MGL22-08 Cruise Report

CHINOoK project: Cascadia Hydrothermal circulation IN Ocean (K)rust

August 2022

CHINOoK

R/V Langseth (Lamont Doherty Earth Observatory)
August 1-20, 2022 (ports: Newport, Oregon, USA)
Chief Scientist: Glenn Spinelli (glenn.spinelli@nmt.edu)

NSF award OCE 2034896 "Collaborative Research: Quantifying the thermal effects of fluid circulation in oceanic crust entering the Cascadia subduction zone" to Spinelli, Harris, and Tréhu.

Scientific Participants
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Note: this document is in local time except when listed (for GMT add 7 hours to the local (Pacific) time).

CHINOoK project objectives

Accurate estimates of subduction zone temperatures are required to understand a variety of critical processes, including controls on seismogenic and aseismic behavior on subduction megathrusts. For the Cascadia subduction zone, the dearth of instrumentally recorded interplate seismicity requires a reliance on indirect methods (including temperature) to estimate the extent of the seismogenic zone. The degree to which fluid circulation redistributes heat within the subducting plate has profound implications for the thermal structure of the Cascadia subduction zone. In Cascadia, a lack of heat flux data immediately seaward of the deformation front is a significant knowledge gap for understanding subduction zone temperatures. This study is designed to fill this hole by collecting seismic reflection profiles and making heat flux measurements at sites offshore Washington and Oregon with a focus on quantifying the extent and vigor of hydrothermal circulation in the Juan de Fuca plate. Hydrothermal circulation associated with basement relief generates large anomalies in heat flux across the seafloor; this signal provides a test for the presence and vigor of hydrothermal circulation. Combining data from multiple sites will provide information on whether hydrothermal circulation is local or regional. The central hypotheses are: 1) Hydrothermal circulation is ubiquitous in the upper oceanic crustal aquifer; it persists in the aquifer covered by a thick mantle of sediment near the deformation front and in the shallowly subducted crust; and 2) Pseudofaults along propagator wakes are zones of high permeability through the full thickness of the crust; thus, they are zones of enhanced fluid and heat circulation relative to areas outside of propagator wakes. Comparisons of mean heat flux values with those predicted from lithospheric cooling models can allow assessment of whether heat in addition to the basal heat flux is added to the system (e.g., heat transported seaward through the subducting oceanic crust and/or heat advected upwards through faults in propagator wakes).

Overview

There were many successes in the MGL22-08 cruise, despite losing 8 days (out of 23) of scheduled ship time to mechanical issues. Overall, we collected a total of 732 km of seismic reflection profiles and 58 heat flux measurements. Major accomplishments include:

1) completion of 18 high-quality heat flux determinations at the MARGIN site (Fig. 1), which appear to be indicative of both lateral heat redistribution within the basaltic basement aquifer and thermally-significant vertical fluid seepage through a ~1155 m thick sediment section over the peak of the buried basement high,

2) acquisition and preliminary processing of seismic reflection profiles along 6 lines (107 km total) across and around Nubbin Knoll, showing the nature of the basement (including the presence of a previously unknown buried basement high to the east of Nubbin Knoll) and the distribution of overlying sediments (Fig. 1),

3) completion of 26 high-quality heat flux determinations around Nubbin Knoll, which are indicative of the basement outcrop being a site of discharge of warm (~15 ˚C) fluid from the basement aquifer to the ocean (Fig. 1),

4) acquisition and preliminary processing of seismic reflection profiles along 13 lines (625 km total) in the Pseudofault #2 area, showing complicated basement topography, extensive faulting through the overlying sediments, and a prominent unconformity in the sediment section (Fig. 1),

5) completion of 14 high-quality heat flux determinations around Diebold Knoll, which may be consistent with recharge of cold seawater into the basement outcrop (Fig. 1).

We had 15 days of operations from the time we left port until the time we returned. Of this, 3 days were required for transits from/to Newport harbor and between our research sites. Of the remaining time, we had 4.5 days of seismic data acquisition and 7.5 days of heat flow operations.

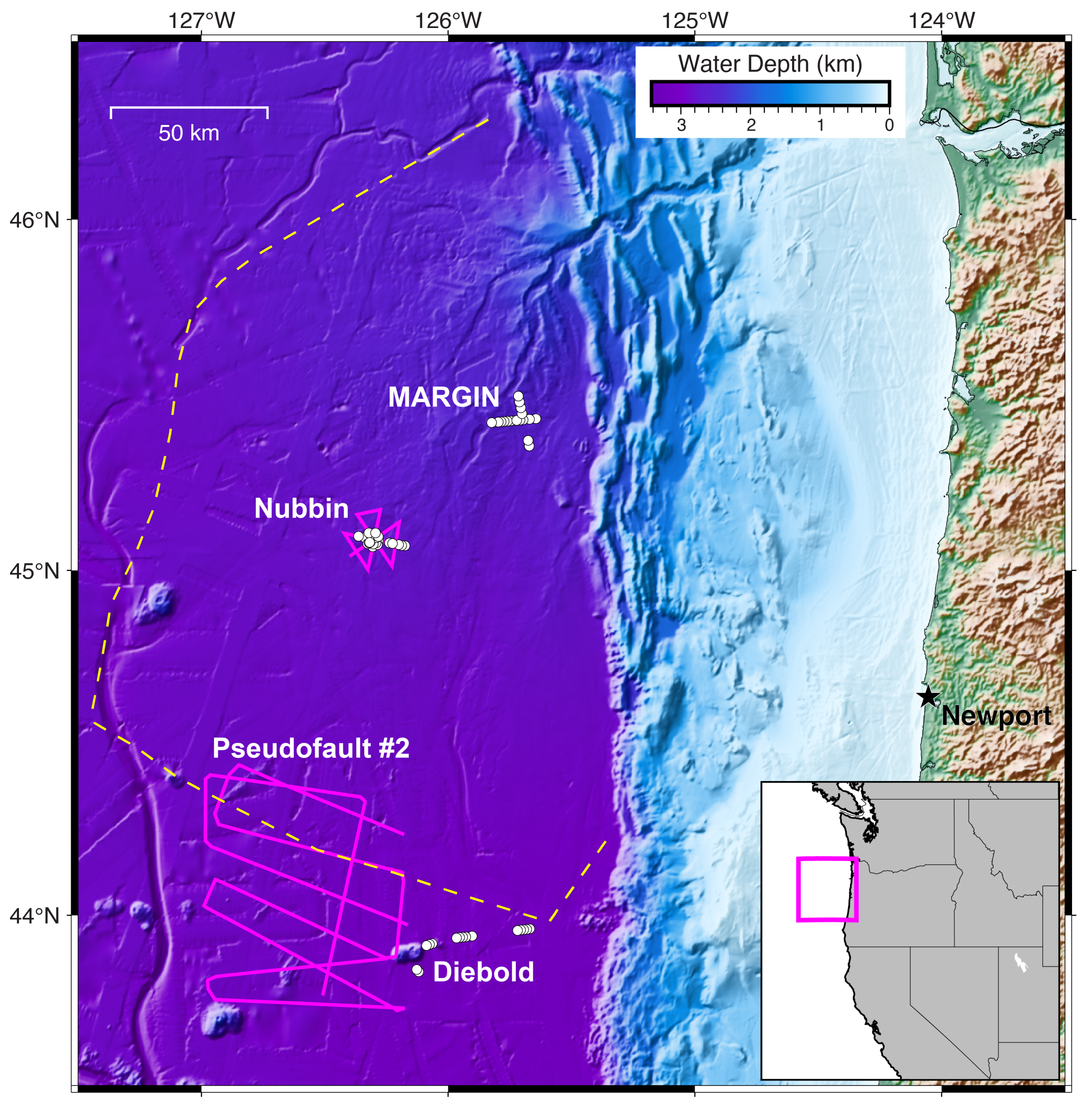

Figure 1: Map showing the locations of seismic reflection profiles (magenta lines) and heat flux determinations (white circles) completed in the MGL22-08 cruise. The yellow dashed line is the outline of the Astoria Fan (after Carlson and Nelson, 1987).

Daily summaries

Wednesday August 3, 2022

We were scheduled to leave port on Wednesday August 3, 2022. However, the bow thruster on the R/V Langseth was not working. An additional day was spent in port while the problem with the bow thruster was diagnosed and corrected.

Thursday August 4, 2022

We left port at 06:30. We transited to the Nubbin site, where we began seismic operations. The streamer and airguns were deployed, but the airguns were not working properly. The airguns were recovered for testing, then redeployed. Line N01 crossing Nubbin knoll collected only multibeam data because the airguns were not working. Line N01 ended just before midnight Aug. 4.

Friday August 5, 2022

The airguns were tested, and now were working properly. Line N02, southwest of Nubbin Knoll (not crossing the knoll), was completed at 01:50 – the first successful seismic data acquisition of the cruise. We collected seismic data along 6 lines crossing and around Nubbin Knoll, completing seismic operations at ~19:00 local time. Then, we began transiting to the MARGIN site to begin heat flow operations.

Saturday August 6, 2022

We arrived at the MARGIN site ~01:00 local time. We deployed the heat flow probe and collected heat flow data at 7 locations along a transect from east-to-west (on seismic profile PD11 from the CASIE21 project), crossing a buried basement high at the MARGIN site. Communications with the heat flow probe were not working, so we had no real-time information from the probe. We completed 7 penetrations (HF1-1 through HF1-7; eastern half of an east-to-west transect), then recovered the probe. Upon downloading the data, we discovered that temperature data during the penetrations were not recorded properly. OSU engineers worked on troubleshooting the probe; it seems likely that there was a firmware issue with the thermistor string. We replaced the thermistor string and redeployed the probe (heat flow station HF2).

Sunday August 7, 2022

We started the day completing the first heat flow measurement with the new thermistor string, at site HF2-1 (at the MARGIN site). We deployed at HF2-1, made a heat flow measurement, and brought the probe back up to the ship to confirm that the probe was functioning properly. HF2-1 was the first successful heat flow measurement of the cruise. We completed heat flow station HF2, making 7 heat flow measurements along the western half of an east-to-west transect across the MARGIN basement high. The heat flow probe is collecting good data; however, while deployed it cannot communicate back to the ship (all data is recorded internally, then downloaded upon retrieval of the probe at the end of a heat flow station). We completed heat flow station HF3 at the MARGIN site (penetrations HF3-1 through HF3-5), reoccupying some of the locations on the eastern half of the east-to-west transect across the MARGIN site. The heat flow probe was recovered shortly after midnight.

Monday August 8, 2022

We transited to heat flow station HF4, the final heat flow station at the MARGIN site (along the north-south trending MARGIN seismic profile from the Ridge-to-Trench study). We made 11 heat flow measurements at this station, then recovered the probe to the deck. Data from penetrations HF4-1 and HF4-2 are complete. Prior to penetration HF4-3, the temperature data recording seems to go haywire; no useable data were recorded for penetrations HF4-3 through HF4-7. For penetrations HF4-8 through HF4-11, useable data was recorded on 6 of the 11 thermistors, allowing for determination of heat flow at those locations. The OSU engineers onboard examined the probe and the data. They thought there was an issue (possibly a loose wire or connection) in the thermistor string that was used. We swapped a different thermistor string into the probe for the next heat flow station. Testing the probe on deck, the whole system seemed to be working fine.

Tuesday August 9, 2022

We transited from the MARGIN site to near Newport for 2 OSU engineers to disembark (via fast rescue boat to the OSU dock). Following the crew transfer and taking on some additional equipment (a few 12 kHz bottom-finding pingers), we transited to Nubbin Knoll to begin heat flow operations there.

Wednesday August 10, 2022

We deployed the heat flow probe and started heat flow operations at Nubbin Knoll shortly after midnight. Heat flow station HF5 was started at the eastern end of an east-to-west transect across Nubbin Knoll. We made 6 penetrations (HF5-1 through HF5-6), but due to a problem with programing the probe prior to deployment, the data were not recorded. Heat flow station HF6 continued the east-to-west transect crossing Nubbin Knoll (2 penetrations east of Nubbin Knoll, and 5 penetrations west of Nubbin Knoll). The data showed a similar issue to that observed on penetrations HF4-8 through HF4-11, half of the thermistors recorded data properly, but half did not. Following some email exchanges with support onshore, it was hypothesized that there could be some moisture accessing one of the connections on the data logger or from the thermistor string to the data logger.

Thursday August 11, 2022

Around 2 AM, we recovered the heat flow probe. Then, we disconnected all the electrical connections, thoroughly cleaned them, greased them precisely according to the connector manufacturer specifications, carefully reconnected them, and tightened it all down. We deployed the probe for a single penetration as a test; then, recovered it again (heat flow station HF7). Now, all the thermistors are working again. We continued to collect heat flow data around Nubbin Knoll. Heat flow station HF8 comprised 4 penetrations, one ~1 km southwest of Nubbin Knoll, and 3 immediately adjacent to the southern flank of Nubbin Knoll (one to the southeast, one south, and one southwest). Data from these 4 penetrations all look good and complete. Heat flow station HF9 comprised 4 penetrations adjacent to the north flank of Nubbin Knoll; the data are good and complete.

Friday August 12, 2022

Around 12:30 AM, we deployed the heat flow probe for station HF10. This station comprised 2 penetrations north of Nubbin Knoll. We recovered the probe, then transited to reoccupy the waypoints used for station HF5 to collect data at those sites which previously failed. This heat flow station (HF11) traverses a buried basement high to the east of Nubbin Knoll and comprises 4 penetrations. The wind picked up and changed direction, so we recovered the probe and transited to the west end of the line and made the final two penetrations (HF12). Finally, we transited to station HF13 for 3 additional heat flow penetrations on the southwestern flank of Nubbin Knoll.

Saturday August 13, 2022

We completed heat flow station HF13 and recovered the probe to the deck at ~02:00. This completed the heat flow operations around Nubbin Knoll. We transited from Nubbin Knoll to the Pseudofault #2 area to begin seismic operations. We began deploying the streamer for seismic operations at ~06:00; the streamer and guns were fully deployed by ~08:00. By midnight, we collected seismic reflection data along lines P01-P03.

Sunday August 14, 2022

We continued collecting seismic reflection profiles. Over the course of the day, we collected data along lines P04-P07. We started line P08, which continued past midnight.

Monday August 15, 2022

We completed collecting seismic reflection data along line P08. Then, completed the seismic survey with lines P09 and P10. Seismic operations were completed ~12:00. We transited to a site between Diebold Knoll and the deformation front to collect heat flow data. We completed heat flow station 14 (5 penetrations). After recovering the heat flow probe, we transited to the eastern end of planned heat flow station that will approach Diebold Knoll (and a small outcrop immediately to its east) from the east. We deployed the heat flow probe for station HF15.

Tuesday August 16, 2022

We completed heat flow station HF15 (10 penetrations). After recovering the heat flow probe, we made a short transit across a small outcrop east of Diebold Knoll. We completed heat flow station HF16 (3 penetrations) in a small sediment filled saddle between Diebold Knoll and the small outcrop to its east. We transited across Diebold Knoll to its west side. We deployed the heat flow probe and started heat flow station HF 17.

Wednesday August 17, 2022

We completed heat flow station HF17 (3 penetrations). For the sites near Diebold Knoll up to this point (stations HF15, HF16, and HF17) there have been more partial penetrations and instances where the probe did not penetrate (i.e., tipped over) than we saw with the heat flow stations at the MARGIN and Nubbin sites. The seas are a bit rougher, which could be contributing to this; perhaps the sediment in the area is less conducive to penetrations. We transited to the south side of Diebold Knoll for heat flow station HF18. We made 2 penetrations in heat flow station HF18. While transiting from HF18-2 to the waypoint for HF18-3, the starboard engine stopped working. We limped the short remainder of the way to the waypoint for HF18-3. However, upon arrival, we were unable to maintain station. We recovered the heat flow probe, cutting station HF18 short. We transited (at 4.5 kts; reduced speed due to the inoperable starboard engine) to the southern end of the Pseudofault #2 site to begin seismic operations. We started seismic operations at the Pseudofault #2 site ~13:00.

Thursday August 18, 2022

We continued seismic operations at Pseudofault #2, completing them ~16:00. We began transiting to Newport to have the problem with the starboard engine diagnosed and (hopefully) repaired.

Friday August 19, 2022

We finished transiting to Newport, arriving at the dock at ~14:00.

Saturday August 20, 2022

A diver went under the Langseth, but found no obvious external issue that may cause the starboard propulsion issues. The Chief Engineer and engineering crew discovered that a bushing within a gearbox near the starboard prop became dislodged. The bushing was chewed up within the gearbox, in the process destroying the inner workings of the gearbox. LDEO is shipping a replacement gearbox. The timeframe for having the gearbox installed and the ship tested and ready for service is ~3 weeks.

End of cruise MGL22-08.

Seismic reflection report

Seismic data acquisition and processing was led by Anne Tréhu (Oregon State) with assistance from the rest of the Science Party. High resolution seismic reflection data were acquired using the new LDEO 144-channel streamer with 6.25 m group spacing and 2 GI-guns in 45/105 in^3 normal mode fired together as the source. Streamer depth was controlled by 6 birds (one/section) and held at a nominal depth of 4 m, with the observer alarm activated if a bird was outside the range of 3-5 m. The nominal gun depth was 4 m. The geometry for the seismic surveys is shown in Figure 2. The offset between the source and first channel was nominally 100 m (160 m for line MGL2208008P01). Actual near offset indicated by the P190 navigation data varied. Nominal shot interval was 25, resulting in a CMP interval of 3.125 m and 18 traces/CMP (Table 1).

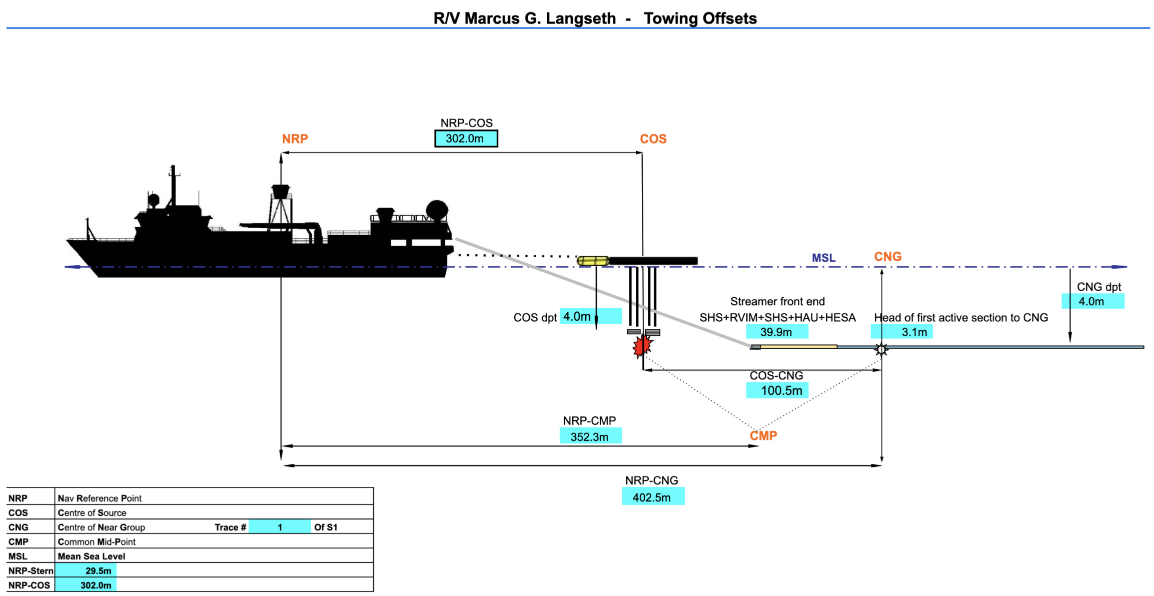

Figure 2: Configuration of seismic source and streamer.

Table 1: General Geometry of MGL22-08 Seismic Acquisitions

Shot spacing (m)	25
Channel spacing (m)	6.25
Number of channels	144
CMP spacing (m)	3.125
Maximum traces per CMP	18

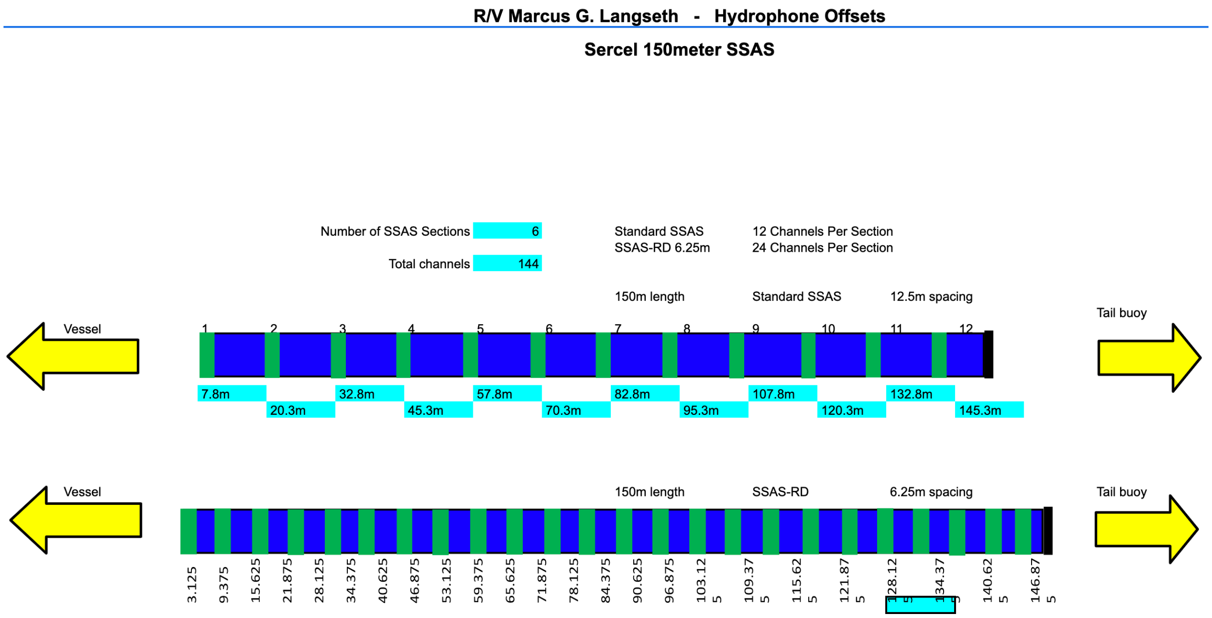

Figure 3: Hydrophone offsets.

Maps of the 2 seismic surveys are shown in Figures 4 and 5. For the first survey, 4 lines were shot crossing Nubbin Knoll, a small crescent-shaped feature on the seafloor 21 km north of DSDP Site 174 and ~65 km west of the deformation front. The second survey produced a series of 8 lines across a feature in the magnetic anomalies generally known as Pseudofault 2 (Wilson, 2002). A summary of the start and end times and locations for the seismic lines is in Table A-1.

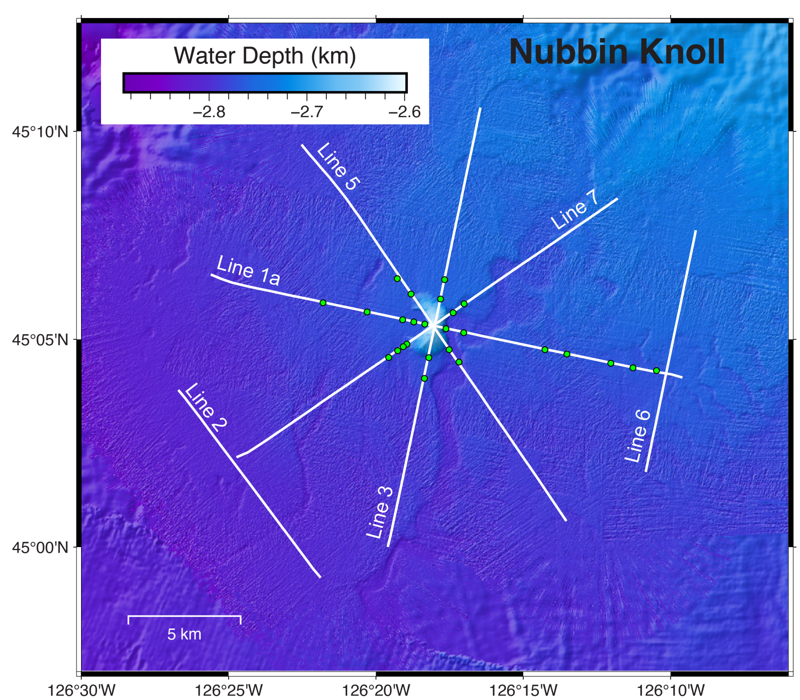

Figure 4: Locations of seismic track lines (white lines) and heat flow penetrations (green circles) at the Nubbin Knoll site. Line names are located near the starting position of each line.

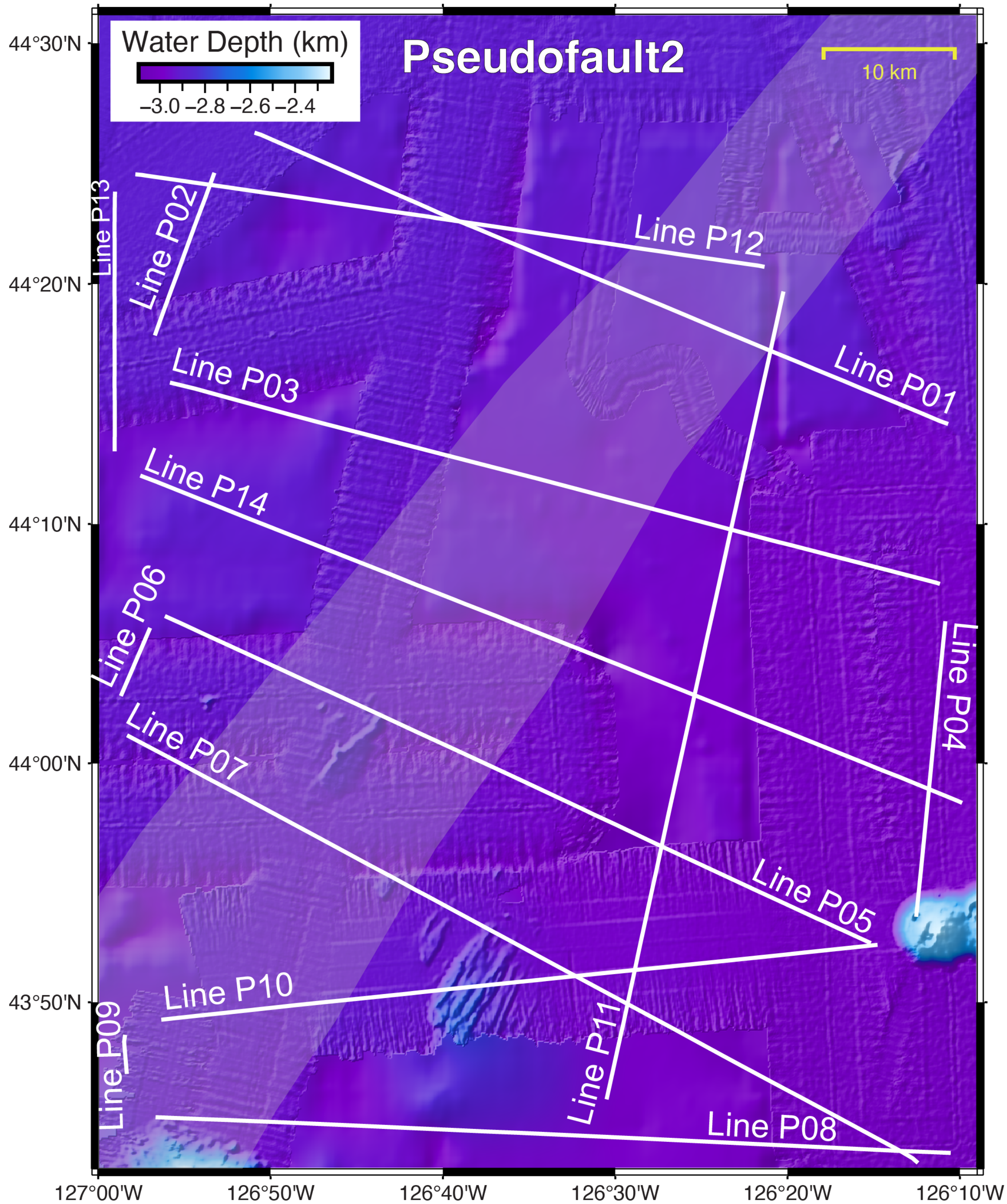

Figure 5: Locations of seismic track lines at the Pseudofault 2 site. Line names are located near the starting position of each line. Gray shading shows the inferred location of Pseudofault #2 from Wilson (2002). Underlying bathymetry from GMRT; bathymetry will be updated with the addition of swath bathymetry acquired simultaneously with the seismic data.

The raw data were delivered as SEG-D and accompanying UKOOA P1-90 location files. Data were processed onboard through migration. Initially data were processed using SIOSEIS and SeismicUnix assuming a constant spacing between the source and receiver, constant shot spacing, and no streamer feathering; in addition, the science party explored using a trial license to the commercial seismic processing software Reveal from Shearwater geophysics, which used the more accurate P190 navigation data to define the geometry. Matthew Perry and Robert Perrin led the effort to use the Reveal software.

The processing SIOSEIS/SeismicUnix hybrid processing flow included:

- Conversion of SEG-D shot files to SEG-Y line files, including decimation of data from 2000 sps to 1000 sps using the most recent version of SIOSEIS, which had been updated prior to the cruise to read the current version of seg-d format.
- Geometry assignation and sorting into CMP gathers assuming a constant spacing between the source and receiver, constant shot spacing, and no streamer feathering.
- Correction for normal moveout assuming a constant velocity of 1490 m/s
- Bandpass filtering (20-200 Hz)
- Stacking
- Trace mixing and further decimation of data to 6.25 m CMP spacing and 500 sps
- Frequency-wavenumber migration
- Data display using Seismic Unix

The processing sequence using Reveal included:

- Definition of project geometry from the P190 data files. Two separate projects (Nubbin and Pseudofault2) were defined.
- Conversion of SEG-D files to line files in the internal Reveal format (.seis) without decimation
- Sorting of data into CMP gathers using the P190 files
- Preprocessing for noise reduction
- Velocity analysis (performed by students after being trained by Matt Perry and Rob Perrin)
- QC of velocity analyses
- Application of NMO and stack
- Stolt migration (3.125 CMP spacing, 1000 sps)

With Reveal, the general processing workflow for each line began with merger of the P1-90 and SEG-D files to create both SEIS database files (for further use in Reveal), and SEG-Y files (for use in Seismic Unix). Within Reveal, two separate flows were created, one to load P1-90 files, and another to load SEG-D files and merge them with their respective P1-90 file. During the SEG-D read flow, only those traces associated with channel set 2 were merged (channel set 1 being auxiliary traces); the shot header was set equal to the source point header. The latter was necessary to ensure the proper fields were in place for merger with the P1-90 file. The line header was also set manually. During initial testing of these flows, it was discovered that the line header within each seismic line was automatically set to 1. This resulted in subsequent errors in processing since Shearwater Reveal attempted to process all these data as a single line, thereby binning and CMP mapping did not make sense. By manually setting the line header, we overcame this issue and we were able to process multiple lines within a single Shearwater Reveal project without further incident. To merge the P1-90 database with the SEG-D files, 2 headers were selected for matching criteria while 13 additional headers were set to ensure proper header mapping which would be used in later processing and exporting of SEG-Y files. The two headers used to match were the source point (SRC_POINT) and the channel (CHANNEL). The 13 additional headers set were SRC_X, SRC_Y, REC_X, REC_Y, SRC_WATER_DEPTH, REC_DEPTH, CABLE, GUN, JULIAN_DAY, TIME_HHMMSS, HOUR, MINUTE, and SECOND. The offset, midpoint coordinates, binning coordinates and CMP coordinates were also calculated.

Once merger was successful, the data were sorted into CDP/CMP bins. After CDP sorting, the data were preprocessed prior to root-mean-squared (RMS) velocity analysis and follow-on normal moveout (NMO) correction and CMP stacking. A bandpass filter between 20 and 400 Hz was applied to the data. Both ends of the filter had a 20 dB/octave falloff. The data were also resampled from 0.5 Hz to 1 Hz. For additional denoising, we applied an F-X Deconvolution algorithm. F-X Deconvolution is used to remove random noise through the enhancement of flat to slightly curving events. The frequency range considered was that of the applied bandpass filter (20-400 Hz) and a window length of 500 ms. The filter was composed of 5 points while the number of traces used in the prediction filter was 21. A pre-whitening factor of 1% was used and low frequencies were preserved.

The preprocessed CDP gathers were ingested into a velocity picking flow where velocities were picked every 200th CDP. Using the velocity tables for each seismic line, we applied NMO correction and CDP stacking. With the stacked seismic lines now available, we finished the initial processing by applying Stolt migration using a constant velocity of 1500 m/s and saved the results in both SEIS and SEG-Y format.

Al Mukhatzhanov loaded preliminary post-stack migrated sections into Schlumberger's Petrel interpretation software to generate maps of the basement surface. The seismic data for Nubbin Knoll clearly defined the shape of the nearly buried seamount and revealed the presence of a nearby completely buried seamount (Fig. 6). Shipboard processing of the data provided a framework for planning the heat flow campaign in this region.

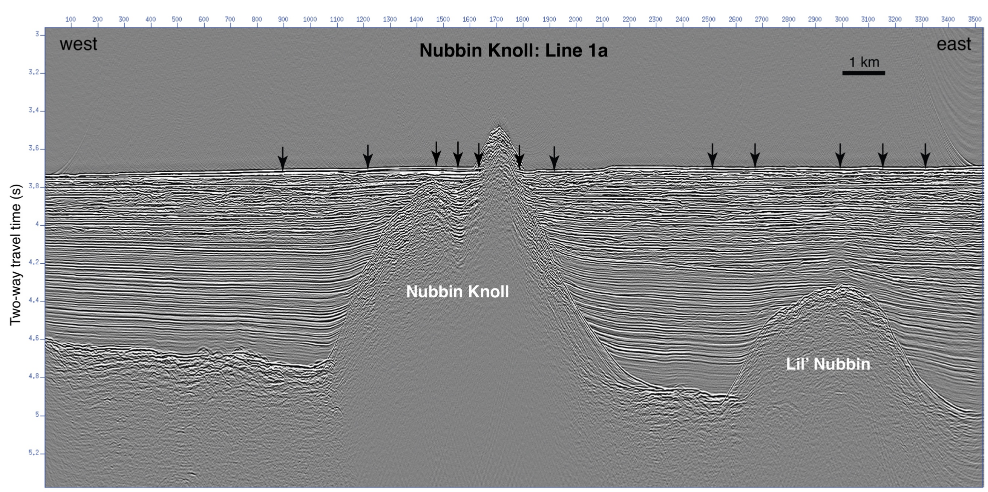

Figure 6: An example seismic profile across Nubbin Knoll, Line 1a (see location in Fig. 4). Arrows show locations of heat flux penetrations.

Seismic sections from Pseudofault2 revealed a complex pattern of basement highs and lows that suggest that this southern end of Pseudofault2 is a broad zone of deformation that is continuous with the region interpreted by Wilson (2002) to be Pseudofault3 rather than a "classic" pseudofault (Fig. 7). This interpretation is consistent with a broad zone of low amplitude magnetic anomalies. Future work on these data include integration with data from RR1718 (Tominaga et al., 2018) and MGL2104 (Carbotte et al., 2021) to reconstruct the tectonic and stratigraphic history of the southeastern Juan de Fuca plate as well as a framework for planning future heat flow measurements.

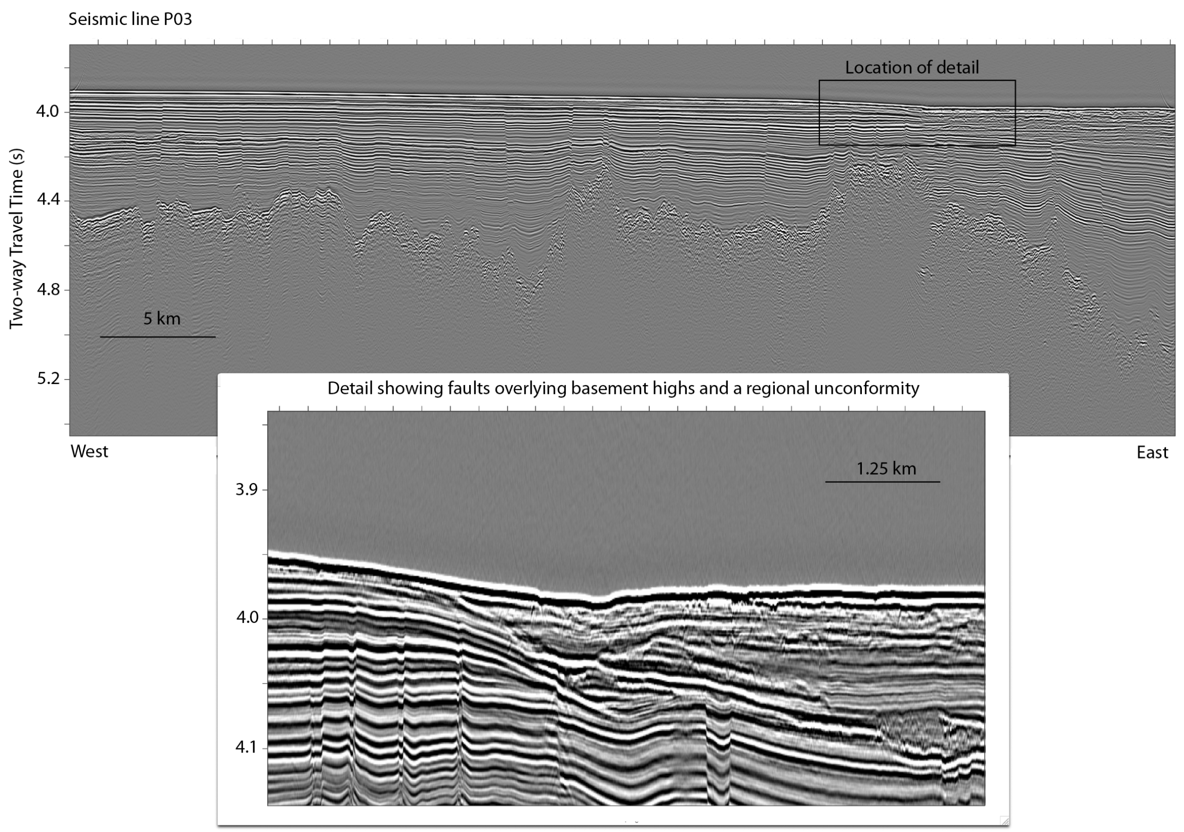

Figure 7: An example seismic profile in the Pseudofault #2 area, Line P03 (see location in Fig. 5).

Shot data have been archived in the Rolling Deck to Repository database. Raw Sed-D, P190, and processed Segy files will be archived with the Academic Seismic Portal maintained at the LDEO. Data will be freely available after an initial moratorium period of 2 years.

Heat flow report

The heat flow team was led by R. Harris (Oregon State) and G. Spinelli (New Mexico Tech), with assistance at sea from Anne Tréhu (Oregon State) and the rest of the Science Party. The primary goal of the heat flow program was to collect data to test for the presence of hydrothermal circulation and help constrain the nature and extent of thermally significant fluid circulation within the basaltic basement aquifer of the oceanic crust just seaward of the Cascadia deformation front. This objective involved measuring heat flow along transects over buried basement highs and adjacent to the edges of basement outcrops, collocated with seismic data from which sediment thickness data could be determined, followed by analytical and numerical modeling to determine patterns of fluid flow necessary to generate observed thermal conditions.

The primary tool used for collection of new heat flow data was a multipenetration heat flow probe (MHFP) consisting of a 3.5-m, 11-thermistor, violin-bow heat flow system. Temperature time series used for both the determination of the thermal gradient and thermal conductivity are logged into solid-state memory in a data logger located in the probe weight stand. The data logger, thermistor string, and acoustic modem were on loan from ROQ Inc.. Temperatures were recorded every two seconds. Other parameters logged by the system include time, water temperature, a stable reference resistance, and acceleration that is used to derive tilt and arm/trigger the heat pulse for thermal conductivity measurements. Acoustic telemetry using a WHOI modem was tried. The modem worked on deck and when the probe was a short distance from the modem in water, but did not work at the depths at which observations were made, ~2500 m. The cable for the modem was 100 feet and the modem was submerged to a depth greater than 60 feet. The lack of acoustic telemetry from the probe was a short-coming. We do not know why the telemetry system did not work when the probe was at depth, but we speculate that it could be the shape of the R/V Langseth hull.

Most heat flow stations consisted of 3-11 measurements separated by approximately 1 km. MHFP operations were run from the starboard rail using the A-frame, trawl wire and traction winch. Personnel from the R/V Langseth ran the winch. Deployments and recoveries of the probe were safe, efficient, and quick. After HF4, a pinger was attached to the trawl wire 50 m above the MHFP weight stand. After arriving at each way point, we let the probe settle for about 15 minutes. This period seemed long enough for the wire to become close to vertical. MHFP measurements were made by lowering the heat flow probe into the seafloor at 60 m/min. Tool penetration was typically followed by 7 minutes during which the thermistor tube approaches thermal equilibrium with the surrounding sediments. A calibrated heat pulse was automatically fired when the acceleration sensor sensed stability during the 7 minute equilibration period, and the thermal response of the thermistor tube was monitored to determine in-situ thermal conductivity. During previous cruises a pressure sensor was used to monitor stability, but during this cruise we used an accelerometer to monitor stability. Overall, using the accelerometer to detect stability worked well. Heat pulses were not generated in the water column and were always generated during a penetration. Final parameters for the heat pulse are stored in the data files and power varied between 2200 and 2300 J. After a measurement was completed, the probe was raised approximately 100 m above the seafloor while the ship transited at ~1 kt to the next site.

Multipenetration heat flow data were parsed into individual penetration files and processed using SlugHeat, a Matlab program based on the hfred/hflow set of processing programs. Kristen Dickerson played a key role in processing the heat flow data (with direction from Rob Harris), while also working to modernize the user interface for SlugHeat. Additional analysis will be required to finalize the heat flow values listed in this report (Table A-2), but values are unlikely to change by more than a few percent as a result of reanalysis. At this stage, no corrections have been applied for sedimentation, or local topography.

A listing of heat flow measurement locations and other information is presented in Table A-3, and plots showing locations and preliminary values (binned within ranges of interest) are shown in Figures 8-10. A total of 58 successful heat flow measurements were made. In-situ thermal conductivity was determined during most tool penetrations, and data were generally of high quality. Final processing of MGL22-08 data will require a careful assessment of data quality.

Although this cruise report is publicly available soon after completion of the cruise, access to Table A-2 (i.e., with the heat flux determinations) is restricted until 2 years after the end of the cruise (August 20, 2022). For more information, please contact Chief Scientist Glenn Spinelli directly.

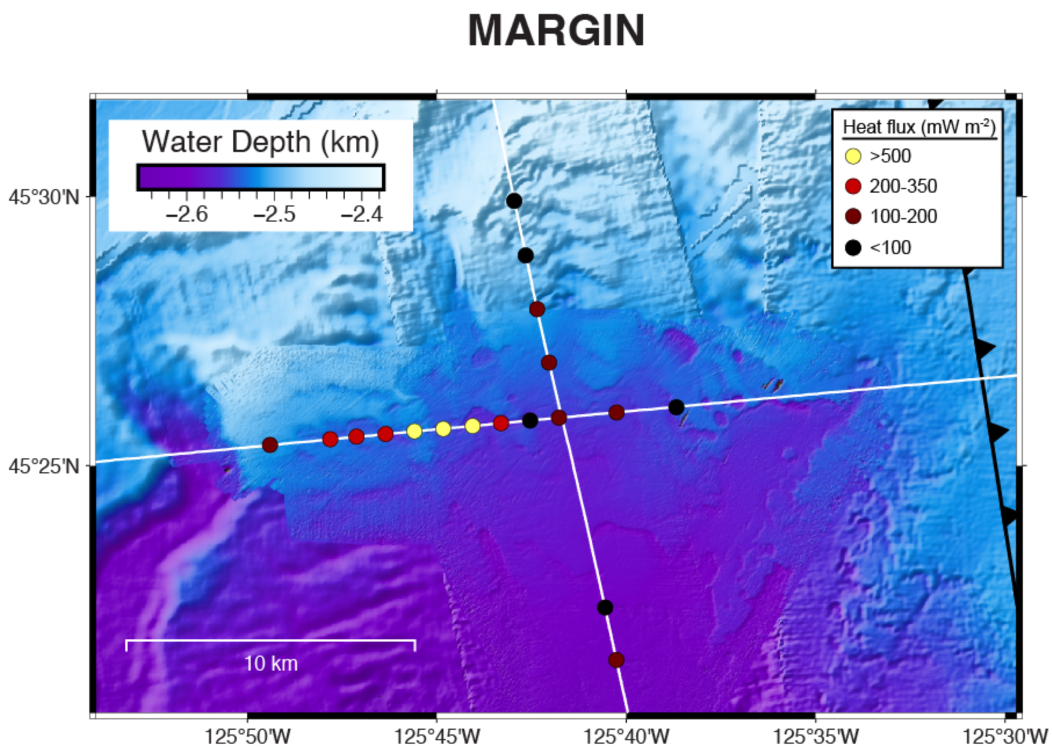

Figure 8: Preliminary heat flux results, MARGIN site. White lines show locations of seismic profiles (from prior cruises). Barbed black line is deformation front.

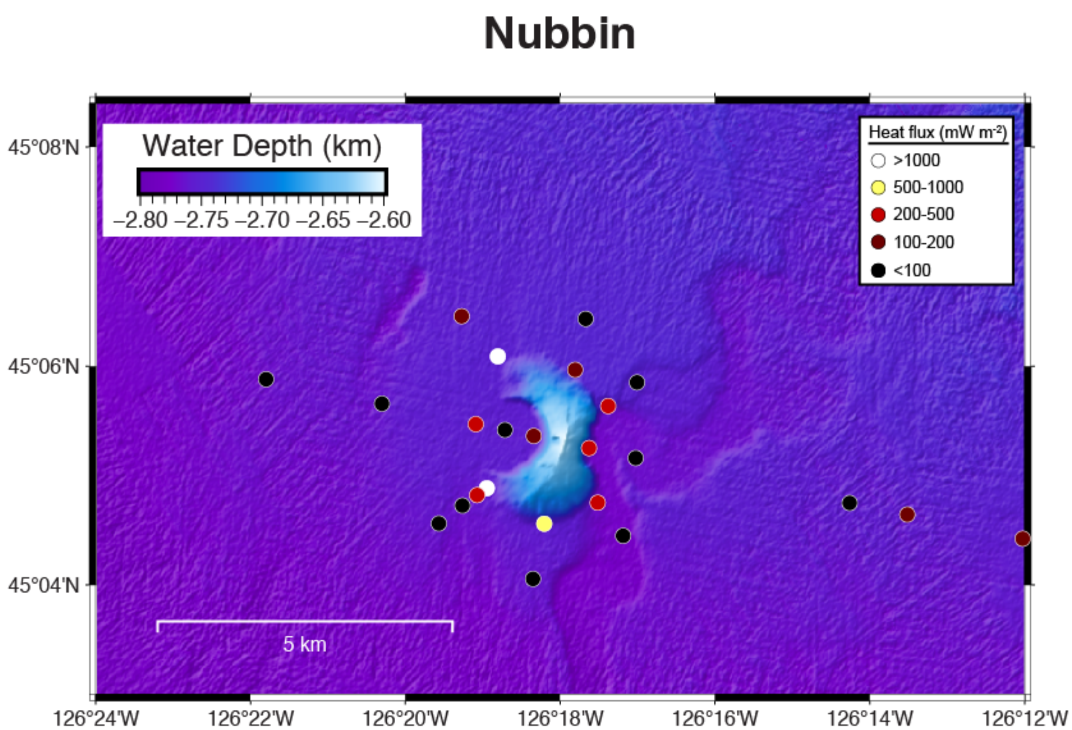

Figure 9: Preliminary heat flux results, Nubbin site.

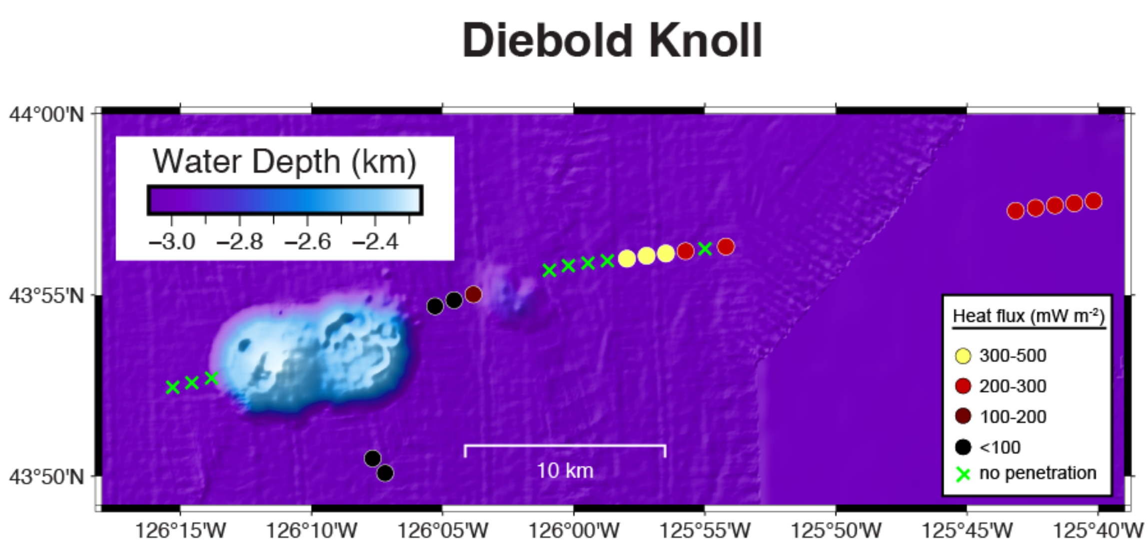

Figure 10: Preliminary heat flux results, Diebold Knoll.

Auxiliary Data Sets

In addition to the primary seismic reflection and heat flux data, auxiliary data sets were recorded. These data are archived through the Rolling Deck to Repository website, which also includes a copy of this cruise report.

XBTs

Expendable Bathythermographs (XBTs) were generally taken once per day to provide sound velocity profiles through the water column for processing the multibeam data. A summary of the XBT casts is provided in Table A-4; results of casts are shown in Figure 11.

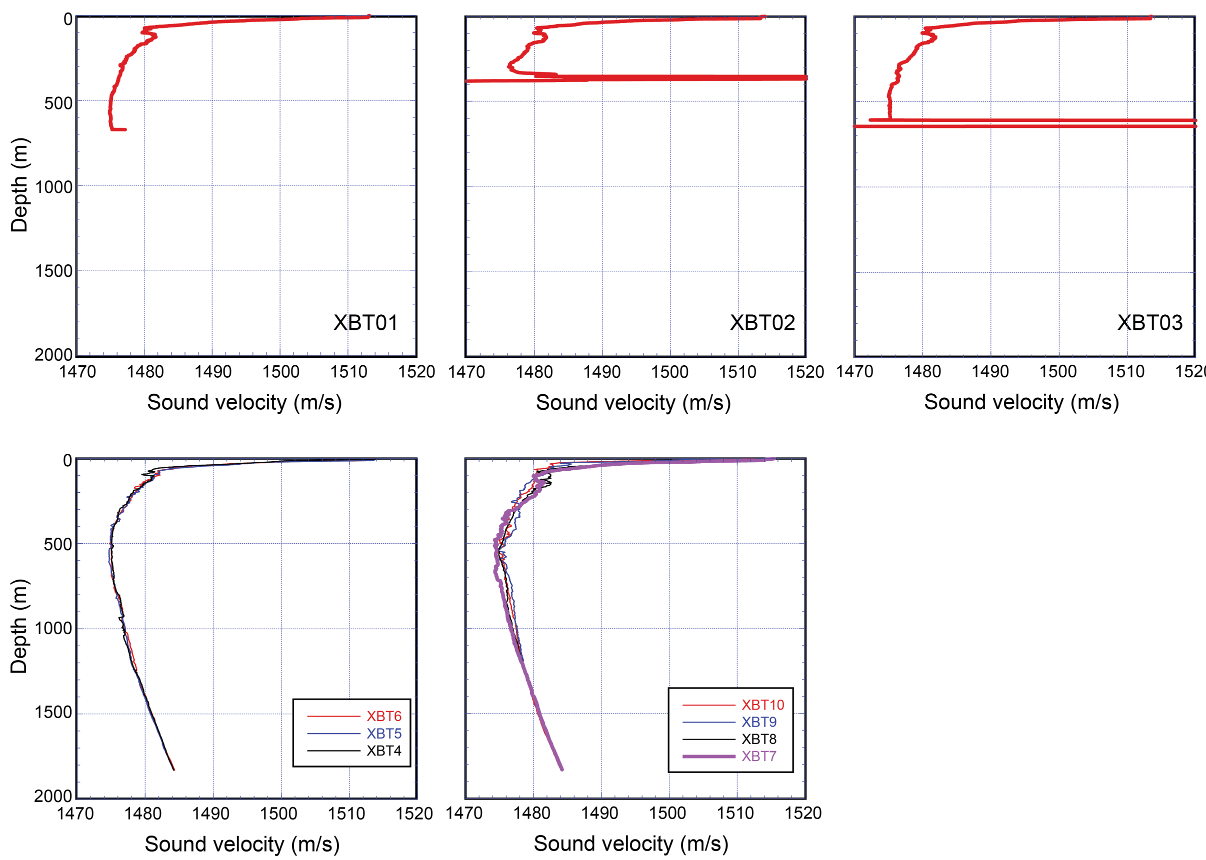

Figure 11: Summary of results from XBT casts.

Multibeam

The EM-122 swath bathymetry system was operated during transits and seismic surveys. The system recorded water depth, seafloor reflectivity, and water column data. The sound velocity profile was updated approximately daily using data from XBTs. The EM-122 data are available through the Rolling Deck to Repository website. Although the science party did not include a multibeam processing specialist, Ariful Islam volunteered to perform some basic processing of the data using MB-System (open source software for processing multibeam data: https://www.mbari.org/technology/mb-system/). Figure 12 shows an example of the processed multibeam bathymetry data around Nubbin Knoll.

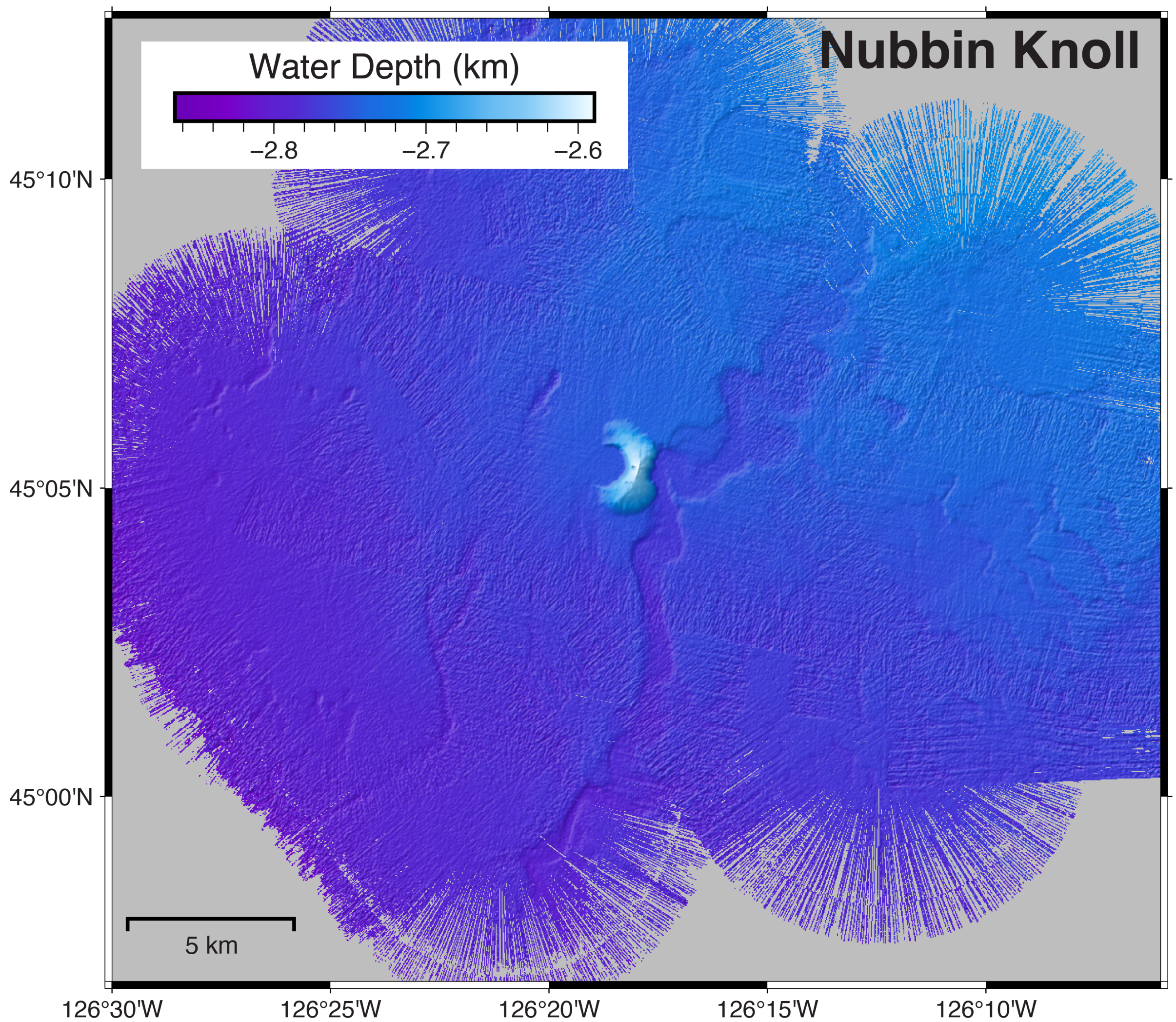

Figure 12: Processed multibeam bathymetry data around Nubbin Knoll.

3.5 kHz subbottom profiler

The 3.5 kHz subbottom profiler operated during most of the cruise, except during heat flux operations when the 12 kHz transducer was used to "listen" to the 12 kHz bottom-finding pinger attached to the wire 50 m above the heat flow probe. Data were recorded in native Knudsen "keb" format and can be played back using Knudsen's software package PostSurvey.

Gravity

Gravity data were collected throughout the cruise using a Bell BGM-3 gravimeter. These data are available from the Rolling Deck 2 Repository website.

ADCP

ADCP data were acquired throughout the cruise and are available through the Rolling Deck 2 Repository website. Data were used to evaluate currents during the cruise, but these data were not analyzed further.

Meteorological data

Meteorological data were collected with a Viasala WXT-520 weather station. Standard meteorological data from the cruise are available through the Rolling Deck 2 Repository website.

Acknowledgments

We thank the officers and crew of the *R/V Marcus Langseth* cruise MGL22-08 for their assistance. We thank Mandy Kiger, Justin McLeod, Ben Russell, and Mike Hutnak for their efforts preparing/maintaining the heat flow probe and components used. This work was supported by the NSF OCE-1924331 (RNH), OCE-2034872 (RNH and AMT), and OCE-2034896 (GAS).

Table A-1: Line log for seismic data.

		Start of Line						End of Line						Start		End	
Line #	Seq #	Date	Time (UTC)	Latitude		Longitude		Date	Time (UTC)	Latitude		Longitude		File #	Shot #	File #	Shot #
				Deg.	*decimal minutes*	*Deg.*	*decimal minutes*			*Deg.*	*decimal minutes*	*Deg.*	*decimal minutes*				
MGL2208001N01	001	2022-08-05	3:27	45	04.06933	-126	09.50517	2022-08-05	3:58	45	04.52183	-126	12.68183	001	1935	171	2105
MGL2208002N02	002	2022-08-05	7:16	45	03.93467	-126	26.89483	2022-08-05	8:43	44	58.97833	-126	20.94217	172	3071	649	3547
MGL2208003N03	003	2022-08-05	9:00	44	59.80883	-126	19.66917	2022-08-05	11:19	45	10.71483	-126	16.40650	650	3974	1477	4800
MGL2208004N05	004	2022-08-05	12:41	45	09.72233	-126	22.57750	2022-08-05	15:06	45	00.56867	-126	13.49250	1478	4983	2309	5812
MGL2208005N06	005	2022-08-05	15:43	45	01.62367	-126	10.89450	2022-08-05	16:55	45	07.66233	126	09.12883	2310	6060	2768	6517
MGL2208006N07	006	2022-08-05	17:33	45	08.22633	-126	12.08500	2022-08-05	19:51	45	02.11583	-126	25.19500	2769	7013	3621	7833
MGL2208007N01a	007	2022-08-05	21:08	45	06.63333	-126	25.85017	2022-08-05	23:33	45	04.01950	-126	09.44750	3622	7967	4504	8849
MGL2208008P01	008	2202-08-13	16:00	44	14.10700	-126	10.39900	2202-08-13	22:12	44	26.29650	-126	51.00167	4505	8920	6845	11260
MGL2208009P02	009	2202-08-13	22:37	44	24.76683	-126	53.17233	2202-08-14	0:00	44	17.61683	-126	56.82183	6846	12059	7386	12623
MGL2208010P03	010	2202-08-14	0:22	44	14.43767	-126	48.11117	2202-08-14	6:51	44	07.56867	-126	11.60283	7390	13571	9864	16045
MGL2208011P04	011	2202-08-14	7:14	44	06.30000	-126	10.74000	2202-08-14	10:17	43	52.50083	-126	13.01233	9867	17021	10864	18018
MGL2208012P05	012	2202-08-14	10:45	43	52.51400	-126	15.29417	2202-08-14	18:01	44	06.20617	-126	57.10183	10866	19022	13309	21465
MGL2208013P07	013	2202-08-14	18:59	44	01.73167	-126	59.45833	2202-08-15	2:08	43	43.01767	-126	12.21200	13310	22030	16193	24913
MGL2208014P08	014	2202-08-15	3:11	43	43.66767	-126	10.76017	2202-08-15	10:09	43	45.20567	-126	57.07800	16194	25844	18684	28334
MGL2208015P09	015	2202-08-15	10:35	43	47.13067	-126	58.34433	2202-08-15	10:57	43	48.83717	-126	58.31600	18686	29051	18816	29181
MGL2208016P10	016	2202-08-15	11:16	43	49.25067	-126	56.33950	2202-08-15	17:12	43	52.42267	-126	14.61433	18818	30002	21079	32263
MGL2208017P11	017	2202-08-17	22:49	43	42.71033	-126	31.48700	2202-08-18	8:23	44	20.20717	-126	20.31583	21080	34143	23921	36984
MGL2208018P12	018	2202-08-18	8:34	44	20.67367	-126	21.10417	2202-08-18	13:52	44	24.54367	-126	58.06183	23923	37064	25905	39046
MGL2208019P13	019	2202-08-18	14:03	44	23.75000	-126	59.04883	2202-08-18	16:00	44	12.61317	-126	58.88700	25907	40060	26732	40885
MGL2208020P14	020	2202-08-18	16:11	44	12.10250	-126	57.85300	2202-08-18	23:32	43	58.33800	-126	09.83850	26736	41070	29495	43829

Table A-2. Summary of heat flux measurements (will be made available after 2 year moratorium following completion of the cruise).

Table A-3. Summary of heat flux measurement locations, number of sensors with usable data

Heat flow station	Penetration #	Latitude	Longitude	# of sensors [a]	Notes
HF1	1-7				No data; Firmware issue; Replace thermistor string
HF2	1	45° 25.7352'	-125° 44.0551'	7	western half of E-to-W line across MARGIN (note: HF1 failed to collect data)
HF2	2	45° 25.6810'	-125° 44.8277'	10	
HF2	3	45° 25.6375'	-125° 45.5870'	11	
HF2	4	45° 25.5830'	-125° 46.3530'	11	
HF2	5	45° 25.5355'	-125° 47.1167'	9	
HF2	6	45° 25.4873'	-125° 47.8116'	7	
HF2	7	45° 25.3820'	-125° 49.4010'	11	
HF3	1	45° 26.083'	-125° 38.677'	11	eastern half of E-to-W line across MARGIN (note: reoccupying HF1 sites, which failed)
HF3	2	45° 25.9862'	-125° 40.2519'	8	
HF3	3	45° 25.8910'	-125° 41.7777'	11	
HF3	4	45° 25.8364'	-125° 42.5405'	11	
HF3	5	45° 25.7873'	-125° 43.3054'	11	
HF4	1	45° 21.3793'	-125° 40.2610'	7	S-to-N line across MARGIN basement high
HF4	2	45° 22.3570'	-125° 40.5598'	11	
HF4	3	45° 23.3745'	-125° 40.8848'	0	temperature data goes wonky
HF4	4	45° 24.3998'	-125° 41.2043'	0	
HF4	5	45° 24.901'	-125° 41.371'	0	
HF4	6	45° 25.4051'	-125° 41.5323'	0	
HF4	7	45° 26.3995'	-125° 41.875'	0	
HF4	8	45° 26.9108'	-125° 42.0355'	6	only top 6 thermistors useable
HF4	9	45° 27.9070'	-125° 42.3520'	6	only top 6 thermistors useable
HF4	10	45° 28.9030'	-125° 42.6518'	6	only top 6 thermistors useable
HF4	11	45° 29.917'	-125° 42.9546'	6	only top 6 thermistors useable
HF5	1-6				Data logger program turned off
HF6	1	45° 05.1669'	-126° 17.0231'	6	E-to-W transect across Nubbin; only bottom 6 thermistors useable
HF6	2	45° 05.2527'	-126° 17.6257'	6	only bottom 6 thermistors useable
HF6	3	45° 05.3629'	-126° 18.3409'	6	only bottom 6 thermistors useable
HF6	4	45° 05.4177'	-126° 18.7155'	6	only bottom 6 thermistors useable
HF6	5	45° 05.4707'	-126° 19.0904'	6	only bottom 6 thermistors useable
HF6	6	45° 05.6580'	-126° 20.3018'	6	only bottom 6 thermistors useable

HF6	7	45˚ 05.8804'	-126˚ 21.7983'	6	only bottom 6 thermistors useable
HF7	1	45˚ 04.0578'	-126˚ 18.3534'	11	Single site S of Nubbin (test probe after cleaning, resealing connections; all thermistors good)
HF8	1	45˚ 04.4515'	-126˚ 17.1853'	11	SE of Nubbin in channel
HF8	2	45˚ 04.7530'	-126˚ 17.5158'	11	SE edge of Nubbin
HF8	3	45˚ 04.5610'	-126˚ 18.2051'	11	S edge of Nubbin
HF8	4	45˚ 04.8850'	-126˚ 18.9488'	11	SW edge of Nubbin
HF9	1	45˚ 05.6360'	-126˚ 17.3813'	11	NE edge of Nubbin
HF9	2	45˚ 05.9675'	-126˚ 17.8057'	11	N edge of Nubbin
HF9	3	45˚ 06.0897'	-126˚ 18.8059'	11	NW edge of Nubbin
HF9	4	45˚ 06.4566'	-126˚ 19.2732'	11	NW of Nubbin
HF10	1	45˚ 05.8525'	-126˚ 17.0077'	11	NE of Nubbin
HF10	2	45˚ 06.4329'	-126˚ 17.6706'	11	N of Nubbin
HF11	1	45˚ 04.2455'	-126˚ 10.4795'	11	E of Lil' Nubbin
HF11	2	45˚ 04.3146'	-126˚ 11.2796'	9	East flank of Lil' Nubbin
HF11	3	45˚ 04.4228'	-126˚ 12.0256'	11	Above summit of Lil' Nubbin
HF11	4	45˚ 04.5312'	-126˚ 12.7742'	0; tilt too high	West flank of Lil' Nubbin
HF12	1	45˚ 04.7510'	-126˚ 14.2611'	11	W of Lil' Nubbin
HF12	2	45˚ 04.6452'	-126˚ 13.5172'	11	West flank of Lil' Nubbin
HF13	1	45˚ 04.5626'	-126˚ 19.5690'	11	1000 m SW from highest HF (~1.5 W/m^2) at SW edge of Nubbin
HF13	2	45˚ 04.7259'	-126˚ 19.2626'	11	500 m SW from highest HF (~1.5 W/m^2) at SW edge of Nubbin
HF13	3	45˚ 04.8227'	-126˚ 19.0731'	11	200 m SW from highest HF (~1.5 W/m^2) at SW edge of Nubbin
HF14	1	43˚ 57.5939'	-125˚ 40.1715'	7	Between deformation front and small outcrop east of Diebold
HF14	2	43˚ 57.5308'	-125˚ 40.9081'	9	
HF14	3	43˚ 57.4773'	-125˚ 41.6454'	11	
HF14	4	43˚ 57.4018'	-125˚ 42.39'	6	
HF14	5	43˚ 57.328'	-125˚ 43.1407'	6	
HF15	1	43˚ 56.3391'	-125˚ 54.1902'	6	E-to-W transect approaching small outcrop east of Diebold
HF15	2	43˚ 56.2796'	-125˚ 54.9968'	0; tilt too high	
HF15	3	43˚ 56.2083'	-125˚ 55.7413'	8	
HF15	4	43˚ 56.1486'	-125˚ 56.4832'	6	
HF15	5	43˚ 56.0809'	-125˚ 57.225'	5	
HF15	6	43˚ 56.0077'	-125˚ 57.9675'	9	
HF15	7	43˚ 55.9494'	-125˚ 58.7169'	0; tilt too high	
HF15	8	43˚ 55.8852'	-125˚ 59.4583'	0; tilt too high	

HF15	9	43˚ 55.8124'	-126˚ 0.2023'	0; tilt too high	
HF15	10	43˚ 55.6858'	-126˚ 0.9287'	0; tilt too high	
HF16	1	43˚ 55.02'	-126˚ 3.8267'	5	Saddle between Diebold and small outcrop to east
HF16	2	43˚ 54.8573'	-126˚ 4.5603'	7	
HF16	3	43˚ 54.6956'	-126˚ 5.2923'	0; tilt too high	
HF17	1	43˚ 52.7078'	-126˚ 13.8175'	0	W of Diebold
HF17	2	43˚ 52.5828'	-126˚ 14.5632'	0	
HF17	3	43˚ 52.4521'	-126˚ 15.295'	0	
HF18	1	43˚ 50.0851'	-126˚ 7.195'	4	S of Diebold
HF18	2	43˚ 50.4887'	-126˚ 7.6701'	4	

a – Number of sensors that penetrated the seafloor and appear to have provided useful data.

Table A-4. Summary of XBT casts.

Event	Date	Time (UTC)	Latitude	Longitude	Instrument	EM122 CBD (m) at splash point	Export Salinity Value (ppt)	Surface velocity (m/s)	6.1m velocity (m/s)	Last Good Depth (m)	Water Temp at LGD (˚C)	Velocity at LGD (m/s)
XBT Seq 1	Fri Aug 05	21:16	45.105447	-126.41216	XBT_T5	2775	28.034	1513.44	1513.01	672.35	4.98	1477.2
XBT Seq 2	Fri Aug 05	22:08	45.090583	-126.31318	XBT_T5	2753	28.112					
XBT Seq 3	Fri Aug 05	22:14	45.088878	-126.30148	XBT_T5	2769	28.176	1513.84	1513.36	608.23	4.33	1473.46
XBT Seq 4	Tue Aug 09	6:41	45.498337	-125.71575	XBT_T5	2747	26.98	1513.99	1487.38	1830.52	2.11	1484.21
XBT Seq 5	Fri Aug 12	0:48	45.09379	-126.28938	XBT_T5	2752	27.476	1514.38	1490.85	1830.52	2.11	1484.2
XBT Seq 6	Fri Aug 12	19:42	45.0746	-126.20716	XBT_T5	2772	27.537	1514.03	1513.15	1830.52	2.14	1484.33
XBT Seq 7	Sat Aug 13	23:28	44.336312	-126.92564	XBT_T5	2903	27.228	1515.44	1489.03	1830.52	2.12	1484.22
XBT Seq 8	Sun Aug 14	19:57	43.988993	-126.89201	XBT_T5	2922	26.938	1515.63	1514.31	1830.52	2.12	1484.25
XBT Seq 9	Mon Aug 15	22:22	43.959713	-125.66925	XBT_T5	3040	24.804	1507.03	1501.56	1830.52	2.14	1484.35
XBT Seq 10	Tue Aug 16	20:41	43.928067	-126.0151	XBT_T5	3010	22.772	1512.47	1507.56	1830.52	2.11	1484.19
XBT Seq 11	Wed Aug 17	22:38	43.700488	-126.52818	XBT_T5	2977	28.288	1516.88	1491.46	891.78	3.87	1476.17
XBT Seq 12	Thur Aug 18	20:52	44.0535	-126.44283	XBT_T5	2978	28.436	1513.34	1512.58	1830.52	2.07	1484.02

Table A-5. Science Party on MGL22-08

#	Name	Location	Email	Position
1	Glenn Spinelli	NMT	glenn.spinelli@nmt.edu	Professor
2	Rob Harris	OSU	robert.harris@oregonstate.edu	Professor
3	Anne Tréhu	OSU	anne.trehu@oregonstate.edu	Professor
4	Mandy Kiger	OSU	kigera@oregonstate.edu	Technician
5	Kristin Dickerson	UCSC	krdicker@ucsc.edu	Student
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7	Danqi Jiang	UT	dqjiang@utexas.edu	Student
8	Tom Kyritz	NMT	thomas.kyritz@student.nmt.edu	Student
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10	Ben Norvell	NMT	benjamin.norvell@student.nmt.edu	Student
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12	Matt Perry	PSI	mperry@psi.edu	Research Assoc.
13	Clara Stanbury	LANL	cstanbur@ucsc.edu	Student
14	Ben Russell	OSU	brussell@coas.oregonstate.edu	Engineer
15	Justin McLeod	OSU	justin@embeddedsolutions.us	Engineer
16	Breck Crum	LDEO		Captain
17	Cody Bahlau	LDEO		Science officer
18	Josh Kasinger	LDEO		Airgun tech
19	Mark Walker	LDEO		Compressor tech
20	Paul Parolski	LDEO		Seismic acquis.
21	Brian Agee	LDEO		Airgun tech
22	Amanda Dubuque			PSO
23	Cassandra Frey			PSO
24	Ana Lira			PSO
25	Michelle Klein			PSO
26	Jimena Ortega			PSO
27	Maritza Martinez			PSO

Table A-6. Cruise log (local time)

Event	Duration (hrs)	Duration (days)	Start, date & approx. time	End, date & approx. time
Wait on bow thruster repair	24	1	08/03/22 06:00	08/04/22 06:00
Leave Newport harbor	2	0.08	08/04/22 06:00	08/04/22 08:00
Transit to Nubbin Knoll	8	0.33	08/04/22 08:00	08/04/22 16:00
Seismic data acquisition at Nubbin Knoll	27	1.13	08/04/22 16:00	08/05/22 19:00
Transit to MARGIN	8	0.33	08/05/22 19:00	08/06/22 03:00
Heat flow at MARGIN, station HF1	13	0.54	08/06/22 03:00	08/06/22 19:00
Heat flow station HF2 (incl. transit from previous station)	18	0.75	08/06/22 19:00	08/07/22 13:00
Heat flow station HF3	12	0.50	08/07/22 13:00	08/08/22 01:00
Heat flow station HF4	24	1.00	08/08/22 01:00	08/09/22 01:00
Transit to near Newport for crew transfer	12	0.50	08/09/22 01:00	08/09/22 13:00
Transit to Nubbin site	11	0.46	08/09/22 13:00	08/10/22 00:00
Heat flow station HF5	11	0.46	08/10/22 00:00	08/10/22 11:00
Heat flow station HF6	16	0.67	08/10/22 11:00	08/11/22 03:00
Heat flow station HF7	5	0.21	08/11/22 03:00	08/11/22 08:00
Heat flow station HF8	8	0.33	08/11/22 08:00	08/11/22 16:00
Heat flow station HF9	6	0.25	08/11/22 16:00	08/11/22 22:00
Heat flow station HF10	6	0.25	08/11/22 22:00	08/12/22 04:00
Heat flow station HF11	10	0.42	08/12/22 04:00	08/12/22 14:00
Heat flow station HF12	6	0.25	08/12/22 14:00	08/12/22 20:00
Heat flow station HF13	5	0.21	08/12/22 20:00	08/13/22 01:00
Transit to Pseudofault2	5	0.21	08/13/22 01:00	08/13/22 06:00
Seismic data acquisition at Pseudofault2	54	2.25	08/13/22 06:00	08/15/22 12:00
Transit to Diebold site for heat flow	2	0.08	08/15/22 12:00	08/15/22 14:00
Heat flow station HF14	8	0.33	08/15/22 14:00	08/15/22 22:00
Transit to heat flow station HF15	1	0.04	08/15/22 22:30	08/15/22 23:30
Heat flow station HF15	13.5	0.56	08/15/22 23:30	08/16/22 13:00
Heat flow station HF16	7	0.29	08/16/22 13:00	08/16/22 20:00
Heat flow station HF17	7	0.29	08/16/22 20:00	08/17/22 03:00
Heat flow station HF18	7	0.29	08/17/22 03:00	08/17/22 10:00
Transit to Pseudofault2	3	0.125	08/17/22 10:00	08/17/22 13:00
Seismic data acquisition at Pseudofault2	27	1.13	08/17/22 13:00	08/18/22 16:00
Transit to Newport	22	0.92	08/18/22 16:00	08/19/22 14:00
In port for engine repair			08/19/22 14:00	+ ~2-3 weeks
End of cruise due to ship mechanical issues				