z Diverting to avoid gear
- 1237Z High subbottom reflectivity at the end of line mp09
- 1237Z EOL mp09; Chirp pulse changed to 0.5-7.2kHz, 30ms.
- 1242Z SOL mp10
- 1437Z R/V Sharp's speed continues to exhibit significant variability due to currents (4.4-5 kts). This causes fish to have variable depth.
- 1527Z Diverting to avoid gear
- 1540Z Steep discontinuity in subbottom reflector again – marked in Fugawi.

- 1619Z EOL mp10
- 1627Z SOL mp11
- 1710Z another waypoint in Fugawi to note change in subbottom reflector depth
- 2006Z EOL mp11
- 2012Z SOL mp12
- 2159Z EOL mp12; sonar off. Start CSS ops.
- 2238Z chir on deck. CTD in water. Waypoint MPCTD4: 40 deg 29.7468' N, 70 deg 36.3729' W
- 2380Z Fire CSS shot 1. Waypoint CSS1 on Fugawi: 40 deg 29.7891 'N, 70 deg 36.0340' W
- 2313Z Fire CSS shot 2. Waypoint CSS2. 40 deg 29.7718' N 70 deg 36.0074 'W
- 2314Z Dolphins spotted. Shutting down CSS
- 2336Z Chirp back in water and pinging.

26 JULY:

- 0007Z SOL mp12a, heading west
- 0154Z EOL mp12a
- 0159Z SOL mp13, heading east
- 0229Z deviating for fishing gear
- 0538Z EOL mp13
- 0544Z SOL mp14
- 0920Z EOL mp14
- 0930Z SOL mpd01 – diagonal line
- 1312Z EOL mpd01; pulling fish out for CTD and CSS. Will skip #15 to keep in synch with bridge numbering.
- 1329Z CTD6

- 1337Z CTD7
- 1503Z Fish in water
- 1522 SOL mp16; ship's course a bit off of line.
- 1856Z EOL mp16
- 1910Z SOL mp17
- 2246Z EOL mp17
- 2252Z SOL mp18

27 JULY:

- 0155Z reducing speed from ~5.2 to 4.5 kts
- 0226Z EOL mp18
- 0232Z SOL mp20
- 0421Z EOL mp20 (halfway through line). Recover CHIRP to do CTD.
- 0428Z CHIRP on deck
- 0443Z Acquiring CTD7. 40 deg 27.9031' N 70 deg 36.1485' W
- 0445Z CHIRP in water' positioning for mp20a
- 0507Z SOL mp20a
- 0659Z EOL mp20a
- 0706Z SOL mp22
- 0821Z entering 12 m thick mud layer area
- 1045Z EOL mp22
- 1056Z SOL mp24
- 1436Z EOL mp24

- 1441Z SOL mp26
- 1457Z diverting to avoid gear
- 1532Z The sand layer suddenly drops and then return to original position
- 1632Z EOL mp26; Chirp off and recover to do CTD and CSS
- 1650Z Acquiring CTD8. 40 deg 26.9950' N 70 deg 36.1817' W
- 1700Z CSS going in water
- 1715Z Attempt to fire CSS. No fire
- 1728Z CSS9
- 1748Z CSS10
- 1756Z CSS11
- 1801Z Attempt to fire CSS. No fire.
- 1809Z CSS12
- 1822Z CHIRP fish back in water
- 1828Z SOL mp26a
- 2016Z EOL mp26a
- 2033Z CTD9
- 2054Z SOL mp28, heading east; discovered that pressure sensor was not attached to CHIRP at last stop. Will pull fish in to put it on and then continue line 29.
- 2251Z EOL mp28
- 2326Z SOL mp28a

28 JULY:

- 0114Z EOL mp28a
- 0126Z SOL mp30

- 0512Z EOL mp30
- 0518Z SOL mp32
- 0856Z EOL mp32
- 0902Z SOL mp34
- 1237Z EOL mp34
- 1252Z SOL mpd02
- 1546Z EOL mpd02; fish recovered for doing patch test form multibeam over depression (seep?). Will continue on mpd02 when completed
- 1726Z CTD10
- 1806Z SOL mpt01; transit to next spot; line name was not changed on continuation of diagonal. Will leave line name as-is.
- 1914Z EOL mpt01
- 1925Z SOL mp35, heading west; dropping speed from 5.2 kts to 4.5 kts
- 2306Z EOL mp35
- 2311Z SOL mp37

29 JULY:

- 0028Z deviating to avoid gear
- 0250Z EOL mp37
- 0303Z SOL mp39
- 0608Z strong reflector in mud layer.
- 0642Z EOL mp39
- 0651Z SOL mp41
- 1032Z EOL mp41
- 1041Z SOL mp43

- 1424Z EOL mp43; start of N/S cross-lines
- 1508Z SOL mpn02; started line while still transiting east. Will continue recording as we turn south on the line to get crossing with northernmost line. Will do the same at south end.
- 1517Z Turning to stbd to come into line. New heading will be 179.
- 1547Z Deviating to avoid gear
- 1626Z EOL mpn02
- 1626Z SOL mpn03
- 1051Z Turn to north completed.
- 1811Z EOL mpn03
- 1811Z SOL mpn04
- 1958Z EOL mpn04
- 1958Z SOL mpn05
- 2000Z Lowering CHIRP fish from ~18 m to ~35 m depth to test response to changing depth.
- 2007Z Lowering fish to 45 m for data quality testing
- 2016Z CHIRP back at 18 m depth. Data quality not noticeably improved during test
- 2029Z Turn onto S-N line
- 2142Z EOL mpn05
- 2142Z SOL mpn06
- 2158Z ship turning onto N-S track
- 2312Z EOL mpn06
- 2312Z SOL mpn07
- 2244Z ship across shipping lane

30 JULY:

- 0005Z ship missed the starting point of the N-S track. Turning around to try again. Will continue recording CHIRP until ready to restart line.
- 0023Z EOL mpn07
- 0023Z SOL mpn07a
- 0144Z EOL mpn07a; recover CHIRP to do CSS experiment
- 0155Z CHIRP on deck
- 0511Z CSS13 fired
- 0654Z CSS14 fired
- 0710Z CSS misfires. Brought on deck and a leak found. Putting CHIRP in the water to transit to mp19
- 0735Z SOL mpd03 – recording during short transit
- 0759Z EOL mpd03
- 0801Z SOL mp19
- 1146Z EOL mp19
- 1154Z SOL mp21; ship is having difficulty with swells and currents
- 1537Z EOL mp21; recover CHIRP. Transit to mooring site to recover it.
- 1711Z CTD11?
- 1829Z Finished pulling in mooring. Transiting to start of mp23
- 1941Z Fish in water
- 1951Z SOL mp23
- 2336Z EOL mp23
- 23??Z SOL mp25
- 2351Z EOL mp25; need to restart line due to multibeam reboot

31 JULY:

- 0015Z SOL mp25a
- 0355Z EOL mp25a
- 0402Z SOL mp27
- 0739Z EOL mp27
- 0748Z SOL mp29
- 1135Z EOL mp29
- 1142Z SOL mp31
- 1208Z deviation to avoid gear
- 1344Z EOL mp31; snagged gear.
- 1356Z were able to unhook fish w/o bringing on board. Will circle back to continue line.
- 1412Z SOL mp31a; Ship had difficulty getting on line, so there will be a gap; CHIRP data appear noisier since snagging. Will pull up at end of line anyway for CTD and transiting to patch up multibeam holes, so can inspect then. Otherwise it's pinging fine and water column is clear; (subsequent inspection of processed lines indicates no change in data quality)
- 1551Z EOL mp31a
- 1605Z CTD12; CHIRP is now on deck while we infill some multibeam gaps
- 1857Z CTD13

01 AUG:

- 0033Z Lost Fugawi GPS for a few minutes
- 0043Z CTD15
- 0208Z Fish in water at start of mp36
- 0216Z SOL mp36

- 0312Z Diverting to south to avoid fishing gear
- 0548Z EOL mp36
- 0556Z SOL mp38
- 0755Z deviating to avoid gear
- 0915Z EOL mp38
- 0932Z SOL mp40
- 1251Z EOL mp40; noticed data had stop scrolling at last time of 1222Z (28 minutes ago) – this was about the when John was showing Mohsen the source characteristics on the sonar tab – John thinks he might have accidentally turned it off then. Nearly at end of line so not much data lost.
- 1251Z Pinging resumed.
- 1300Z SOL mp42
- 1622Z EOL mp42; somewhere along mp42 there was a big change in fish depth. Subsequent processing required a shift of 25 seconds to match pressure depth record to CHIRP record, likely indicating significant shift if the clock. This shift was applied to mp36, mp38, mp40 and mp42. We think pressure sensor clock is not drifting significantly because, if so, it would be indicated by a red icon with the TruWare software. So we suspect that CHIRP top-side clock may drift badly; bringing fish on deck to do hydrophone test. Attaching hydrophone to fish to hang 10 m below and record outgoing pulse. Will lower fish ~20 m below surface and ping at 1 Hz. This was later upped to 5 Hz.
- 1630Z Running test; ping with both pulses used in survey: 0.5-7.2 kHz, 30ms and 0.7-12 kHz, 20 ms, 2 minutes each, and then 2 minutes of ambient.
- 1702Z Small fish in water for test. Will reshoot along mp36; starting pinging with 2-10 kHz, 20 ms pulse. Good penetration to base of mud. Nice layering. Had to gain way down.
- 1719Z Failed to start recording. Oops.
- 1719 SOL mp36_216; nice layering in perched sediment pod.
- 1729Z EOL mp36_216; change pulse to 2-12 kHz, 20 ms
- 1730Z SOL mp36_216a; record looks very similar to previous pulse. Now picking up a reflection below mud/sand transition. Nice sediment pond >10 m deep.

- 1739Z EOL mp36_216a; change to 2-15 kHz, 20ms
- 1740Z SOL mp36_216b; had to drop the gain WAY down to see record. Much harder to see anything.
- 1743Z EOL m36_216b; subsequent investigation of records indicated that the first two pulses were recorded at a time spacing of 0.092 ms, double the usual 0.046 ms, whereas the third pulse was recorded at 0.046 ms. Why???. Recovering CHIRP.
- 1750Z 216 CHIRP on board. CHIRP Survey complete!!! Will do another CTD and fill in another multibeam gap before heading home.
- 1804Z CTD14; heading back to Lewes.

END OF LOG

 Prior to leaving, the science team members had a meeting on July 31, 2015, at 1:00 pm local time to discuss what we thought were the major findings.

1. Sedimentation - Goff and Steffen have produced a rather mature 2-D plot of mud sediment or thickness in the survey box. The basic geological structure of the mud patch is that the fine-grained sediments were deposited within a depression formed first by erosion of Pleistocene sediments of unknown composition, followed by a mantling of Holocene sands organized into an oblique sand-ridge morphology. The mud is seismically laminated, i.e., has increasing impedance contrasts with increasing age (depth of deposition).
2. Bathymetry - To first order, the surface of the mud is very flat. There are areas of depression (10-100 m diameter). It will be interesting to see if the areas of depression have an acoustical effect.
3. Water column - CTD's have been ongoing during Leg 1. They show significant variability. There exist channels in the measured SSPs. It will be interesting to correlate the SSP with oceanography related satellite images of warm water fronts associated with the Gulf Stream and associated eddies. To give an idea of the SSP variability, Chris noted that once a CTD measurement was made, only 10 minutes of multibeam data could be processed with less than 5 cm accuracy. After a timespan of 10 minutes the depth resolution rapidly increased to a value of greater than 40 cm.
4. The measured received signals made on the UD/WHOI moorings show significant time spreads (~ 800 ms at 14 km range). This suggests that seabed attenuation at the lower frequencies is very low. There may be east/west variability of the attenuation.

As noted we headed back to Lewes on Saturday, August 01, 2015 at about 18:00 UTC.

Overview Table of Leg 2 Coring, CTD and Bottom Water Collection

Table 4 shows an overview of the coring operations, CTD and bottom water collection during Leg 2. The use of Table 4 is described in Figure 29.

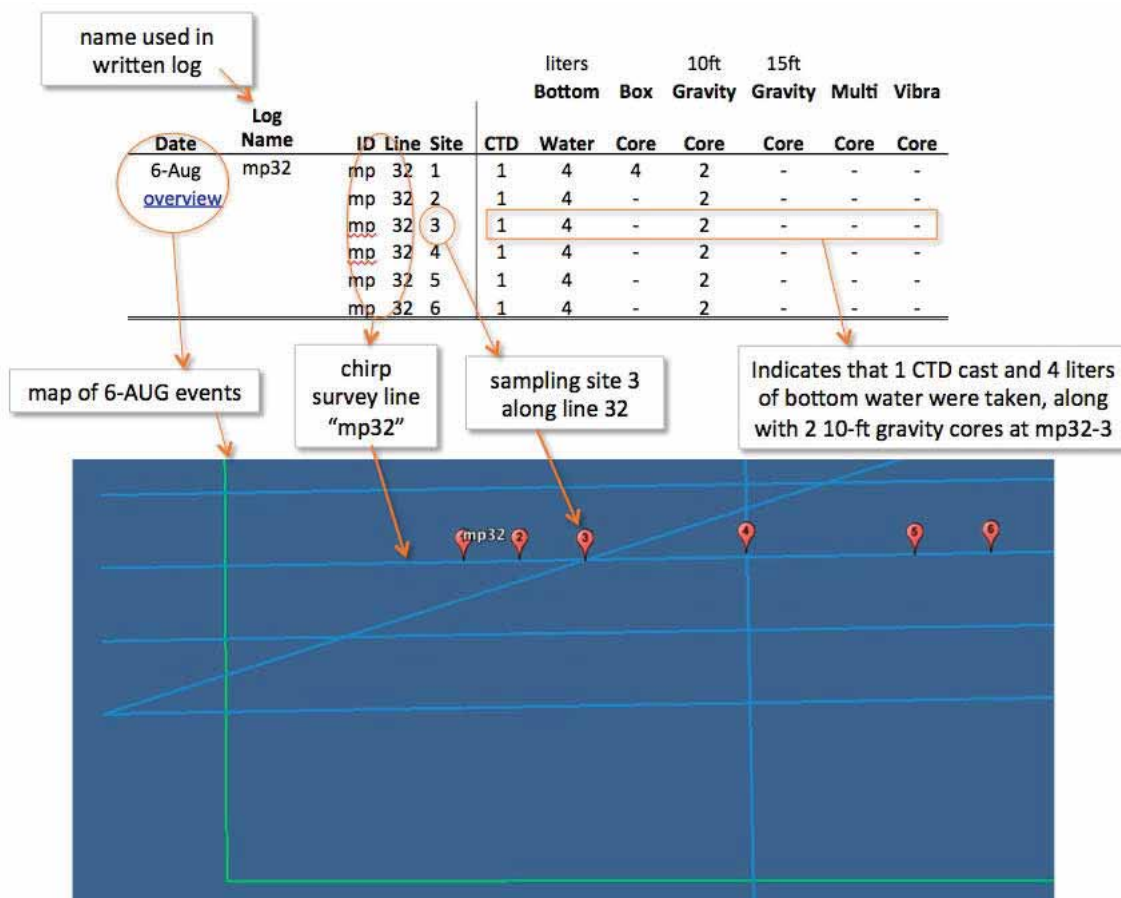


Figure 29: The left-most column is the date of collection. The "log name" lists the name given to a site used in the hand-written logs and on the cores liners and samples themselves. The entries for "ID," "Line" correspond to the naming convention of the associated CHIRP survey lines run on leg 1, for example one will find a CHIRP survey lines named "mp32." The "mp" refers to mud patch and the 32 is a unique line identifier. The sampling sites were always located along a survey line, and each site was numbered. The Figure illustrates the data collected at site "mp32-3," where 1 CTD cast was made, 4 liters of bottom water were collected, and 2 10-ft-long gravity cores were collected.

Table 4: Overview of coring/CTD collected during Leg 2.

Date	Log Name	ID	Line	Site	CTD	liters Bottom Water	Box Core	10ft Gravity Core	15ft Gravity Core	Multi Core	Vibra Core
<u>6 AUG</u>	mp32	mp	32	1	1	4	4	2	-	-	-
		mp	32	2	1	4	-	2	-	-	-
		mp	32	3	1	4	-	2	-	-	-
		mp	32	4	1	4	-	2	-	-	-
		mp	32	5	1	4	-	2	-	-	-
		mp	32	6	1	4	-	2	-	-	-
<u>7 AUG</u>	tioga	tioga	1	1	2	4	-	2	-	1	-
	mp32	mp	32	1	1	-	-	-	-	1	-
		mp	32	6	1	-	-	-	-	1	-
<u>8 AUG</u>	seep1	mp	05b	3	1	2	4	-	-	2	-
	seep2	mp	05b	4	1	2	-	-	-	-	-
	seep3	mp	05b	5	1	2	-	-	-	-	-
	seep4	mp	05b	2	1	2	-	-	-	-	-
	seep5	mp	05b	1	1	2	-	-	-	-	-
<u>10 AUG</u>	ISO1	mp	38	1	1	-	-	1	-	-	-
	ISO2	mp	10	1	1	-	-	1	-	-	-
	ISO3	mp	6	1	1	-	-	1	-	-	-
	ISO4	mp	3	1	1	-	-	1	-	-	-
	ISO5	mp	18	1	1	-	-	1	-	-	-
	ISO6	mp	23	1	1	-	-	1	-	-	-
	ISO7	mp	31	1	1	-	-	1	-	-	-
<u>11 AUG</u>	Sam1	mp	30	1	1	-	-	1	-	-	-
	Sam2	mp	30	2	1	-	-	1	-	-	-
	Sam3	mp	30	3	1	-	-	1	-	-	-
	Sam4	mp	27	1	1	-	-	1	-	-	-
	Sam5	mp	34	1	1	-	-	1	-	-	-
<u>12 AUG</u>	mp32	mp	32	8	-	-	-	1	1	-	-
		mp	32	7	-	-	-	1	1	-	-
	mpd02	mpd	02	2	1	-	-	1	-	-	-
		mpd	02	6	1	-	-	1	-	-	-
		mpd	02	7	1	-	-	1	-	-	-
Date	Log Name	ID	Line	Site	CTD	Bottom Water liters	Box Core	Gravity Core 10ft	Gravity Core 15ft	Multi Core	Vibra Core
Totals					30	38	8	31	2	5	0

SECTION V. Leg 2: Daily Operations Log.

For each day (archived here using the local date on the ship) that science operations were conducted, a table of events is given with position coordinates (as given to the Captain), with the UTC time of the first operation at each station. A map is shown indicating the relative location of the day's operations, with the (Twichell, McClennen et al. 1981)¹ mud layer thickness contours overlaid. The Leg 1 CHIRP transect showing the locations of the Leg 2 coring operations is also given. A pointer into the chief scientist's log book is given. Color-coded arrows spatially relate the coring operations to the CHIRP record.

Goal for each day and corresponding location:

6 AUG: CTD, bottom water collection, box and gravity coring were conducted along CHIRP line mp32, in the southwest corner of site, which was the location of thinnest mud layer within the experimental site. Our goal was to get the bottom of our 10-foot-long gravity corer as close to the sand layer underlying the mud as possible. Cores along this transect had varying concentrations of sand and shell in the core catcher at the bottom of the core, indicating that we did start to see the underlying sand layer, but that there is a gradient into the layer, rather than a very sharp boundary. We never fully got into the sand layer. The bottom-most sediment in the cores was still primarily composed of mud.

7 AUG: We were continuing our quest to penetrate the sand layer. John Goff had CHIRP data, collected on an earlier cruise, from a site referred to as "tioga 1-1," which was a little further west of line mp32 than the coring locations from 6 AUG, and outside the range of the leg 1 CHIRP survey. This CHIRP data showed that the mud was a little thinner at tioga than at the previous location. Two gravity cores and two CTD casts were taken at tioga. Then multi-core deployments were conducted at tioga, and two sites along line 32 from 6 AUG. Bottom water was collected at tioga, but not again at the sites along line 32, since they were collected there the previous day. Single CTD casts were conducted at the sites along line 32. Since CTD were obtained at mp32-1 and mp32-6 on two subsequent days, this data could show the day-to-day variability at these two sites.

8 AUG: The location for this day was the site of a pockmark, visible in Leg 1 CHIRP and multi-beam data. There were several pockmark in the general vicinity, but the one visited on this day also had CHIRP data that indicated the possible presence of a fresh water seep. In addition, at the center of the seep, referred to as station "seep 1," there was a very clear indication of a soft reflector just above the ocean bottom. This appears as white "fuzz" in the CHIRP data. Box cores and multi cores were taken from the center of this pockmark, at station seep 1. CTDs were collected along a transect that crossed the center of the seep. Significant infauna was found in the box core collections and in the multicore collections at this site. Laboratory sound speed measurements and infauna taxonomy were conducted in the ship's wet and dry labs.

9 AUG: The failure of the vibra-corer placed the gravity corer (which was brought along as a backup) into the role of primary coring tool. An insufficient number of coring pipes and core catchers were brought to fulfill the primary role, hence a return to shore was required. Arrangements were made via Y. T. Lin at WHOI to purchase the coring pipe (10 foot and 15 foot 3 inch SCH 40 PVC), and have it delivered to the NOAA dock at Woods Hole. The R/V Sharp arrived at Woods

Hole early in the morning of the 09 Aug., and the day was spent purchasing additional supplies and making core catchers, to facilitate continued use of the gravity corer. Weather then prevented departure until the morning of the August 10, so the R/V Sharp spent the night at the NOAA dock at Woods Hole and the crew enjoyed shore leave. A photograph of the R/V Sharp at the NOAA dock appears in Figure 30.



Figure 30: The R/V Sharp at the NOAA dock in Woods Hole on August 9, 2015, taking on supplies and weathering a storm.

10 AUG: The R/V Sharp departed the NOAA dock for the experimental site at about 05:00 local time. The focus now shifted from penetrating into the sand, to sampling the mud itself. A transect across the mud patch from the NW to the SE was planned, along a 100 ms isobath, which corresponds to about the 72 m isobath (see Figure 31), and gravity cores and CTD casts were obtained at the sites shown. A subset of this transect also corresponds to an isothickness section of the mud patch. As seen in Figure 31, the section between station mp10_1 and station mp23_1 is over primarily purple and blue mud thickness color, hence the dashed line indicates an approximately range-independent acoustic path, which might serve as the simplest case for inversion studies, assuming the mud itself (and the water column) is uniform along the path, which remains to be seen.

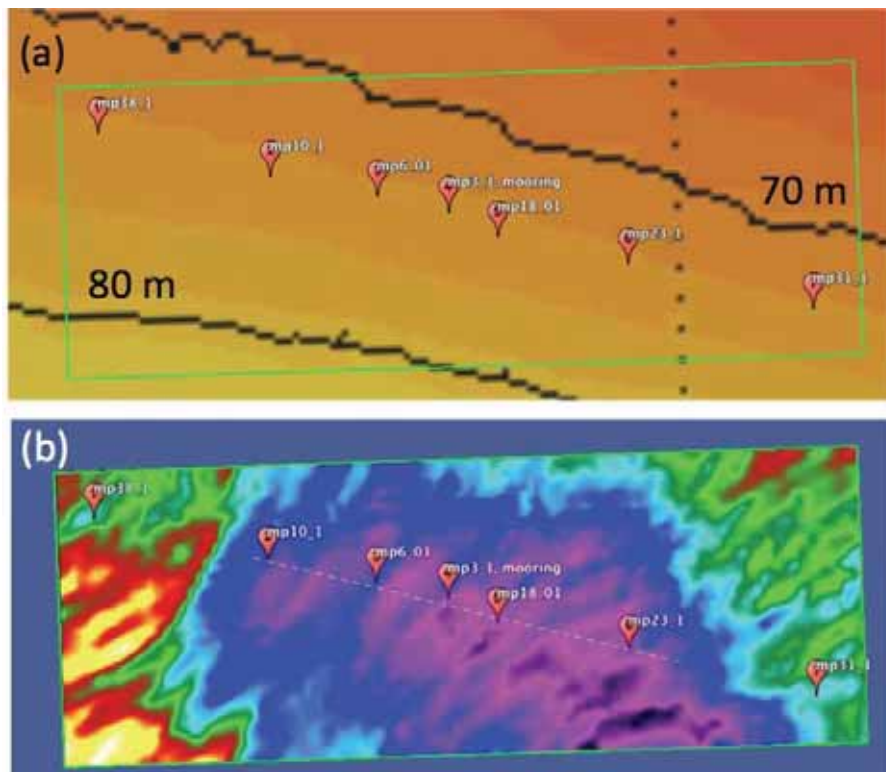


Figure 31: The isobathymetric “ISO” transect is shown in (a) where the 70 m and 80 m contour lines are shown. In (b), the associated mud thickness is shown. The dashed line then represents a potential range-independent propagation path to serve as a baseline for future inversion study cases.

11 AUG: The majority of the coring so far was along one-dimensional transects that either followed CHIRP lines, or crossed the entire site (see Figure 31). The goal of this coring was to get a two-dimensional view of the mud layer in the region where it was the thickest (toward the SE corner), at least according to the [Twichell¹](#) data, see Figure 32. The site was referred to as the “Samurai Cross” in the log. Some acousticians see the figure of a samurai in the darkest purple of the mud thickness contour (see Figure 32). The Samurai is wearing traditional armor and a traditional samurai helmet, is taking a large step with one leg, and lunging forward with his sword raised above his head. Weather prevented coring the latter half of the day.

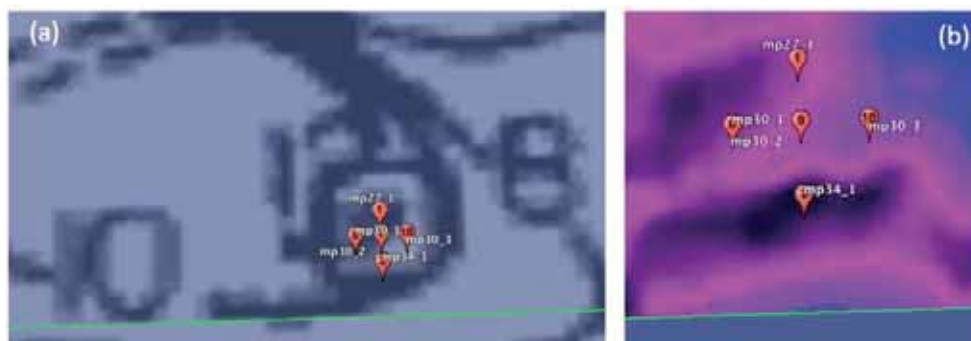


Figure 32: The [Twichell¹](#) mud thickness contour (a) and the sites of the August 11 coring. The same coring sites (b) overlaid on the mud thickness results from the Leg 1 CHIRP survey.

12 AUG: Bad weather continued and we could not core until midday. The goal this day was to go back to line 32 and complete the transect that was begun on August 6. These are referred to as mp32_7 and _8. The next coring of the day was conducted along a transect that crossed the site from SW to NE. Eight sites along this diagonal transect were planned, but only three new sites were collected due to poor weather. The SW-most site (mp32_1) along this transect was collected on August 6. The central site (mp3_1) along this transect was the location of the acoustic and oceanographic mooring, collected on August 10. The remaining sites were collected on this day. During the deployment at mp32_7, we attempted a longer core barrel, 15 feet in length, but recovered less than 10 feet of sediment. In the final coring operation of the trip, we went back to site mp32_8 and attempted another 15-foot core, and recovered about 13-feet of sediment.

Trying to Get into the Sand I – August 6, 2015

time of first operation on station		Local Date 6-Aug				Wilson log pages: 4-8						
latitude		longitude		ID	Line	Site	CTD	liters		Multi	Vibra	
deg. (N)	dec. mins	deg. (W)	dec. mins					Bottom	Box			Gravity
UTC												
11:25	40 26.094	70 45.925	mp 32	1	1	4	4	4	2	-	-	
17:04	40 26.095	70 45.789	mp 32	2	1	4	-	2	-	-		
18:26	40 26.094	70 45.629	mp 32	3	1	4	-	2	-	-		
20:16	40 26.102	70 45.237	mp 32	4	1	4	-	2	-	-		
21:32	40 26.105	70 44.827	mp 32	5	1	4	-	2	-	-		
22:28	40 26.110	70 44.642	mp 32	6	1	4	-	2	-	-		

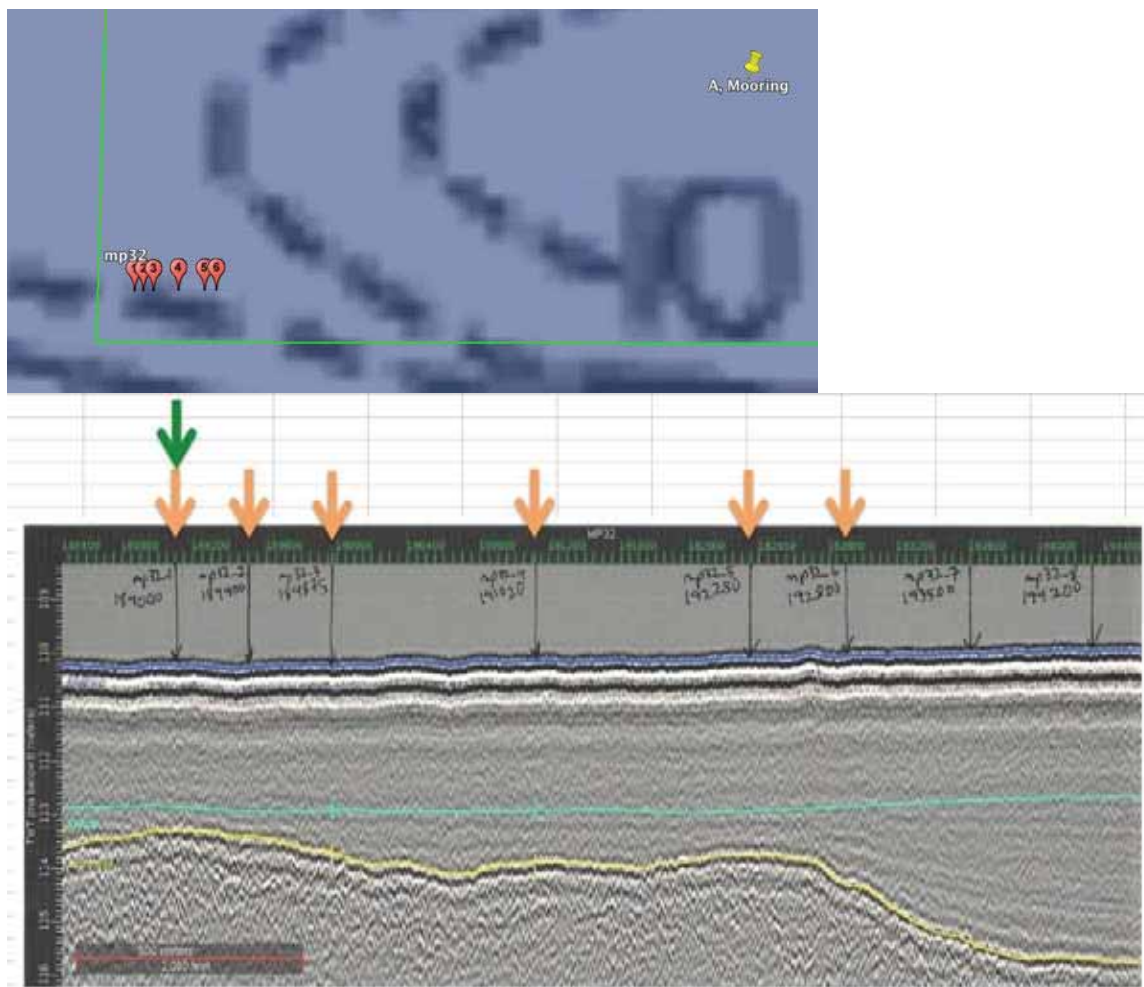


Figure 33: Six core locations where the mud was thin with the hope of penetrating into the sand.

Trying to Get into the Sand II – August 7, 2015

SCE 2015 Survey Cruise

Wilson log pages: 9–12

time of first operation on station	Local Date				ID	Line	Site	CTD	liters								
	7-Aug		7-Aug						Bottom Water	Box Core	Gravity Core	Multi Core	Vibra Core				
UTC	latitude	longitude	deg. (N)	deg. (W)	deg. (N)	deg. (W)	deg. (N)	deg. (W)									
14:59	40 29.976	70 47.553	40	70	40	70	40	70	tioga	1	1	2	2	-	2	1	-
20:15	40 26.094	70 45.925	40	70	40	70	40	70	mp	32	1	1	-	-	-	1	-
21:28	40 26.110	70 44.642	40	70	40	70	40	70	mp	32	6	1	-	-	-	1	-

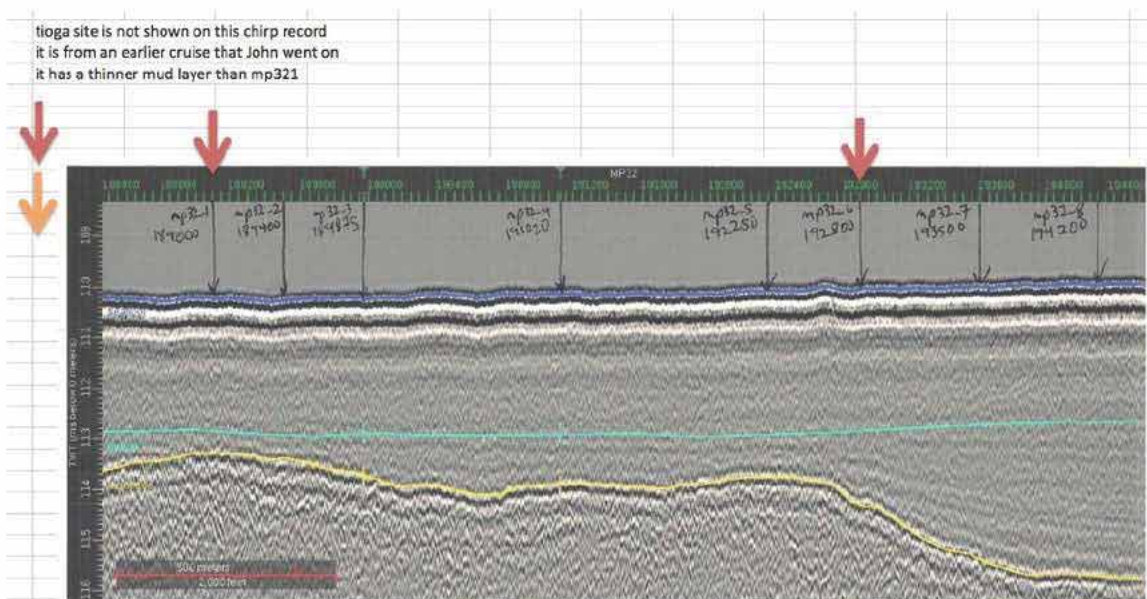
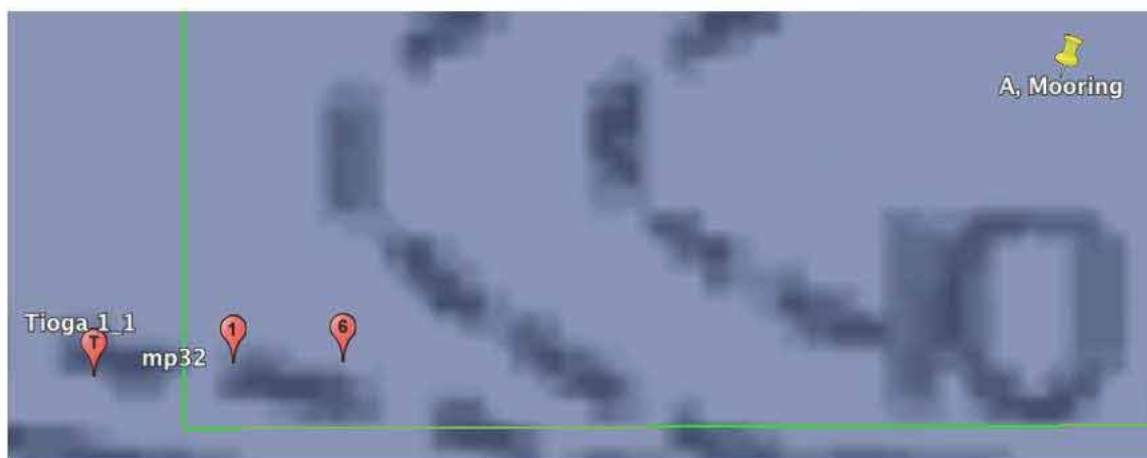


Figure 34: Second attempt to penetrate into the sand at thin mud locations.

Figure 33 and Figure 34 show locations where coring in the thin mud section of the survey site was conducted for the purpose of penetrating into the sand. Unfortunately, the gravity cores were unable to penetrate into the sand layer; however, it was observed that at the bottom of the cores

there existed coarser material, including shell hash. It was hypothesized that the shell hash could be part of a transition zone between the mud and sand. In a later visit to the United States Geological Survey annex at Woods Hole, an examination of a 30-year old core discussed in [Twichell](#) seemed to be consistent with this hypothesis.¹ A photograph from the multicore camera obtained from site mp32-1 is shown in Figure 35. The original unprocessed image is shown in Figure 35a. A number of dark depressions (identified with arrows) can be seen, possibly burrows. One can also see that the bottom in this location is covered with brittle stars. This is illustrated with false color in Figure 35b, where the arms of a very large number of brittle stars appear in color-enhanced pink. (Confirmation that these are brittle stars is discussed later in this section.) The inset (c) shows a patch of the bottom at higher magnification and the pink brittle star arms are clearly visible all over the bottom. In addition, a number of sea pens are also visible in (a) and in enhanced color in (b). Both types of infauna were collected for taxonomy.



Figure 35: Unprocessed bottom camera image (a) from site mp32-1, shown in (d). Processing reveals brittle stars (b) and (c), and sea pens (b). Only three of the sea pens are pointed out, but more are present. A number of burrow locations are present (a).

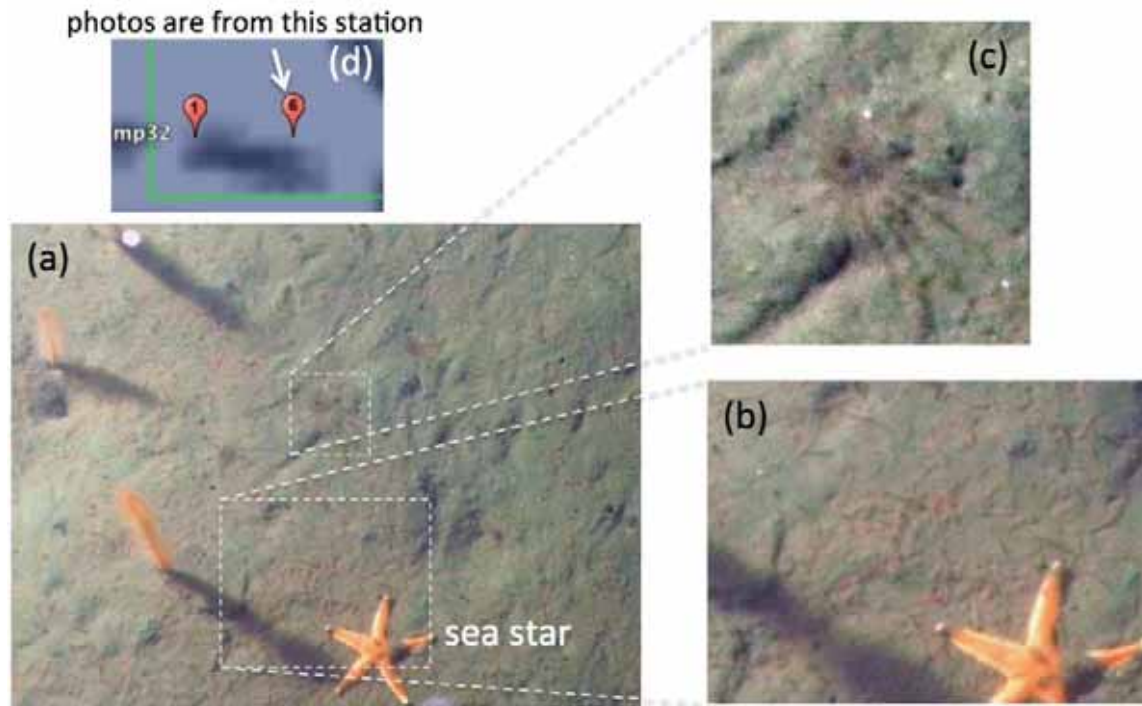


Figure 36: Processed bottom camera image subsection (a) from site mp32-6, shown in (d). Brittle stars (b) and sea pens (a) are present along with sea stars and something like a sea urchin (c).

Moving to site mp32-6 (1.8 km to the east) one finds a similar ecosystem on the ocean bottom, as shown in Figure 36. This image is from a higher altitude than the previous image (Figure 35) and processing does not result in as much contrast between the sediment and the brittle stars, but they are visible in Figure 36. It appears that the surface density of brittle stars is lower at this site (mp32-6) than at the previous site (mp32-1). Sea pens are visible too, and new two organisms appear, a sea star (a) and something that looks like sea urchins (c). There are three of the sea urchin-like animals visible in (a).

Some of these animals were collected and brought to the surface during the coring. Sediment samples obtained by the multicorer contained live brittle stars within burrows, with typically one arm reaching out of the burrow into the water column (see Figure 37a). Confirmation that these were brittle stars was obtained from other multicore samples, where brittle stars in their burrows were visible through the transparent core tube wall (see Figure 37b). These animals continued to live for several days and laboratory sound speed measurements (described in another part of this report) were conducted both with and without brittle stars present in the sediment.



Figure 37: The top of the sediment within a multicore sample (a) collected on August 7. The view is from outside the core tube, and brittle stars are visible on the sediment surface, which still contains bottom water over the sediment. Other multicore samples displayed brittle stars visibly within their burrows against the transparent core tube wall, as shown in (b).

Investigating the Seep Pockmark – August 8, 2015

SCE 2015 Survey Cruise						Wilson log pages: 12–15								
Local Date						8-Aug								
time of first operation on station	latitude		longitude		Log ID	ID	Line	Site	CTD	liters Bottom Water	Box Core	Gravity Core	Multi Core	Vibra Core
	UTC	deg. (N)	dec. mins	deg. (W)										
10:00	40	28.967	70	30.080	Seep1	mp	05b	3	1	2	4	-	-	-
12:46	40	28.967	70	30.064	Seep2	mp	05b	4	1	2	-	-	-	-
12:49	40	28.968	70	29.998	Seep3	mp	05b	5	1	2	-	-	-	-
13:00	40	28.967	70	30.107	Seep4	mp	05b	2	1	2	-	-	-	-
13:10	40	28.967	70	30.195	Seep5	mp	05b	1	1	2	-	-	-	-
19:44	40	28.967	70	30.080	Seep1-1	mp	05b	3	-	-	-	-	1	-
20:47	40	28.967	70	30.080	Seep1-2	mp	05b	3	-	-	-	-	1	-

Only Seep 1 is shown on the map due to the close proximity of the other sites. See below for Seep 2 through 5.

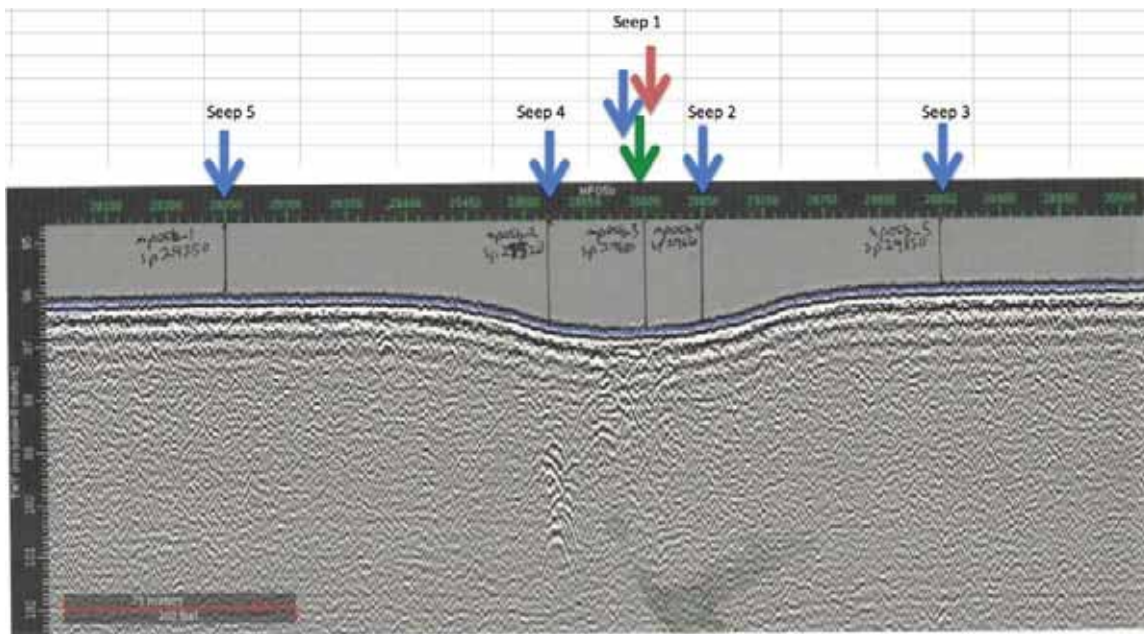


Figure 38: Seep locations.

A photograph from the multicore deployment, illustrating infauna and other features on the bottom at station Seep1, is shown in Figure 39. Some nodules that appear more gray in color than the majority of the surface are present. Close inspection and color augmentation illuminate many brittle stars, as in the other sites where bottom imagery is available, but the surface density of brittle stars appears to be lower here than in Figure 35 and Figure 36.

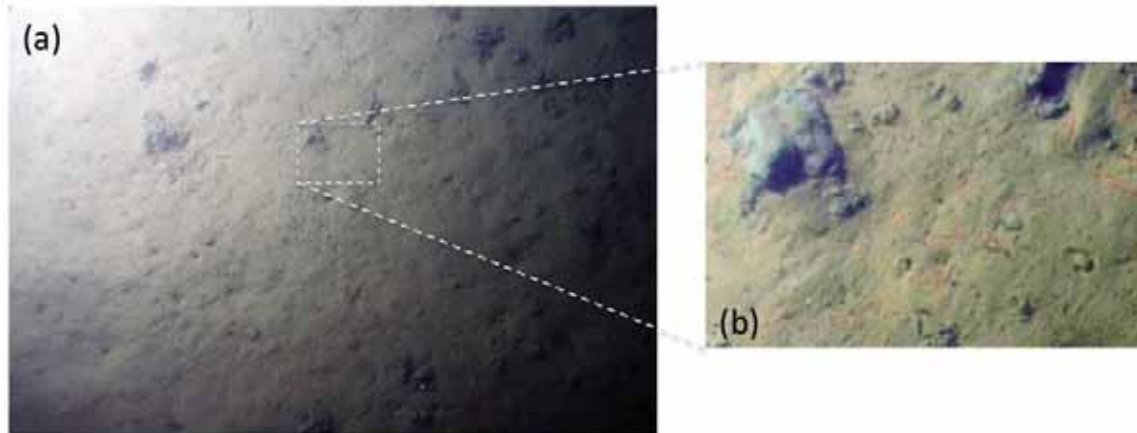


Figure 39: A bottom camera image from Seep 1 is shown in (a). Magnification and color enhancement reveal brittle stars.

Shore Leave in Woods Hole – August 9, 2015

No data this day. The ship was in port picking up supplies and then weathering a storm.

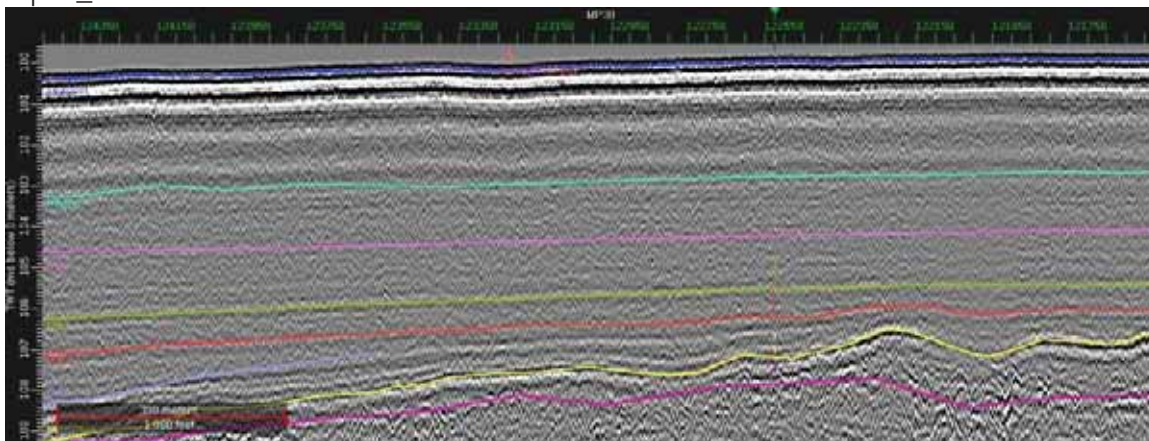
The Isobathymetric Transect – August 10, 2015

time of first operation on station		Local Date				SCE 2015 Survey Cruise							Wilson log pages: 16-17	
		10-Aug											↓	
UTC		latitude		longitude		Log ID	ID	Line	Site	CTD	liters		Multi	Vibra
		deg. (N)	dec. mins	deg. (W)	dec. mins					Bottom	Box	Gravity	Core	Core
17:19	40 30.467	70 45.592	ISO1	mp	38	1	1	-	-	1	-	-	-	-
18:46	40 29.484	70 40.966	ISO2	mp	10	1	1	-	-	1	-	-	-	-
20:02	40 29.010	70 38.124	ISO3	mp	6	1	1	-	-	1	-	-	-	-
20:51	40 28.643	70 36.238	ISO4	mp	3	1	1	-	-	1	-	-	-	-
21:40	40 28.114	70 34.947	ISO5	mp	18	1	1	-	-	1	-	-	-	-
23:15	40 27.487	70 31.500	ISO6	mp	23	1	1	-	-	1	-	-	-	-
0:49	40 26.457	70 26.589	ISO7	mp	31	1	1	-	-	1	-	-	-	-

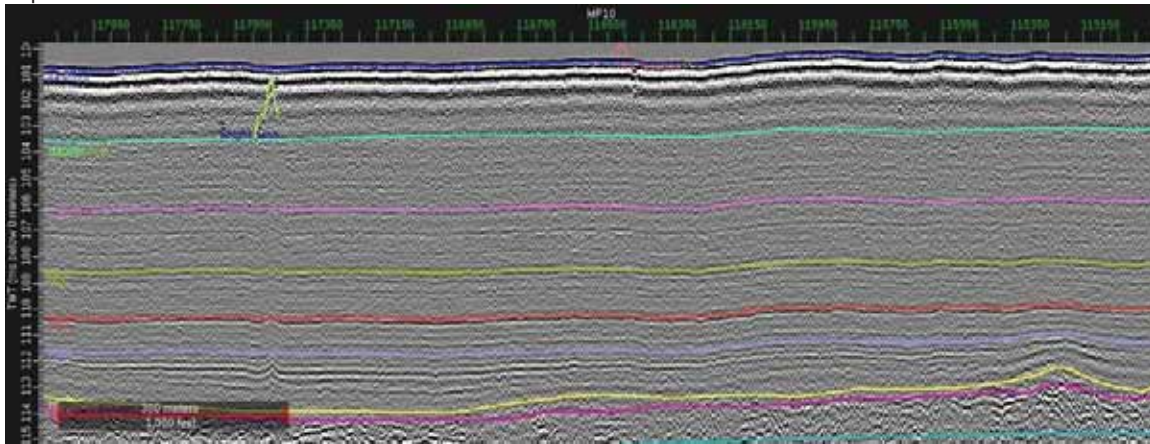


CHIRP sub-bottom profiles for each of the ISO sites appear below. The red carat locates the coring site.

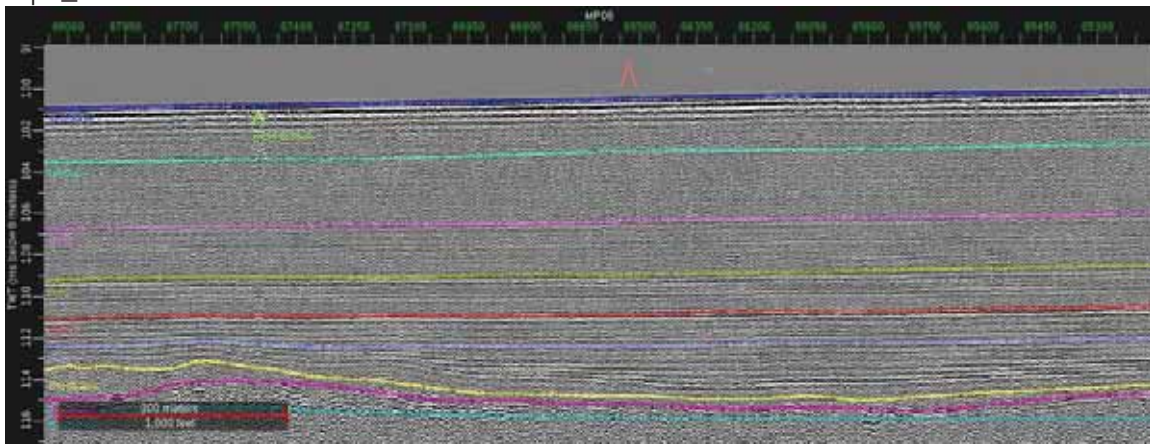
mp38_1



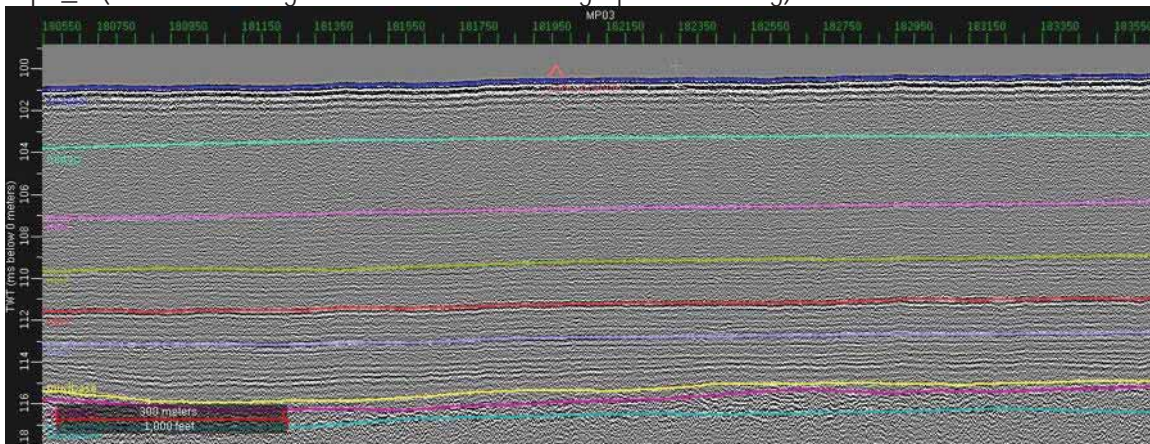
mp10_1



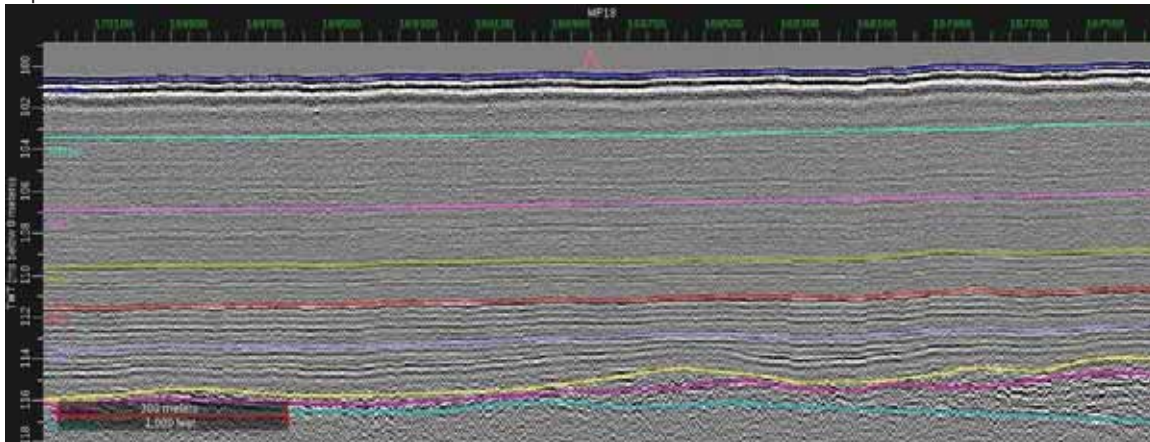
mp6_1



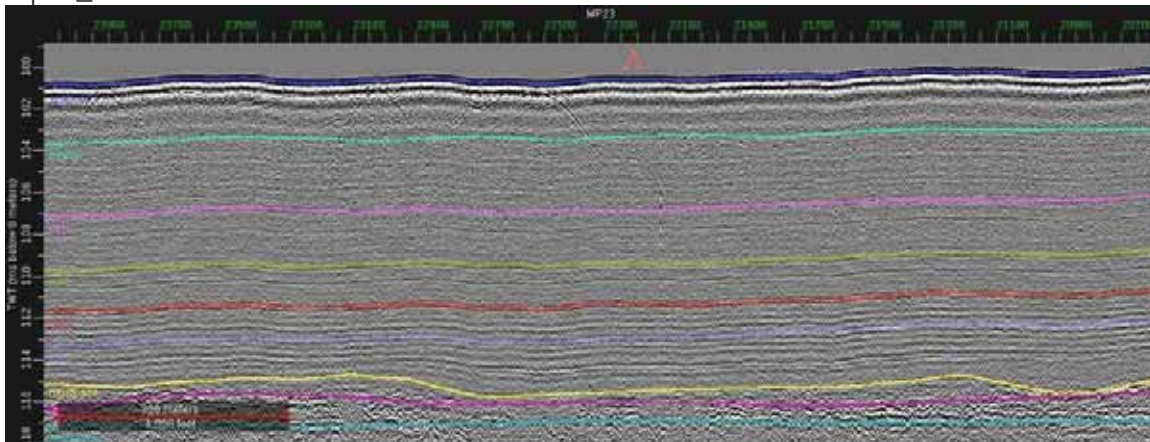
mp3_1 (location of Leg 1 acoustic and oceanographic mooring)



mp18_1



mp23_1



mp31_1

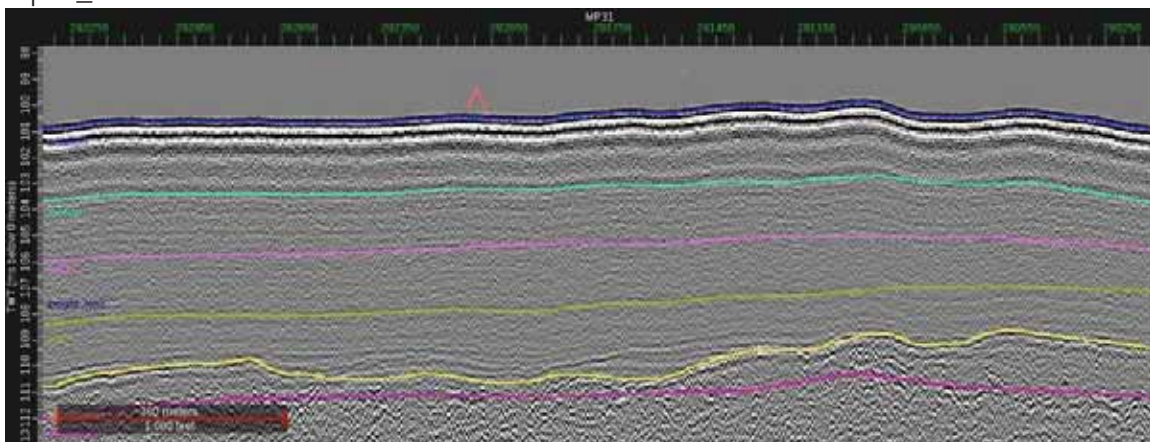


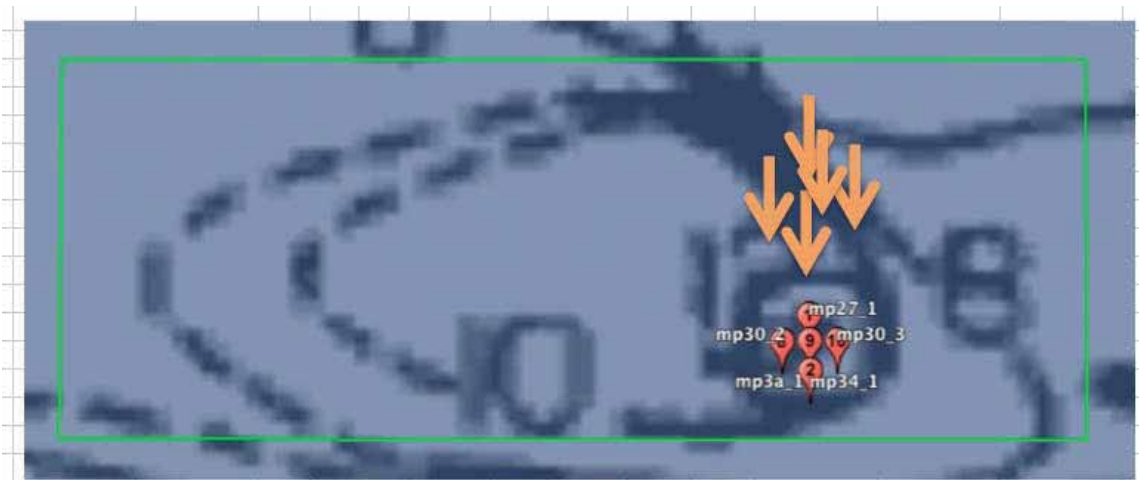
Figure 40: CHIRP sub-bottom profiles for the ISO sites.

The Deepest Part of the Mud – August 11, 2015

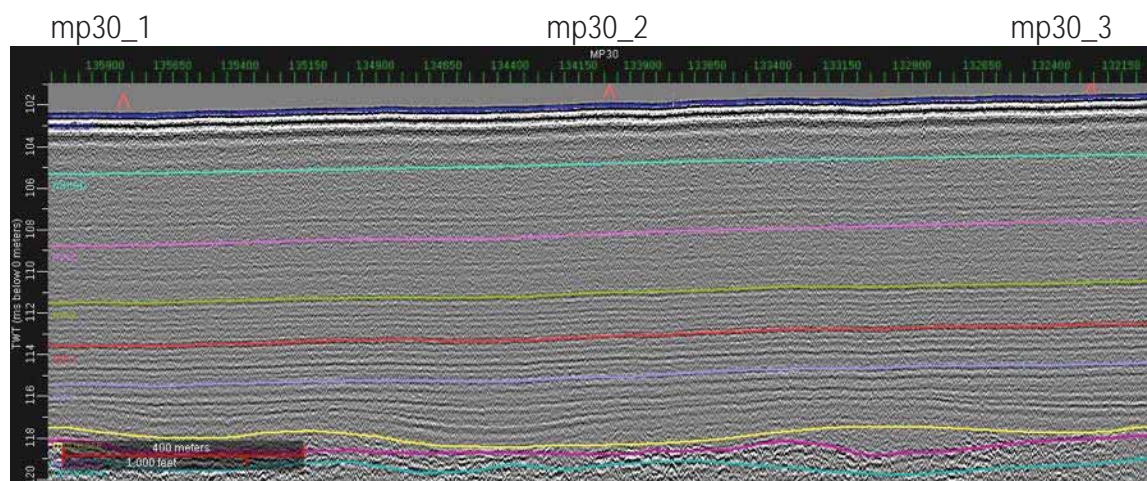
SCE 2015 Survey Cruise

Wilson log pages: 18–19

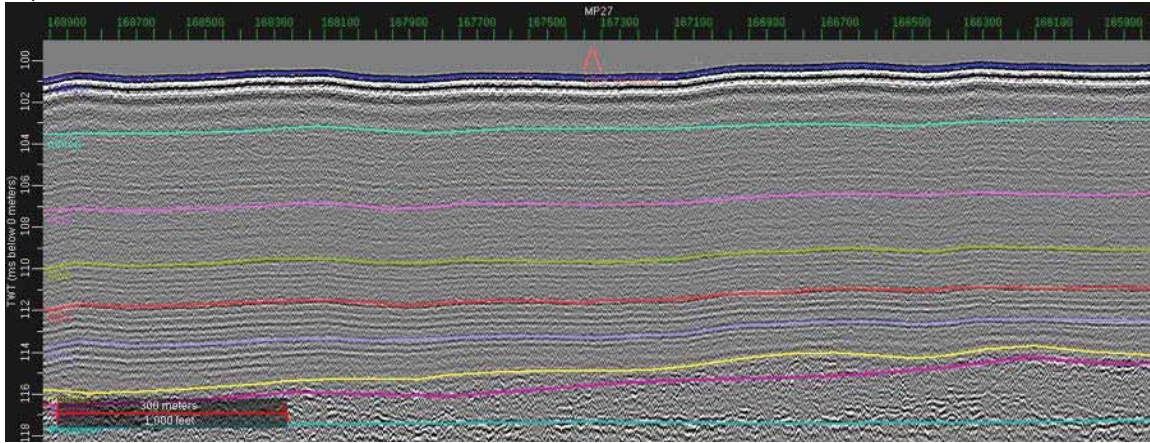
time of first operation	Date				Log ID	ID	Line	Site	CTD	liters			Multi	Vibra
	11-Aug		Bottom	Box						Gravity				
on station	latitude		longitude						Water	Core	Core	Core	Core	
10:45	40	26.533	70	31.590	Sam1	mp	30	1	1	-	-	1	-	-
11:46	40	26.547	70	31.021	Sam2	mp	30	2	1	-	-	1	-	-
12:22	40	26.547	70	30.455	Sam3	mp	30	3	1	-	-	1	-	-
13:13	40	26.946	70	31.033	Sam4	mp	27	1	1	-	-	1	-	-
14:25	40	26.080	70	31.012	Sam5	mp	34	1	1	-	-	1	-	-



CHIRP sub-bottom profiles for each of the ISO sites appear below. The red carats locate the coring sites.



mp27_1



mp34_1

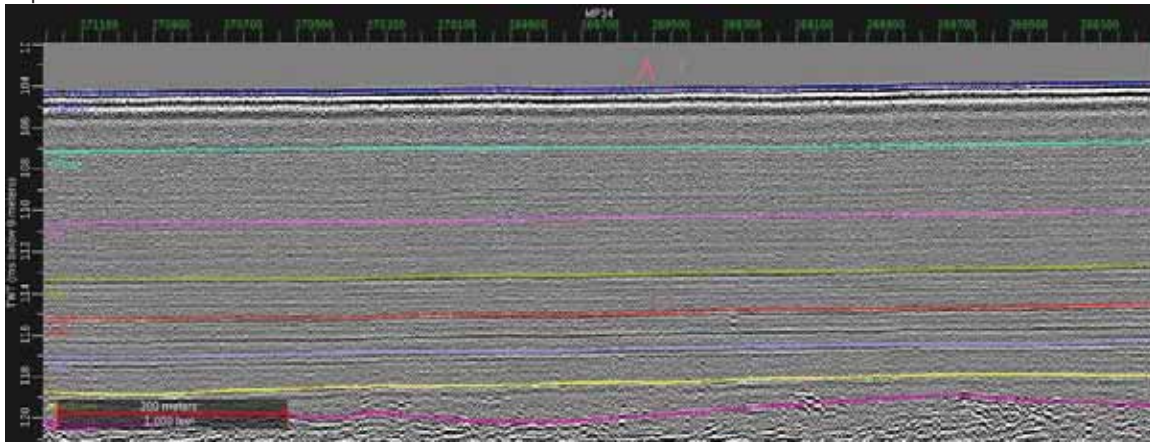
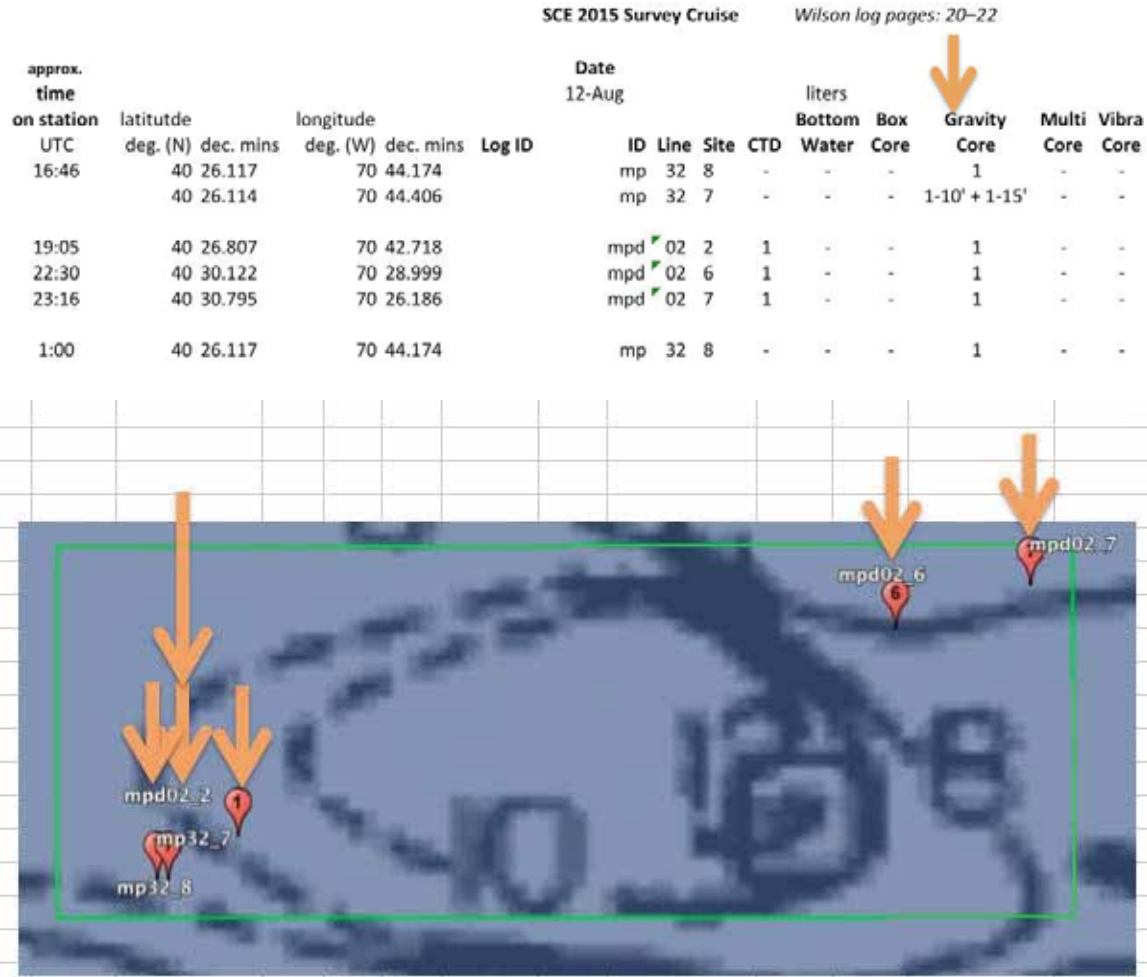
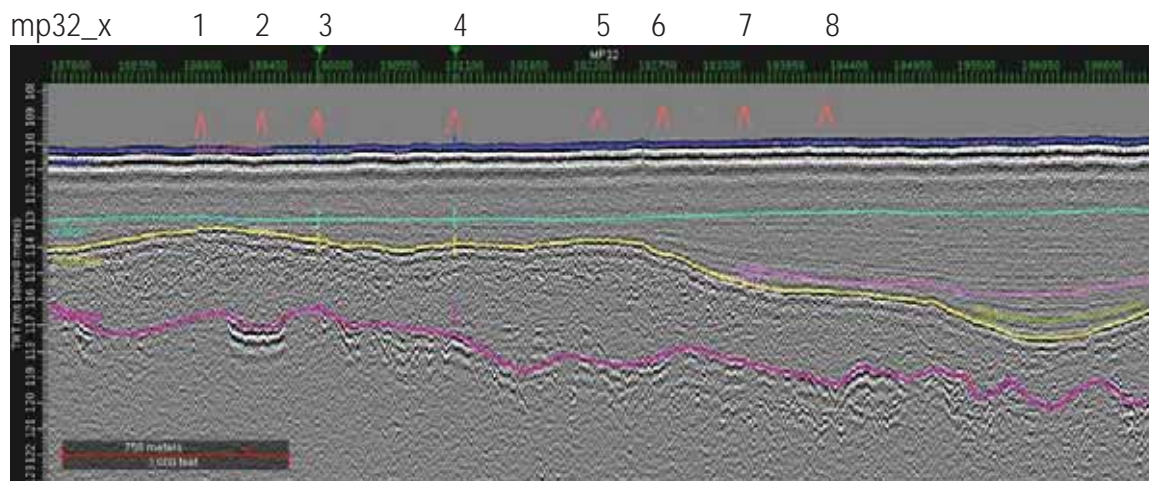


Figure 41: CHIRP sub-bottom profiles for additional ISO sites.

Back to Line 32, the Other Diagonal, and the Long Cores – August 12, 2015

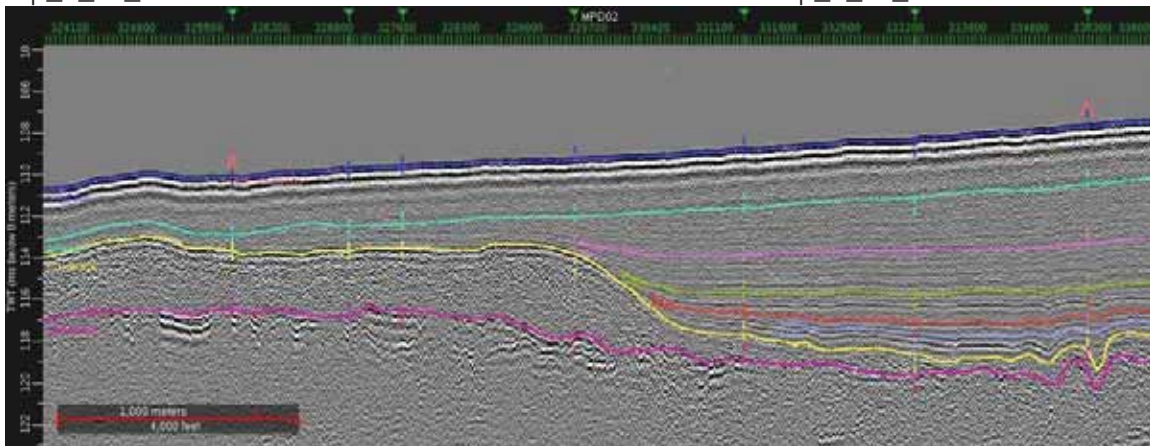


CHIRP sub-bottom profiles for each of the ISO sites appear below. The red carats locate the coring sites.



mp_d_02_1

mp_d_02_2



mp_d_02_6

mp_d_02_7

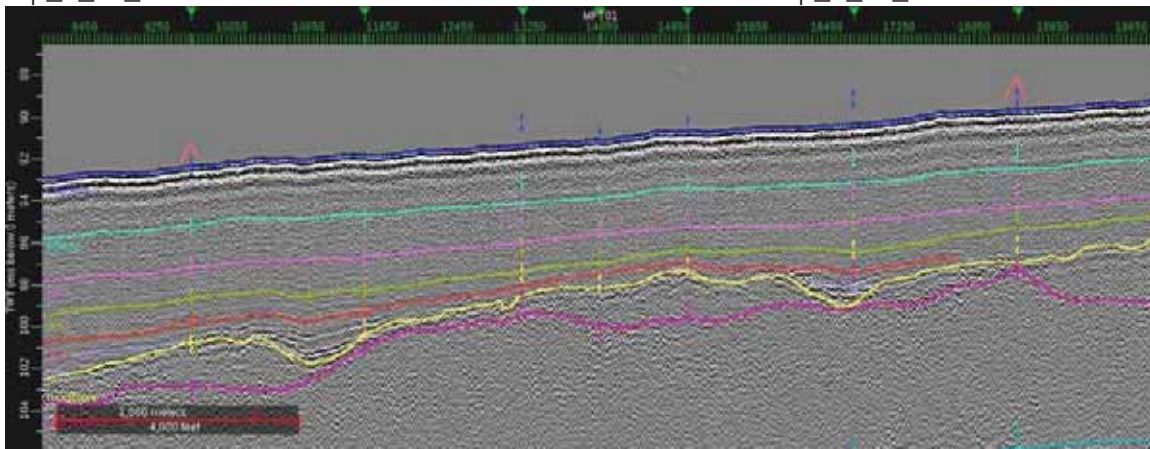


Figure 42: CHIRP sub-bottom profiles for the ISO sites.

SECTION VI. Overview of Shipboard Laboratory Measurements.

In this section, the various shipboard laboratory measurements that were conducted on sediment materials collected during the cruise are discussed. These include core logging, high frequency time-of-flight sound speed and low frequency time-of-flight shear speed measurements, low frequency resonator-based sound speed measurements, and infauna collection.

Core Logging

Allen Reed from NRL:SSC brought two automated core loggers onboard the R/V Sharp for the purpose of logging the collected cores as soon as possible after recovery. Both core loggers suffered mechanical or computer failures, and essentially no core logging was completed during the cruise. The cores were shipped back to NRL:SSC and the core logging was conducted there, wrapping up around September 22, 2015. An example of core logging data is shown in Figure 47 for the core from station mpd_02_2, collected on August 12. That core was sectioned into four subsections, which are indicated with horizontal dashed white lines in the figure. At this writing, core logging data analysis is ongoing. Core logging data will be on the SCE website, when it is ready, and until then, contact Allen Reed for more core logging information.

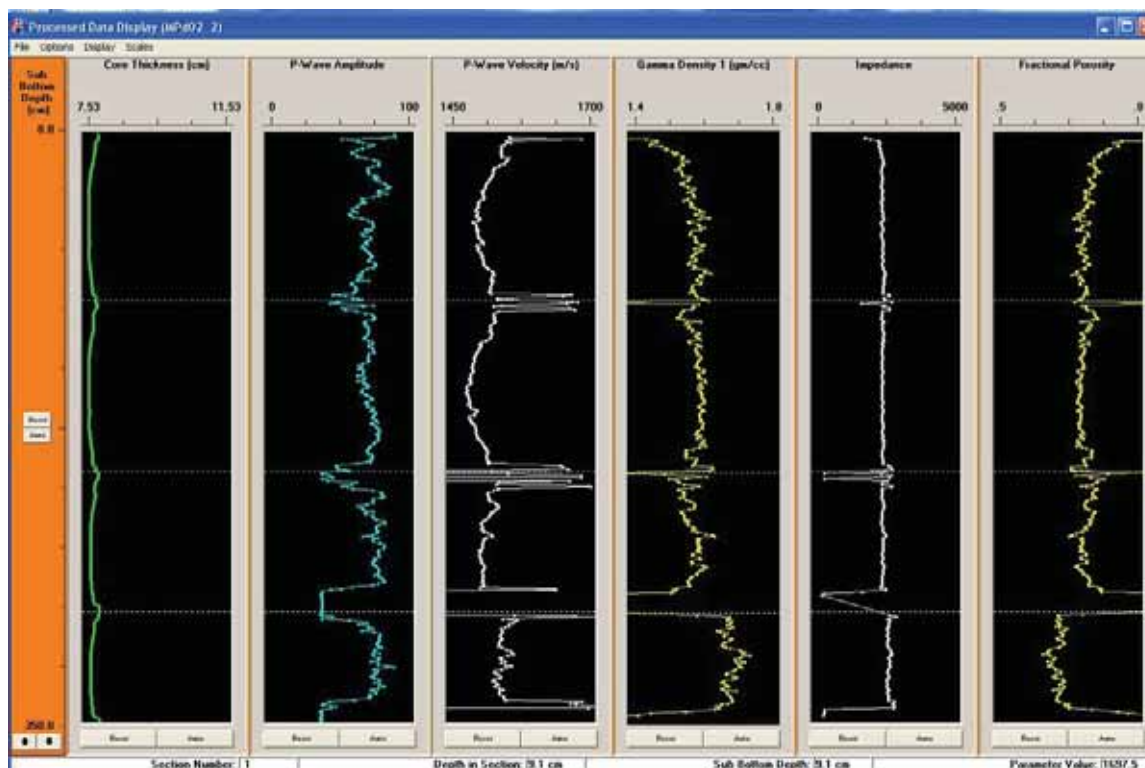


Figure 43: Core logging results for the core from station mpd_02_2, collected on August 12.

High Frequency Sound Speed and Low Frequency Shear Speed

Kevin Lee and Megan Ballard (both from ARL:UT) conducted a number of ship-board measurements the shear and compressional wave speed of marine sediments collected using a box

core. A description of the box with photographs is contained in the coring section of this report. Upon removal from the seafloor, the sediments were placed into either a custom made wooden retrieval box or an Igloo 38-Quart Wheelie Cool cooler for measurements in the laboratory. Measurements were made by inserting a pair of transducers into the sediment and recording waveforms at a number of separation distances. Positioning of the transducers was controlled using frames constructed from 80-20 material. The measurement containers set up with transducers and positioning frames are shown in the shipboard laboratory in Figure 44. The sample container used for each collection along with where the sample was collected from and other supporting information is summarized in Table 5.

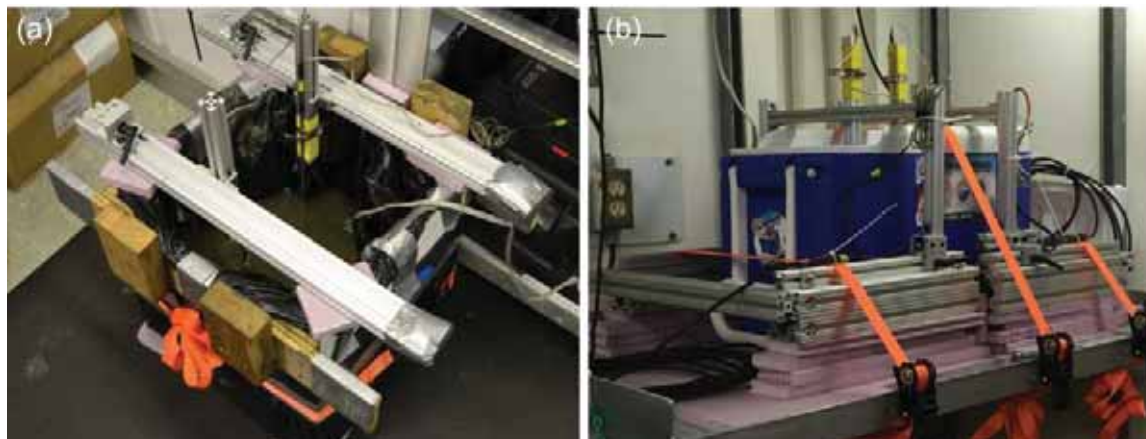


Figure 44: Sample containers for laboratory measurements shown with transducers: (a) custom made wooden retrieval box lined with a plastic trash bag and (b) Igloo 38-Quart Wheelie Cool Cooler.

The first set of acoustic probe measurements was conducted on sediment from site MP32-1. The measurements were recorded in the wooden retrieval box. The wooden retrieval box was designed so that the interior base dimensions were 14"x14" to fit the open jaws of the box core to receive the marine sediment with minimal sample disturbance. It took two collections of sediment by the box core to fill the wooden retrieval box enough to make acoustic measurements. The sediment had a less dense mud layer several centimeters thick, which overlaid a more compacted mud. By placing the second collection of sediment on top of the first, the structure of the mud was significantly affected.

The wooden retrieval box was filled on the deck of the ship, and then the sample was brought into the lab and measurements of the shear and compressional wave speed were acquired. Figure 45a shows the mud immediately after it was deposited into the wooden retrieval box: a more liquid layer of mud is observed over a block of dense mud. Several hours later, the mud was photographed again, and a large number of brittle stars were observed on the surface of the mud. These brittle stars can be seen in Figure 49b. Because there was not a layer of water over the mud, the brittle stars all came to the surface and died.

First, an attempt was made to make shear wave measurements using the "Shirley" benders [D. Shirley, "An improved shear wave transducer," *J. Acoustic Soc. Am.* 63 (5), 1643-1645 (1978)]. These measurements were not successful because the signal to noise ratio was too low. Next, the "Richardson" benders [M. Richardson and K. Briggs, "*In situ* and laboratory geoacoustic measurements in soft mud and hard-packed sand sediments," *Geo-Marine Letters*, 196-203 (1996)] were utilized for shear wave measurements. These benders were able to produce a higher signal

level and they were used for the all the shipboard measurements. The shear wave measurements for the MP32-1 site were calculated based on data from four separation distances. The estimated shear wave speed was 8.7 m/s in the band from 200 Hz to 400 Hz, as shown in Figure 49d. Compressional wave measurements were also acquired using the “Richardson” benders, with the faces of acoustic elements orientated towards each other. The estimated compressional wave speed, also calculated based on data from four separation distances, was 1537 m/s in the band from 10 kHz to 500 kHz, as shown in Figure 49c.

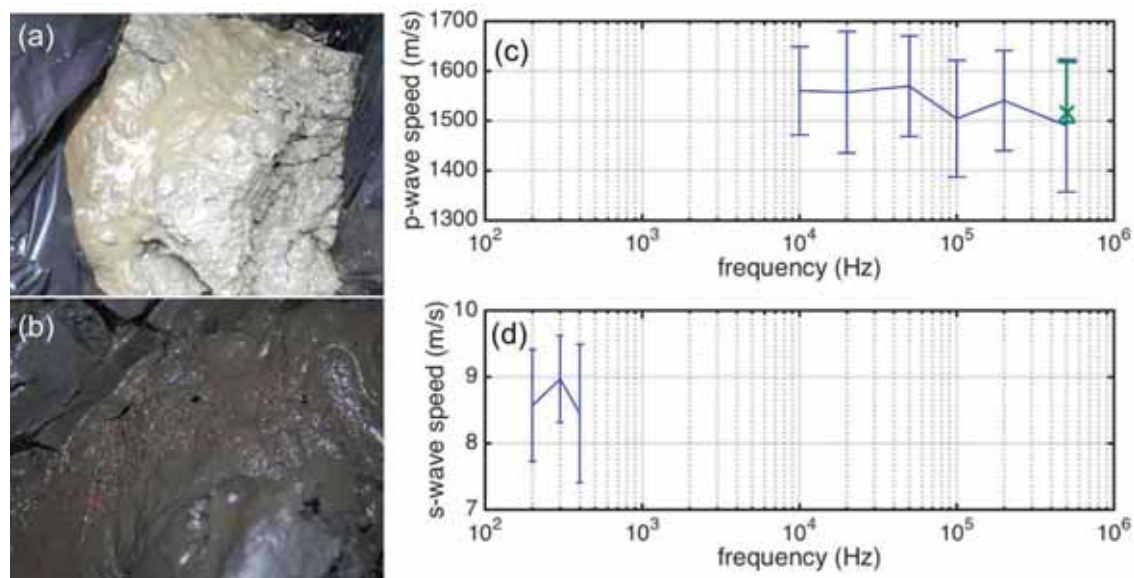


Figure 45: The photographs show the sediment (a) immediately after collection at 9:02 and (b) later in the day at 15:24. The difference in the color of the mud is from the different lighting conditions. Measurements of (c) compressional wave speed (box core measurements from lab in black; core logger measurements from multicore in green) and (d) shear wave speed in sediment collected from the MP32-1 site.

Additional sediment samples were collected from the Seep 1 site using the box core. The wooden retrieval box was filled in the same way described previously, and measurements of compressional and shear waveforms at several separation distances were recorded. A layer of water covered the mud and the infauna were assumed to survive throughout the experiment. However, positional uncertainty caused these measurements to be unsuitable for estimating wave speed. Because the wooden retrieval box became water saturated after several hours and had to be removed from the dry lab, no additional measurements could be acquired from this sample.

Sediment from the Seep 1 site was also used to fill the Wheelie Cool cooler. To fill the cooler, sediment from the box core had to be dumped into a container with dimensions greater than the open jaws of the box core and then transferred to the cooler. It took two collections from the box core to fill the cooler. The Wheelie Cool cooler with its positioning framework is shown in Figure 44a and Figure 44b. The advantages of the Wheelie Cool cooler are that it is water tight and equipped with rigid framework for higher accuracy transducer positioning. The acoustical experiments in cooler were carried for several days.

First a series of shear wave measurements were acquired. At each separation distance, waveforms were recorded over an extended period (approximately 24 hours) to understand the settling of the mud over time. Figure 46a and 46b show data from the settling measurements for a separation distance of 7.46 cm. The delay time of the peak on the received waveform from measurements recorded over a 22.5 hour period is shown in Figure 46a. In general, a reduction in the delay is observed as settling time increases. Selected waveforms from the settling experiment are shown in Figure 46b. For longer settling times, the shear wave arrives earlier and (in general) with greater amplitude. For each of the separation distances, the settling measurements were acquired; the data shown here are representative of the other separation distances. The shear wave speed estimated from the settled shear wave data was 6.1 m/s over the band 200 Hz to 400 Hz, shown in Figure 46c. Allowing the mud to settle slightly increased in the estimated wave speed; using the shear waveforms recorded initially after positioning the transducers yielded an estimated shear wave speed of 5.3 m/s.

The shear wave speed measured at the Seep 1 site is slower than the shear wave speed estimated at the MP32-1 site. One possible explanation for this difference is that the sediment sample at the MP32-1 was not completely water saturated. Another difference is that the infauna were alive during the shear wave measurements in the cooler, but were probably not alive during the measurements in the wooden retrieval box.

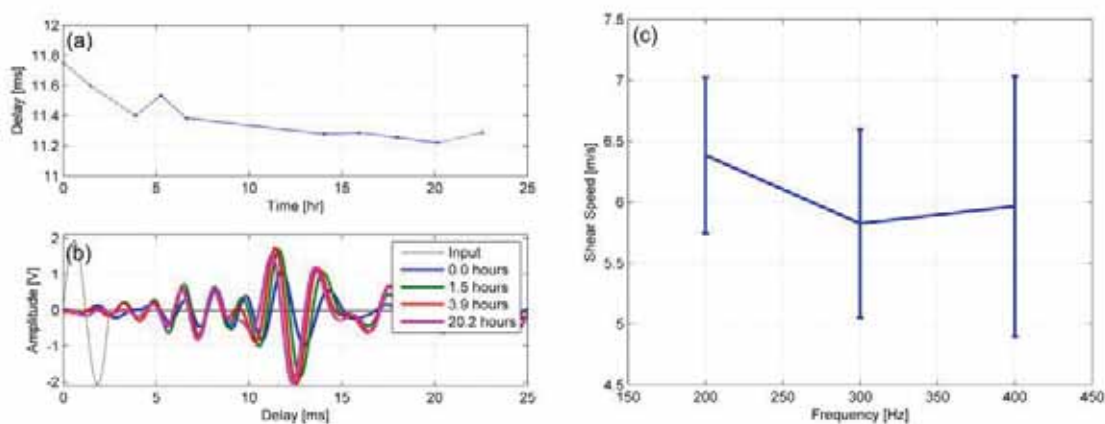


Figure 46: Shear wave settling measurements from Seep1 site at 400 Hz: (a) delay time of the peak on the received waveform from measurements recorded over a 22.5 hour period and (b) selected waveforms from the settling measurements. (c) Shear wave speed estimated from the settled data.

After the shear wave measurements were completed, the compressional wave data were recorded. Settling measures were acquired for up to 15 hour periods at six separation distances. Figure 47a and Figure 47b show data from the settling measurements for a separation distance of 7.46 cm. The delay time of the peak on the received waveform from measurements recorded over a 15-hour period is shown in Figure 47a. In general, a reduction in the delay is observed as settling time increases. Selected waveforms from the settling experiment are shown in Figure 47b. For longer settling times, the compressional wave arrives earlier and with greater amplitude. The delay time is shown as function of separation distance by the blue dots in Figure 47c. Comparing the measured delay to the linear fit (red line) there is evidence of a trend in the data. Specifically, the larger separation distances, which were recorded first, are biased toward a shorter delay time than specified by the linear fit.

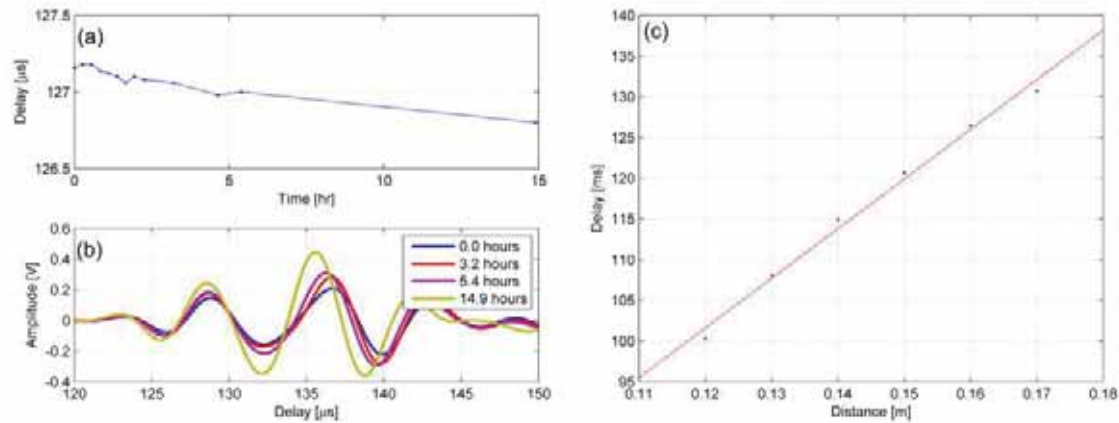


Figure 47: Compressional wave settling measurements from Seep1 site at 200 kHz: (a) delay time of the peak on the received waveform from measurements recorded over a 15 hour period and (b) selected waveforms from the settling measurements. (c) Measured delay time versus position (dots) with a line fit (line) for a frequency of 100 kHz.

During the time the compressional wave data were collected, the brittle stars were observed to migrate from the center of the cooler to the left side of the cooler. By the time the measurements were completed, the infauna was fully concentrated on the left side of the cooler and had stopped moving. It is believed that they ran out of oxygen and died. Therefore, two additional sets of compressional wave data were acquired to obtain an estimate compression wave speed without infauna (sampling the center of the tank) and with infauna (sampling the left side of the tank). However, the infauna were believed to have died by the time these measurements were acquired. The sound speed estimates from both the left side and center of the tank were based on four separation distances. The estimated wave speeds are shown in Figure 48a. The estimated wave speed from the region where the dead infauna were present (1467 m/s) was significantly lower the region where no infauna were observed (1588 m/s). Comparing the compressional wave speed with no infauna present from the Seep1 sediment collection to the MP32-1 collection which was also believed to be absent of infauna, similar compressional wave speeds were estimated.

As another attempt to understand the change in the Seep 1 sediment acoustic properties over time, sound speed was calculated from the difference of the nearest pair of separations divided by the difference in the corresponding delay times. The data show a clear trend in decreasing sound speed as separation distance is decreased. Recalling that the measurements for the greatest separation distance were recorded first, this can be interpreted as a decrease in sound speed over time. The estimate of the sound speed is confounded by the significant period of time that elapsed between when each position was acquired. For this reason, the values of the estimated sound speed are not representative of the true sound speed, but the data are an indicator of the change in the sediment properties.

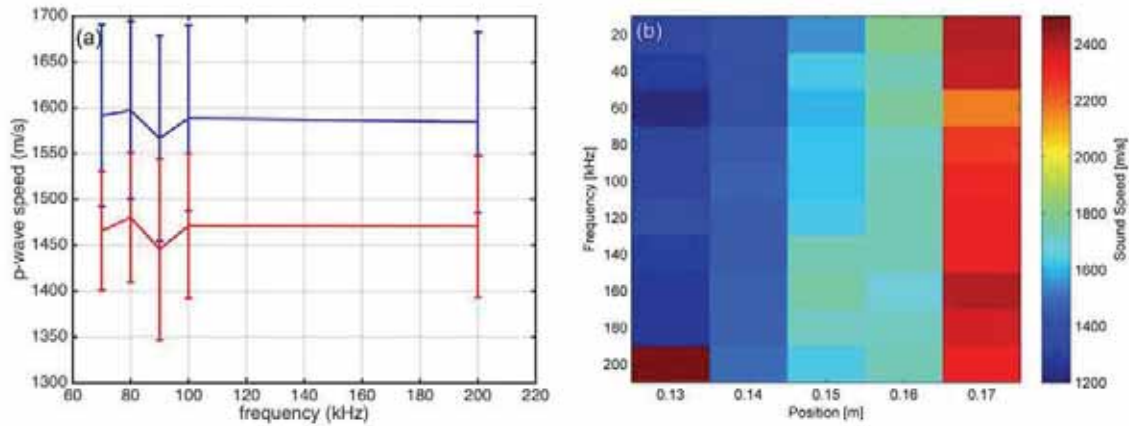


Figure 48: (a) Compressional wave from the center and left side of the tank. (b) Sound speed calculated from settling data, using the nearest pairs of measurements.

After completing the acoustic measurements shown in Figure 48a, sediment samples were extracted from the center and left side of the cooler, from the middle of the propagation path. These samples were packaged in syringes, frozen, and shipped back to ARL:UT for later analysis. Micro-CT imaging of these samples to identify possible mechanisms responsible for the observed difference in the compressional wave speed has been proposed.

Table 5: Infauna collection sites, sampling methods, and comments.

Date	Station	Core type	Measurements	Comments
6-AUG-2015	mp32-1	Wooden Retrieval Box	Shear and Compressional Wave Speed	Exposed mud at the surface of the sample the sample may have signified incomplete saturation of the mud. The worms died, possibly because the mud was not completely saturated.
7-AUG-2015	Seep1	Wooden Retrieval Box	Shear and Compressional Wave Speed	Positional Uncertainty caused these measurements to be unsuitable for analysis
8-AUG-2015	Seep1	Wheelie Cool Cooler	Shear and Compressional Wave Speed and Settling	Settling measurements were acquired over several days. By the time the final wave speed measurements were completed the worms had died.

Low Frequency Resonator-Based Sound Speed Measurements

A low frequency acoustic resonator measurement system was onboard the ship during Leg 2, and a subset of MC-800 multicore samples were investigated using the resonator technique. The samples were transferred from the MC-800 core tubes into the resonator using an extrusion technique. At the time of publication, results from this work are not yet available, but analysis is underway. It is expected that low frequency (1 kHz to 5 kHz) sound speed measurements will eventually be available. In addition, a settling experiment was also conducted, in which the sound speed was measured as a function of settling time after collection. Contact Preston S. Wilson (pswilson@mail.utexas.edu) for more information about this work.

Infauna Collection and Processing

Kevin Lee, Megan Ballard, and Gabe Venegas (all from ARL:UT) collected infauna samples from a subset of box cores and multicores and processed the samples on board for shipping to and later analysis by Kelly Dorgan (DISL). The samples were collected in different manners, as described below, depending on the core-type and other laboratory shipboard measurements taken on the samples prior to processing. All samples were processed using the same method, also described below.

For box core samples, the box core contents were first transferred to a secondary container. The sediment was then sampled from the secondary container using a 2-7/8-inch inner diameter plastic core liner. High-frequency compressional wave and low-frequency shear wave measurements were conducted as described previously in the secondary containers prior to sub-sampling and sieving for infauna content.

The MC-800 multicorer had eight cores, which were plunged simultaneously into the seabed. At least one of the cores from these sites was reserved for infauna processing. Each core was transferred directly into the processing sieve in these cases. The core inner diameter was 3-7/8-inches. In other cases, some of the MC-800 cores were sub-sampled with a 1-7/8-inch inner diameter plastic core liner, and then transferred to an acoustic resonator tube for low-frequency sound speed measurements. After the resonator measurements were completed, the entire sub-sample was then processed for infauna content.

All samples were processed by sieving the sediment through a 500-micron sieve under a running seawater faucet in the wet lab of the R/V Sharp. Once all of the fine sedimentary material was sieved out, all of the remaining materials—infauna, shell fragments, and worm tubes—were placed into sample containers holding 190-proof, non-denatured ethanol to preserve the infauna specimens for later analysis. Rose Bengal was added to the ethanol (0.5 g/L) to stain the infauna tissue. The sample containers were then marked with the core location, core type, and core or sub-core tube diameter, and then stored for shipping to Kelly Dorgan at DISL at the end of the survey. Two additional infauna samples sent to DISL were a sea pen collected from the MC-800 frame at the station Tioga and a worm tube with worm inside from the box core at station Seep1. Examples of the collected infauna specimens, which were photographed at DISL under an optical microscope after the survey, are displayed in Figure 49a – Figure 49c. Additional analysis will be carried out to determine animal morphology and estimate infauna density based on collected specimens.

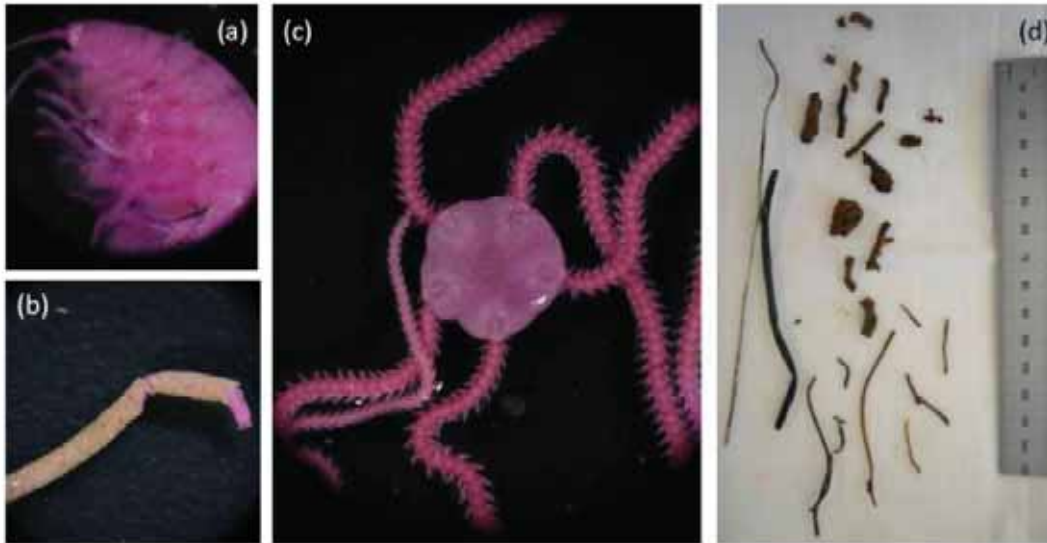


Figure 49: Post survey photographs taken under an optical microscope at DISL show (a) an amphipod crustacean, (b) a worm with its tube still intact, and (c) a brittle star. A collection of worm tubes and worm tube fragments collected from the box core at the station Seep1 is shown in (d).

Several intact worm tubes and worm tube fragments were also collected from box cores at the station Seep 1, stored in a container with bottom water, and shipped to ARL:UT at the end of the survey. Kevin Lee and Preston Wilson plan to conduct ultrasonic measurements on the worm tubes to begin characterizing their acoustic scattering properties. The worm tubes and worm tube fragments are shown in Figure 49d.

Table 6 below summarizes all of the infauna collection activities from the second leg of the cruise. The date, station, core type, number of sub-samples, and core liner inner diameter (ID) used for sampling are indicated. The comments indicate if onboard laboratory acoustic measurements were performed on the sediment samples prior to sieving for infauna, the samples were taken directly from the MC-800, or there are other relevant details.

Table 6: Summary of infauna collection.

Date	Station	Core type	# of sub-samples	Core liner ID (inches)	Comments
6-AUG-2015	mp32-1	Box core	4	2-7/8	Compressional and shear wave measurements collected prior to sieving
7-AUG-2015	Tioga	MC-800	1	3-7/8	Sample taken directly from core liner
7-AUG-2015	Tioga	MC-800	1	1-7/8	Low-frequency sound speed resonator measurements

					taken prior to sieving
7-AUG-2015	Tioga	MC-800	1	N/A	Sea pen collected from MC-800 frame
7-AUG-2015	mp32-6	MC-800	1	3-7/8	Sample taken directly from core liner
7-AUG-2015	mp32-6	MC-800	1	1-7/8	Low-frequency sound speed resonator measurements taken prior to sieving
8-AUG-2015	Seep1	Box core	5	2-7/8	Compressional and shear wave measurements collected prior to sieving
8-AUG-2015	Seep1	Box core	Individual worm tubes	N/A	Worm tubes collected for acoustic scattering measurements
8-AUG-2015	Seep1-1	MC-800	1	3-7/8	Sample taken directly from core liner
8-AUG-2015	Seep1-1	MC-800	1	1-7/8	Low-frequency sound speed resonator measurements taken prior to sieving
8-AUG-2015	Seep1-2	MC-800	1	3-7/8	Sample taken directly from core liner

Parametric Sub-Bottom Profiler

A parametric sub-bottom profiler was brought onboard for use during leg 2, but technical difficulties with the equipment prevented the collection of useable data. For more information about this work, please contact William Sanders (William.Sanders@nrlssc.navy.mil).

Seabed Characterization Experiment Survey Cruise 2015 Website

The common shared data will be archived on a website which is currently under construction. The web address is <http://www.arlut.utexas.edu/sbcex>.

Bibliography

1. Twichell, D. C., C. E. McClennen, et al. (1981). "Morphology and processes associated with the accumulation of the fine-grained sediment deposit on the southern New England shelf." *Journal of Sedimentary Research* 51(1): 269–280.