Cruise Report - NBP2402

February 3, 2024 – February 23, 2024

Lyttelton, New Zealand to McMurdo Station, Antarctica

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Science Overview

Understanding Earth warming requires studies on chemical and biological cycles in both polar regions and many environments in between. Methane is studied because it is abundant throughout the Earth and has approximately 25 times greater warming capability than carbon dioxide. While the Arctic has been the primary Earth climate change focus, the Antarctic, including the Ross Sea, has a vast reservoir of carbon and has recently been recognized to be one of the most rapidly warming regions on Earth. Our emphasis on the Ross Sea is supported with recent studies, which show long time past changes in temperature and sea level. This large amount of carbon appears to be sealed in the form of gas hydrate, an ice-like material rich in methane that forms within sediment pore space, as evidenced by key seismic data including patterns that suggest the methane could be from a petroleum source. The primary goal of this project is to assess the potential for carbon release from the melting of gas hydrates with climate change, assessment of how vigorous this activity is currently.

This project is broken into two parts, a geophysical survey and a coring and sampling program, both of which focus on the west flank of the Discovery Rift, and onto the Lee Arch of the Terror Rift system in the Ross Sea. Each requires separate data acquisition components conducted in sequence with geophysical surveying preceding coring. This report covers the first survey on the *RVIB N. B. Palmer* conducted in February 2024 to conduct the geophysics needed to characterize the region, assess the distribution and concentrations of gas hydrate, and determine targets for the subsequent coring and sampling program. The second coring and sampling cruise will follow on the *RVIB N. B. Palmer* in March 2025.

The Carbon sources that will be investigated include phytoplankton, glacier ice, shallow sediment carbon, and oil contained in deep sediment, and methane trapped in gas hydrates. Data collection will include seismic profiling, broad geochemical data, and geo-microbiology parameters. Data obtained will provide a new understanding of climate change and the effect on the ocean carbon budget. We bring together an outstanding team of experts in geophysics, ocean water column and seafloor chemistry, and biology. With global recognition of climate change there is need for uniform, thorough assessment across the Earth to develop adequate understanding of carbon cycling and related warming. With this accomplishment there will be a data baseline of our current condition and provide capability to assess current and future anthropogenic influence on the natural Earth carbon cycle. Education related to Earth warming requires thorough provision of information through all academic levels, government and the public. Our project will fund 4 graduate students and support the training of undergraduate researchers. Results will be disseminated internationally to non-scientific audiences through field blogs, PI Websites, numerous education and outreach activities, as well as being incorporated into graduate and undergraduate courses. Additionally, this project will provide training and support for undergraduate, graduate, and early career researchers at a Hispanic Serving Institution.

Cruise Summary

Over a 10-day period between February 13 – 23, we conducted two active source seismic data operations on the *RVIB N. B. Palmer* across the Terror Rift in the Ross Sea to acquire the data needed to meet the science objectives described above. The data acquisition consisted of two separate operations.

During the first operation, we deployed 11 ocean bottom seismometers (OBS) at 10 stations spaced ~ 5.4 km apart across the western flank of the Discovery Rift and eastern flank of the Lee Arch ~ 50 km south of the Drygalski Ice Tongue (Figures 1 & 5). Upon arrival at the survey, the weather was favorable with modest winds and calm seas. We began OBS deployments at Station 1. After successfully deploying the first OBS, we attempted to range to the instrument on the seafloor, but were unable to get a range response. We deployed a second OBS at Station 1 to see if the problem was due to that specific instrument. This was also unsuccessful and we had to abandon more attempts at ranging to any of the instruments due to time constraints. The remaining 9 OBS were deployed successfully and we switched to seismic shooting to these instruments. At the start of the OBS line, we had some airgun issues (guns failing to fire or dropping out of timing specs), and had to restart the line twice, but succeeded in shooting a complete line in 3 segments. Once shooting was complete, we returned to retrieve the instruments. At the time we released the first instrument, the weather worsened with high winds (25 kts sustained), snow, fog, and poor visibility. Spotting the instrument on the surface in these conditions and recover it in the rough seas became very challenging and risky. During instrument recovery, a large wave knocked down three of the MTs and caused minor injuries. The instrument was recovered, but it was apparent that we were not going to be able to recover the rest under those conditions.

Due to the bad weather, we decided to move to the area north of the Drygalski Ice Tongue, where we could deploy the multichannel seismic gear in the lee of the ice and prepare to shoot the long N-S seismic line. With reasonably calm conditions, we successfully deployed the seismic gear and started working our way to the south to begin shooting the line and conduct the multichannel portion of the survey. As we progressed south, the weather worsened. The winds were 30 -35 kts sustained with gusts to ~60 kts.

As we passed the western side of the Drygalski Ice Tongue, we encountered several windblown lines of brash ice that were kms long, ~ 500 – 1000 m wide. We passed two of these with no problem for the towed equipment. The Palmer was able to push a wide enough swath that stayed open long enough for the guns and streamer to pass through. However, we encountered a 3rd line of brash ice that had larger ice that stood up higher in the water. As we passed through this line of ice, the high winds moved these larger pieces into the Palmer's wake very quickly and several of them apparently crashed into the airguns and worked under the lead-in section of the streamer. We believe the streamer rode over the top of the ice (the bird depths successively rose to the surface from front to back) and hooked a large chunk. Suddenly, we could no longer detect the tail of the streamer. We noted the location, and immediately retrieved all of the gear to find the ice had damaged the airgun umbilical, air hoses, and solenoids, and the tail half of the streamer was gone. Once all gear was recovered, we returned to the location where we thought the incident occurred and began a search. Despite high winds and poor visibility, and the very small tailbuoy (~ 1 m long), which was our only target for spotting the streamer, we were able to find the streamer tailbuoy in between large chunks of floating ice. We were successfully able to attach a yale grip and line to the

tail of the streamer, and untangle it from several ice chunks. We recovered all of the streamer and birds, but three of the 50-m sections no longer functioned, and 3 birds were too badly damaged to use.

Following the streamer recovery, we tested and rebuilt the streamer and airguns with available parts. The airgun umbilical and hoses were replaced with spares. We used a spare streamer section and remaining functional streamer to configure a 104-channel, streamer with 650 m of active section, 75 m shorter than our original streamer length.

With the streamer reconfigured and recovered on the winch, we successfully recovered the remaining 10 OBS in calm weather, and began the multichannel survey. We encountered multiple problems with airgun solenoids and air hose leaks, which required us to abandon using two GI guns for our multichannel acquisition. We discovered that the replacement air hose that we used for spares was not adequate and were forced to use the best of the used hoses that had been working prior to the ice crash. Fortunately, we were able to make this work, but for just a single airgun.

We managed to acquire 615 km of seismic profiles despite continual issues. The weather was often poor with high winds and rough seas. We encountered very large pancake ice that cut the streamer lead-in section and it had to be replaced with a spare. We had numerous airgun issues that required 6-8 hours of repairs each time. Ultimately, we acquired nearly all of the originally planned mcs lines, except for the long extensions of the N-S lines. Despite the acquisition issues, the data are high quality and we will be able to achieve our survey objectives.

Summary Sheet

RVIB Nathaniel B. Palmer Cruise NBP2402

Cruise dates: February 3, 2024 – February 23, 2024 (21 days)
Ports: Lyttelton, New Zealand to McMurdo Station, Antarctica

MCS:

Seismic Source: One gun in 105/105 in^3 mode
Streamer: Geometrics GeoEel solid digital streamer, 104 channels, 6.25 m groups, 756 m max offset.
Depth control: five Ion 5011 compass depth controller birds. (5010 w/o compass?)
Shot spacing: 12.5 m
Recording parameters: 500 µs sampling, 4 second records.
Total number of km for streamer data: 615 km

OBS:

OBS Instruments: GeoPro SEDIS VI deployed with 3 component sensors and geophone
Seismic Source: Two GI guns in 105/105 in^3 mode
Shot spacing: 25 m
Total number of OBS drops: 11 (10 stations on Line R7 at 5.4 km spacing)

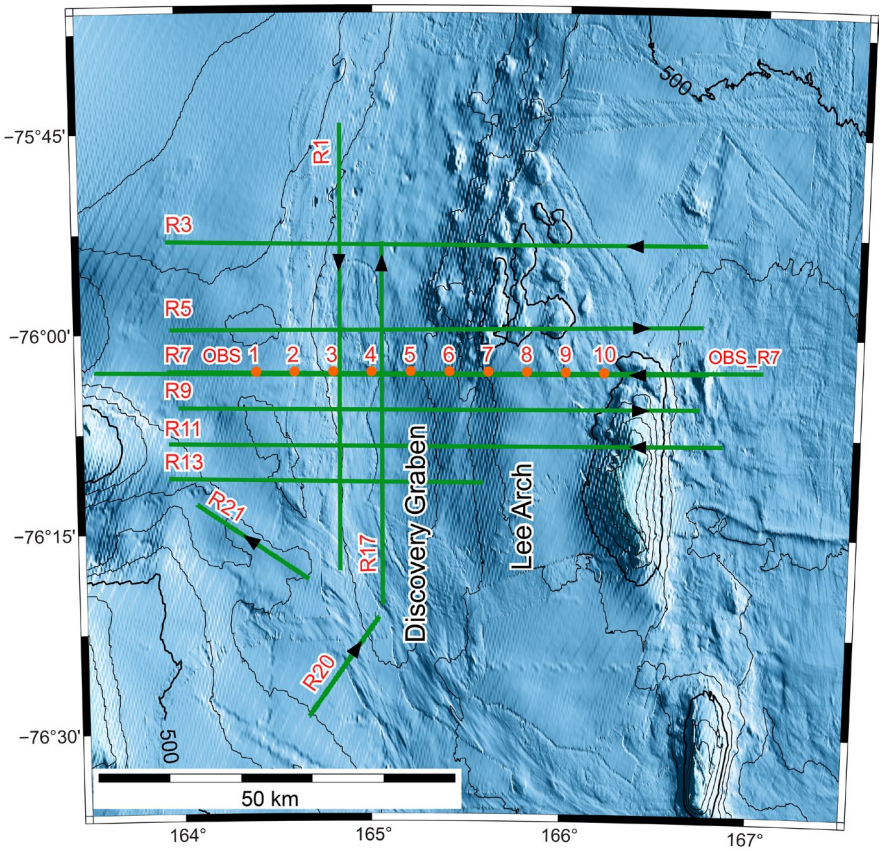


Figure 1. Shaded relief bathymetry map showing locations of multichannel seismic lines (R1-R21) and OBS stations (OBS 1 – OBS10). Arrows show the shooting direction. Note that OBS 1 and OBS2 were both deployed at OBS Station 1. Contour interval is 100 m.

Participants

Figure 2. NBP2402 cruise participants.

Edison-Chouest Crew

Brandon Bell	Master
Rick Weimken	Chief Mate
Ryan MacLellan	2nd Mate
Alexander Donovan	3rd Mate
Johnny Pierce (JP)	Chief Engineer
Tom Tougas	1st Engineer
Jason Cheng	2nd Engineer
James Donovan	3rd Engineer
Fernando Naraga	AB – Seaman
Bienvenido Aaron	AB-Seaman
Jermaine Dela Cruz	AB Seaman
Akashia James	Cook
Jullian Isaacs	AB-Cook

Gerry Simeon	AB – Cook
Ronnie Carpio	AB - Seaman
Gernie Dela Cruz	OS –Cook
Lauro Garde	AB – Seaman
Danilo Plaza	Oiler
Ric Tamayo	Oiler
Luel Aragon	Oiler
“OG” Pagdanganan	Oiler

Antarctic Support Contract

Cindy Dean	MPC
Barry Bjork	IT
Lily Petersen	IT
Hila Shooter	MT
Jack Greenberg	MT
Matt Louis	MT
Steve Hudson	Doctor
Scott Walker	IT
Sheldon Blackman	IT
Andrew Micks	MT
Emma Hayward	MT
Annabelle Adams-Beyea	MLT

Science Party

Nathan Bangs, University of Texas –	Chief Scientist
Ingo Pecher, Texas A&M Corpus Christi –	PI
Hoa Yu, Texas A&M Corpus Christi -	Research Scientist
Jess Hillman, NIWA -	Research Scientist
Finn Warnke, University or Auckland -	PhD Student
Hannah Organ, Texas A&M Corpus Christi -	PhD Student
Steffen Saustrup, Texas A&M Corpus Christi -	OBS Technician
Brendon Mendenhall, Scripps Institution of Oceanography -	MCS Technician
Nick Benz, Scripps Institution of Oceanography -	MCS Technician
Amanda Dubuque,	Lead PSO
Edgar Alvarado,	PSO
Heber Hulzar,	PSO
Jimena Ortega,	PSO
Leo DeLaRosa,	PSO
Michelle Klien,	PSO

Narrative

The following describes events of each day during NBP2402. Note that all times are local time (+13 hours throughout the cruise).

Jan 28th

Science party arrived in Christchurch, NZ.

Jan 29th

Taxied to CDC for issuing Extreme Cold Weather gear (ECW) and Covid testing. One positive Covid test of an individual who as not in our immediate group, and not critical to the cruise.

Jan 30th

Free day

Jan 31st

We moved onto *Palmer* at 9:00 AM. Safety briefing and settling into cabins.

Feb 1

Shipment arrived near the end of the day and looked complete. Streamer container was opened and everything was craned onto Palmer.

Feb 2

Container was unpacked and streamer control units moved into forward dry lab. OBS boxes were moved into the Wet Lab to begin setup for the OBS.

Feb 3

Moved to fuel dock and loaded 380,000 gal. of fuel.

Feb 4

Left the dock at 9:00 AM and headed south. Mild to moderate seas in the open water. Weather forecast looked good. We received permission to acquire multibeam on the NZ EEZ, and turned on multibeam once we reached water depths of a few 100 m. Moderate seas with white caps.

Feb 5

Transit with multibeam. Moderate seas with white caps.

Feb 6

Transit with multibeam. Seas calmed down in the afternoon.

Feb 7

Transit with multibeam. Reasonably calm seas and some sunshine.

Feb 8

Sunny morning with modest seas. Spotted our first icebergs. Crossing the Antarctic Circle.

Feb 9

Continued transit.

Feb 10

Met with MTs etc. to go over operations. Seas picked up with high winds.

Feb 11

Met with PSOs to establish gun operation and shut down procedures. Seas still high with strong winds (35 kts. Sustained). Winds slowing our progress.

Feb 12

Arrived on OBS station 1 at ~ 10:30 PM. Began OBS deployment upon arrival.

Feb 13

We deployed OBS1 successfully. We tried to range to the instrument, but were unable to receive range information back from the instrument. Initially we tried pinging with the hull mounted unit, but had no success with generating an acoustic signal. Next, we tried the old deck unit lowered over the side. That unit succeeded in sending the communication signal, but we were unable to receive any range response. We tried repositioning ~500 m offset from the OBS, and again directly over the instrument. Neither worked. We tried the newer deck unit and also had no success. Assuming an issue with OBS77, we tried deploying a second OBS and lowering deck unit in the water down to ~ 25 m. Ranging still did not work. We deployed OBS75 at the same location (OBS station 1) and we had no better success with ranging. We decided to continue with the rest of the deployment hoping to range OBS#5. That was also not successful, and we gave up ranging to the any of the instruments.

Following the OBS deployment at ~ 7:00 AM, we transited to a point ~ 10 km from the start of R7 and began deploying guns. Gun deployment finished ~ 10:00 AM.

At the second OBS crossing, OBS9, we had a 7 min. gap in shooting. We decided to circle and pick up the missing shots. At the same time we noticed issues with firing delays and missed shots on the two GI guns. We decided to retrieve the airguns to fix them during the break. Gun recovery and replacement took 4 ½ hours and shooting resumed.

Feb 14

Winds picked up to 20-25 kts from the south. Temperature dropped to -8° C with windchill of –32° C. Finished shooting OBS line R7 at ~ 5AM and retrieved the guns. OBS recovery began at ~ 7:00 AM. We positioned 500 m downwind of Station 1. The first OBS was released to surface at 8 AM. Strong winds and heavy snow began to fall during the OBS rise to the surface, and visibility dropped to a few hundred meters. Fortunately, we were able to spot the OBS, but strong winds blew the vessel and OBS around quite a bit. Maneuvering took multiple attempts to get the instrument close enough to the vessel to grab the recovery line. A wave hit the MTs hard and slammed them into winch support beams, causing minor injuries.

Because of the high winds and the sea state, we decided to suspend the OBS retrieval and headed to the northernmost MCS, Line, R17, to begin MCS operations. Moved north of the Drygalski ice tongue to get into calm seas in the lee of the ice tongue and within the floating ice to have good conditions to prepare for streamer deployment. Most of the evening and night was spent preparing the streamer and birds.

Feb 15

We move south to open water to begin streamer deployment at ~ 3 AM. Seas were calm this morning near the ice tongue and the winds subsided, which made for good conditions for streamer work. The streamer and guns were deployed and working well; however, the winds were 30 -35 kts sustained with gusts to ~60 kts. As we slowly moved south past the ice tongue at ~ 2 kts, we passed a few lines of brash ice that seemed to be no problem for the towed gear. We had the streamer down deep, ~ 30 m. At the south side of the Drygalski, we ran into a line of brash ice. We seemed to have made it through, and the captain spotted the tailbuoy after it crossed the main brash ice line. However, soon after, the gun array caught on a ice chunk and the guns stopped firing.

At about the same time, the streamer caught an ice chunk and the tension on the cable caused it to break at section 8 of the 15 sections deployed. We retrieved the front half of the streamer along with two of the five depth control birds. We had a record of the position where we lost the tail section and decided to return to the location to look for the lost sections. Fortunately, the captain spotted the tailbuoy floating between two ice chunks and we were able to move up to it within the floating ice.

After about three hours we were able to attach a Yale grip and line to the tailbuoy and recover it. Ultimately, we were able to retrieve all of the streamer sections and all 5 depth control birds. At this point we have everything back, but there was damage that needed extensive work before it could be redeployed. At that time we didn't know the extent of the damage, but estimated at least 12 hours of repairs.

We moved to an area protected by Drygalski and worked on the damaged gear. The weather was still poor in the rest of the survey area, but the forecast was for it to improve. With the better weather, we will moved back south to finish retrieving OBS and try to acquire as much mcs data as our equipment and time allow.

During the ice crash, the ice parted the tow lines to the guns and the guns remained attached by the umbilicals. This strained the umbilicals to the point of parting internal wire connections. The gun towing rail took the largest hit. Some of the individual gun umbilicals were disturbed, but the guns themselves were fine. The spare umbilical had to be swapped out on the gun umbilical reel.

Feb 16

We positioned to the north of Drygalski to find a calm spot to do streamer work on deck. Winds were still 25 – 30 kts, but the swell was low in that position. We began work on the recovered streamer by flaking recovered sections on deck. The initial task was to test which sections and digitizers were still working. After removing the obviously damage sections 7 and 12, we split the 8 recovered 8-channel, 50 m sections into the front and rear that we called the deep and the shallow assuming that the streamer sank in the cold water and hung at the tail from the buoyancy of the floats on the tail buoy. The "deep" tested well, but we discovered no continuity into sections in the "shallow" segment. We began breaking apart the streamer sections to test them individually using the deck cable. The issue we had to resolve was to determine which sections and which digitizers could be reused in order to rebuild the entire streamer and move it on the reel.

We made a miscalculation when we powered up the streamer on the reel to test which sections remained attached to the ship. We left the 4 inches of section 7 that remained with the streamer attached to its corresponding can. The SPSU recognized streamer section 7 and indicated that it was still there. Because of this our count of the sections was off by one, and this interfered with subsequence tests of all of the sections that remained on the reel after the streamer parted. Testing streamer sections was slow because it required connecting and rebooting the SPSU each time. We eventually were able to assemble a 13-section streamer with 104 channels (100 working channels). There was also some bird damage to three of the birds. Bird 3 took the hardest hit with bent wings, broken plastic casings and flooded components. Fortunately, all of the lithium batteries were fine and were reused.

Feb 17

We transited from the Dyrgalski ice tongue to the OBS drop area. Seas dropped to nearly flat in the OBS drop area. OBS pick up began ~ 5:30 AM. We set 500 m downwind from the drop site. Each instrument had ~ 15 min rise time. Radio beacon was not picked up until very close and long after spotting. We were able to spot OBS on radar and visually once we knew one was up. Pancake ice began to appear extensively, with greater amounts toward the east as we traversed along R7. The release command did not seem to be working to release OBS 9 and OBS 10. These were deployed in shallower water than the rest and the speculation at the time was that the offset was too large to achieve the same angle to the instrument as with the deeper water instruments, which was thought to be a problem for the acoustic release signal. Multiple attempts to trigger the release were made with high and low gain, with both old and new transponders, and with greater and smaller

range to the instruments. Ultimately, both of these instruments released and were recovered. The radio beacon helped locate these instruments once we discovered that the Yagi antenna was needed to boost the weak signal from the OBS and to determine the signal bearing. All 11 deployed instruments were retrieved and had data.

Feb 18

We began GeoEel deployment in the early hours. The seas picked up due to 25 kt winds with higher gusts. The shortened streamer was deployed and tested. Redeployment included 13, 50-m sections with 4 bad channels making a total of 104 channels. High sea state required turning off the line and into the winds pushing us offline to the SE. Guns were deployed using the replacement umbilical. Guns began firing ~5 AM and data looked good other than swell and wave noise. Guns developed an air leak at ~ 6 AM and had to be retrieved to fix. Gun misfiring and guns tanged with the streamer in turns due to high seas. The gun tangling was aggravated by the slow speed through the water. This required gun retrieval again. We replace Gun #2 and it was back in the water ~ 2:30 PM. Finally we began a test line back to the start of Line R7 with both GI guns firing.

Weather remained bad all day with 25-30 kt winds and temperatures ~ -11° C. Wind chill remained ~ -32° C all day. These conditions slowed deck work greatly.

At ~ 7:00 PM, Gun #1 failed due to an air leak. Guns were retrieved. Brendon Mendenhall dug deeper into the airgun operations and discovered that the air hose used for replacement was rated at only 2200 psi and deemed to be of poor quality. It was also at least 10 years old and had been sitting on the *Palmer* for that time. We decided to replace the air hoses with used hoses that had been used up until the ice crash. They were considered suspect after the ice crash and were replaced with the poor quality hose. We checked to see if the engine room had suitable hose, but no solution there. Gun work began around midnight.

Feb 19

Gun work began to replace air hoses with used hoses. Air temp -8° C and tough working conditions. Airgun turnaround was 6-8 hours. Guns redeployed at ~ 6:00 AM. Seas calmed and we began encountering lots of pancake ice. After a long delay with the gun work, we began testing and lining up on Line R7. We deviated from the line due to an iceberg and had a shutdown due to a whale sighting. At ~ 12:30 PM, Gun 2 developed an electrical problem preventing the generator from firing. We switched to just one gun for the rest of the line. We continued shooting for the rest of the day.

Feb 20

The shooting continued very smoothly. The seas remained calm and data quality was quite good. With a sustained speed of ~ 5.3 kts we made good progress along the revised grid. We had shutdowns due to Minke whales and had to deviate due to icebergs. At this rate we estimated that we could come close to finishing the revised grid before heading to McMurdo on the 22nd.

Feb 21

Large (2 ft) pancake ice began to interfere with the streamer/birds. The streamer tended to rise to the surface at the front. The streamer was moved down to ~ 6 m and speed reduced to ~4.5 kts to help keep the head of the streamer down. The streamer tow point was also moved to be more centered with the vessel. The stability improved once we passed through the large pancakes, but we still had some difficulty with keeping the front end deep.

We developed an air leak on Gun #1, the only operating gun, and had to bring it in to fix at the start of line R13. We swapped air hoses from Gun #2 onto Gun #1 as fast as we could.

Heavy snow and poor visibility prevented us from re-deploying the guns. While looking into the gun isues, we also looked to see the condition of the streamer and birds. We discovered that ice had cut into the sheathing on the streamer lead-in. The lead-in needed to be swapped out. We also discovered damage to the birds from the large pancake ice.

We redeployed the streamer with new (spare) tow lead. We waited for visibility to improve to get clearance from PSOs. Once the half hour PSO watch period began, we redeployed Gun #2 and headed for the start of the N-S line in the revised (version 3) shooting plan. We began to encounter large pancake ice (2-3 ft).

Feb 22

We moved the streamer inboard to keep it away from pancake ice. This seemed to help. At the crossing with line R3, we discovered the gun float had sunk. The guns were retrieved and found the gun float had deflated. This was likely due to scraping across pancake ice. The float was replaced and the guns were redeployed. All turns required someone to watch from stern to observe streamer and guns to assure they remained separated and away from pancake ice. During the day we begin to suspect that the Norwegian float that we used as a replacement tailbuoy for the streamer was gone. Shooting stops at 10:30 PM and guns and streamer were then recovered. The replacement tailbuoy was gone.

Feb 23. – Arrive McMurdo mid morning.

Equipment

Source

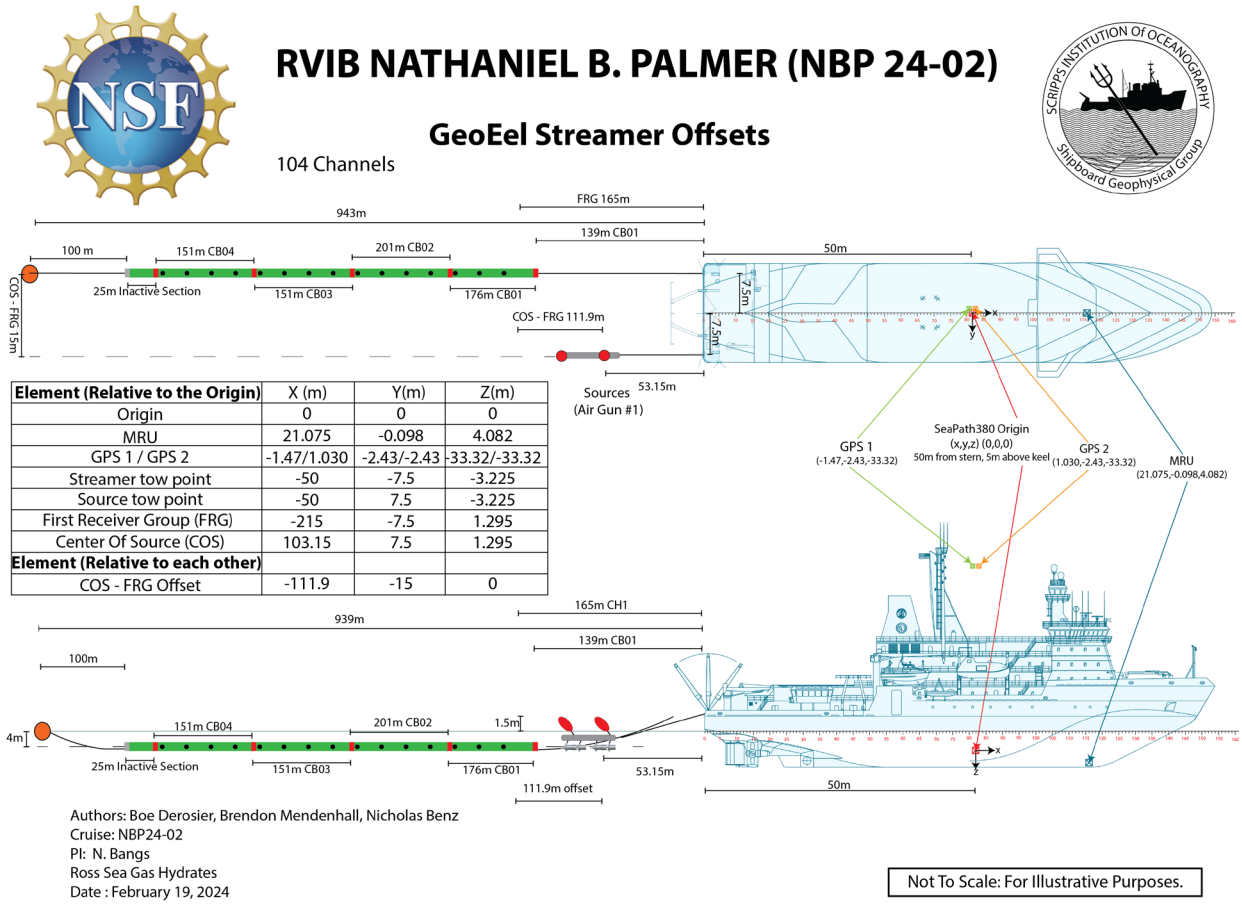
For our source, we used Sercel Generator-Injector (GI) airguns in 105/105 cubic inch mode. During the OBS shooting, we used two GI guns in the 105/105 configuration fired simultaneously on distance at 50 m intervals. For the mcs profiling, we initially attempted to use two airguns again, this time firing at 25 m, but due to problems with air hoses, etc., we decided to used just one airgun to reduce the frequency of retrieving the airguns for repairs and increase the time for acquisition.

Airgun shots were triggered on distance derived from the NaviPac real time ship positioning system, which communicated with the HotShot airgun trigger to send the firing signal. Both of these systems were provided as part of the Scripps high-resolution seismic system.

Streamer

For the seismic profiling, we used the Scripps high-resolution portable multichannel seismic system. The streamer consisted of a Geometrics GeoEel, solid streamer. We initially deployed 15, 50 m, 8 channel sections with 6.25 m group spacing and 5 depth control birds; however, we acquired very little data with this configuration before the problems with the ice that damaged 3 of the sections and 3 birds. All of the rest of the multichannel data were acquired using 13 sections (650m active streamer in total), with 4 (needs to be checked) depth control birds.

The seismic streamer data were recorded on the NaviPac system provided by Scripps. The NaviPac received GPS positions and determined off line and down line positions used for triggering airguns on distance. The NaviPac determined position for signal triggering that was passed on to the HotShot gun controller, which then sent triggers to the guns. The NaviPac also recorded streamer data to disk in SEGD format.



Element (Relative to the Origin)	X (m)	Y(m)	Z(m)
Origin	0	0	0
MRU	21.075	-0.098	4.082
GPS 1 / GPS 2	-1.47/1.030	-2.43/-2.43	-33.32/-33.32
Streamer tow point	-50	-7.5	-3.225
Source tow point	-50	7.5	-3.225
First Receiver Group (FRG)	-215	-7.5	1.295
Center Of Source (COS)	103.15	7.5	1.295
Element (Relative to each other)			
COS - FRG Offset	-111.9	-15	0

Figure 3. Diagram showing the streamer offset configuration used for multichannel seismic acquisition throughout NBP2402. We used 13, 50-m, 8 channel, GeoEel sections, which provided a 650 m active section.

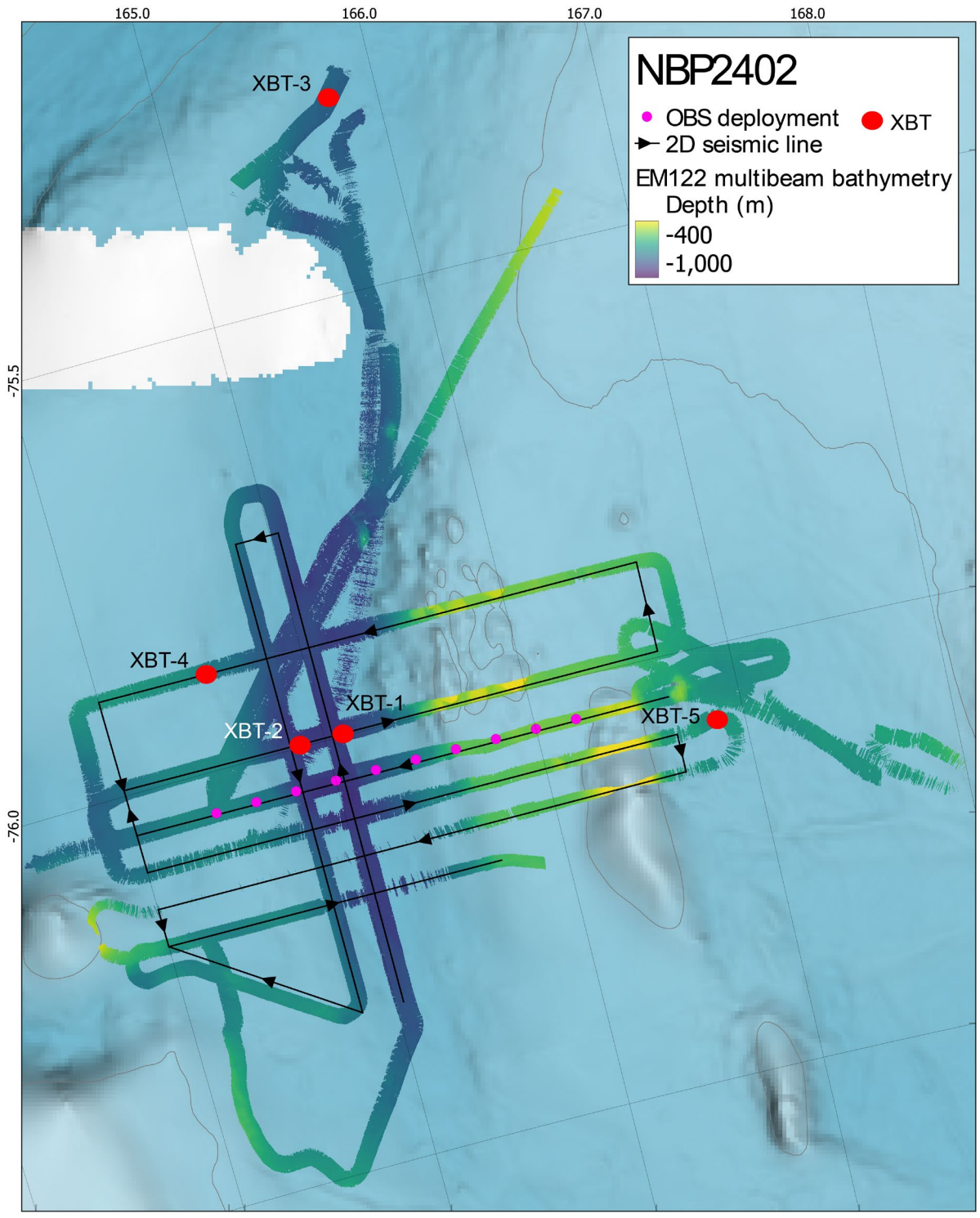


Figure 4. Survey Track lines with multibeam profile data (blue-yellow colors), mcs profiles (black lines), XBTs (red circles) and OBS deployment locations (purple dots). OBS are located along Line R7 (purple dots). Arrows indicate shooting direction.

Seafloor mapping and subseafloor profiling

Multibeam bathymetric data were acquired during the entire survey (Figure 4). These data filled in missing gaps to existing coverage throughout the survey area. The multibeam data were acquire using a hull mounted EM 122 Multibeam Systems Simrad 12 kHz full-ocean-depth swath mapping system.

In addition to multibeam data, we also ran the *Palmer's* 12 kHz bottom tracker and the Knudsen 3260 Chirp (10 kW) 3.5 kHz sub-bottom profiler to obtain high-resolution profiles of the near seafloor sediments.

XBT

Five expendable bathymetric thermograph (XBT) profiles were acquired throughout the cruise (Figure 4). Due to the cold water (~ 0° C), seismic velocities were very low (~ 1450 m/s) and thermal gradients were very low throughout the water column. These data are available in the NBP2402_CruiseData/ocean/xbt folder.

Data

We acquired data in two phases. The first phase was OBS acquisition, followed by multichannel seismic profiling (Figure 5).

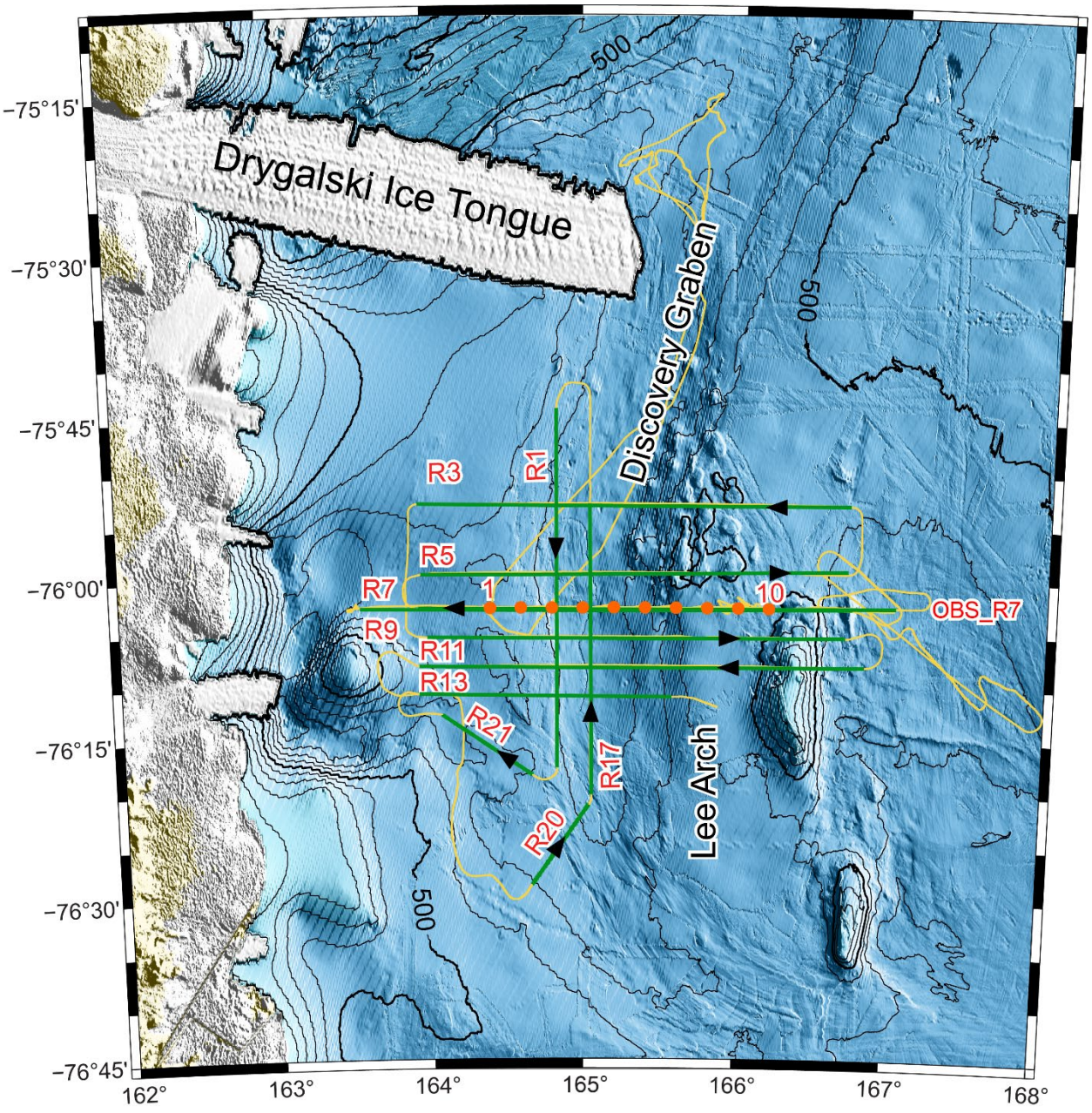


Figure 5. Shaded relief bathymetry map showing survey region. Contour interval is 100 m. Ship track is shown in yellow. Green lines show the locations of multichannel survey lines (R1 – R21). OBS station locations (OBS 1 – 10) are shown with the orange circles on Line R7. Spacing between OBS is ~ 5.4 km. Arrow show the shooting direction during acquisition.

OBS

All 11 OBS instruments deployed were successfully recovered and all recorded shots on all 3-component geophones and hydrophone. All have strong first arrivals that can be identified and recognized above noise (e.g. Figure 6) as well as later phases. Previous shot noise interferes at ~ 12 – 15 km offsets, but first arrivals can be identified up to the ends of the records at ~ 40 km and appear to have slopes consistent with velocities up to 7-8 km/s. These arrivals are from much deeper than where our interests are with gas hydrate, but these records could be used for a crustal scale study in the future.

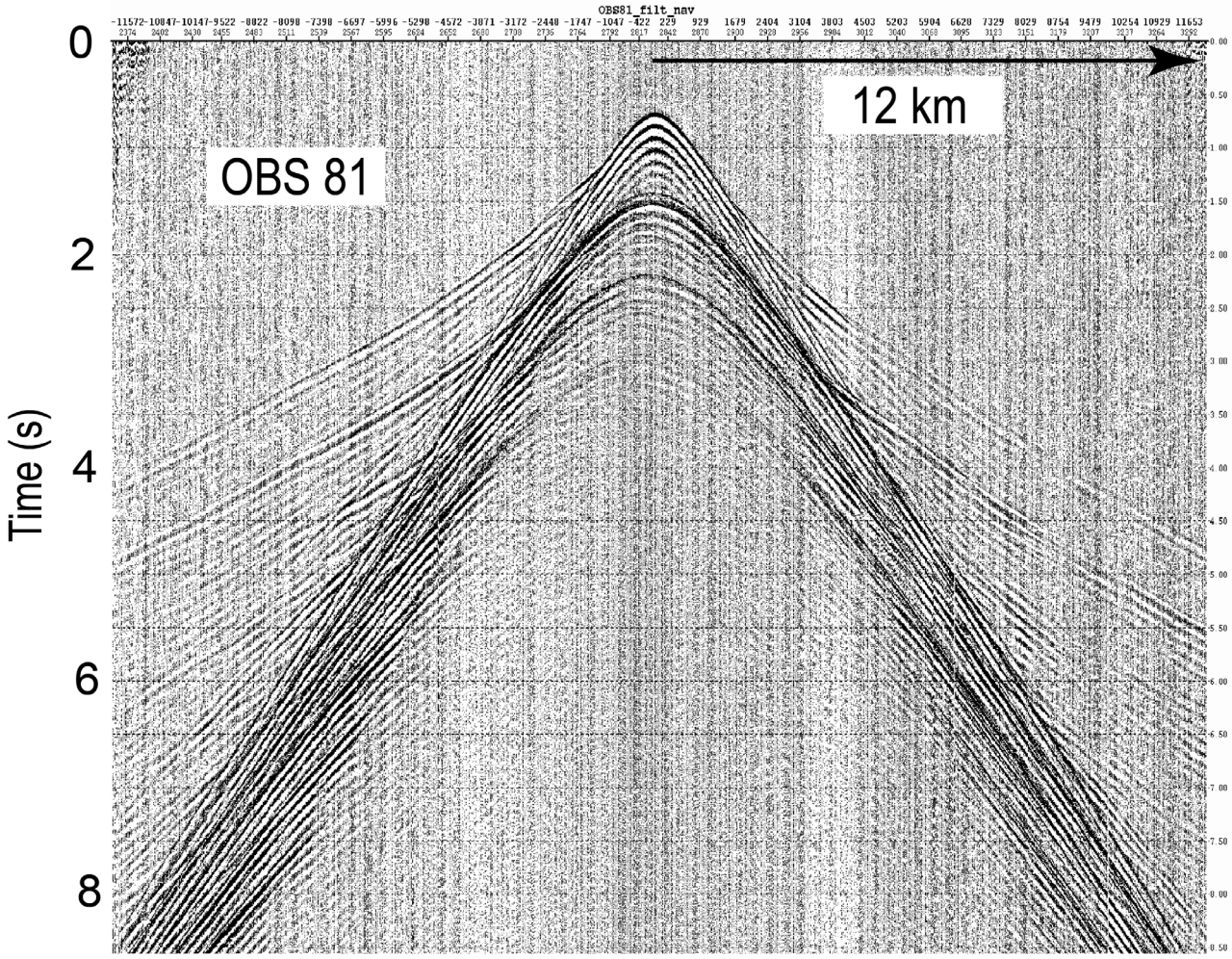


Figure 6. The near offset (up to 12 km) portion of the OBS 81 hydrophone record. OBS 81 was deployed at OBS Station 7. Data have been sorted by offset and filtered to remove low frequency noise below 4 Hz, and plotted with no velocity reduction. First arrivals are strong for this offset range. The full range of offsets shows first arrivals extending across the entire record up to ~ 40 km offsets.

Shot timing:

In order to obtain accurate velocities from our high-resolution OBS recordings, we investigated schemes to obtain very accurate shot timing. Our goal was shot times recorded to ~ 1 msec. With little time for testing before the initial OBS line acquisition, we were not certain that the Scripps NaviPac was capable of determining shot times to this resolution. The times logged in files are each "event" generated by NaviPac, which is then sent to the HotShot firing system – and therefore these times are expected to be some nearly constant time (Brendon Mendenhall suggested 50ms) before each shot is actually generated. It's important to note that these times are time sent to and are not from the HotShot. There folders with NaviPac shot trigger times for the OBS line in 3 segments, R7obs, R7obs_b, and R7obs_c. Within these folders will be the raw NaviPac shot time files and files post-processed by Fynn Warnke on board to remove duplicates and perform other simple edits to remove irregularities identified during the cruise (files R7obs_c20240213_070140_C_postproc and R7obs_c20240213_074410_C_postproc. There is a "stats" file generated by Fynn to show how much editing his "processed" files contain.

In order to improve the accuracy of the shot times, these shot events were also sent in real time to the Palmer RVDAS system, where each event was time-tagged by the RVDAS system and logged in near-real-time (on the order of 1 second delay). Those RVDAS are logged in file NBP2402gen3. They may or may not show some constant (again, on the order of a second) delay from the NaviPac files. Note that the first date/time columns are the RVDAS times, which claim to have ms accuracy. The actual shot times are the second date/time in each file, only accurate to the second. We expect that shots can be identified by shot times recorded to the nearest second by both systems, and shot times to the nearest msec can be derived from the RVDAS records.

Following the OBS recovery, we discovered an issue with the record timing in some of the instruments. The instruments are deployed with clocks set by synchronization using GPS signals shortly before deployment. The instruments are supposed to immediately switch to UTC time by subtracting and offset of exactly 18s. We discovered that this correction does not always happen and the instrument records with the GPS time. Which instruments could fail in this way and conditions that cause this failure are not known. The instruments that failed to make this correction are OBSs 77, 75, at Station 1, OBS 49, 83, 44, 84, 81, 73, 60 at Stations 2,3,4,6,7,8,10, respectively. A correction of exactly 18s, was applied to each of these instruments.

Multichannel seismic profiles.

We acquired 615 km of high-resolution multichannel seismic lines across the eastern flank of the Lee Arch and western flank of the Discovery Graben (Figure 5). An example of the data quality is shown in Figures 7 and 8, along Line R7. This line overlaps with the previously published Line IT90AR-63S (Geletti and Busetti, 2011), and shows many of the same structures including the BSR. Preliminary processing includes noise filtering,

binning into 6.25 m bins, velocity analysis, normal moveout and stack of nominally 52 traces in each bin. A strong airgun bubble pulse appears on many of the records that we think may have been due to an issue with the injector pulse not properly firing and leaving a strong bubble at ~100 ms after the generator pulse. Predictive deconvolution was applied to help suppress this bubble without too much interference with the primary signals.

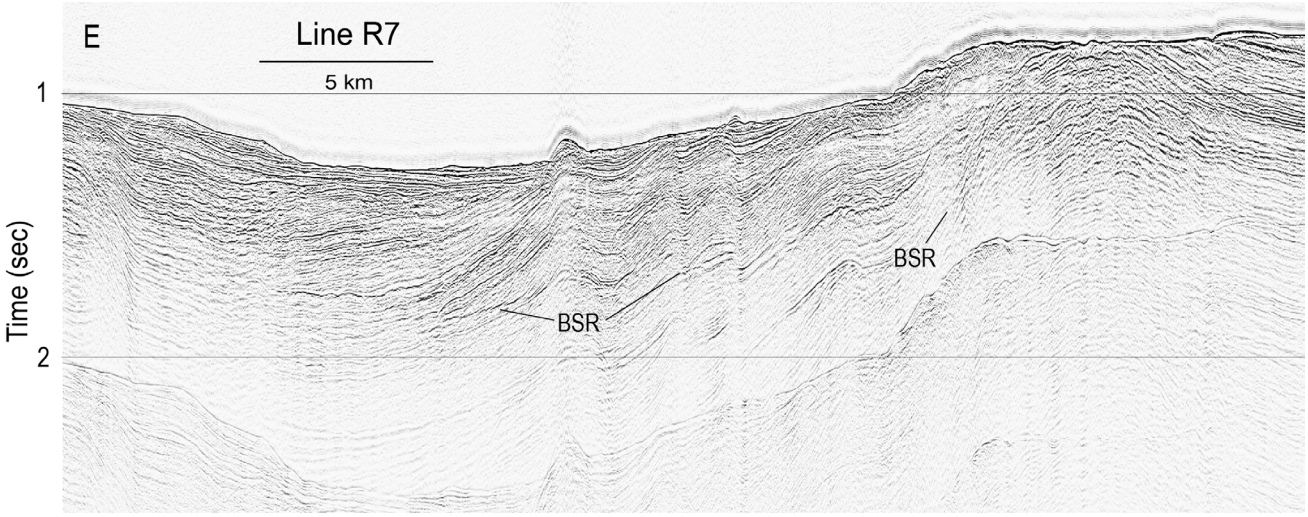


Figure 7. A portion of seismic line R7 showing bottom simulating reflections (BSRs) along the eastern flank of Lee Arch. These data have had low-frequency towing noise removed, a high pass filter (> 8 Hz), predictive deconvolution to remove source bubble energy ~ 100 msec following the primary signal, binned into common midpoint bins, normal moveout and stack.

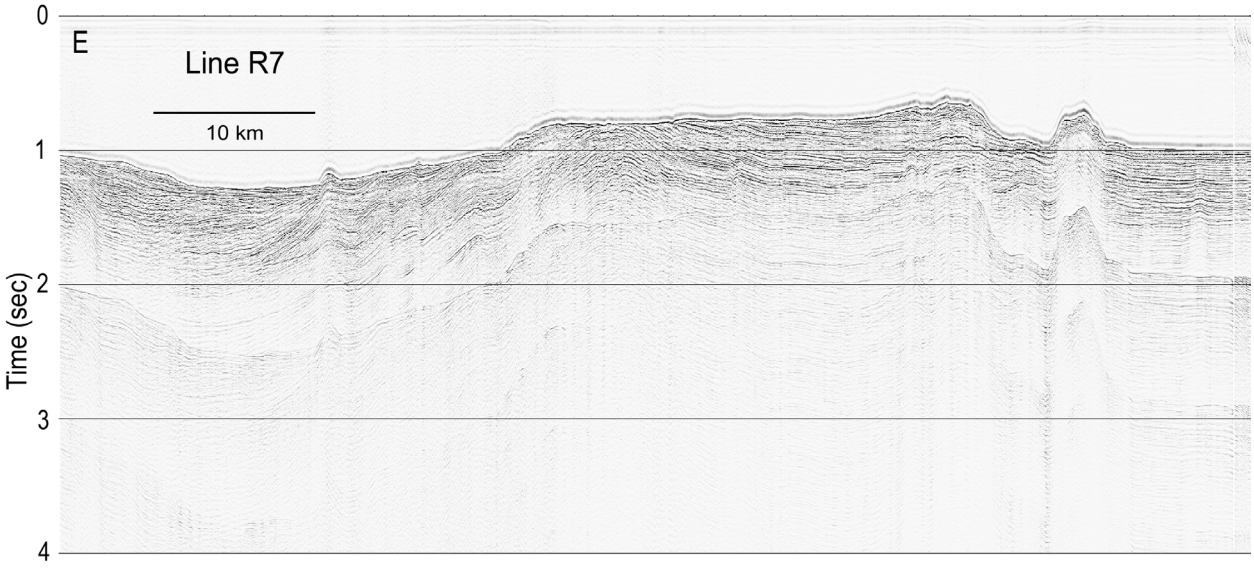


Figure 8. The entire section of seismic line R7. These data have had low-frequency towing noise removed, a high pass filter (> 8 Hz), predictive deconvolution to remove source

bubble energy ~ 100 msec following the primary source signal, binned into common midpoint bins (12.5 m), normal moveout and stack.

Reference

Geletti, R., and M. Busetti (2011), A double bottom simulating reflector in the western Ross Sea, Antarctica, *J. Geophys. Res.*, 116, B04101, doi:10.1029/2010JB007864.

Appendix – Line information

Note: times are provided in - year Julian day hour minute second – format. XY positions are UTM zone 58C.

Julian Day	34		43	44	45	46	47	48	49	50	51	52	53	54
Calendar	3-Feb-24		12-Feb-24	13-Feb-24	14-Feb-24	15-Feb-24	16-Feb-24	17-Feb-24	18-Feb-24	19-Feb-24	20-Feb-24	21-Feb-24	22-Feb-24	23-Feb-24

From segy headers

Line	First good	Last good	First shot time	Last shot time		First shot x,y		Notes
R1	1010	5926				495342 1593840		
R3	1007	7054				546589 1576747		
R5	1006	6627				471892 1565123		
R7	1248	7845				556881 1558852		
R9	1006	6804				473150 1554197		
R11	1006	7165				548576 1548656		
R13	1005	4502				471522 1544370		
R17	1006	5048				501499 1527086		
R20	1006	2350				491329 1511473		
R21	1020	2406				490880 1530642		
OBSR7	1001	4962	2024:43:10:59:35 PM	2024:44:15:41:25.952		546734 1558811		Line breaks led to missing shots 1801 - 2027

From Seismic Line Log

Line	First FFID	Last FFID	First shot time	Last shot time	Shot	First shot Lat,Lon	Last shot Lat,Lon		Notes
R1	1001	5926	2024:52:18:15:27	2024:53:00:51:08	55188-60107	?	-76.2970 164.8303		
R3	1001	7054	2024:50:15:12:02	2024:50:23:01:08	25866-31920	-75.87038 166.71472	?		
R5	1001	6627	2024:50:0:59:?	2024:50:13:41:57	19264-24933	-75.9954 163.9548	-75.9890 166.7054		
R7	1248	7845	2024:49:19:10	2024:50:05:02:00	11850-18695	?	-76.0478 163.9365		
R9	1001	6804	2024:51:01:47:15	2024:51:09:19:04	33959-39763	-76.0931 163.9929	-76.0923 166.6969		
R11	1001	7165	2024:51:10:42:25	2024:51:19:09:?	40702-46869	-76.1377 166.8226	-76.13777 163.94005		
R13	1007	4503	2024:53:04:52:25	2024:53:09:30:01	62961-66457	-76.1811 163.9369	-76,1869 165.5766		
R17	1001	5048	2024:52:09:07:46	2024:52:14:29:32	49926-53974	-76.3396 165.0546	-75.886168 165.044308		
R20	1001	2351	2024:52:07:10:44	2024:52:08:56:21	48470-49822	-76.4791 164.6640	-76.3553 165.0349		
R21	1020	2406	2024:53:01:27:52	2024:53:03:25:07	60534-61940	-76.3076 164.6660	-76.2144 164.0854		
OBSR7	1446	5406	2024:43:22:59:56	2024:43:15:41:39	1446-5406	-76.0476 166.7365	-76.04770 163.5601355		Line breaks led to missing shots 1801 - 2027

Relevant portions of NaviPac logs at start, end, and problematic portions of the lines.

Events,Data: FFID_TapeNumber_ActiveChannels {FFID},Time,Data: Multibeam Depth {NMEA},Speed Made Good (SMG),Position: COS: East,North,Lat,Long,DAL,DOL,Position: FRG Offset: East,North,Lat,Long,DAL,DOL,

R1
51778, 1001.0000, 18:15:13.523, 728.4400, 2.59, 495330.0230,1594043.4486, -075°44.279449', 164°49.810909', 3649.99, 12.621, 495337.9082,1594155.0307, -075°44.219460', 164°49.828812', 3538.41, 4.735
51787, 1010.0000, 18:15:57.374, 726.6200, 2.56, 495330.0788,1593930.9516, -075°44.339941', 164°49.810326', 3762.49, 12.565, 495339.1320,1594042.4450, -075°44.280002', 164°49.830777', 3651.00, 3.512
56703, 5925.0000, 00:51:09.336, 757.7400, 2.71, 495516.5556,1531668.7092, -076°17.819376', 164°49.827108', 61024.98, 0.762, 495522.1022,1531780.4320, -076°17.759311', 164°49.840421', 60913.27, -5.104
56703, 5925.0000, 00:51:11.346, 757.7400, 2.70, 495516.8329,1531663.3706, -076°17.822247', 164°49.827702', 61030.32, 0.500, 495522.7695,1531775.0734, -076°17.762193', 164°49.841900', 60918.63, -5.756
Note: the last two entries in the Navipac log have shot number 5925. This one is the second, and follows 4 s after the first. I presume should be 5926.

R3
25310, 1001.0000, 15:12:06.701, 552.1400, 2.73, 546755.4390,1576735.6315, -075°53.224286', 166°43.080784', 3424.94, -164.648, 546862.9289,1576704.6694, -075°53.239245', 166°43.319615', 3317.45, -195.610
25316, 1007.0000, 15:12:34.652, 553.1000, 2.72, 546680.3934,1576747.7553, -075°53.218942', 166°42.914652', 3499.98, -152.524, 546788.1508,1576717.7375, -075°53.233392', 166°43.154008', 3392.23, -182.542
30392, 6082.0000, 21:46:12.356, 667.9000, 2.71, 483240.8376,1577434.1424, -075°53.167309', 164°23.058095', 61937.53, 730.907, 483352.3047,1577424.7714, -075°53.172970', 164°23.303568', 61826.09, 721.181
31362, 7052.0000, 23:01:04.165, 653.8300, 2.69, 471108.6231,1577345.2867, -075°53.122491', 163°56.316455', 1900.12, 662.425, 471219.8236,1577357.4190, -075°53.117041', 163°56.561992', 1788.96, 674.943

R5
18962, 1001.0000, 05:59:43.520, 754.8600, 2.56, 471744.2274,1565081.6829, -075°59.721829', 163°57.238500', 3762.44, 269.868, 471632.9211,1565070.5631, -075°59.726745', 163°56.990882', 3651.20, 281.609
18967, 1006.0000, 06:00:08.561, 754.9300, 2.56, 471806.8605,1565095.8063, -075°59.714832', 163°57.378144', 3824.99, 255.395, 471695.4094,1565086.2462, -075°59.718911', 163°57.130269', 3713.60, 265.578
24623, 6626.0000, 13:42:00.430, 610.8000, 2.71, 545741.0676,1564864.0882, -075°59.620745', 166°41.595802', 897.10, 78.492, 545630.3656,1564880.1450, -075°59.613819', 166°41.349040', 786.38, 62.513
Note: the last two entries in the Navipac log have shot number 6626. This one is the second, and follows 4 s after the first. I presume should be 6627.

R7
12126, 1001.0000, 19:14:47.582, 668.6700, 2.05, 557459.7380,1558861.6306, -076°02.642345', 167°08.085110', 2212.44, 86.949, 557570.4057,1558845.3391, -076°02.648945', 167°08.332895', 2101.77, 70.657
12373, 1248.0000, 19:39:39.216, 676.8100, 2.11, 554372.9683,1558915.4482, -076°02.671817', 167°01.205895', 299.99, 139.093, 554483.6106,1558898.9855, -076°02.678626', 167°01.453592', 189.26, 123.249
18960, 7844.0000, 05:02:02.110, 758.0600, 2.69, 471366.5872,1559222.1377, -076°02.868427', 163°56.165380', 73306.79, -18.162, 471477.9194,1559211.2801, -076°02.875341', 163°56.413092', 73195.40, -28.397
Note: the last two entries in the Navipac log have shot number 7844. This one is the second, and follows 4 s after the first. I presume should be 7845.

R9
32953, 1001.0000, 01:47:33.011, 735.0800, 2.68, 472997.0483,1554193.8582, -076°05.587125', 163°59.608427', 4825.00, 6.046, 472886.7326,1554212.3841, -076°05.576152', 163°59.362467', 4714.58, -11.863
32958, 1006.0000, 01:47:56.335, 733.7000, 2.68, 473059.5532,1554191.1515, -076°05.589153', 163°59.748087', 4887.52, 8.404, 472948.9903,1554208.1397, -076°05.579006', 163°59.501513', 4776.86, -7.967
38755, 6803.0000, 09:19:08.582, 640.0500, 2.67, 545530.2542,1553744.6987, -076°05.600423', 166°41.837654', 72359.58, 49.677, 545419.2655,1553758.6363, -076°05.594646', 166°41.588652', 72248.52, 36.360
Note: the last two entries in the Navipac log have shot number 6803. This one is the second, and follows 4 s after the first. I presume should be 6804.

R11
38757, 1001.0000, 10:42:30.687, 678.0500, 2.75, 548726.7066,1548690.3969, -076°08.265652', 166°49.331575', 5662.48, -65.913, 548838.5218,1548693.5752, -076°08.262086', 166°49.582077', 5550.68, -62.110
38762, 1006.0000, 10:42:53.758, 677.5600, 2.73, 548663.8757,1548685.0336, -076°08.269577', 166°49.191060', 5725.28, -71.627, 548775.6961,1548688.0211, -076°08.266115', 166°49.441589', 5613.47, -68.015
44923, 7165.0000, 19:09:18.088, 650.2800, 2.69, 471653.3012,1549187.1529, -076°08.266194', 163°56.402737', 72737.45, -0.124, 471763.9974,1549171.0563, -076°08.275915', 163°56.650388', 72626.67, -15.601
44923, 7165.0000, 19:09:20.774, 657.1000, 2.68, 471646.2385,1549187.7736, -076°08.265792', 163°56.386920', 72744.52, 0.457, 471756.8779,1549171.2911, -076°08.275720', 163°56.634428', 72633.79, -15.406
Note: the last two entries in the Navipac log have shot number 7165.The last shot may actually be 7166..

R13 Missing because it was the last line and not updated before final backup. Needs to come from Brendon.

R17
46559, 1001.0000, 09:08:01.762, 813.8000, 2.59, 501436.4990,1526934.8091, -076°20.367907', 165°03.269336', 7637.36, 390.027, 501440.4841,1526823.0198, -076°20.428014', 165°03.278641', 7525.57, 393.845
46564, 1006.0000, 09:08:26.420, 813.7700, 2.57, 501424.3480,1526997.3135, -076°20.334304', 165°03.241551', 7699.88, 377.970, 501430.4795,1526885.6214, -076°20.394358', 165°03.255739', 7588.18, 383.934
50605, 5047.0000, 14:29:35.010, 848.3700, 2.61, 501204.0876,1577516.9131, -075°53.169518', 165°02.654109', 48219.76, 233.530, 501183.9923,1577406.8725, -075°53.228697', 165°02.609993', 48109.75, 213.270
Note: the last two entries in the Navipac log have shot number 5047. This one is the second, and follows 4 s after the first. I presume should be 5048.

R20
45208, 1001.0000, 07:10:55.821, 679.9700, 2.68, 491244.4188,1511351.2155, -076°28.734115', 164°39.871492', 1874.98, -60.993, 491165.2081,1511272.2319, -076°28.776340', 164°39.688353', 1765.34, -83.173
45213, 1006.0000, 07:11:19.158, 681.9500, 2.68, 491280.0523,1511402.5901, -076°28.706601', 164°39.954079', 1937.50, -59.793, 491201.3931,1511323.0573, -076°28.749123', 164°39.772211', 1827.70, -81.210
46557, 2350.0000, 08:56:22.835, 819.3900, 2.67, 500922.3049,1525172.4093, -076°21.315758', 165°02.101462', 18742.93, 337.973, 500840.5719,1525096.0387, -076°21.356848', 165°01.915328', 18634.07, 312.245
Note: the last two entries in the Navipac log have shot number 2350. This one is the second, and follows 4 s after the first. I presume should be 2351.

R21
57131, 1001.0000, 01:28:02.557, 662.6300, 2.61, 491167.3636,1530466.0692, -076°18.456042', 164°39.943529', 4273.89, -1449.568, 491253.7049,1530394.9501, -076°18.494544', 164°40.138676', 4162.57, -1460.576
57150, 1020.0000, 01:29:37.557, 658.5200, 2.60, 490960.7450,1530602.1889, -076°18.382215', 164°39.476159', 4521.31, -1451.527, 491046.0943,1530529.8824, -076°18.421358', 164°39.668999', 4410.15, -1464.074
58536, 2406.0000, 03:25:07.739, 702.9600, 2.63, 475685.1951,1540689.3434, -076°12.871117', 164°05.151542', 22826.43, -1576.697, 475790.3662,1540651.2413, -076°12.892477', 164°05.387418', 22717.85, -1549.796
58537, 2407.0000, 03:25:12.739, 701.7300, 2.62, 475673.0511,1540694.6638, -076°12.868156', 164°05.124339', 0.00, 0.000, 475778.5510,1540657.4817, -076°12.889024', 164°05.360987', 0.00, 0.000

OBSR7 Time,Events,Position: COS: East,North,Lat,Long,DAL,DOL,Data: Multibeam Depth {NMEA},
22:59:16.826, 1001, 546734.1761,1558811.0222, -076°02.858598', 166°44.195621', 7198.12, -14.976, 506.6600 R7OBS
22:59:26.383, 1002, 546711.6123,1558810.7957, -076°02.859077', 166°44.145359', 7220.68, -15.252, 505.0100 R7OBS
22:59:35.950, 1003, 546690.8234,1558809.8456, -076°02.859916', 166°44.099099', 7241.47, -16.248, 504.3400 R7OBS
01:12:56.499, 1963, 527959.0704,1559189.2092, -076°02.892587', 166°02.332873', 16714.01, 321.873, 510.6300 R7OBS
Events,Time,Data: Multibeam Depth {NMEA},Position: COS: East,North,Lat,Long,DAL,DOL, R7OBS
1965, 01:19:10.040, 510.5800, 527077.2162,1559219.8694, -076°02.884316', 166°00.366072', 17595.93, 350.591 R7OBS
2088, 01:33:39.257, 0.0000, 525803.3627,1559811.1363, -076°02.577826', 165°57.505267', 63478.29, -939.052 R7OBS
2263, 07:01:40.962, 509.4300, 531989.2291,1559092.6092, -076°02.903640', 166°11.319832', 12683.65, 234.148 R7OBS_b
2322, 07:12:24.211, 509.9500, 530533.8933,1559153.3205, -076°02.886398', 166°08.073410', 14139.12, 291.654 R7OBS_b
2323, 07:44:10.871, 508.9200, 530541.6067,1559236.1313, -076°02.841799', 166°08.087054', 14131.59, 374.482 R7OBS_c
2324, 07:44:27.780, 515.0900, 530509.1415,1559230.7657, -076°02.845018', 166°08.014926', 14164.04, 369.045 R7OBS_c
2325, 07:44:39.857, 515.0900, 530484.2163,1559229.1438, -076°02.846148', 166°07.959443', 14188.96, 367.368 R7OBS_c
2326, 07:44:51.594, 545.2200, 530459.2314,1559225.1939, -076°02.848529', 166°07.903927', 14213.94, 363.363 R7OBS_c
2327, 07:45:02.813, 545.2200, 530434.2788,1559217.6265, -076°02.852854', 166°07.848636', 14238.87, 355.741 R7OBS_c
2328, 07:45:13.781, 509.2900, 530409.2785,1559211.0209, -076°02.856663', 166°07.793197', 14263.86, 349.080 R7OBS_c
2329, 07:45:24.722, 509.8300, 530384.2251,1559205.3094, -076°02.859991', 166°07.737602', 14288.90, 343.313 R7OBS_c

2330, 07:45:35.313, 509.6400, 530358.1603,1559201.6446, -076°02.862229', 166°07.679665', 14314.96, 339.591 R7OBS_c
5034, 15:41:07.952, 732.1600, 462358.7883,1559042.4677, -076°02.864005', 163°36.080947', -35.56, 30.677 R7OBS_c

NBP 2402 - OBS deployment logs

Station	OBS	X	Y	UTM X UTM Y	Deployed	Time	Retrieved	Time	Nearest Shot	water depth
1	77	164.400665	-76.048402	483869.99 1559331.89	2/12/2024	10:18:35	2/13/2024	19:35:29	4112	694
1	75	164.4001167	-76.048225	483855.04 1559351.49	2/12/2024	12:11:35	2/16/2024	17:03:47	4112	694
2	49	164.5991667	-76.048225	489212.08 1559396.89	2/12/2024	13:16:32	2/16/2024	18:37:42	3900	724
3	83	164.7994383	-76.048218	494602.09 1559425.13	2/12/2024	13:43:41	2/16/2024	19:37:45	3685	845
4	44	164.997488	-76.04834	499932.39 1559420.68	2/12/2024	14:09:01	2/16/2024	20:40:05	3474	887
5	85	165.199722	-76.048103	505375.34 1559438.04	2/12/2024	14:35:53	2/16/2024	22:12:10	3258	829
6	84	165.40007	-76.048035	510767.53 1559418.23	2/12/2024	15:28:41	2/16/2024	23:13:33	3048	739
7	81	165.600495	-76.048095	516161.58 1559365.83	2/12/2024	15:57:29	2/17/2024	0:08:50	2833	559
8	73	165.800995	-76.048003	521557.65 1559312.04	2/12/2024	16:24:29	2/17/2024	1:06:14	2619	545
9	82	166.001068	-76.047997	526941.91 1559230.53	2/12/2024	16:52:04	2/17/2024	9:36:00	2405	516
10	60	166.200393	-76.04813	532305.44 1559115.67	2/12/2024	19:18:04	2/17/2024	6:42:48	1608	523