MGL2105 CRUISE REPORT

TOQUES:
Transform Obliquity on the Queen Charlotte fault and Earthquake Study

July 18-Aug 23, 2021
Seattle to Ketchikan

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1. Cruise Objectives

Due to previously observed spatial and temporal changes in obliquity, including a transition from underthrusting to strike-slip plate motion, the Queen Charlotte Fault (QCF) provides an ideal setting in which to investigate changes in strain accommodation along a continent-ocean transpressive margin. The Transform Obliquity on the Queen Charlotte Fault and Earthquake Study (TOQUES) addresses two fundamental science questions:

1) How is transpressive strain accommodated and partitioned at transform plate boundaries?

2) What are the primary physical conditions controlling deformation and seismogenesis along an oceanic-continental strike-slip fault?

To answer these questions, we collected a combined active-source and passive-source marine seismological dataset along a ~450 km length of the Queen Charlotte fault (QCF), offshore Canada and southeast Alaska (Fig. 1).

Our experiment will: 1) characterize crustal and lithospheric velocity structure along and across the main QCF fault trace, and 2) investigate changes in fault geometry and sedimentary reflection signature along and across the margin, and 3) measure microseismicity and earthquake distribution within key fault segments. Cruise MGL2105 objectives align with (1) and (2). MGL2106 will deploy broadband ocean bottom seismometers to address (3).

1.1 Scientific Motivation:

The offshore continental slope location of the QCF, the accessibility of the fault from major U.S. and Canadian ports, and the fault's geologic setting along a margin with high sedimentation rates (e.g. Walton et al., 2014) make the QCF an ideal location to explore the evolution of transpressive deformation and the relationship between structure and seismicity using marine seismic tools. The long, relatively simple geometry and highly localized strike-slip strain along much of the main QCF trace (Brothers et al., 2017; Fig. 3), allow us to isolate the kinematic parameters, such as fault obliquity, and rheologic parameters, such as oceanic plate age and corresponding thermal structure (Fig. 2), that affect short- and long-term deformation in strike-slip systems. Further, the primary plate boundary fault appears to directly coincide with the PAC-NA contact. These factors stand in contrast to other strike-slip plate boundary systems, such as the San Andreas, which have evolved to preferentially deform within weaker continental crust, initiate multiple active auxiliary fault strands, and are located partially onshore, heightening logistical costs of comprehensive high-resolution imaging compared to a marine experiment.

Figure 1

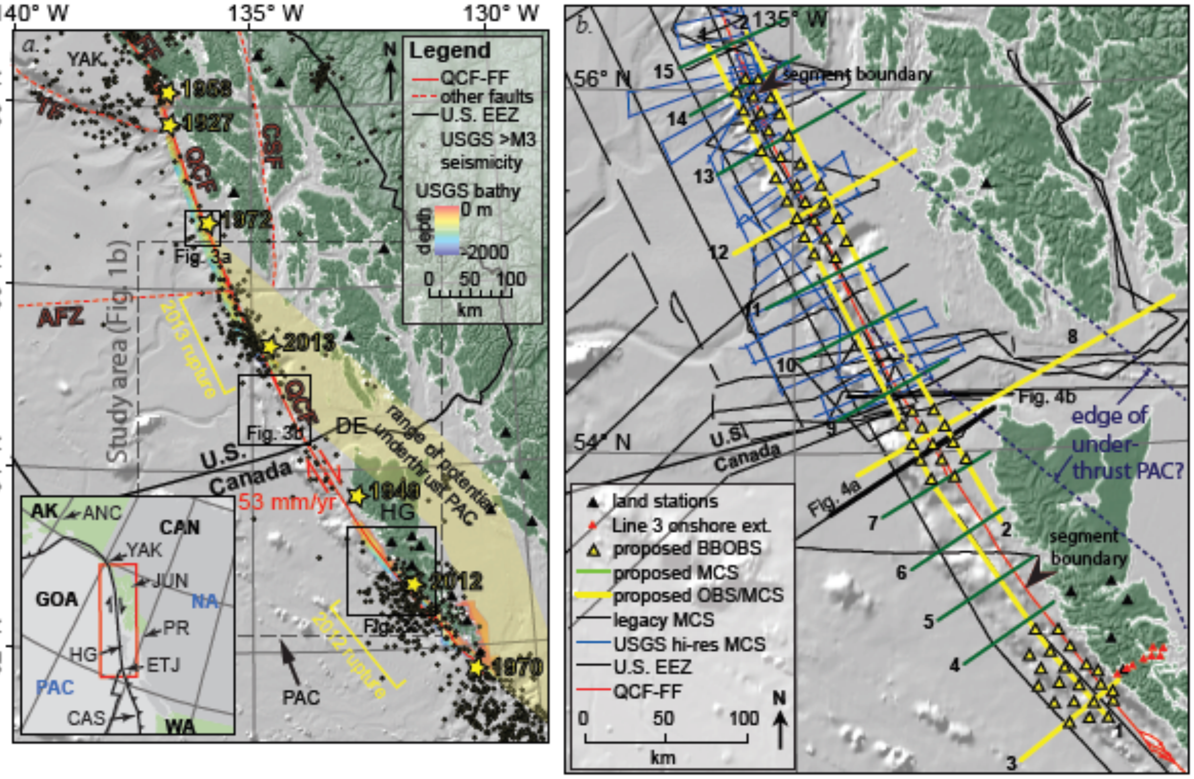


Figure 1. (a) Inset and location map with tectonic setting along the QCF. New high-resolution USGS and Canadian bathymetry along the QCF plotted in color. USGS seismicity annotated in yellow. Shaded yellow area shows range of possible positions of the leading edge of an underthrust NA slab (Smith et al., 2003; Cao et al., 2017). Black triangles indicate broadband land seismometers. AFZ: Aja Fracture Zone. AK: Alaska. ANC: Anchorage. CAN: Canada. CAS: Cascadia. CSF: Chatham Strait Fault. DE: Dixon Entrance. ETJ: Explorer Triple Junction. FF: Fairweather Fault. GOA: Gulf of Alaska. HG: Haida Gwaii. JUN: Juneau. NA: North American Plate. PAC: Pacific Plate. PR: Prince Ruppert. QCF: Queen Charlotte Fault. TF: Transition Fault. WA: Washington. YAK: Yakutat. (b) Proposed survey stations and lines. Study area outlined in Fig. 1a. Bold black lines are legacy seismic sections shown in Fig. 4.

Figure 2

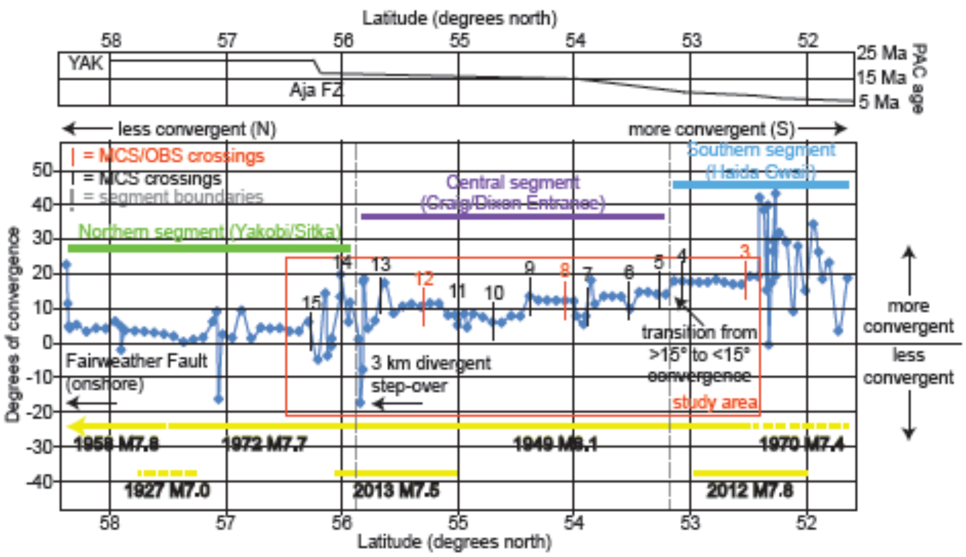


Figure 2. Obliquity along strike of the QCF calculated using fault geometry and Pacific Plate (PAC) motion along discrete 10 km segments of the fault (DeMets et al., 2010). Approximate rupture zones compiled from Doser and Lomas (2000), Lay et al. (2013), Plafker et al. (1994), Rogers (1982), and Yue et al. (2013). PAC age plotted above.

Legacy geophysical data along the QCF provide a first look at the shallow plate boundary structure but also raise fundamental questions (Fig. 4). In the ~23 years since the last MCS data were acquired in the region, advances in both seismic data acquisition and processing have made it possible to target detailed structures across the plate boundary zone at deep crustal depths to explain heterogeneous characteristics of plate boundary deformation. Utilizing modern geophysical methods, including a 15 km MCS streamer, OBS seismic refraction, and targeted BBOBS instrumentation, our study will fill crucial gaps in existing geophysical data by providing the first comprehensive information on crustal velocities, microseismicity, and the nature of fault zone and plate structure at depth along much of the margin.

Figure 3

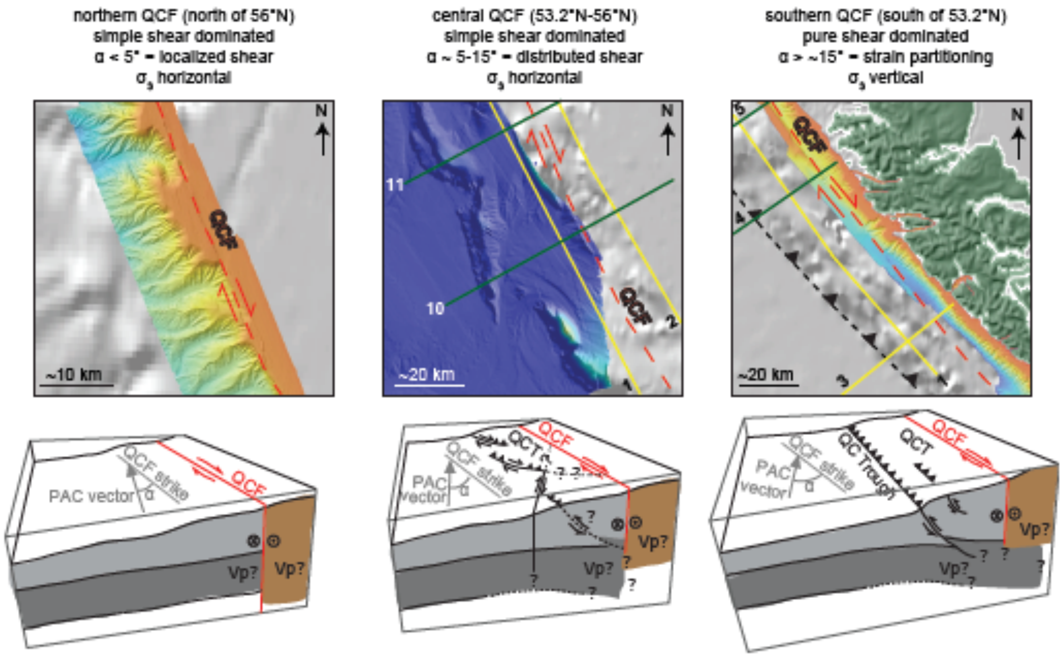


Figure 3. (top row) Zooms of high-resolution bathymetry within each of the three hypothesized kinematic regimes (north, central, and south from left to right: data from Brothers et al., 2017; Gardner et al., 2006; Barrie et al., 2013). (second row) Corresponding schematic diagrams illustrating strain accommodation within the three hypothesized stress regimes and approximate convergence angle (modified from Tréhu et al., 2015). Location of bathymetric images outlined by black boxes in Fig. 1a.

Figure 4

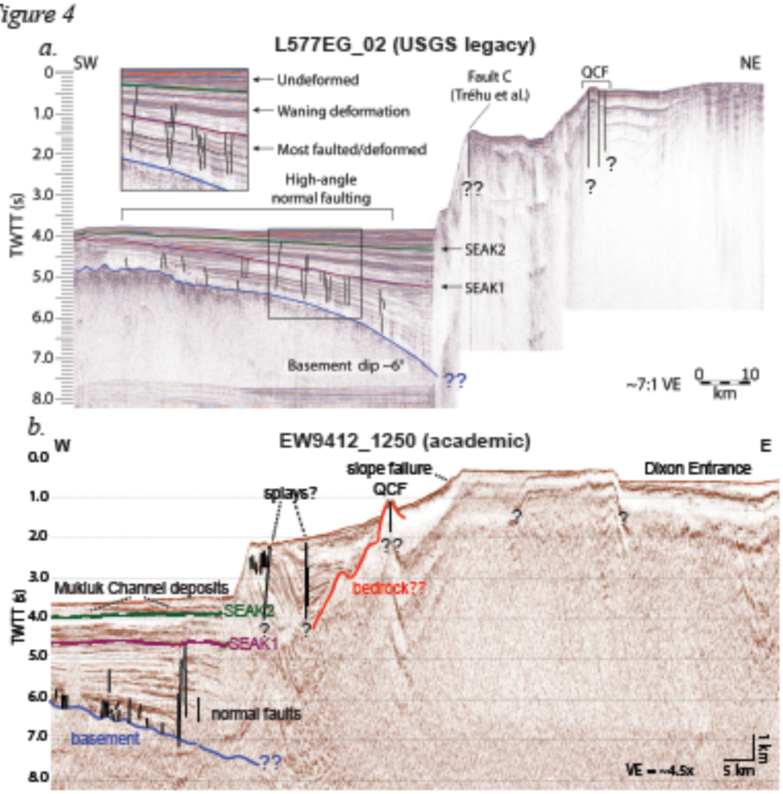


Figure 4. Seismic reflection crossings across the central QCF. Top image shows downwarped Pacific Plate (modified from Walton et al., 2015) and the bottom image shows preliminary reprocessed EW9412 line 1250 across the QCF in a similar region near the Dixon Entrance (reprocessing, unpublished; original processing, Scheidhauer et al., 1999). Both images highlight the need for improved imaging at depth and better data quality on the shelf.

1.2 Geophysical Targets

The field campaign targets a ~450 km-long section of the QCF that occupies a range of obliquity between ~1˚ and ~15˚ (Figs. 1b, and 2) and encompasses two potential fault segment boundaries. Specific targets for investigation include:

Target 1 – Fault-parallel crustal and lithospheric velocity structure along each side of the main QCF trace (OBS Lines 1 and 2 and BBOBS array—Cruise MGL2106)
Target 2 – Fault-parallel sedimentary reflection signature and deformational structures along each side of the main QCF trace that may delineate major and minor fault segments, including rotational or strike-slip features formed in response to segmentation (MCS Lines 1 and 2)
Target 3 – Deep structural response to increased convergence: degree of crustal thickening vs. faulting vs. underthrusting (all cross fault profiles: OBS Lines 3, 8, 12 and BBOBS arrays), distribution of crust-penetrating faults and fault connectivity within kinematic segments (all cross fault profiles: MCS Lines 3-16)
Target 4 – Shallow structural response to increased convergence: degree of slip partitioning vs. stress reorientation within hypothesized fault segments (all cross fault profiles: MCS Lines 3-16)
Target 5 – QCF primary fault zone architecture including the width and depth extent of a low-velocity damaged zone, and variability along strike (cross fault profiles: OBS Lines 3, 8, 12 and BBOBS array—Cruise MGL2106)
Target 6—Microseismicity within the northern fault segment, including Craig aftershock hypocenters with precise depth determinations and stress directions from earthquake focal mechanisms (BBOBS array—Cruise MGL2106).

1.3 Experiment Plan

We acquired ~4200 km of multi-channel seismic reflection data and ~1260 km of coincident wide-angle reflection/refraction profiles over 38 days. The Canadian Coast Guard vessel *John P. Tully*, deployed and recovered the short period ocean bottom seismometers used for the wide-angle refraction profiles (Roland and Walton, co-chief scientists). The seismic source for the reflection and refraction survey was a 6600 cu. in. tuned airgun array. The MCS data was collected using a 15-km-long solid-state hydrophone cable with 1200 receiver groups separated by 12.5 m. The shot interval was 50 m, with a recording time of 17 s. This experimental configuration yields a common midpoint (CMP) fold of 150 and CMP spacing of 6.25 m.

Along the refraction lines (Lines 1, 2, 3, 8, and 12), the Tully deployed short-period OBS at ~5-12 km intervals, with spacing of ~5 km over the central ~40 km of the fault zone for fault-normal crossings. Shot spacing was 150 m to mitigate the effects of previous shot noise. As a consequence of the longer shot interval, MCS data collected along OBS lines will yield a lower CMP fold of 50. Following refraction shooting of a single line, short-period instruments on that line were be recovered, serviced, and redeployed on a subsequent refraction line while Langseth transitted or MCS data was acquired.

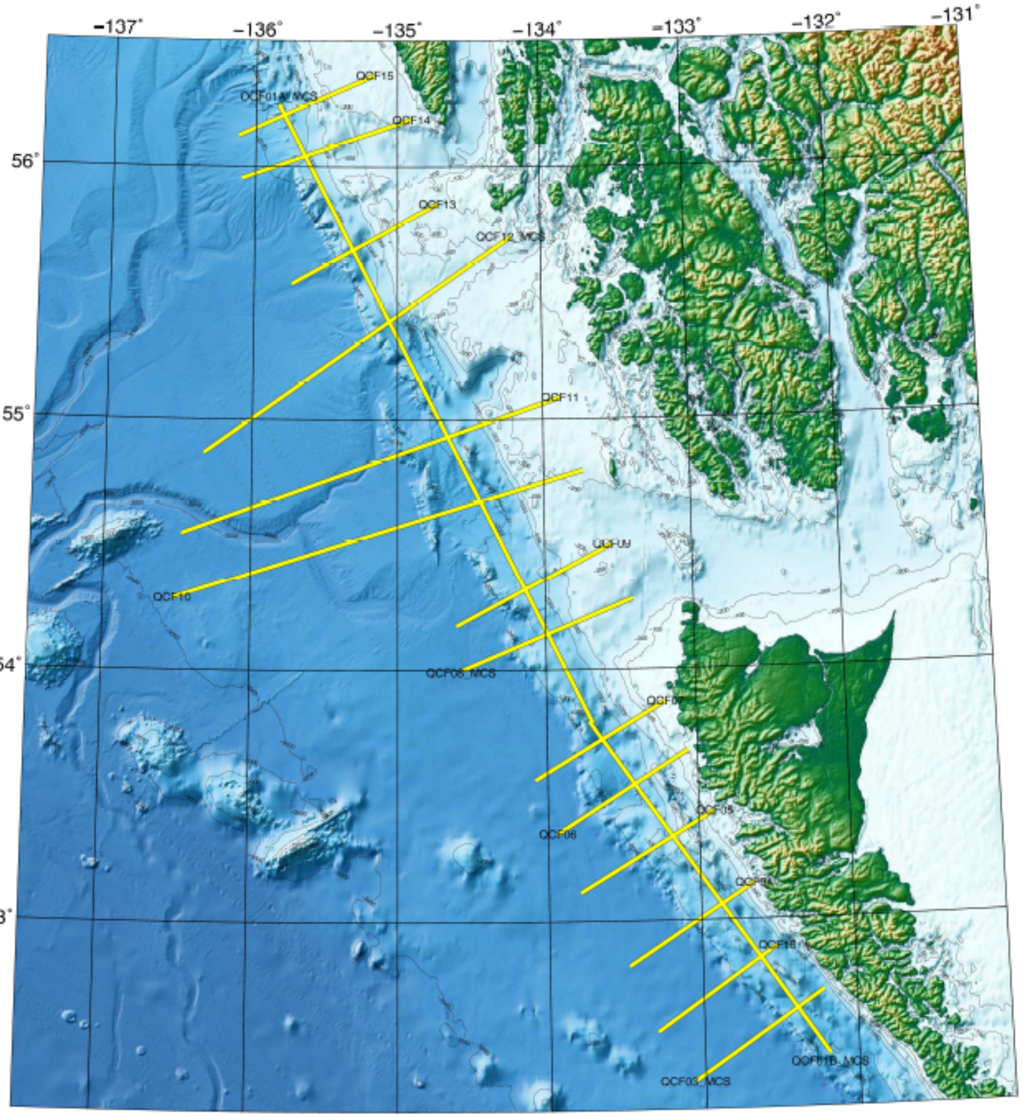


Figure 1.5 Pre-plotted MCS acquisition with line names.

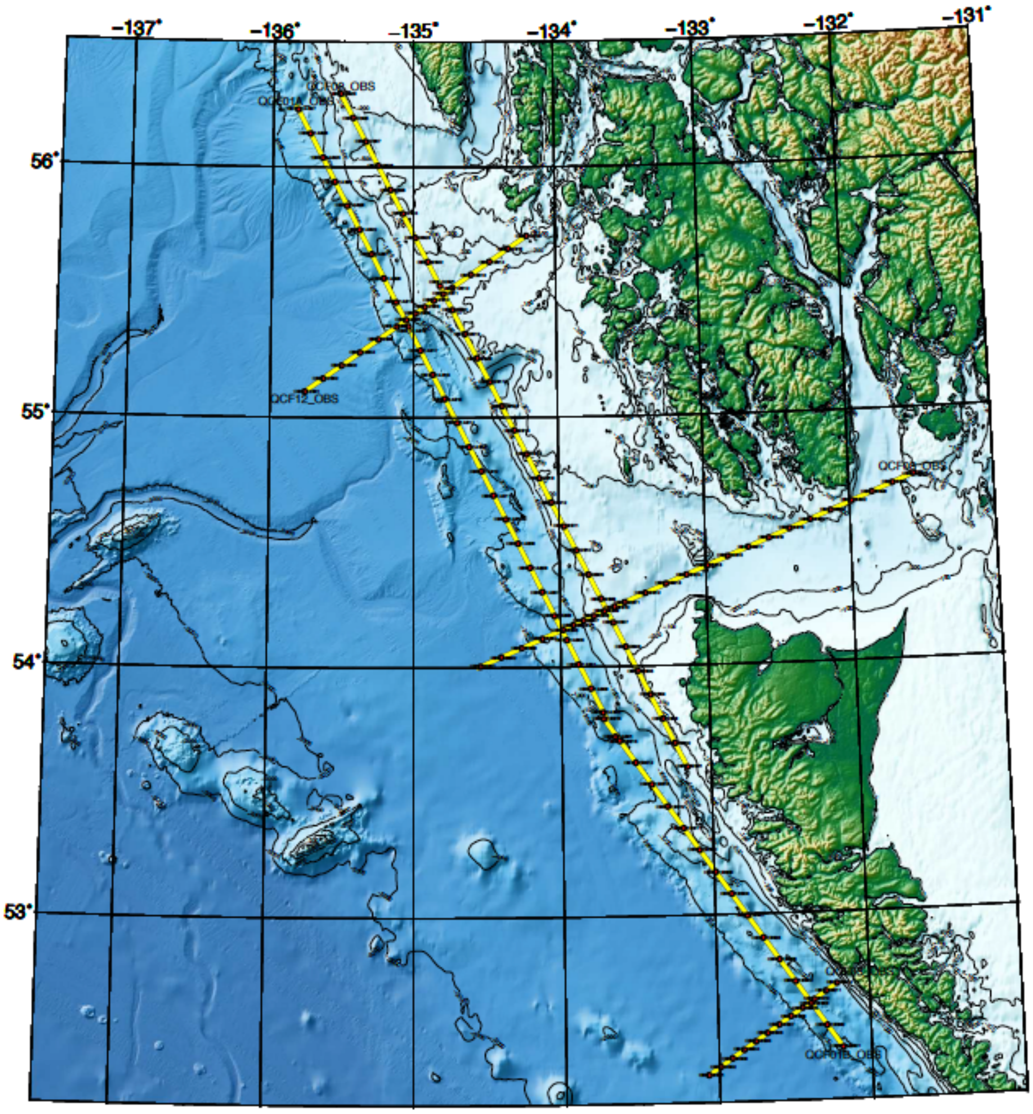


Figure 5.2 Preplotted OBS profiles with OBS locations and line names.

2. Cruise Summary

The cruise departed Seattle, WA, on July 18 and arrived in Ketchikan, AK, on Aug 23. We sailed for 36 days from port to port and actively collected data for 32 days. Summary of operations in Table 2.1. During the cruise, we acquired wide-angle reflection and refraction data along three fault crossing transects and two along-margin profiles, totaling ~1200 km. OBS were deployed and recovered by a separate cruise and science party aboard the CCGS John P Tully. There were 123 OBS deployments and recoveries in total. We acquired MCS data along 14 fault crossing transects and one margin-parallel transect on the Pacific side of the QCF fault trace with a 15 km streamer. OBS shots were at 150 m spacing and MCS shots were at 50 m spacing. Three OBS transects (12, 01A and 02) were acquired with the 15 km streamer deployed. In addition to the seismic data, we also acquired a suite of underway geophysical and oceanographic data including gravity, magnetics, bathymetry, high-frequency sub-bottom profiling and ocean temperature.

Table 2.1. Summary of Operations

Date	**Operation/Action**
July 9	Science party begin quarantine in Seattle
July 16	Science party aboard Langseth
July 17	Langseth fueling
July 18	Depart Seattle, Pier 91
July 20	Onsite, begin shooting OBS Line QCF01B
July 24	Begin deploying 15 km streamer
July 25	Begin MCS data collection on MCS Line QCF03
Aug 5	Finish OBS shooting with OBS Line QCF02
Aug 19	Finish MCS primary shooting with MCS Line QCF01A
Aug 21	Finish MCS reshoots with MCS Line ACF03
Aug 23	Arrive Ketchikan
Aug 24	Science party departs ship

2.1 MCS and OBS Shooting

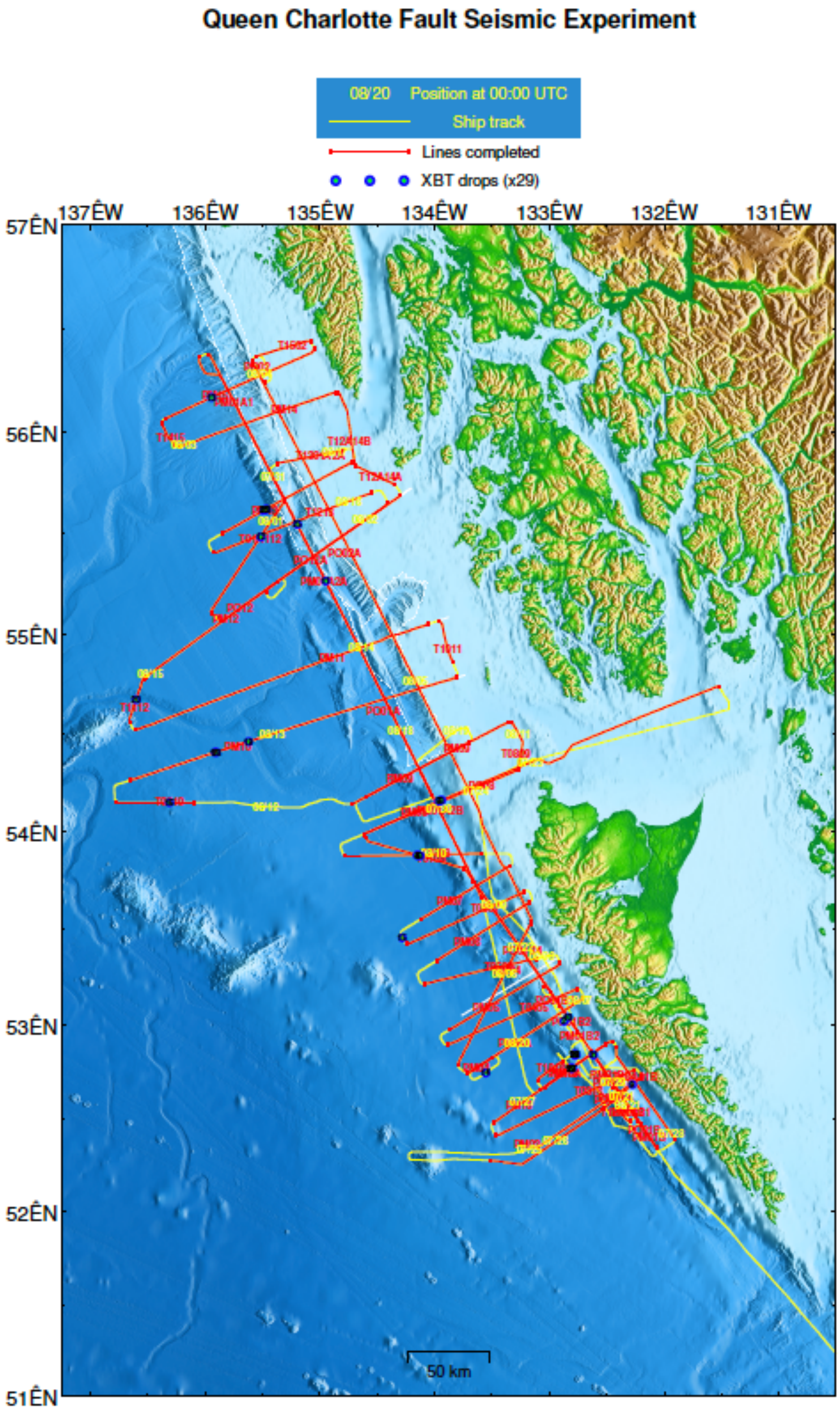
Following Tully OBS deployments on QCF01B-OBS, QCF08-OBS and QCF03-OBS, we began data acquisition on July 20, at the southern end of profile QCF01B-OBS (OBS spacing 12 km). We deployed the 4-string, 36-element, 6600 cu. In. air gun array and began shooting at 150 m shot spacing. We continued with guns only for QCF08-OBS (OBS spacing 5-10 km) and QCF03-OBS (OBS spacing 7 km). We recovered the guns prior to transit between QCF08 and QCF03. Following acquisition of QCF03-OBS, we recovered the guns and deployed the 15 km streamer. We redeployed the guns and began MCS data acquisition with OCF03-MCS. During this period, the Tully recovered the OBS and redeployed on QCF01A-OBS and QCF12-OBS. We continued acquiring data in the following order: OCF03-MCS, QCF16, QCF01B-MCS, QCF01A-OBS, QCF01A-MCS part 1, QCF12-OBS, QCF14, QCF15, QCF02-OBS. After we acquired QCF01A-OBS, the Tully recovered those instruments and deployed stations on QCF02-OBS. After shooting OBS02-OBS, the Tully finished recovery and started transit to port. We continued MCS acquisition until Aug 21 with the remaining profiles in order: QCF04, QCF05, QCF06, QCF07, QCF08-MCS, QCF09, QCF10, QCF11, QCF12-MCS, QCF13, QCF01A part 2. We also reshot parts of QCF09, QCF16, QCF03-MCS, QCF01B-MCS due to missing data from cetacean shut downs and sub-par data due to loss of streamer control while shooting QCF09. Summary of line names and shooting parameters in Table 2.2.

Table 2.2. Profiles and Shooting Parameters in Order of Acquisition*

Preplot Name	**Line ID**	**OBS spacing**	**Streamer depth**	**Shot spacing**
QCF01B-OBS	PO01B	12 km	No streamer	150 m
QCF08-OBS	PO08	5-10 km	No streamer	150 m
QCF03-OBS	PO03	7 km	No streamer	150 m
QCF03-MCS	PM03	No OBS	12 m	50 m
QCF16-MCS	PM16	No OBS	12 m	50 m
QCF01B-MCS	PM01B	No OBS	12 m	50 m
QCF01A-OBS	PO01A	12 km	12 m	150 m
QCF01A-MCS	PM01A1	No OBS	12 m	50 m
QCF12-OBS	PO12	5-10 km	12 m	150 m
QCF14	PM14	No OBS	12 m	50 m
QCF15	PM15	No OBS	12 m	50 m
QCF02-OBS	PO02	12 km	12 m	150 m
QCF04	PM04	No OBS	12 m	50 m
QCF05	PM05	No OBS	12 m	50 m
QCF06	PM06	No OBS	12 m	50 m
QCF07	PM07	No OBS	12 m	50 m
QCF08	PM08	No OBS	12 m	50 m
QCF09	PM09	No OBS	16 m	50 m
QCF10	PM10	No OBS	14 m	50 m
QCF11	PM11	No OBS	14 m	50 m
QCF12	PM12	No OBS	14 m	50 m
QCF13	PM13	No OBS	14 m	50 m
QCF01A-MCS	PM01A2A	No OBS	14 m	50 m
QCF09-reshoot	RM09	No OBS	16 m	50 m
QCF01A-MCS	PM01A2B	No OBS	14 m	50 m
QCF16-reshoot	RM16	No OBS	14 m	50 m

*not including turn/transit lines and multi-segments because of cetacean shutdowns

Figure 2.1. Trackline Map



3. Cruise Narrative

July 9-16: Seattle quarantine period. During our week of quarantine we held daily “happy hour” meetings over Zoom that also included shore-based science party members and one joint meeting with *Tully* science party. These meetings included check-ins and ice-breaking activities and informal presentations by students and co-chief scientists. The students each presented on a relevant Queen Charlotte fault paper covering earthquake behavior and structure and tectonics. Worthington gave an overview of mission science objectives and background and Phrampus gave an overview of his work with NRL. Each day, the science party was assigned a different ‘buddy’ to check in with and join for outside exercise time of ~1.5 hrs.

July 16: Science party boards Langseth.

July 18: We departed Seattle at 0930 PDT and began our transit to QCF01BS01. We crossed into Canada at approximately 1630 PDT. All hands conducted the mandatory MOB drill and a fire drill. The weather is very favorable and it looks like a great day to get this job started!

July 19: All day transiting to the southern end of QCF01B-OBS and should be there July 20 in the late morning. Planned with captain and CSO to begin with a 4-hour run in for gun staging, deployment and testing. PSOs will begin their ramp up during the staging and deployment. Projected time on site is midday July 20. Science party started standing watch at 1200 PDT.

July 20: Finished transiting to southern end of QCF01B-OBS. Deployed guns at ~1100 PDT, began ramp up and started shooting ~1300 PDT, ~10 km south of the southernmost OBS. Started Knudsen, MAGGIE and PAM. Multibeam not starting—troubleshooting currently. Due to air leakage on deck, gun string 2 pulled in. Shooting at 75% volume starting at ~1530, repaired and back out at ~1645. PSO shutdown (whale in Canadian waters) SP1151 at 1710 PDT. Turned around to reshoot data gap. Restart with SP1346 at 1845. PSO shutdown (whale in Canadian waters) SP1523 at 2145 PDT. Due to PSO viewing requirements, cannot ramp up till morning. Slow ship to 3.5 kts thru water. Start multibeam at 2225 PDT.

July 21: At ~03:00 turn around to reshoot part of data gap starting at O1BS07 for line PO01B (data gap between 1BS05 and 1BS07 will remain), after conversation with Tully. Back on line PO01B at ~0700, near station 01BS07. Two shutdowns due to whale sightings in Canadian waters at ~0915 PDT and ~1200 PDT. We turned around to reshoot these data gaps—each shutdown and turn around took ~1.5-2 hrs. Science meeting at 1300, students presented seismic data processing progress on practice seismic lines. Back on line shooting at 0130 PDT. Finished PO01B at 2300 PDT and started T0108. Anticipated to start PO08 at 0600 PDT tomorrow. Super calm seas all day.

July 22: Start of line PO08 at 0610 PDT this morning. Deviation to south at ~1700 PDT to avoid <200 m in Canada and reduction in volume at ~1800 to accommodate protected habitat. Picked up magnetometer just to be safe with the current sea state and crab angle—it separated from the ship during the last cruise. Weather and seas a bit more choppy today. Shooting all day, no shut downs.

July 23: Finished shooting PO08 at 0630 PDT—no shutdowns!! Recovered guns and began transit to PO03. Collected bathy survey over eastern ends of Line 04 and Line 05.

July 24: Arrived at PO03 area 0430 PDT. Began gun deployment and ramp up. PSO sighting at 0640 PDT delayed ramp up 1 hr. Start of line at 0800. PDT Uninterrupted shooting to end of line. End of line at 1625 PDT. Began recovering guns at 1635 PDT. Began deploying streamer at 1845 PDT.

July 25: Turn around during streamer deployment to head towards SOL PO03. Finish streamer deployment at 0645 PDT. Started PO03 at 1330 PDT, line offset by 3 km to avoid a weather buoy located near line at OBS station locations 03S06. End of at 2118 PDT and start PO03A at 2121 PDT. New line due to change in heading caused by line offset, need to avoid marine protected area to south. Finished line at original preplot point on eastern end. Calm seas and few PSO observations continue.

July 26: Finish PO03A at 0100 and start turn line T0316. PSO sightings at 0607 PDT (SP 9010) and 0659 PDT, shut downs for both. Ramp up at 0802 PDT and full volume at 0824 PDT (SP 9354). About 15 km missing data from ~2 hrs of shutdown. Picked up line T0316 at and shot uninterrupted through the end of the line. Turned to get on to line PM16 at 1300 PDT. PSO sighting of 2x North Pacific Right Whales at 2100 PDT resulting in shutdown on PM16 as we were entering the toe of the slope. Turned around to reenter on line with a 16 km run in. Guns came online before PSOs went offshift (thank you PSOs!). Will enter PM16A ASAP to continue data collection. Weather continues to be very favorable—everyone doing well!

July 27: Begin shooting turn line T1616A on way back to line 16 at ~0000 PDT, end at 0215 PDT. Begin PM16A at ~0300 PDT with ~16 km run in. Shooting PM16A through morning. PSO shut down at very end of line at 0815 PDT (SP 14230). We kept going and turned onto T16A01B. This profile follows the southern QCF fault trace until turn off to line PM01B. Ramp up finished and shooting T16A01B at 1213 PDT (SP 14522), EOL at 1730 PDT. SOL PM01b at 1918 PDT. PSO shutdown at ~1010 PDT, will not be able to restart before shift end. Turn around to restart on PM01B in morning. Seas are glassy smooth, which is both a cursing and a blessing. No noise in streamer data, but clear sight of any and all protected species!

July 28: Coming onto PM01B (now PM01B1) at ~0300 PDT. At 0515 had to speed up towards start point due to a sinking streamer in the turn. We were shut down three separate times. We circled two times to try to fill in the high priority areas that were missed, like the line crossing of 01B with 03. Right when we came back on line, there was a third sighting and we had to move on. 0630 PDT, back to full volume. Shot through the night. At ~1130 PDT an acoustic arrival wiped out our signal on the streamer, we determined the 8.2 earthquake offshore the Aleutians was the likely cause. It appears a T-wave was generated by the quake, which propagated through the N. Pacific to us offshore Haida Gwaii. After examining the arrivals, they have an apparent velocity of ~1800 m/s (very approximate!) which gives the arrival an azimuth of ~34 deg from the ship heading (ignoring streamer feathering). The approximate azimuth of the quake to our heading was ~37 deg.

July 29: PM01B1 continued through the night, no shutdowns. Started shooting PO01A, short porpoise shutdown at 1350 PDT (SP 21312). We slowed to 3.4 kts SOG and continued steaming during the shuts down. Ramp up at 1430 PDT and full volume at SP 221350. Continuous shooting on PO01A through the night.

July 30: PO01A continues. Timing errors on Gun 4-1: SP 22318-22322. One gun shut down and firing at 95% volume starting at SP 22322. PSO shutdown at ~1930PDT SP22986 for a humpback whale. Fog also rolled in to obscure visuals resulting in a ~50-minute shutdown. Slowed ship to limit data gap and continued acquisition of PO01A.

July 31: We finished PO01A at ~0315 PDT and began our turn for PM01A1. We finished the run in for PM01A1 at 0615 PDT. We had a short PSO shutdown at 0800 (SP 24475). Ramp up began at 0835 (SP 24564) and we were at back to 95% volume at 0859 (SP 24609). We disable gun strings 3 and 4 due to an air leak at 1024 (SP 24841). Shooting at 3300 cubic in for rest of line. We ended line PM01A1 at 1500 PDT and began transit to P012. Went to 75% volume at 1342 PDT (SP 25493). Gun strings were both back in water at 1720 and shooting at full volume (SP 25729).

Aug 1: Finish T01A112 at 0010 PDT and continue onto PO12 at 0115 PDT. Nominal geometry processing continues on acquired lines. 3D binning continues to be unsuccessful. QC'd all processed navigation to date—ie., up to PM01B2. Start of line PO12 at 0115 PDT (SP 27149). PSO shutdown and turn around to fill data gap at 0555 PDT (SP 27395). Ramp up at 0905 PDT (SP 27545) and back on line at SP 27579. Bathymetry processed through July 27. QC of all processed P190 files is complete as of 1800 PDT. Finish PO12A at 1953 PDT. Continue to turn line T12A14A. Recover gun string 1 and 2 for repair during turn, shooting at 50% capacity on T12A14A. Return to 75% capacity near end of T12A14A (SP28592). EOL T12A14A and turn northward to SOL T12A14B at ~2355 PDT.

Aug 2: Continue T12A14B, 100% airgun capacity at 0040 PDT (SP2880). Crossing a large channel during T12A14B. Backscatter shows heavily scoured features, very interesting. Finish T12A14B at 0534 PDT and continue onto PM14 at 0550 PDT. Large multiples (primary and pegleg) are strong in both shallow and deep water, even over the deep-water fan. Why is this? Finish PM14 at 1912 PDT. Start T1415 at 1940 PDT, end at 2126 PDT. Start PM15 at 2156 and continue through the night. Launched a T-5 XBT at 2315 PDT and updated EM122.

Aug 3: Continue PM15, finish line at SP33802 and begin turn line to PO02. Gun auto-fire at 1110 PDT, disable strings 3 and 4, pull them to repair Gun 4-1. Loop around to beginning of PO02 to shoot end of line with full volume. Full volume at 1442 PDT. Start of line PO02A at 0411 PDT (SP 34766). Lost power to last third of streamer at 1700 PDT. Back online at 1720 PDT. Continue PO02A through the night.

Aug 4: Continue PM02A. This is a long one! Swell and wind have picked up. Winds over 20 kts most of the day. Did some investigating into gun and source signature. SEGD gun files show that guns 8 and 9 on String 1 may have faulty sensors following change out between Line PO12A and Line T12A14A. Qualitative investigation of source signal shows consistency across survey.

Aug 5: Continue PM02A. EOL PM02A at 1213 PDT, SP 37090. We have successfully finished the OBS shooting operations!! YESSSS!!! Very stoked. SOL T02A04 at 1225 PDT (SP 37533). Shutdown for porpoises (30 min) at 1540 PDT (SP 38012).

Aug 6: At 0000 PDT GunLink went offline resulting in no firing. At 0005 PDT, GunLink was back online and all guns were firing. We continued to acquire T0204. We finished T0204 at 0036 PDT, and continued onto PM04. During the run-in to PM04 gun 1 on string 4 started to auto fire at 0338 PDT. This required us to pull in both string 3 and 4. We aborted acquisition at 0351 PDT and turned around to restart PM04 (now PM04A). We turned off all guns till we fixed sting 4 since we would not be acquiring data. Weather is still rough, but with no fog so prewatch and the ramp up should not be an issue. End PM04A at 0838 PDT. Continue onto T0405 at 1823. No shutdowns today!

Aug 7: Continue T0405. End line at 0429 PDT and start turn onto PM05. Finish PM05 with no shutdowns at 1517 PDT. Guns shut down to avoid 200m crossing. Ramp up and continue onto T0506 at 1724 PDT. PSO shutdown at 2105 PDT, able to ramp up again at 2212 PDT. PSOs stayed late to allow for ramp up. Thank you PSOs for saving us again!

Aug 8: Continue on T0506, finish at 0141 PDT. Start PM06 at 0433 PDT. End of line PM06 at 1305 PDT (SP 47800). Guns shutdown to avoid <200 m water depth—will turn in <200 m and resume shooting when out of <200 m depth zone. Pulled strings 3 and 4 for maintenance after turn. Start of line T0607 at 1427 PDT (SP 48005). PSO shutdown at 1431 PDT (SP 48011). Ramp up strings 3 and 4 at 1542 PDT, full volume by 1600 PDT (SP 48447). Gorgeous day of warm sunshine—sun's out, guns out! Finish T0607 at 2342 PDT.

Aug 9: Collect an XBT during the turn at 0020 PDT and update EM122 velocity profile. Start PM07 at 0227 PDT. End of PM07 at 1021 PDT. Guns disabled to avoid shooting in <200 m water depth. PSO sighting delayed ramp up. Ramp up and start of line T0708 at 1322 PDT (SP 51536). End of line T0708 at 23:25 PDT.

Aug 10: Start of line PM08 at 0219 PDT (SP 53430). The seas are picking up and swell noise on the streamer increasing. At 0730 PDT, drop streamer to 14 m depth to reduce noise and improve streamer control (SP 54257). At 0850 PDT, first 20 birds dipped to 20 m, streamer at 14 m by 0940 PDT. End of line PM08 at 1412 PDT. Start of line T0809 at 1422 PDT. Lots of wave motion and strong current in Dixon Entrance. End T0809 at 1801 PDT (SP55970). Start PM09 at 1806 PDT (SP56090). Continued large swells and currents coming from our aft resulted in terrible feathering at the beginning of PM09. We dropped the streamer to 16 m at 2017 PDT

(SP56518) to combat some of the swell noise. The moved our notch frequency to ~46.3 Hz, which is not ideal. Multibeam is also having issues with the swell resulting in many data gaps.

Aug 11: One gun offline due to bad shot timing, at 95% capacity (6240 cu in) at 0230 (SP57428). Finish PM09 at 1445PDT (SP 58119). Front/middle section of streamer continuing to have control issues—suspect bird failure or something on the streamer. Decided to pull in guns and streamer up to bird 36 to check. Guns shut down at 1450 PDT, begin streamer recovery at 1740 PDT. Five birds ~12-18 were detached from collars or had missing SRDs. We replaced collars and birds. Begin streamer deployment at ~1630 PDT. Streamer fully deployed at ~2000 PDT. Begin ramp up at 2154 PDT and start the last part of T0910 at 2155 PDT (SP58343). Lowered streamer to 14 m to reduce swell noise at 2201 PDT. Pull in and repair airgun string 3 at 2203 PDT, shooting with 27 guns (4950 cu in).

Aug 12: Back to full volume at 0012 PDT (SP58679). End T0910 at 0348 PDT (SP59175). Start PM10 at 0631 PDT (SP59234). Disabled guns for a few shots due to probable air leak at 0644 PDT. Back to full volume at 0651 PDT (SP59366). Launch an XBT at 1520 PDT and update EM122. Weather is much better, still some swell noise on streamer at 14 m depth. Continuing PM10 all day.

Aug 13: Continue on PM10 through the morning. Down to 35 guns at 0558 PDT (SP63085) near end of line. Pulled gun string 3 for maintenance at beginning of turn line to PM11. Then pulled strings 3 and 4 for maintenance. Shooting with half volume for most of the shelf on PM11. Full volume at PO02 crossing. Foggy today, with continued bigger swells. Streamer still at 14 m to try to mitigate low frequency noise.

Aug 14: Continuing PM11. One hydrophone on airgun string 4 failed at 0107 PDT and was shut off, but source still at full volume. Some noise on the streamer from cargo ship this morning and early afternoon. End of PM11 at 1155 PDT (SP 67465). Start of line T1112 at 1315 PDT (SP 67700). Start of line PM12 at 1640 PDT. Ping pong tournament started today. The head PSO, Cassi, gave a background talk today and showed pictures of some of the detections they've had this trip. Rolling along through deep water.

Aug 15: Continuing PM12 to end of line at 1332 PDT (SP 71600). Pulled the magnetometer due to high seas at 0632 PDT. Start of line T1213 at 1513 PDT (SP 71800). End of T1213 at 1512 PDT (SP71800). Large heave in shallow water resulted in some bad EM122 data.

Aug 16: End of T1213 at 0246 PDT (SP76355). Move streamer to 12 m depth due to quieter seas. Start PM13 at 0445 PDT (SP73828). End PM13 at 1449 PDT (SP 75462). Magnetometer redeployed at 0755 PDT. Start of Line T1301A2A (what???) at 1631 PDT (SP 75600). End of line T1301A2A at 2113 PDT (SP 76329). Start of line PM01A2A at 2215 PDT (SP 76471). Reduced to 35 guns (6540 cu inches) because of misfire on String 3 Gun 7 (SP 76609).

Aug 17: XBT at 0157 PDT. End of line PM01A2A at 2129 PDT (SP 80466). Magnetometer brought on board due to weather.

Aug 18: Start of line RM09 with full volume at 0620 PDT. Streamer depth to 14 m and then to 16 m due to marginal weather and seas. End of line RM09 at 1445 PDT (SP 81920). Science party meeting today, Sarah presented on normal faults outboard of deformation front offshore Haida Gwaii. Laz presented on gravity analysis—corrected profiles along line tracks. We also discussed wrap up plans and will have another meeting during transit to Ketchikan on Sunday (Aug 22). Begin PM01A2B at 2112 PDT (SP82126), streamer still at 16 m due to large swell.

Aug 19: Continue PM01A2B. End of line PM01A2B at 0655 PDT. We finished the primary line locations!!!! Last new shotpoint 83783. Remote interview with Sitka Sound Science Center. Transit to RM16. Start RM16 at 2127 PDT (SP83920), streamer was raised to 12 m during turn.

Aug 20: Continue RM16, end line at 0330 PDT (SP84944). Due to fishing gear in the water, we have to turn South to be sure we cross the QCF (the reason for the reshoot!). This put us into a 5-hour turn to get back onto line 01B for further reshoots. This delay still keeps us in our original time window for end of survey by 0700 PDT Aug 21st. Start of line RM01B at 1221 PDT (SP 85536). Ramp up delayed by one hour due to PSO sighting, during run in so no affect on data acquisition. End of line RM01B at 1819 PDT (SP 86530). We began transit to RM03. During our turn to RM03, winds and waves picked up. The weather deteriorated significantly while approaching. After discussion with the Captain, and technical team, we decided to go down for weather conditions to reduce the risk to the crew and equipment. We were looking at shortened shooting window between the weather buoy and the shoreline, as well as reduced data quality due to the weather and swell noise. We began recovering the guns at 2100 PDT.

Aug 21: We began recovering the streamer after midnight and finished recovery by 0700 PDT. During recovery, one of the students was injured by a blow to the nose—poor Pinar! She recovered and no major damage was done, thank goodness! Operations have wrapped. Science party have finished watches. Co-chiefs have begun copying data and are working on the cruise report.

Aug 22: Transit to Ketchikan.

Aug 23: Arrived Ketchikan ~0830 ADT.

4. COVID-19 Mitigation and Plans

4.1 Pre-Cruise Procedures

The MGL2105 cruise was classified under Tier 1 of the UNOLS COVID guidance dated June 4, 2021 (Vers. 1.3), as crew and science party were not fully vaccinated at the time of sailing.

If the crew and science party are not fully vaccinated

	Tier 1		Tier 2	
	UV	V	UV	V
Pre-travel Testing	PCR[2]	PCR[2]	PCR[2]	None
Self-Quarantine	7 days	7 days	7 days	None
Self-Quarantine exit test	PCR[2] d5 or Ag d7	PCR[2] d5 or Ag d7	PCR[2] d5or Ag d7	N/A
Pre-Boarding Symptom Tracking	7 d prior to boarding	7 d prior to boarding	7 d prior to boarding	7 d prior to boarding
Embark Testing	N/A	N/A		Testing based on Pre-board Symptom Screening

[2] - Reverse transcription polymerase chain reaction or other CDC recognized NAATs also acceptable - Nucleic Acid Amplification Test – see: https://www.cdc.gov/coronavirus/2019-ncov/lab/naats.html
PCR - Reverse transcription polymerase chain reaction
Ag – Antigen test
UV – not fully vaccinated
V – vaccinated

The COVID-19 plan for LDEO crew, marine technicians, PSO's and Science Party was a combination of health risk assessment and screening, quarantine and multiple PCR tests. We had 40 individuals sailing including with ~10 new crew, 2 contractors, 4 PSO's and 6 Science party coming on in Seattle.

All personnel completed a health questionnaire to assess risk and monitor for symptoms prior to traveling. A PCR test was be done by each person prior to travel. Upon arrival, we were taken directly to the hotel where we quarantined for one week in Seattle, WA. Meals were ordered/delivered to rooms during this time and we continued to monitor for symptoms. Each day, we had ~1.5 hrs of socially-distanced unsupervised exercise outdoors. All personnel was tested at day 5 and received negative results before boarding Langseth on day 7.

4.2 Onboard Mask Mandate During Project

Recently the USCG issued MSIB 02-21-CH-2 on COVID-19 Safety Requirements in the Maritime Transportation System regarding the wearing of masks for all vessels including research vessels on June 11. This executive order applies to all vessels and requires that masks be worn at all times when outside of one's staterooms inside the vessel or while eating. The most significant change was the new CDC incorporated guidance that no masks are necessary while outside on vessel decks or exterior.

5. Summary of Data Acquisition

5.1 OBS acquisition

We used the full 36-element, 6600 cu in array of the *Langseth* towed at 12 m for all OBS shooting. The shot interval was 150 m on all profiles, resulting in a time interval between shots of ~1 minute depending on speed over the ground. Shots were recorded on short-period seismometers from Scripps and WHOI spaced at ~5-~12 km along 6 profiles, which were deployed and recovered by the CCGS *Tully*. OBS were spaced at 12 km on the margin-parallel profiles. On the fault-crossing profiles, OBS were spaced at 10 km and densified to 5 km within the nearest 40 km to the QCF fault trace. Shots were also recorded on the Langseth's 15-km-long streamer towed at 12 m depth for profiled 01A, 12 and 02. We used a sample rate of 2 ms and record length of 17s.

5.2 MCS acquisition

We used the full 36-element, 6600 cu in array of the Langseth towed at 12 m for all MCS shooting. MCS profiles were acquired with a shot spacing of 50 m, sample rate of 2 ms and a record length of 17 seconds with the 1200-channel, 15- km-long streamer. Receiver group spacing is 12.5 m. We towed the streamer at 12 m depth below the sea surface for most of the cruise. We lowered the streamer to 14 m and 16 m during marginal weather to reduce swell noise (see Table 2.2, Section 3 and cruise log for additional details). The guns were towed 215.5 m from the stern. The near-offset (from source to near streamer channel) was 220 m. Appendix A includes further information on acquisition parameters.

5.3 Other Underway Data

- Multibeam bathymetry data were acquired with a 11-12 kHz Kongsberg EM 122 and subbottom profiler data were acquired with a 3.5 kHz Knudsen Sounder Suite throughout the study area, except during recoveries of OBS. (See Appendices B and E).
- Gravity data were acquired with a BGM-3 air-sea gravimeter system throughout the cruise (See Appendix B). Gravity tie information in Appendix F.
- Magnetic data were acquired with a G-882 cesium marine magnetometer towed 110 m behind the behind Langseth during MCS acquisition. Magnetometer was recovered during marginal weather (See Appendix B).
- One XBT was done every ~1-3 days throughout the expedition.
- Other underway data were recorded, including pCO2, ACDP, etc.

6. Summary of Onboard Processing

The science party began preliminary data processing and plotting while underway for the multi-channel seismic reflection data, multibeam bathymetry data, and gravity data. Details on processing and data examples are given in relevant appendices.

6.1 Multichannel seismic reflection data

The science party complete preliminary processing of most MCS data up to migrated brute or velocity stacks. We used Paradigm Echos (v. 2017). All science party members participated in seismic processing. Initial background and training for processing was done during a 3-day, remote pre-cruise workshop in June 2021 that included lectures on cruise objectives and seismic processing and hands on practice using Echos 2019 through remote login to University of New Mexico. Additional processing procedures were discussed via student presentations on deconvolution and velocity analysis after practicing with existing data while transiting. None of the student participants had previous experience with seismic reflection processing.

The chief and co-chief scientists developed a standard workflow for baseline data products (up to migrated brutestacks) and created logsheets to help organize the processing steps. Beyond the basic workflow, each student was encouraged to explore different parameters and processing steps to follow their interests, including velocity analysis. Two students created projects out of testing different deconvolutional parameters and WEMA for multiple suppression.

The basic workflow was as follows (see Appendix D for more details):
- Raw SEG-D file were read into Echos
- A nominal marine geometry was assigned for all lines for onboard processing because processed P-190 data were not immediately available.
- Filtering and other data cleaning steps were applied, which included trace editing, bandpass filtering, deconvolution and noise suppression
- Spherical divergence corrections
- Brutestack using 1480 m/s and time migration
- Velocity analysis every 500 CDP
- Stacking and time migration using stacking velocities

After processed P-190 navigation files were available, we QC'ed the navigation and wrote locations and offets into the exported SEGY shot files. We also exported the processed data as SEGY files, either the brutestack or the velocity stacks, if available.

6.2 Multibeam bathymetry data

The science party undertook automated and manual processing of multibeam data using MB-system Version 5.2.1880. Every member of the science party processed at least one day's worth of data. The large majority of bathymetric data was processed at sea. See Appendix E for more details and workflow.

• Data were converted to format MB59, which allows for editing and processing.
• Automated cleaning was applied to all files, which included removing outer 5 pings, removing spikes with slopes >60º.
• Pings were manually edited using mbedit.
• Cleaned data were gridded and plotted.

6.3 Gravity data

Gravity data was processed and plotted by Lazaro Garza.

• Gravitational acceleration and were converted to freeair gravity anomaly
• Gravitational acceleration data were corrected for Eötvös, variations of the gravity field due o Earth's rotation and flattening and filtered in order to remove the effects of wave-induced horizontal and vertical accelerations acting on Langseth.

7. Preliminary Scientific Outlook

Using the shipboard processed data, we can assess our potential to address the experimental objectives and highlight interesting subsurface features for future processing and interpretation. We acquired almost 100% of our targeted MCS profiles and ~98% of our planned OBS data. OBS data were immediately delivered from the Tully to the Navy for initial screening. Here, we summarize major features of the MCS dataset and challenges in acquisition and/or processing.

7.1 Southern Survey Area – offshore Haida Gwaii

In the southern portion of the QCF, offshore Haida Gwaii, our goals were to image the structure of the Queen Charlotte Terrace (QCT), identify evidence of active Pacific plate bending and normal-faulting and characterize the structural relationships between thrusting of the QCT and the main QCF trace. QCF Line 03 crosses the 2021 Haida Gwaii earthquake epicenter and aftershock region.

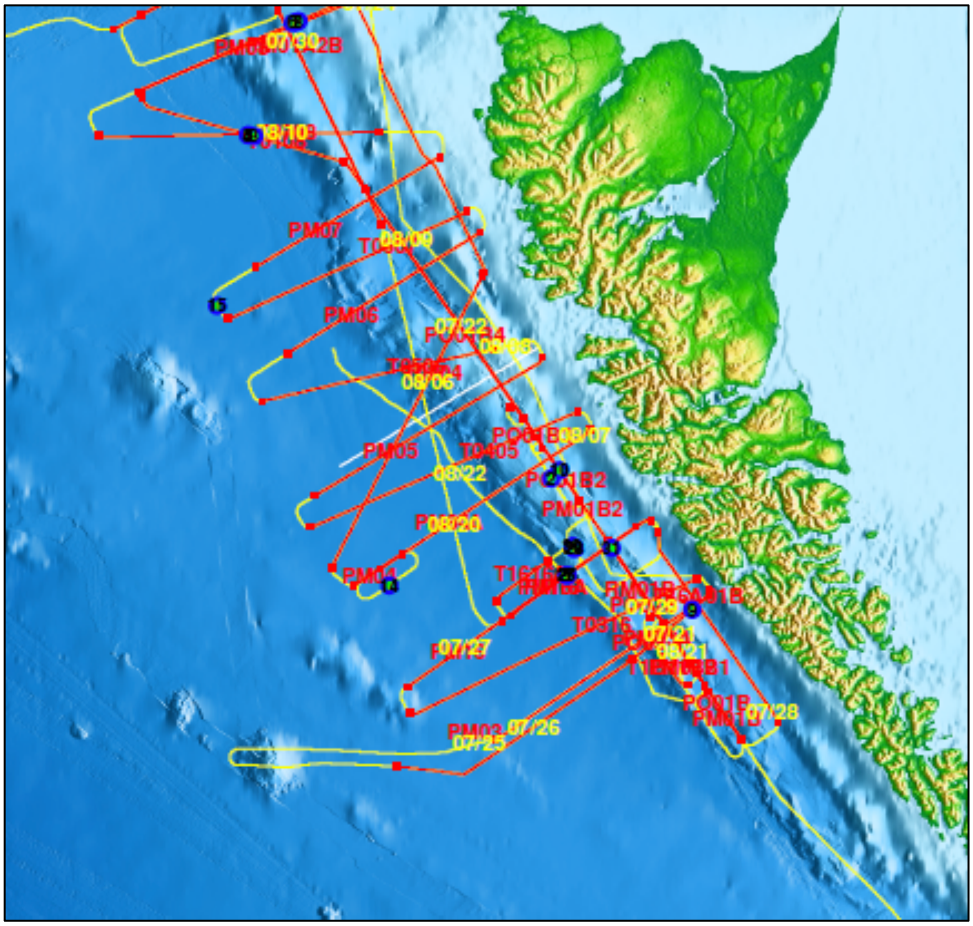


Figure 7.1. Track line map offshore Haida Gwaii.

We collected six primary dip lines and five sawtooth transit lines that cross the QCT deformation front. We also collected an along strike profile west of the QCF fault trace. We shot each dip line in the west-east direction to maximize our chances of crossing the QCF trace, which is close to shore. Additionally, in Canada, we were not permitted to shoot in areas <200 m water depth. The shoreline proximity and depth constraints limited our ability to cross the fault trace with full fold in most cases, as there was not room for a 7.5 km run out at the eastern end of the profiles.

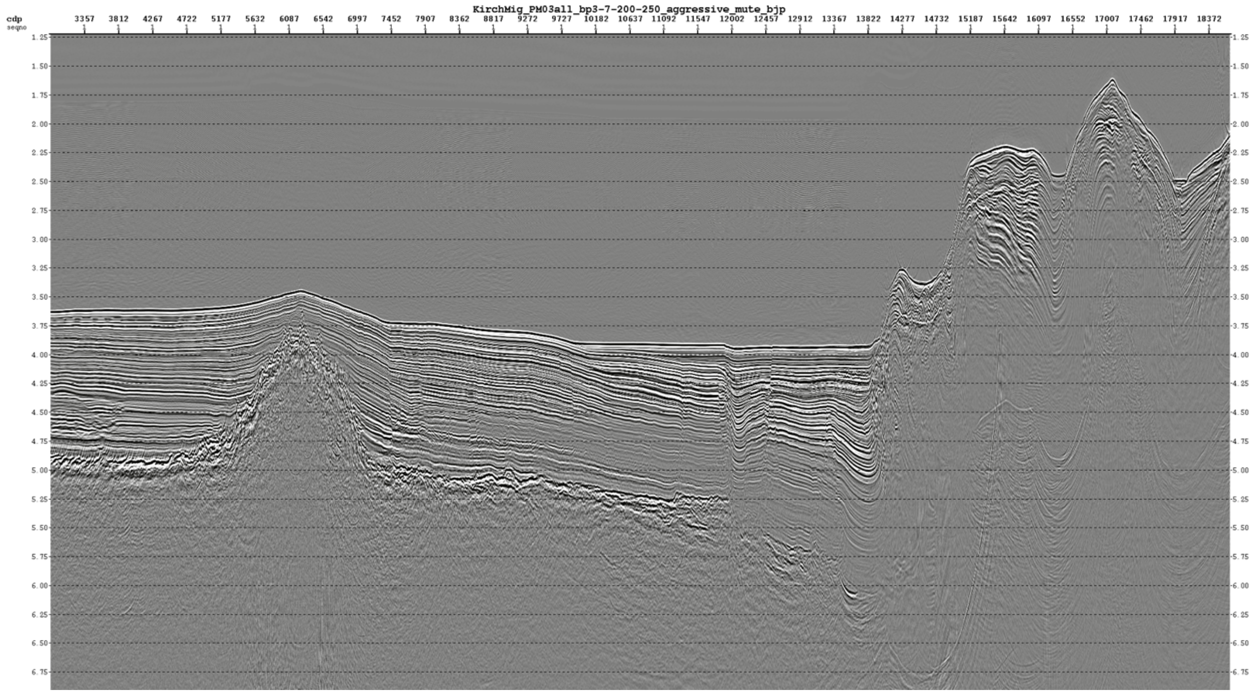


Figure 7.2. QCF03 velocity stack with Kirchoff migration.

We were very successful in imaging structure and stratigraphy on the PAC plate west of the QCT. We observe either active or buried normal faults within the PAC stratigraphy on all profiles. Significant PAC basement offsets are prominent on QCF03, which looks like an active basement-involved normal fault that offsets sediments at the ocean floor. Curiously, QCF16, the next profile north of QCF03, does not show any evidence for this major structure. The normal fault varied between in sequence, step down structures and small, v-shaped grabens. Basement highs on the PAC plate on QCF04, QCF05 and QCF06 represent buried seamounts that were either just barely or not at all visible on the bathymetric data.

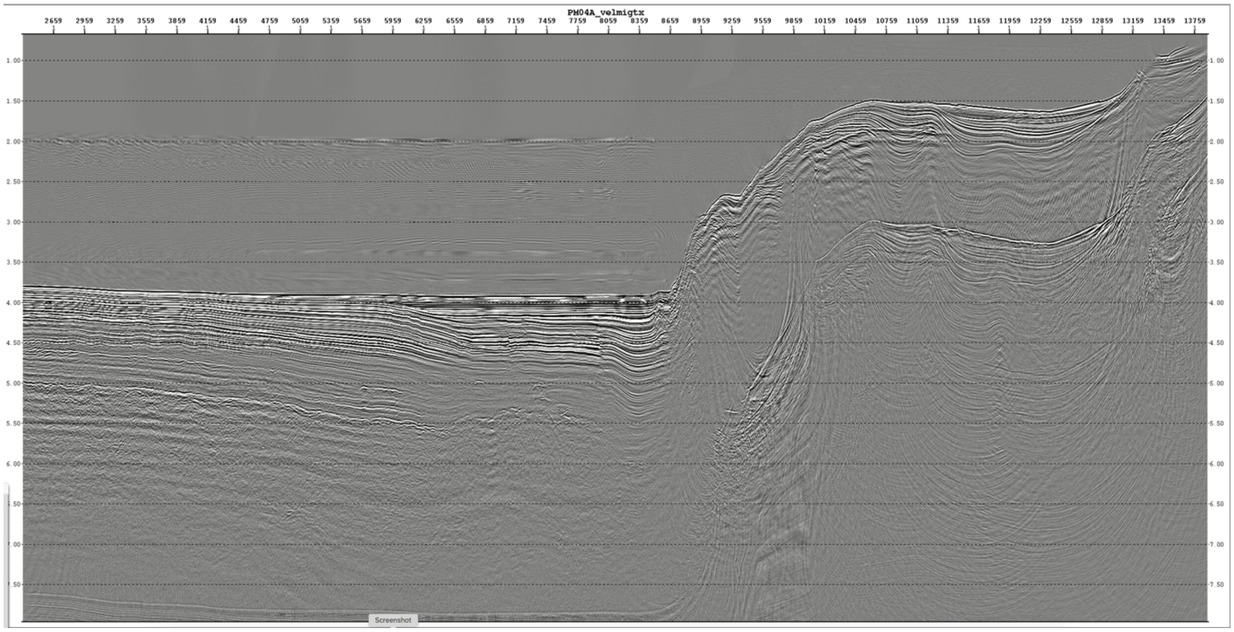


Figure 7.3. QCF04 velocity stack with Kirchoff migration.

On each profile, at the western edge of the mapped QCT, PAC sediments enter what appears to be an abrupt, thrusted deformation front with a steep, west-dipping slope. The PAC basement disappears east of this deformation front on the shipboard stacks. The QCT deformation front appears to be comprised of stacked thrusts, similar to an accretionary prism, though a decollement is not always visible in the shipboard processed sections. Within this frontal slope section, deformation appears to be currently active, as strata are deformed up to the seafloor. Behind the stacked thrust section, each profile shows a shallow slope basin that has minimally deformed to undeformed fill. West of the basin, the slope steepens again towards Haida Gwaii. On most of the southern profiles, the QCF fault trace is located on this upper slope.
Previous mapping using existing bathymetric data and legacy seismic data suggest that the QCT widens from south to north. The TOQUES profiles confirm this geometry. QCF06 and QCF07 depict a wide, more gently sloping structure, with what appears to be fewer active thrust faults and a less pronounced mid-slope basin. Piggyback basins and multiple stages of deformation are evidenced by growth strata, changing thicknesses and pinch-outs within the overlying sediments offshore northern Haida Gwaii.

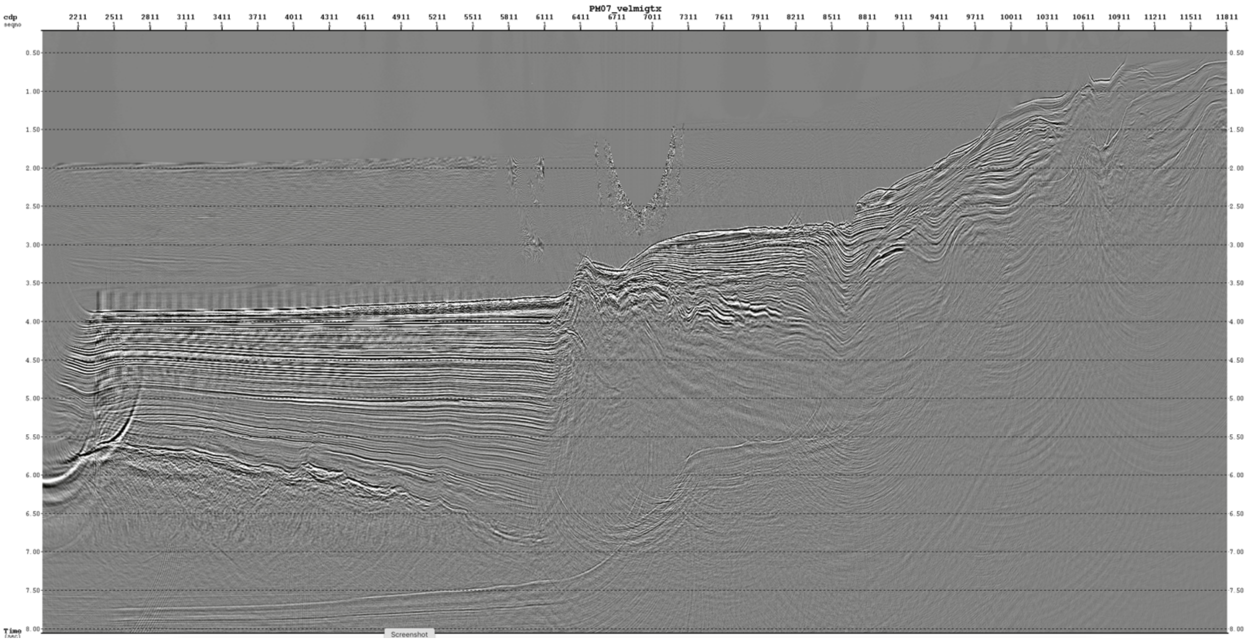


Figure 7.4. QCF07 velocity stack with Kirchoff migration.

Since QCF03 was the first MCS profile we collected, we were able to dedicate more time for advanced processing, including detailed velocity modeling. This processing was led by Ben Phrampus. QCF03 is the only southern transect that clearly shows offset or truncated strata in the subsurface below the mapped QCF fault trace. Imaging the fault will be a primary objective for further processing on the remaining profiles.

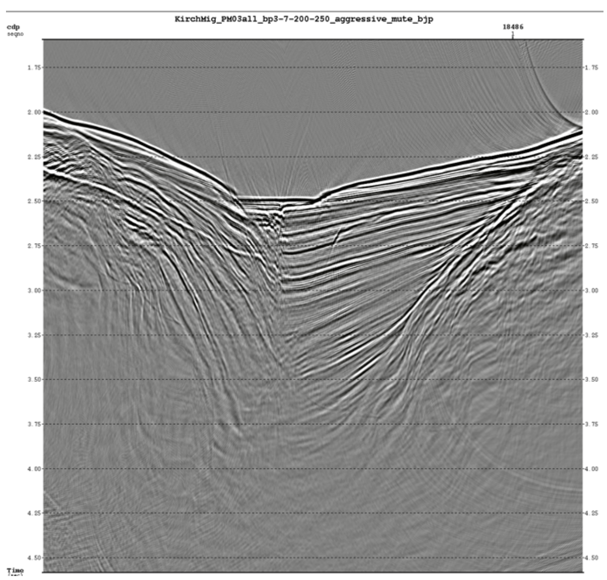


Figure 7.5. Queen Charlotte Fault observed on QCF03

7.2 Central Survey Area – Dixon Entrance Region

North of Haida Gwaii, in the Dixon Entrance region, profiles QCF08, QCF09, QCF10 and QCF11 targeted off fault ridges on the PAC plate, slope basin structure and the main QCF trace. QCF10 and QCF11 also traversed the deep-water channel and fan system. Here, QCF10 and QCF11 are discussed in more detail.

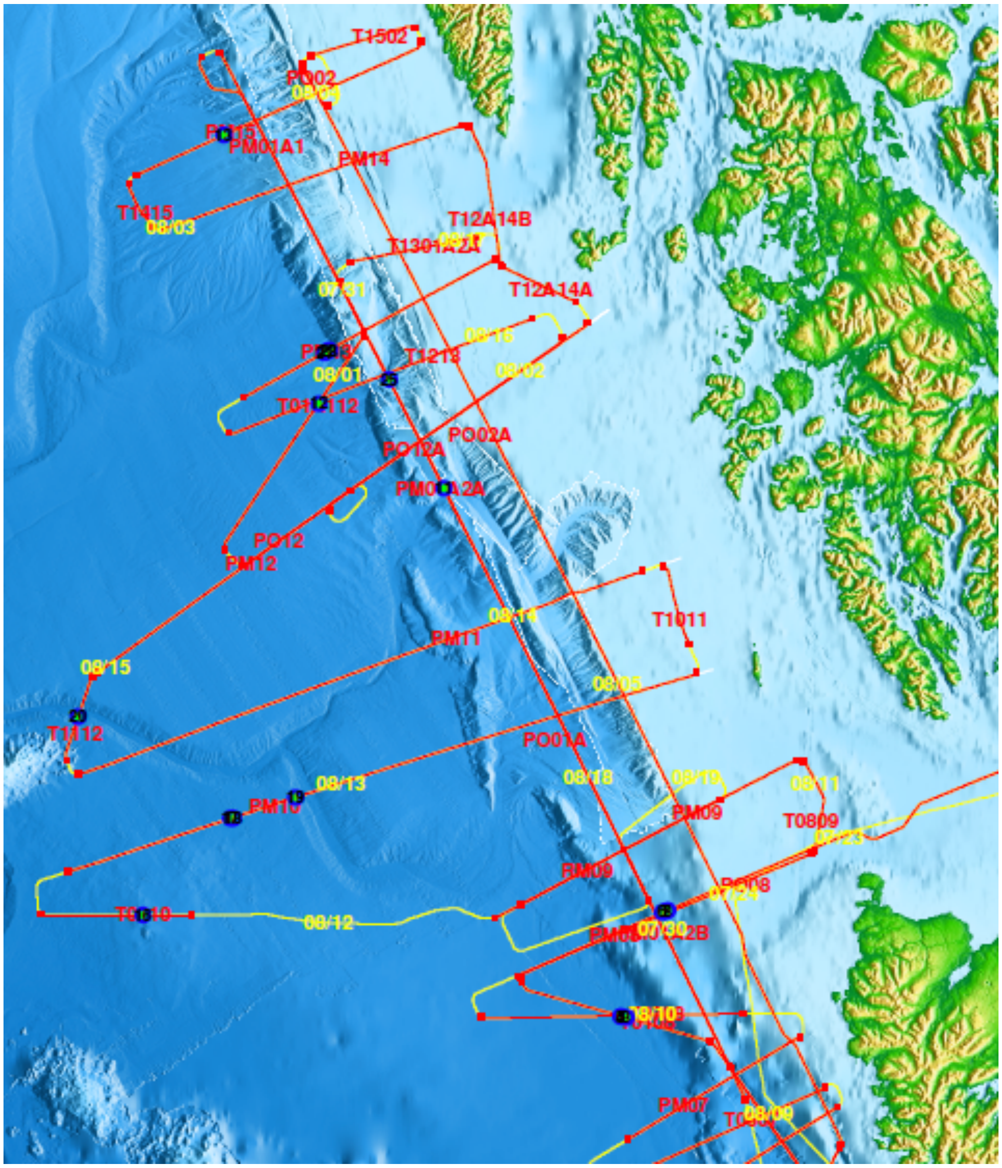


Figure 7.6. Track line map in central and northern survey area.

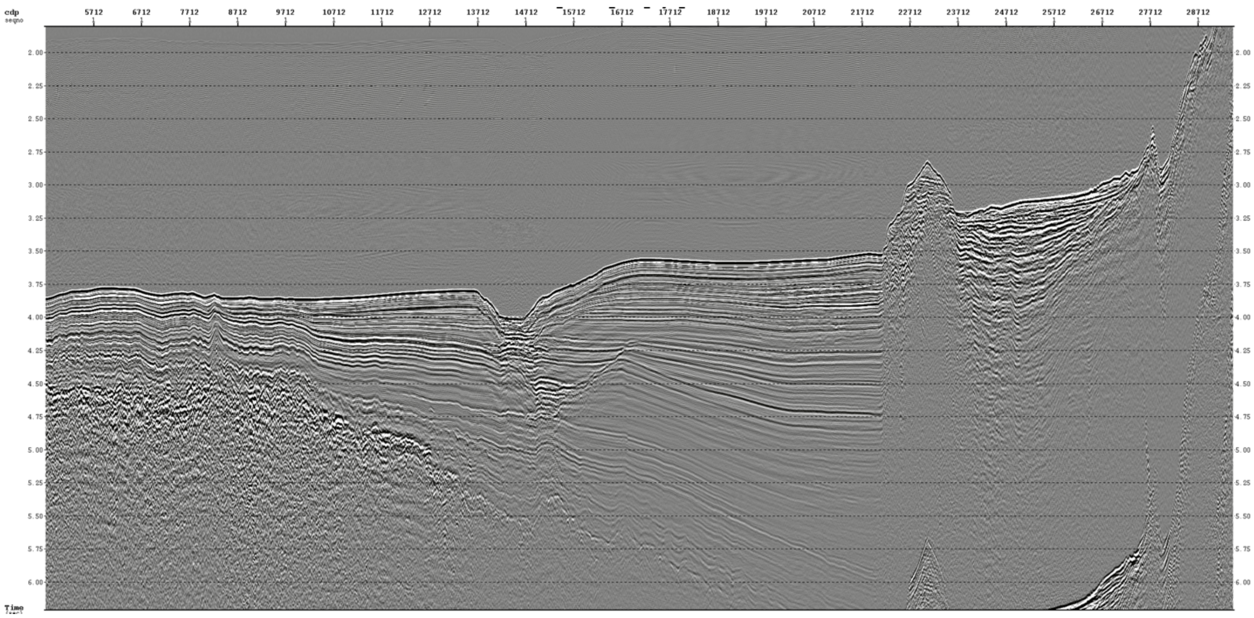


Figure 7.7. QCF10 velocity stack with Kirchoff migration.

In each of these profiles the PAC basement dips slightly to the east and the sediment section on the PAC plate thickens accordingly. When the PAC sediment section encounters the off-fault ridges, the reflectors appear to truncate abruptly. On QCF10 the ridge appears to be comprised of faulted, folded and thrusted sediments, much like the frontal portions of the Queen Charlotte Terrace to the south. Better imaging is needed to determine whether the structures reach the seafloor or are overlain by a thin layer of undeformed sediment. East of the ridge on QCF10, the sediments appear to be undeformed, though ringing energy is a problem for imaging here. The slope then rises steeply to the east and the shallow continental shelf. The QCF fault trace is located in a small slope basin, though it is difficult to see deeper structure.

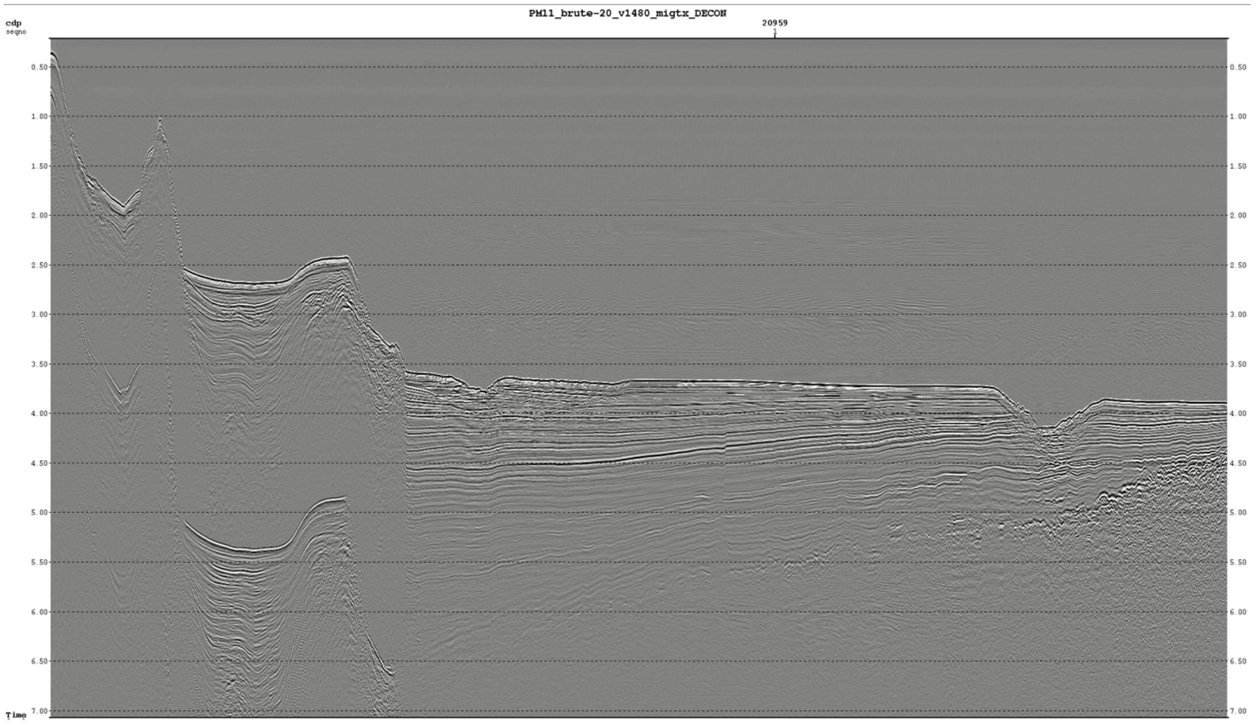


Figure 7.8. QCF11 brutestack.

QCF11 similarly shows east-dipping PAC basement and a thickening sediment section to the east. A seafloor channel cuts the seafloor to the west of the ridge and truncations within the upper ~500 ms TWTT indicate post-erosion sediment fill. An abrupt change in reflection character of the PAC sediments occurs at the off-fault ridge. The ridge structure shows folded and deformed sediments that may be overlain by a layer of undeformed sediments. To the east of the ridge, a mid-slope basin is comprised of flat-lying sediments in the upper section, with folded sediments in the lower section, suggesting multiple stages of deformation. The QCF trace is located in a second slope basin to the east. The near vertical trace here is visible down to ~2800 ms TWTT.

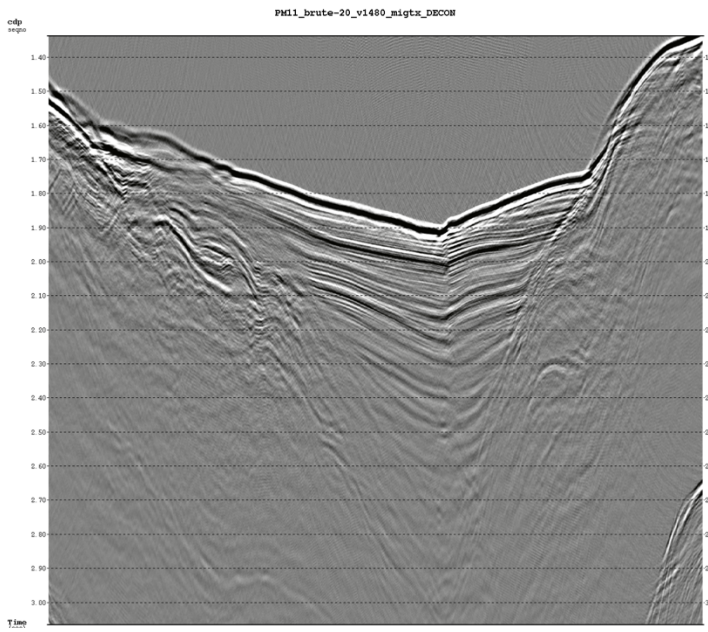


Figure 7.9. Queen Charlotte Fault on QCF11 midslope basin.

Both QCF10 and QCF11 cross the deep water Baranof channel. At the sea floor, the channel is ~6 km wide and ~300 m deep, with a flat bottom and sloped side walls. Channel facies that indicate different stages of channel fill, erosion, avulsion and migration are visible to ~4500-47500 ms TWTT. West of the deep water channel, the PAC basement rises and appears to increase in reflectivity. The sediments that overly the basement high contain many small ridges that may mimic PAC basement roughness.

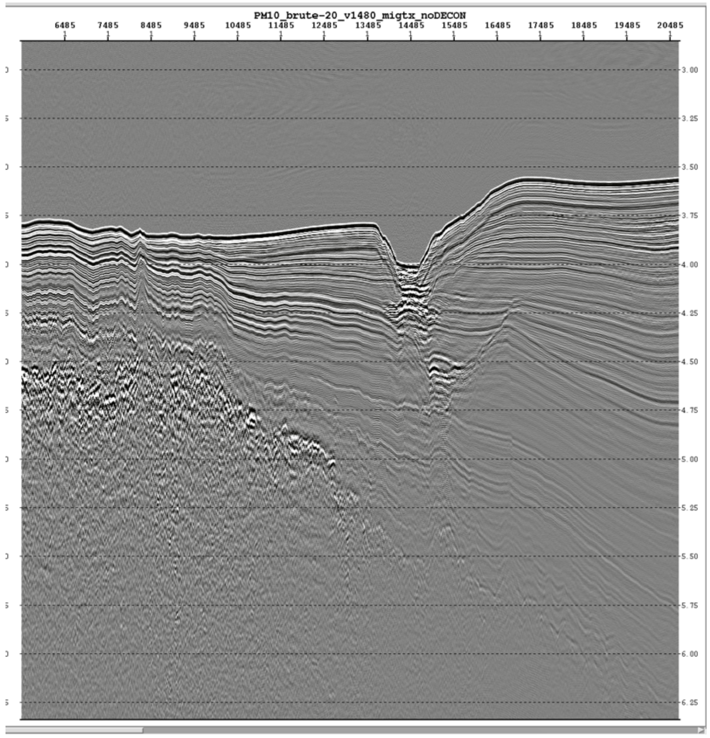


Figure 7.10. Deep water channel observed on QCF10 shipboard brutestack.

7.3 Northern Survey Area – 2013 Craig Epicenter and Northward

Near the latitude of the Craig earthquake epicenter, the ridges on the PAC plate become less distinct and the slope west of the QCF fault trace narrows and steepens (Figure 7.6). QCF12 crosses the QCF near the epicenter of the Craig earthquake. The PAC section of QCF12 shows the same shallower, high reflectivity PAC basement at the western extent as seen on QCF10 and QCF11, with sediments that mimic the basement roughness in the deeper section. The basement dips toward the slope and the sediment package thickens. Adjacent to the slope, the seafloor indicates the presence of a slope-toe channel and the sediment facies generally show more structure on QCF12 than on QCF11 and QCF10. There are also indications of multiple fills channels and erosional structures. Sharp, angled truncations between ~5000 and ~5500 ms TWTT, suggest an earlier stage of deformation.

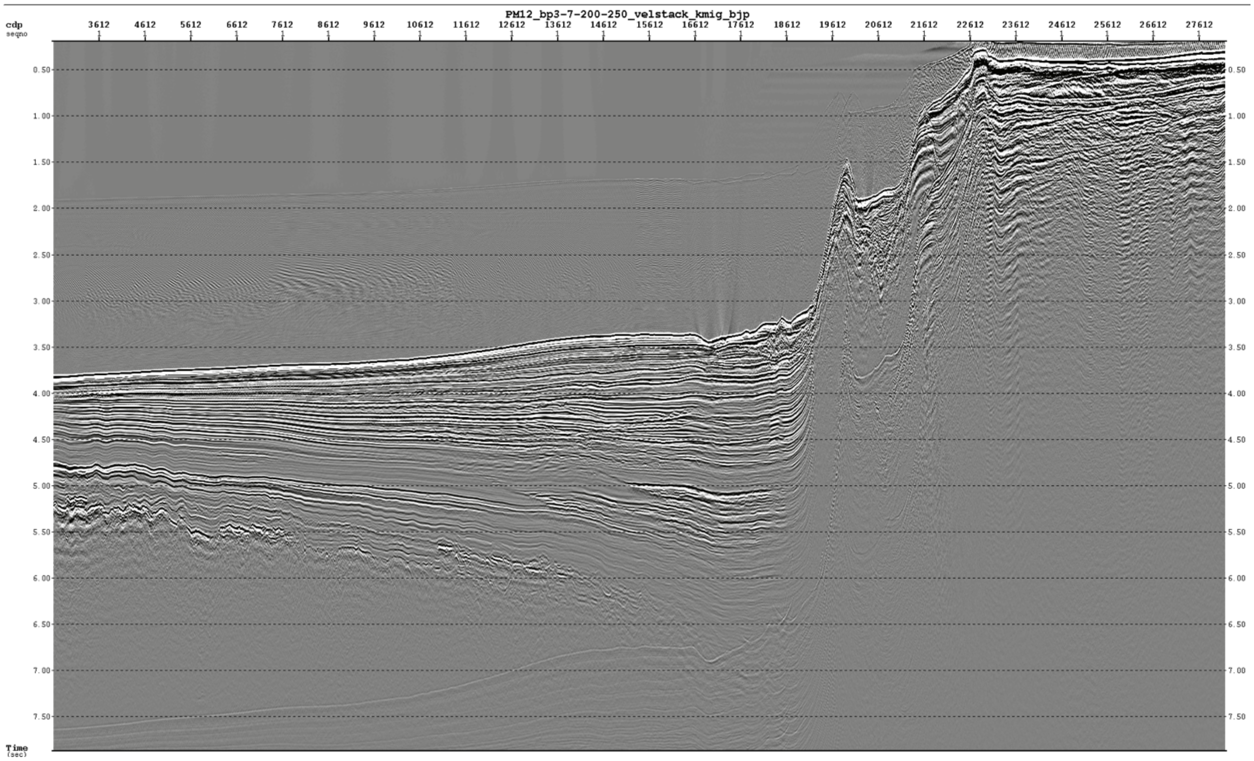


Figure 7.11. QCF12 full profile shipboard velocity stack and Kirchoff migration.

Reflectors that are visible within the slope are folded and deformed. The slope contains a mid-slope basin that appears overlain by flat-lying sediments, and the underlying reflectors containing multiple folds and discontinuities. The QCF trace is near the shelf-break, but vertical, faulted features are not visible on the shipboard stack. Noise from ringing and multiples degrades imaging on the shelf. QCF12 will be a high-priority for reprocessing.

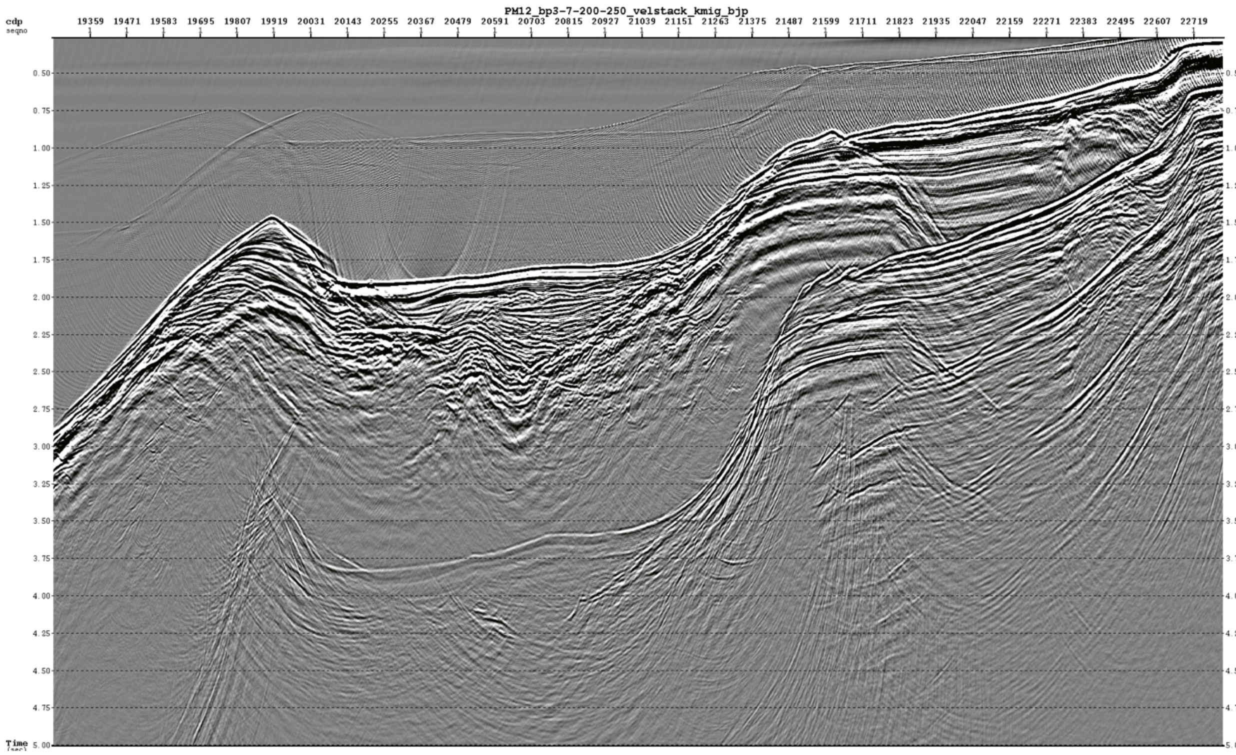


Figure 7.12. QCF12 mid-slope basin and slope.

QCF14 crossed the margin within a large slope fan. We see very little penetration on the PAC side of the fault compared to the other fault-crossing profiles, which may be facies related. The brutestack shows very little energy below the seafloor on the shelf. The QCF fault trace crosses the profile within a small basin near the shelf break, but fault structure is not visible on the shipboard stack.

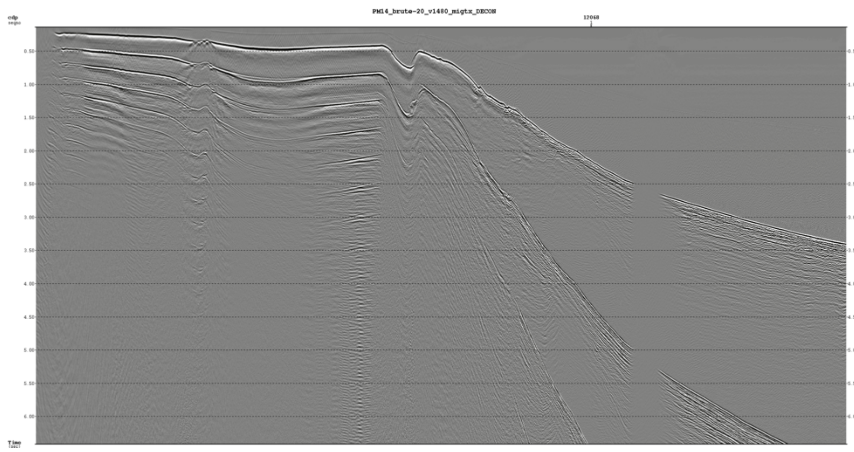


Figure 7.13. Screenshot of QCF 14 shipboard brutestack.

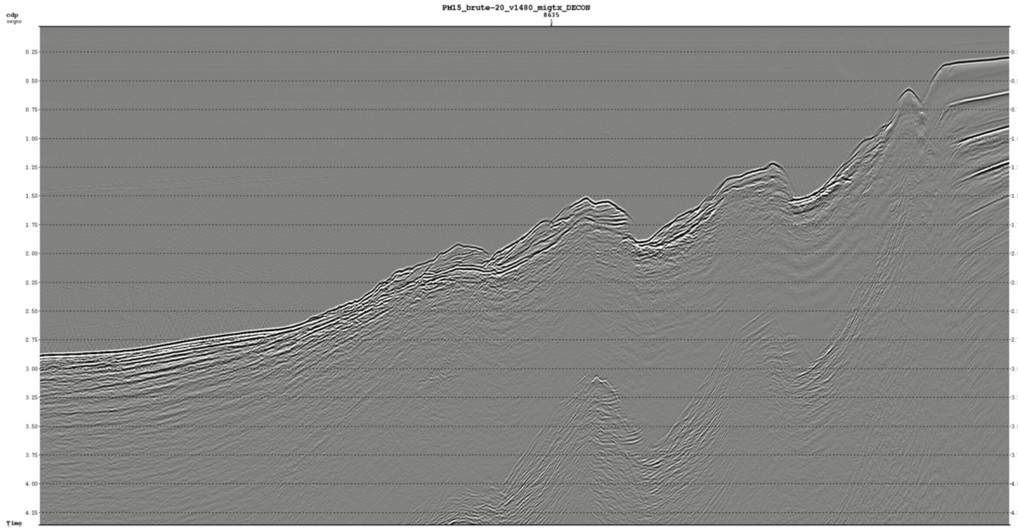


Figure 7.15. QCF15 shipboard brutestack.

QCF15 has similar imaging problems as those observed in QCF14. However, we do see three separate slope basins here that will be targets for reprocessing. Olumide Adedeji tried out multiple deconvolution parameters and algorithms to bring out more structure on the shelf. The results are promising and should be a fruitful avenue for further exploration onshore.

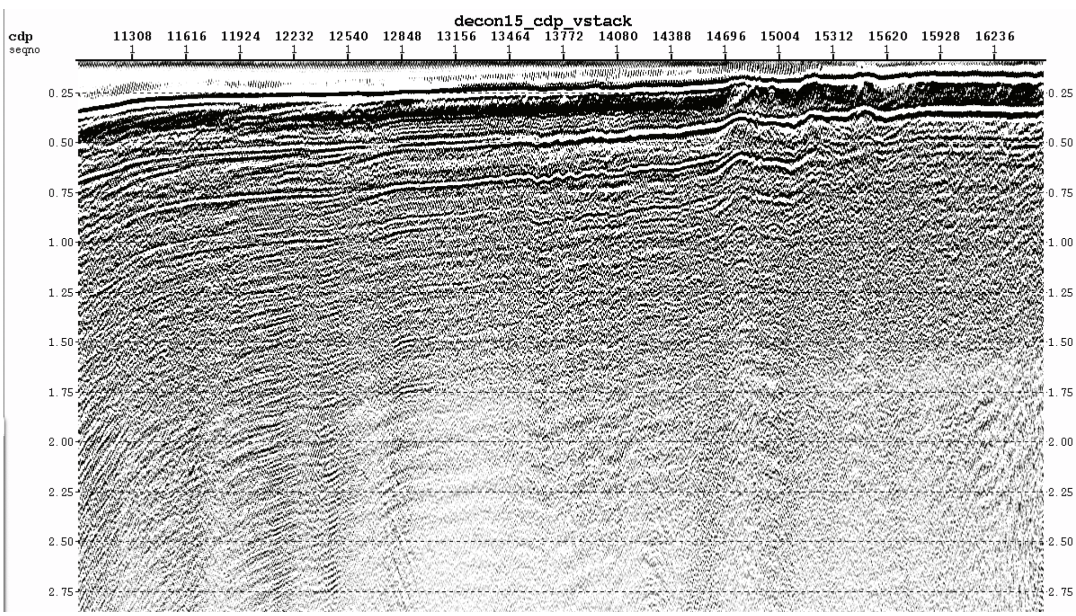


Figure 7.16. QCF15 shelf with gap decon.

7.4 Bottom Simulating Reflectors

Methane hydrates, ice-like solids that consist of methane and water that are stable at moderate pressures and low temperatures, are widespread on continental slope and rise sediments globally. The base of the hydrate stability zone can manifest in seismic data as a strong, reverse-polarity bottom-simulating seismic reflector (BSR). The negative impedance contrast at the BSR is due to the layering of higher-velocity, hydrate-bearing sediments over lower-velocity, gas-charged sediments. The presence of a BSR is a sufficient condition for the occurrence of gas hydrate in sediments with at least small quantities of gas sequestered below. However, hydrate can exist without an underlying BSR if low quantities or no gas is present.

Along the Southern survey area, offshore Haida Gwaii, BSRs are evident both near the toe of the slope (Figure 7.17 – a) and near the main trace of the QCF (Figure 7.17 – b). Generally, the distribution of gas hydrate is discontinuous in this region, with strong BSRs observed beneath bathymetric highs, such as in the deformation front anticlines (Figure 7.18). Reflections below the BSR are often enhanced (Figure 7.18) due to the presence of gas.

The distribution of BSRs is reminiscent of active continental margins, in particular on the Cascadia Margin offshore Washington and Northern Oregon, where similar BSR patterns are observable. Active margins tend to exhibit these patterns of BSRs due to the enhanced fluid flow that occurs on these deformed margins. As sediment enters the deformation front, it is compressed and deformed, which reduces the sediment porosity and dewaters the sediment. This results in an increase in pore pressures and enhances fluid flow along convergent margins. As the fluids migrate, it transports other pore-filling constituents including gas. These fluids tend to focus into bathymetric highs due to buoyancy effects. The sum effect of this process results in fluids and gas focusing along bathymetric highs; where the gas enters the hydrate stability zone, hydrate can form creating an impermeable layer that traps gas, resulting in a BSR. Therefore, the presence of BSRs along the Southern survey area, may suggest recent compressional deformation is occurring resulting in dewatering and fluid migration along the margin.

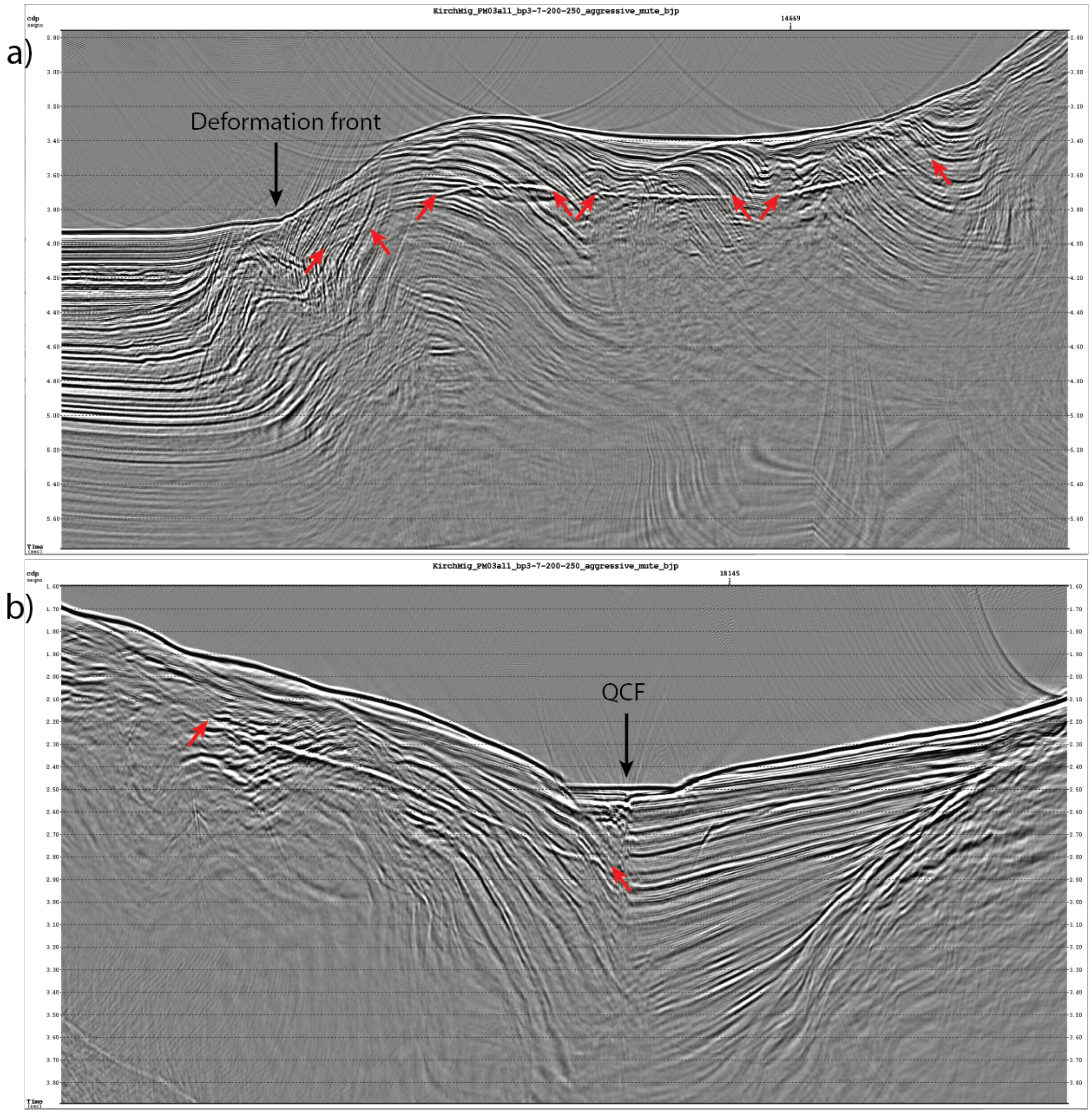


Figure 7.17: a) seaward end of PM03 showing the deformation front and BSRs (between red arrows) nearby. B) BSRs approaching the QCF but are not identifiable across the fault.

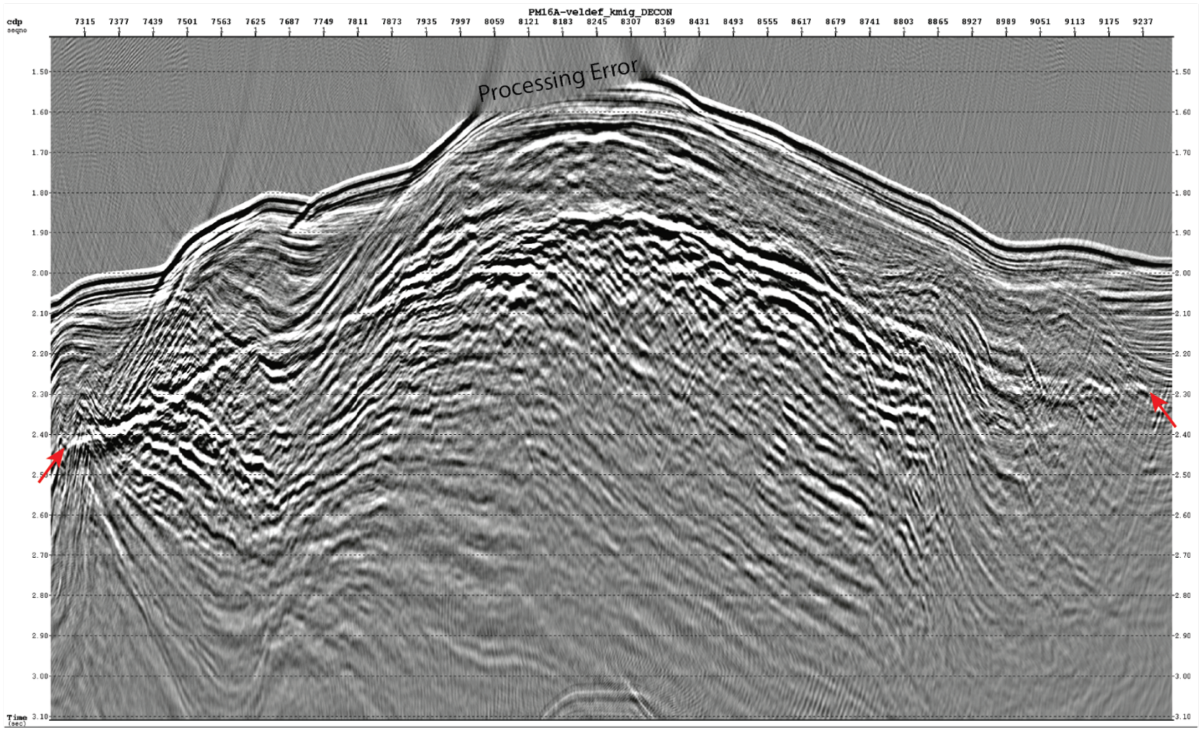


Figure 7.18: PM16A with a BSR (between red arrows) identifiable under a bathymetric high. The enhanced reflections below the BSR is indicative of gas charged layers.

The BSR on PM03 (Figure 7.17) is of particular interest. Here, the BSR approaches the QCF from the west (seaward). Near the QCF the BSR disappears and is not detectable across the fault. However, the BSR nearest to the QCF appears to pull down. This anomaly would suggest lower temperatures near the QCF compared to similar depths on the margin. The most likely cause of this anomaly would be the flow of sea water from the overlying ocean into the QCF, cooling the subsurface. To test the hypothesis of a cooled subsurface about the QCF, a heat flow study could be used to characterize the shallow temperature and fluid flow regime. This could give insights into the hydrological dynamics of the QCF, and other faults on the margin.

Further north, in the central and northern regions, there is no preliminary evidence of BSRs. The absence of geologically recent compression, deformation, and subsequent dewater and fluid flow may result in lower gas concentrations with little hydrate or gas present in shallow sediments. This does not mean there is NO gas or hydrate in the northern regions, only that the concentrations are likely lower than those in the south.

7.5 Airgun Analysis

During MCS data acquisition, we noticed a sudden change in seismic character between MSC lines (PO12A to PM14). PO12A appeared with a “normal” seismic character, and appeared as we expected. However, PM14 showed very little penetration, even in deep water, and had a strong ringing at ~8 Hz which appeared to be due to an “out of tune” gun array (Figure 7.19).

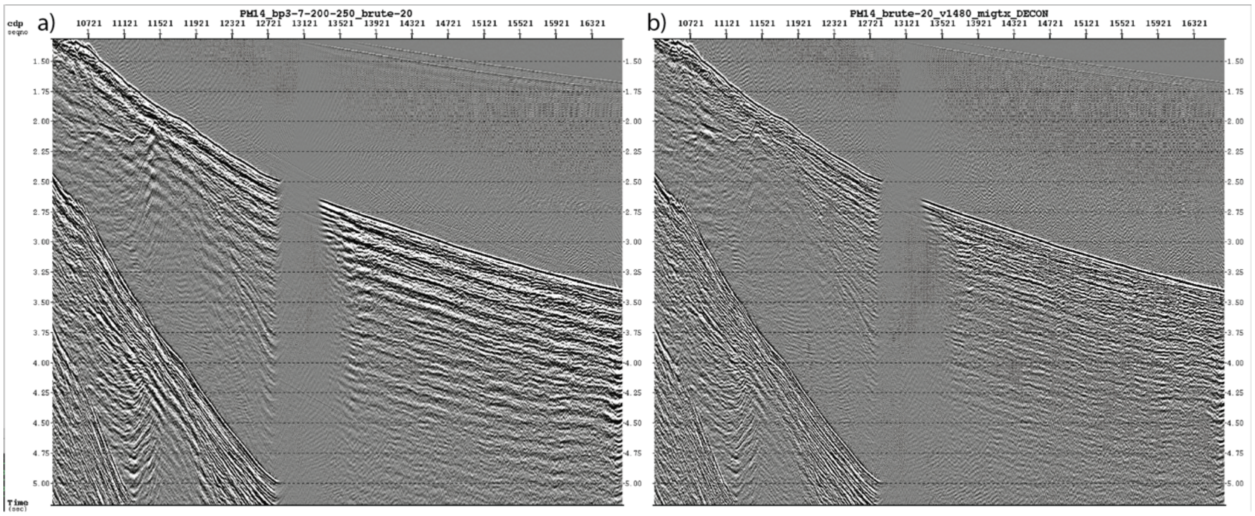


Figure 7.19: a) PM14 brute stack showing little penetration and “ringing” that caused us to address potential source issues. b) deconvolved PM14 brute stack shows much less ringing and brings out deeper reflections.

We were initially concerned there was an issue with the guns, resulting in bad gun timings and giving us an out of tune array, however the source monitoring software had not identified any issues. To alleviate our concerns about the source, we examined the SEGD data generated by the piezoelectric sensors within the guns (1 in each gun), and by the hydrophones located above the guns (3 on each of the 4 gun-strings). We noticed a change in the piezoelectric sensors within the guns between lines PO12A and PM14 (Figure 7.20). However, the near field hydrophones, did not appear to show any change in character. Further, we analyzed the direct arrival across both MCS lines and again noticed no change in character.

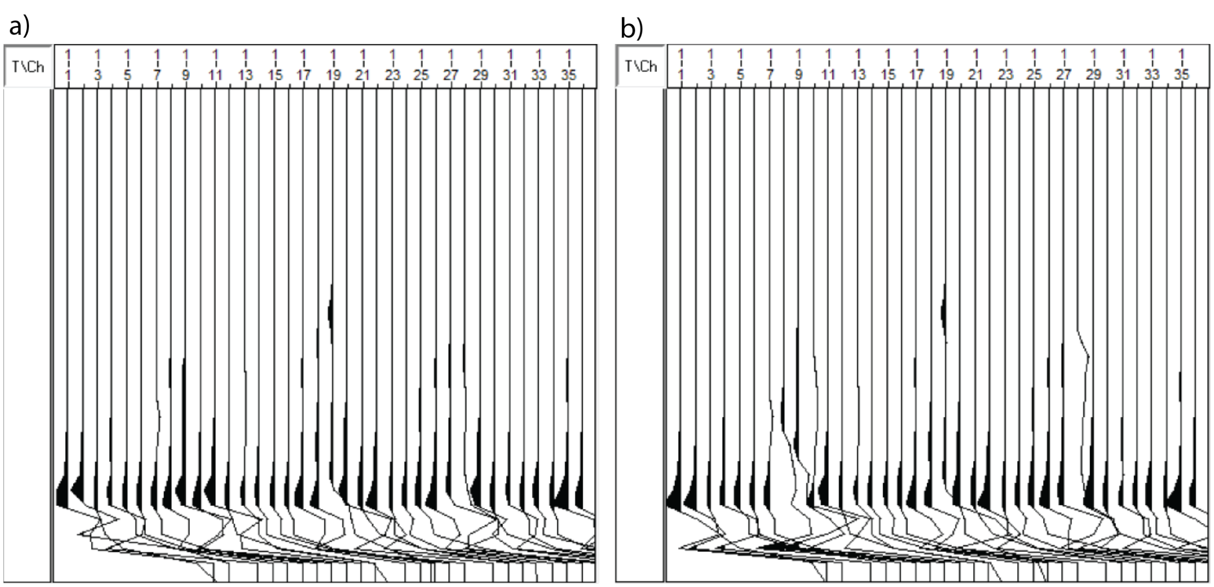


Figure 7.20: Piezoelectric sensors in the guns on line PO12A (a) and PM14 (b). Notice the change in character on channels 8 and 9 between the two lines. Channels 19 and 28 may also be problematic.

We concluded that the “ringing” we were seeing in PM14 and others, was likely geological, and was due to a hard seafloor, combined with the normal “ringing” of the R/V Langseth source, which appears to oscillate at ~8 Hz. With a hard seafloor with little penetration the ringing of the source is able to dominate the amplitudes resulting in a seismic image like Figure 7.19. To remove this effect, we could aggressively filter the data to remove 8 Hz energy, but that would result in the removal of a lot of interesting data! Therefore, we opted to deconvolve the source character (derived from the direct arrival) from the MCS data, which gave us satisfactory results (Figure 7.19-b).

8. Performance of MGL and Equipment

The Langseth and scientific equipment worked well to achieve our scientific objectives. The Captain, crew, and technical staff are excellent.

8.1 MCS equipment

The data we acquired using the 6600-cu-in, 36-element, tuned air-gun rray and 15-km-long streamer are tremendous for imaging both shallow and deep targets in this study. We had very little down time due to equipment failure during our cruise.

When we had streamer control issues, we recovered 10 km of section. The sections that were too deep had multiple bird failures—either the birds or SRDs were hanging off the collars. Aside from this, the 15-km streamer was stable at the usual 12-m towing depth. Initial assessment of data quality indicates a few (up to ~25) bad channels. Aside from that the streamer is recording very high quality data.

Individual guns occasionally misfired or experienced other issues that required us to shoot at less than full volume during some stretches. We recovered and deployed strings 3 and 4 multiple times. These issues cost us very little down time overall.

8.2 Other scientific equipment

The swath bathymetry, backscatter, 3.5 kHz (sub-bottom profiler) and potential field (gravity, magnetics) equipment worked well throughout the cruise. We had a delayed start up in collecting multibeam and had to boot the equipment multiple times. Once started, the data was excellent. The magnetometer had to be recovered in high seas and was redeployed in calmer weather, causing several data gaps.

8.3 Lab facilities and onboard computing

Overall, the science lab space and computational facilities on the Langseth are very good and met our purposes. The Langseth possesses two workstations that can be used by the science party for onboard processing. We decided to use these workstations for our onboard seismic and swath bathymetry processing rather than bring our own workstations and were able to complete a range of onboard processing jobs, including basic processing of all of the MCS data. We occasionally encountered disk space limitations due to the large data volumes generated by the 15-km streamer. Gilles Guertin worked to find several different areas of disk space to accommodate our needs.

The internet and wifi were amazingly fast on this trip—the best we have ever seen at sea! We were able to effectively communicate with colleagues and family onshore. File sharing among the science party was very easy and the networks were easy to navigate.

8.4 Technical staff and crew

The technical staff aboard the Langseth are amazing! They are dedicated, professional, capable, and did a truly excellent job. Todd Jensvold provided excellent advice and guidance to the shipboard scientists. He and Cody Bahlau were indispensible in planning for the data collection effort, providing leadership to the technical teams and interfacing with the bridge. All of the technical staff were very responsive to our requests and needs. Gilles Guertin happily and effectively addressed any and all issues and questions related to the network and computing. The files and information that we needed to conduct onboard data analysis were provided in a very timely manner (exceeding our expectations). Navigation contractor Klay Curtis was hugely reliable in the main lab and on deck, jumping in and showing initiative where ever help was needed. Josh Kasinger was extremely hard-working and provided excellent leadership for the source team, a positive attitude and a can-do spirit.

Likewise, the Captain, officers and marine crew exhibited great dedication and professionalism. The bridge crew came on with little experience and Captain Landow provided great leadership and mentoring. The Captain was flexible and available for discussions of operations and helped immensely in planning routes. The science party also appreciated the Captain's help in with morale-boosting activities such as a cook-out on the main deck and cruise party.

All four of the science watchstanding team were first-timers at sea. They each had a wonderful experience, and truly appreciated the positive, professional and friendly attitudes of the technical and marine crews. Tours of the bridge, engine room and the kitchen were greatly appreciated. The science party also enjoyed the opportunity to participate in the main lab and deck operations and learned a lot about the equipment and safety at sea from the ship's crew.

8.5 Living conditions

The accommodation spaces, gym and other leisure spaces (e.g., movie room) could use a little TLC. Many cushions and blankets were stained. Many lights and latches and locks were broken. We addressed each issue with the crew. Issues that could be fixed at sea were quickly addressed.

The galley staff was hospitable, helpful and cooked delicious food. The fresh vegetables throughout the trip were great! The galley staff were instrumental in keeping up morale and went above and beyond with a cookout on the bridge deck during the cruise and putting together a seafood feast for the end of cruise party, while we were limited to the ship due to COVID restrictions in Ketchikan.

9. Crew and Scientific Party

Table 9.1. Technical Personnel

Participant	Group/Affiliation	Position
Todd Jensvold	LDEO	Chief Science Officer
Josh Kasinger	LDEO	Chief Source Mechanic
Cody Bahlau	LDEO	Technician
Gilles Guerin	LDEO	Technician
Michael Coutal	Contractor	Mechanic
Victor Ubaru	Contractor	Navigation
Klayton Curtis	Contractor	Navigation
Ray Hatton	Contractor	Mechanic
Jack	Contractor	Mechanic
Mark Walker	Contractor	Compressor Mechanic

Table 9.2. Protected Species Observers

Participant	Group/Affiliation	Position
Cassandra Frey	RPS	Lead PSO
Eren Penfield	RPS	PSO
Evana Douglas	RPS	PSO
Lilia Perez	RPS	PSO
Jillian Daniel	RPS	PSO

Table 9.3. Science Party Participants

Participant	Group/Affiliation	Position
Lindsay Worthington	University of New Mexico	Chief Scientist
Ben Phrampus	Naval Research Lab	Co-chief Scientist
Olumide Adedeji	University of New Mexico	Watch-stander
Lazaro Garza	Western Washington U	Watch-stander
Pinar Gurun	Dalhousie University	Watch-stander
Sarah Nolt-Caraway	University of New Mexico	Watch-stander

Marine Crew
The cruise included the regular R/V *Langseth* maritime crew of 20 members. The Captain was Mark Landow. The Chief Engineer was Gerald Butler. The Head Steward was Hervin Fuller.

9.1 Science party shifts

We maintained shifts such that three members of the science party were on shift at all times during the 24 hr working day. Because our science party was on the small side (6 members), each of us pulled a 12 hr shift—big thanks to the students for their hard work and for maintaining these long shifts for 5.5 weeks!! We rotated breaks for outside time and meals. Shift times were offset to mix up the combinations of people on working together throughout the day.

During the shifts, science party members were responsible for maintaining a written and Elog of operations, seismic reflection data processing and multibeam data processing. Each of the students were encouraged to take on other mini-projects that piqued their interest or helped them learn a new skill. These projects included deep dives into specific processing steps such as deconvolution or migration, targeted processing of the multibeam bathymetry data, processing and plotting underway potential fields data, and initial structural interpretations of the seismic lines. Besides short, daily change-over meetings with shift partners, we held once-a-week science party meetings on Wednesdays for one hour, switching the timing to maintain a balance for the schedules. Meetings included progress reports on mini-projects from the students and short, informal science talks or lectures from the co-chief scientists.

Table 9.4. Science Party Shifts

Participant	**Shift (Times PDT)**
Lindsay Worthington	0600-1800
Ben Phrampus	1800-0600
Sarah Nolt-Caraway	1000-2200
Pinar Gurun	2200-1000
Olumide Adedeji	0200-1400
Lazaro Garza	1400-0200

9.2 Science technical staff shifts

Table 9.5. Technical Staff Shifts

Staff	**Shift (Times PDT)**
Todd Jensvold	0600-1800
Cody Bahlau	0000-1200
Victor Ubaru	1200-0000
Gilles Guertin	1200-0000
Klayton Curtis	0000-1200

Josh Kasinger	1200-0000

10. References

Barrie, J. V., K. W. Conway, and P. T. Harris (2013), The Queen Charlotte Fault, British Columbia: seafloor anatomy of a transform fault and its influence on sediment processes, *Geo-Mar. Lett.*, 1-8.

Brothers, D. S., P. J. Haeussler, A. E. East, U. ten Brink, B. Andrews, P. Dartnell, N. C. Miller, and J. Kluesner (2017), A closer look at an undersea source of Alaskan earthquakes, *EOS Trans. AGU*, *98*.

Cao, L., H. Kao, and K. Wang (2017), Contrasting upper-mantle shear wave anisotropy across the transpressive Queen Charlotte margin, *Tectonophysics*, *717*, 311-320.

DeMets, C., and S. Merkouriev (2016), High-resolution reconstructions of Pacific–North America plate motion: 20 Ma to present, *Geophys. J. Int.*, *207*(2), 741-773.

Doser, D. I., and R. Lomas (2000), The transition from strike–slip to oblique subduction in southeastern Alaska from seismological studies, *Tectonophysics*, *316*(1), 45-65.

Lay, T., L. Ye, H. Kanamori, Y. Yamazaki, K. F. Cheung, K. Kwong, and K. D. Koper (2013), The October 28, 2012 Mw 7.8 Haida Gwaii underthrusting earthquake and tsunami: Slip partitioning along the Queen Charlotte Fault transpressional plate boundary, *Earth Planet. Sci. Lett.*, *375*, 57-70.

Plafker, G., L. M. Gilpin, and J. C. Lahr (1994), Neotectonic map of Alaska, *The Geology of North America*, *1*, 389-449.

Scheidhauer, M., A. M. Trehu, and K. M. M. Rohr (1999), Multichannel seismic reflection survey over the northern Queen Charlotte Fault, *Geological Survey of Canada Open File 3779*.

Smith, A., R. Hyndman, J. Cassidy, and K. Wang (2003), Structure, seismicity, and thermal regime of the Queen Charlotte Transform Margin, *J. Geophys. Res.*, *108*(B11).

Tréhu, A. M., M. Scheidhauer, K. M. M. Rohr, B. Tikoff, M. A. L. Walton, S. P. S. Gulick, and E. Roland (2015), An abrupt transition in the mechanical response of the upper crust to transpression across the Queen Charlotte Fault, *Bull. Seismol. Soc. Am.*, *105*(2B), 1114-1128.

Walton, M. A. L., S. P. S. Gulick, R. S. Reece, G. A. Barth, G. L. Christeson, and H. J. A. Van Avendonk (2014), Dynamic response to strike-slip tectonic control on the deposition and evolution of the Baranof Fan, Gulf of Alaska, *Geosphere*, *10*(4), 680-691.

Walton, M. A. L., S. P. S. Gulick, P. J. Haeussler, E. Roland, and A. M. Tréhu (2015), Basement and regional structure along strike of the Queen Charlotte Fault in the context of modern and historical earthquake ruptures, *Bull. Seismol. Soc. Am.*, *105*(2B), 1090-1105.

Yue, H., T. Lay, J. T. Freymueller, K. Ding, L. Rivera, N. A. Ruppert, and K. D. Koper (2013), Supershear rupture of the 5 January 2013 Craig, Alaska (Mw 7.5) earthquake, *J. Geophys. Res.*, *118*(11), 5903-5919.

11. Appendices

Appendix A - Seismic acquisition, equipment and Langseth specifications

*Information in Appendix A is from Science Support Plan prepared by T. Jensvold

Both the MCS and OBS profiles were acquired using 4 sound-source subarrays, consisting each of Bolt source elements with 1,650 cubic inches (in3); yielding a total of 6600 cubic inches (in^3). Each array consisted of a mixture of Bolt 1500LL and Bolt 1900LLX Elements and was configured as four identical linear arrays or "strings". Each sub-array had nine elements; the first and last elements in the sub-array are spaced 6 m apart. Nine elements in each sub-array were simultaneously for a total volume of approximately 6,600 in^3. The array was towed approximately 220 m behind the vessel. Discharge intervals depended on both the ship's speed and two-way travel time (TWTT) recording intervals. The sound sources were discharged approximately every 50 meters during the MCS profiles and every 150 meters during the OBS profiles. The nominal firing pressure of each array is 2,000 pounds per square inch (psi). During firing, a brief (~0.1 s) pulse of sound is emitted. The sound sources were silent during the intervening periods. The tow depth of the sound source arrays was 12 m. On MCS lines, 7.5 km run-out and 15 km run in were built into line changes unless depth/hazard concerns. On OBS lines, 2-5 km run-in and run-out were built into line changes unless depth/hazards concerns.

A.2. Seismic Recording Systems

Recording type	Sercel SEAL 408xl
Sample rate	2ms
Recording length	17 sec
Low Cut Filter	3.0 Hz Digital Filter / 12 dB/OCT
High Cut Filter	200 Hz Digital Filter /276 dB/OCT w/ linear phase
Data format	SEG-D 8058 Rev1 demultiplexed with External Header.
Media	Data recorded directly to disk

A.3. Seismic Streamer

Streamer type	Sercel Sentinel SSAS
No of streamers	1
Streamer length	15 km
No of groups	1200
Group Interval	12.5 m
Group length	12.5m
Streamer depth	12 m
Near offset	~188 m
Spacing of birds	~300 meters with extra redundancy at head and tail of streamer

A.4. Seismic Source

Source type	BOLT Air-Sound Source
Source System	Gun Link 2000
Shot interval	Towed Streamer Component: 37.5 m
Number Sources	1

Source depth	12 m
Volume	6600 in3
Air pressure	1900 +/- 100 psi
Source separation	18 m
Sub Array separation	6m
Max timing error	+/- 2 ms

A.5. In Sea Positioning Systems

Tail-buoy

A Tail-buoy was deployed at the tail of the streamer for positioning. The Tail-buoy was to be fitted with a GPS unit, a radar reflector, a strobe light and AIS.

Source Positioning

Each Sub-Array float had a Posnet rGPS Pod installed.

Streamer Positioning

Streamers were positioned using DigiCourse 5011 compass birds.

DigiCourse Birds

The birds were mounted at 300 m intervals on the streamer. The depth controllers were DigiCourse model 5011.

A.7. Seismic QC Processing

The seismic quality control (QC) was performed by the science party.

Appendix B – Other Underway Data Acquisition

*Information in Appendix B is from Science Support Plan prepared by T. Jensvold

B.1. Sonars

The sonar equipment on vessel include the Kongsberg EM122 12kHz multibeam echo sounder, the Knudsen 3260 3.5 kHz Sub-bottom Profiler, and the RDI OS75 ADCP.

B.1.1. Multibeam Echosounder

Bathymetry data was acquired using a Kongsberg EM-122 within the survey area. The EM122 sound velocity profile (SVP) were processed from the Expendable Bathythermograph (XBT) data and uploaded to the EM122 system by the technical staff. We performed XBTs every 1-3 days.

B.1.2. Sub-bottom Profiler

We also ran the Knudsen 3.5 kHz Sub-Bottom Profiler (SBP) synchronized with the EM122 MBES. **When the** multibeam was not in use, the Knudsen was run in internal sync. Knudsen data was recorded in SEGY, KEA, and KEB formats.

B.1.3. Acoustic Doppler Current Profiler

A RDI OS75 Acoustic Doppler Current Profiler (ADCP) is installed on the vessel and has been in operation since 2011 science mission season. The vendor, Teledyne RDI, ran both Harbor Acceptance (done in San Francisco) and Sea Acceptance (done offshore San Diego) tests, completing the commissioning of the system. Dr. Jules Hummon from University of Hawaii joined the *Langseth* for the JMS inspection cruise and fully installed their on-board system (UHDAS) for logging, processing and QC of the data.

B.2. Magnetics and Gravity

B.2.1. Magnetics

The *Langseth* carries two Geometrics 882 magnetometers and deployed the magnetometer only in the work area. The magnetometer was not deployed during transits to and from the work area. There were segments during which the magnetometer readings were highly variable. During these segments, we recovered the magnetometer and redeployed in calmer seas.

B.2.3. Gravity

The Langseth is equipped with a Bell Aerospace BGM-3 gravimeter. Gravity data will be handled by the R2R data archive group at LDEO (See Data Distribution below). Gravity data were stored in serial data stream while underway and will be archived in the R2R upon completion of the cruise. Gravity ties were performed before and after the cruise, in Seattle and Ketchikan, respectively.

B.3. XBT

The *Langseth* carries Sippican T-5 and T-7 Expendable Bathythermograph (XBT) probes, suitable for general oceanography and sound velocity use in the Multibeam processing. We deployed one probe daily when possible. Science party assisted with all deployments and processing of XBT data. The standard cut-off limit for XBT probes were used.

B.4. Navigation

The navigation equipment on the vessel is as follows:

- Furuno FE700 echosounder
- Furuno DS80 doppler speedlog
- C-Nav 3050 DGPS – two units
- Simrad GC80 gyrocompass
- POS/MV Integrated Nav System
    - Upgraded February 2013
- Seapath 330 Integrated Nav System
- Spectrum Instruments TM-4 Event Logger

These systems provide support to seismic operations and the Multibeam system. These systems were operated by the crew and technical staff, and were turned on or secured as necessary. All of these instruments output serial data and are logged using the Lamont Data System.

The navigation processing was performed by the technical staff using the Concept Sprint Navigation Processing System.

Final data format: UKOOA P190
Final data medium: Electronic

B.5. Meteorological

Langseth has 2 x Vaisala WXT520, installed for wind speed/direction, air temp/humidity, and barometric pressure running on NOAA Shipboard Computer Systems (S.C.S.)

B.6. Surface Seawater

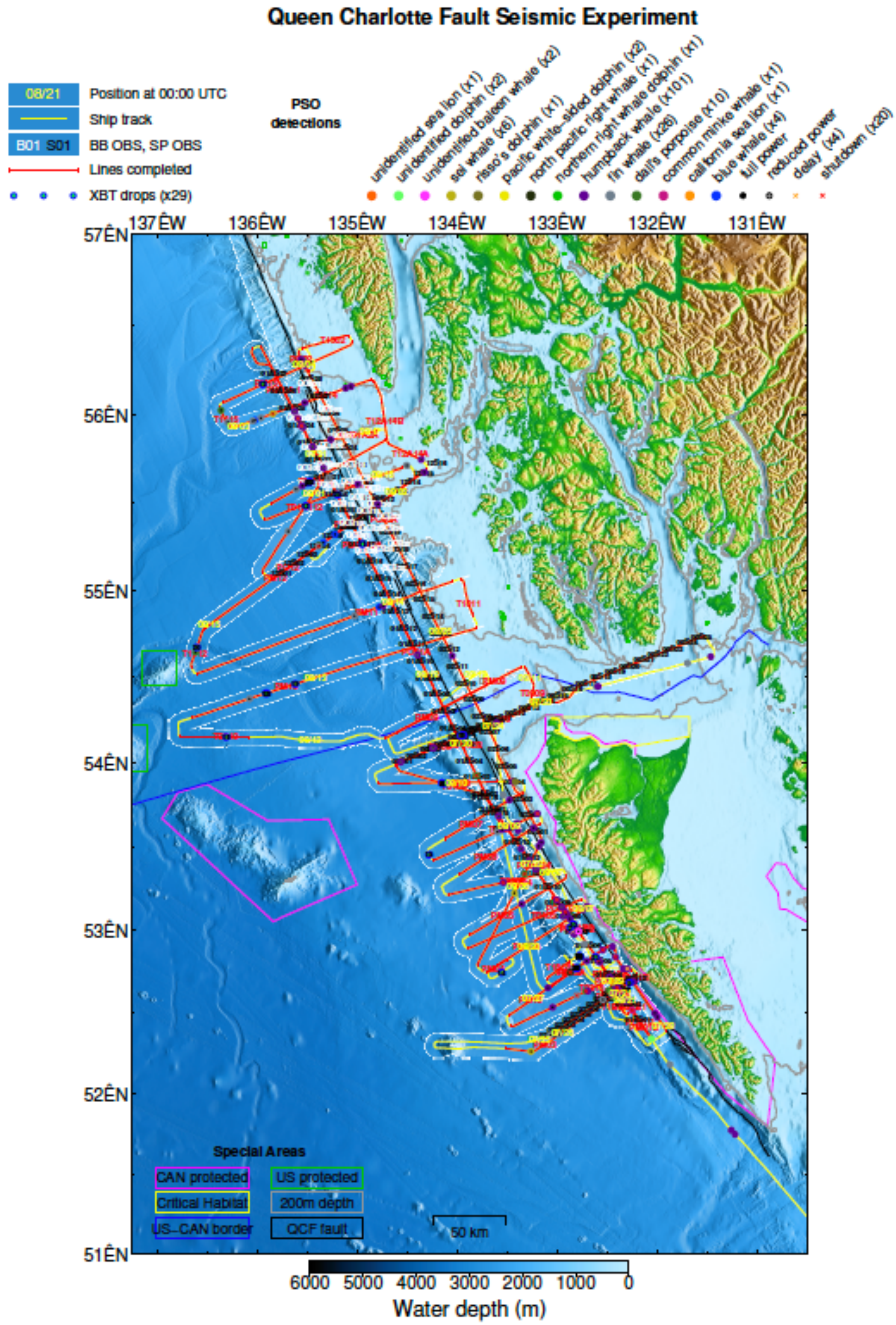
The following meteorological and hydrographical instruments are on the *Langseth* and are routinely operated:

- SBE-45 TSG
- Applied Microsystems MicroSV
- Sea-bird Electronics SBE38 Temperature Sensor

B.7. Lamont Data System (LDS)

All serial data was logged via the Lamont Data System (LDS). LDS data was automatically copied (using rsync) to the cruise directory every six hours.

Appendix C - Maps of acquisition



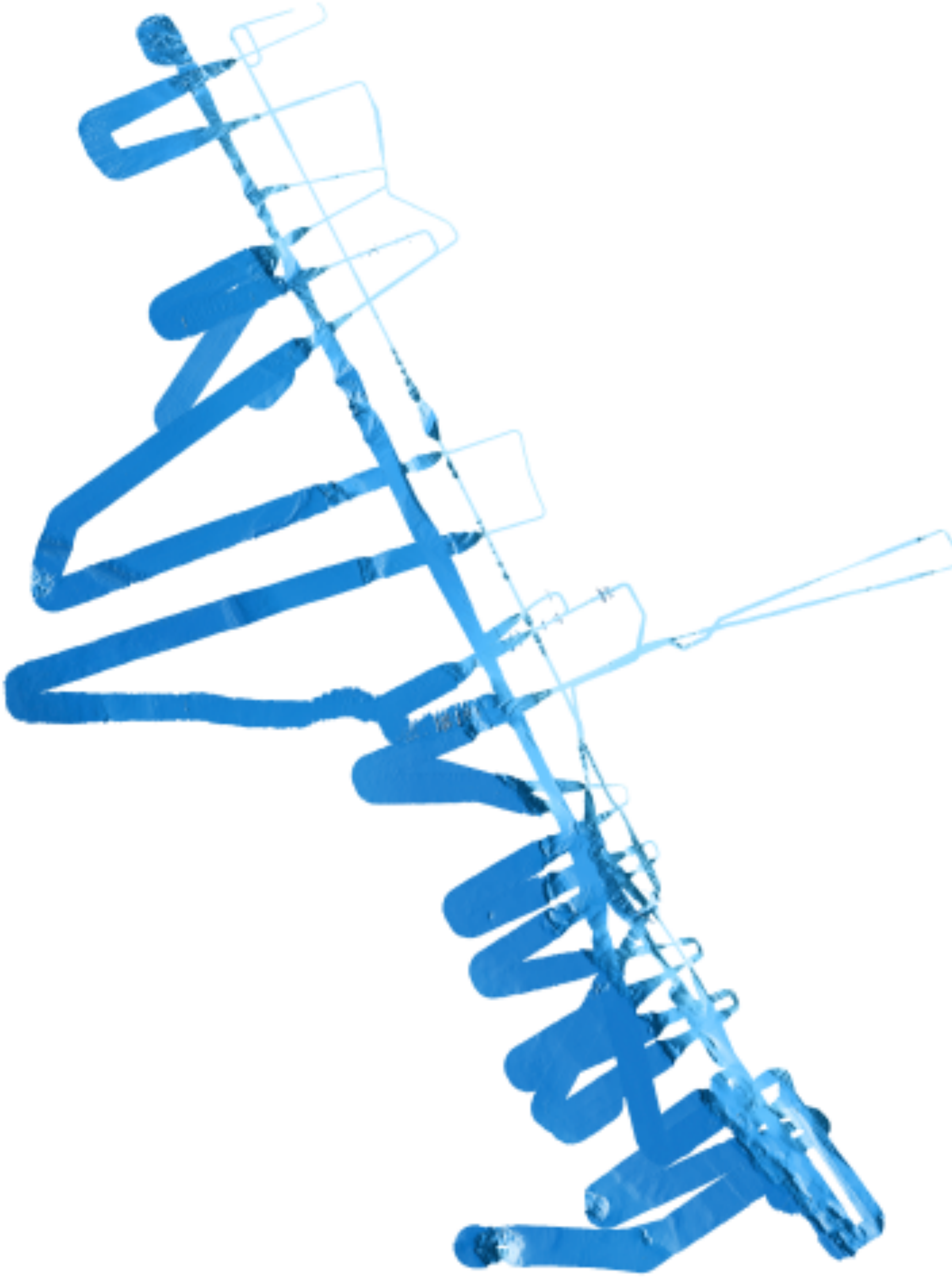
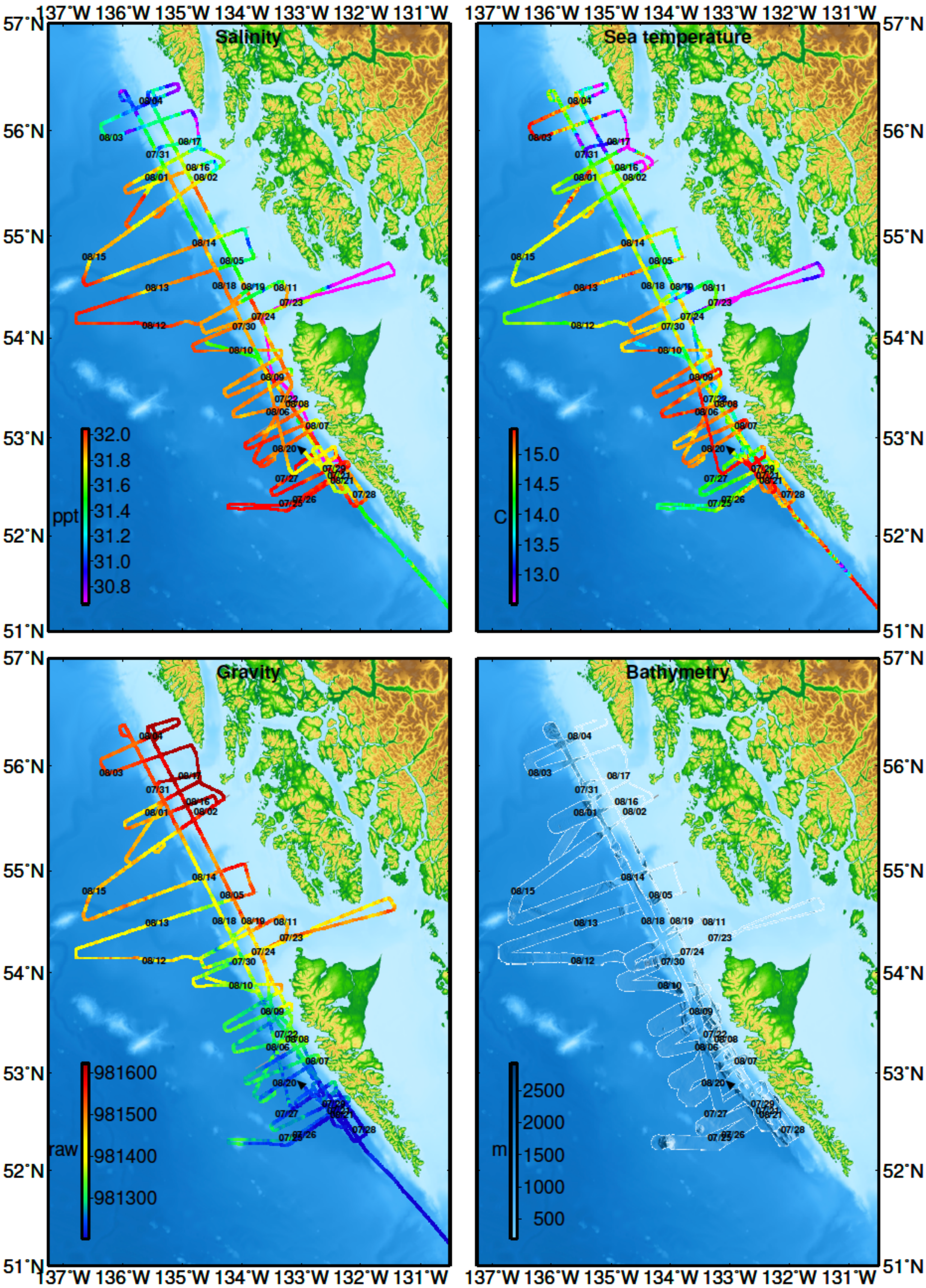


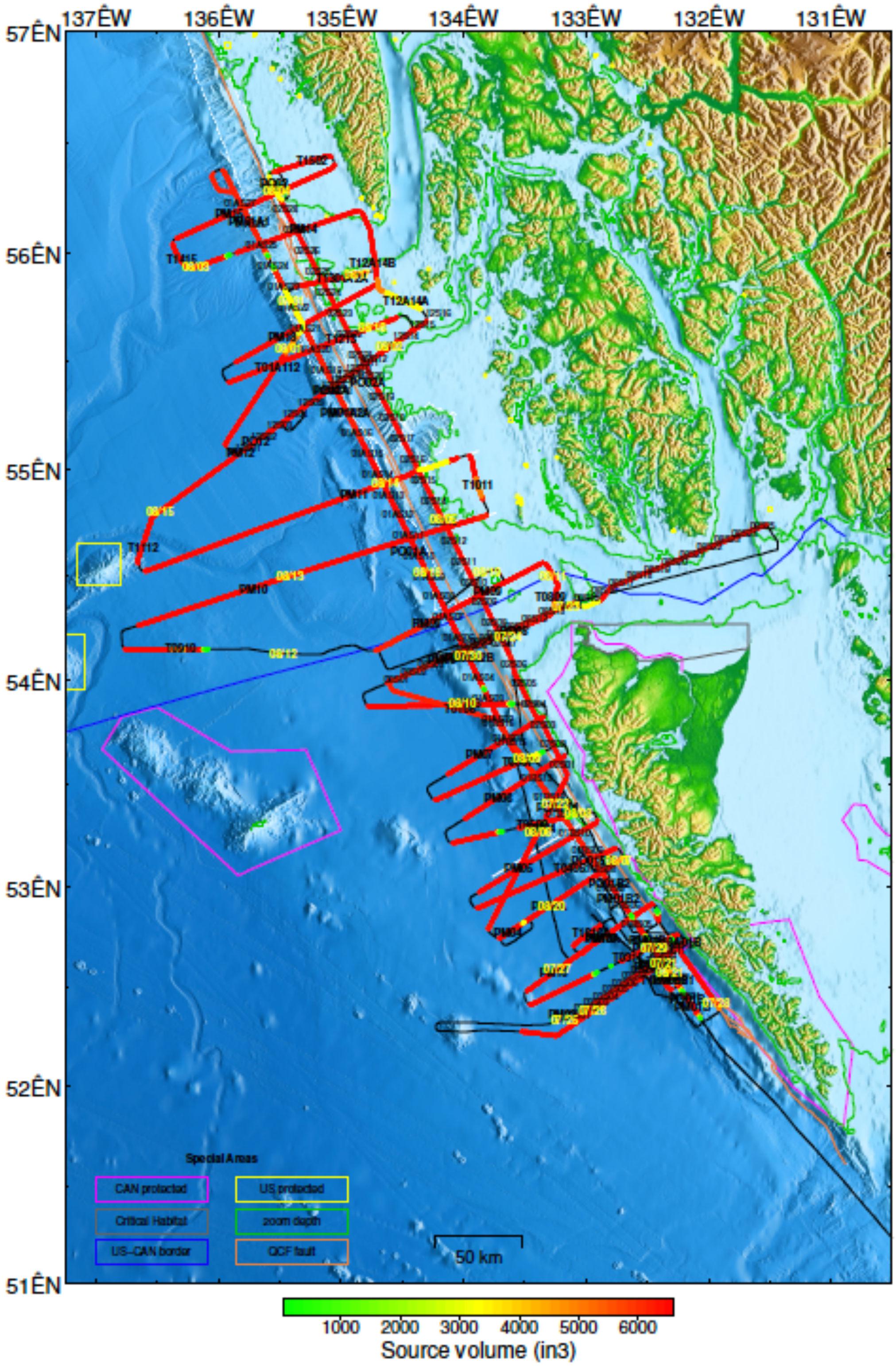
Figure C.2 Multibeam bathymetry collected during MGL2105.

MGL2105 serial data

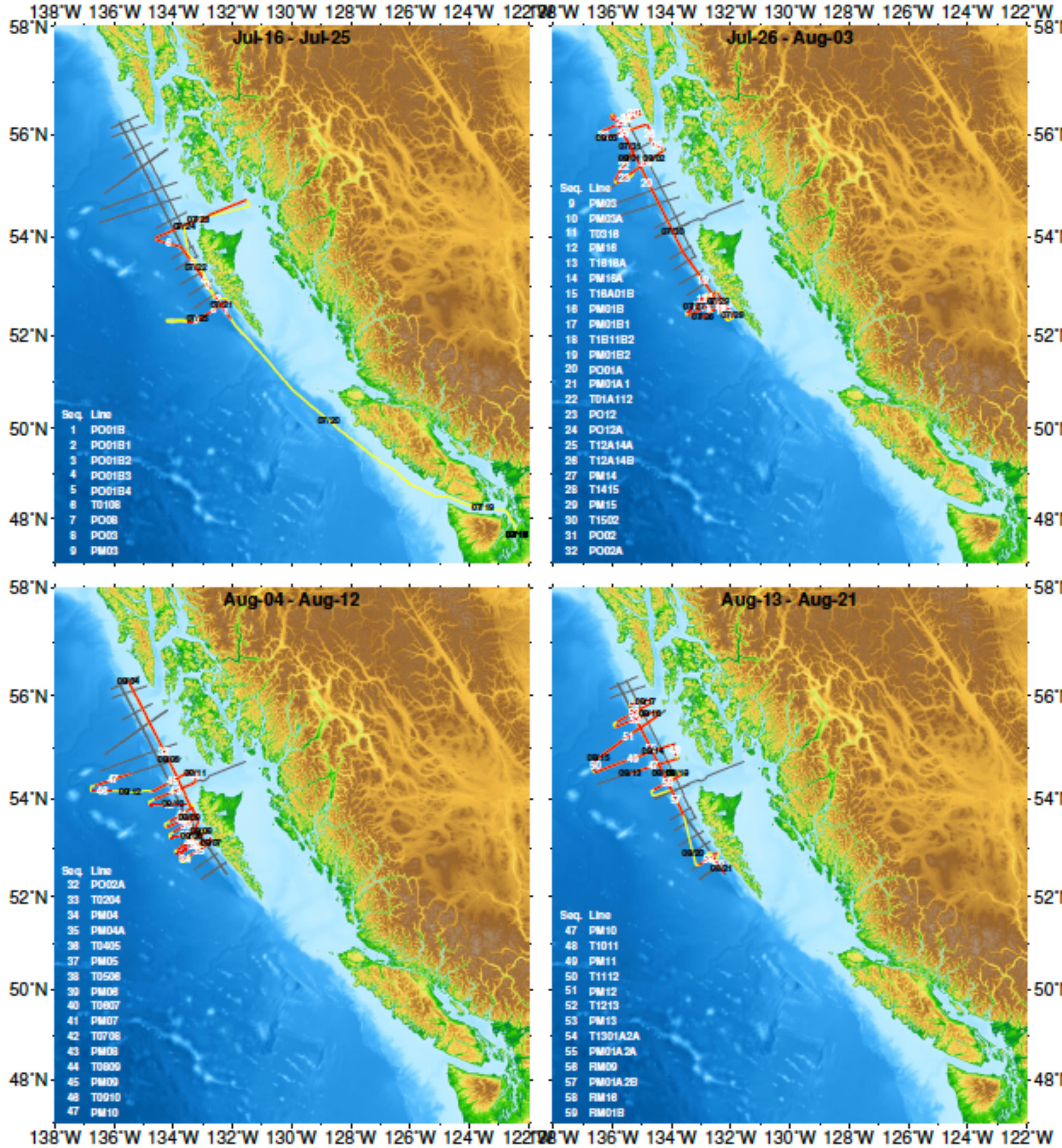


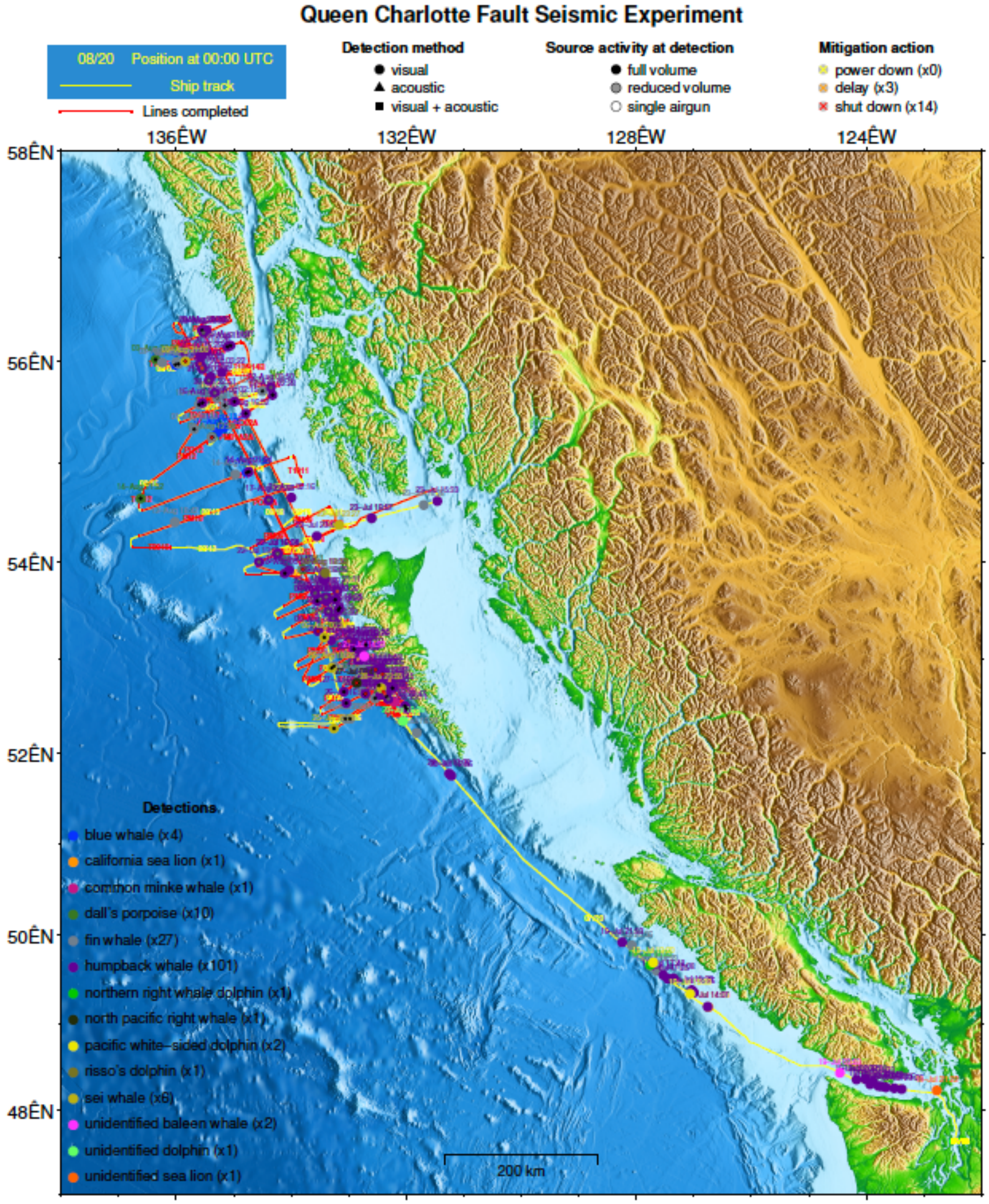
Queen Charlotte Fault Seismic Experiment

Source Volume



MGL2105 navigation




Queen Charlotte Fault Seismic Experiment
08/20 Position at 00:00 UTC
Ship track
Lines completed
Detection method
visual
acoustic
visual + acoustic
Source activity at detection
full volume
reduced volume
single airgun
Mitigation action
power down (x0)
delay (x3)
shut down (x14)
136ÊW
132ÊW
128ÊW
124ÊW
58ÊN
56ÊN
54ÊN
52ÊN
50ÊN
48ÊN
Detections
blue whale (x4)
california sea lion (x1)
common minke whale (x1)
dall's porpoise (x10)
fin whale (x27)
humpback whale (x101)
northern right whale dolphin (x1)
north pacific right whale (x1)
pacific white-sided dolphin (x2)
risso's dolphin (x1)
sei whale (x6)
unidentified baleen whale (x2)
unidentified dolphin (x1)
unidentified sea lion (x1)
200 km

Appendix D - MCS Processing and Onboard Data QC

Onboard processing of MGL2105 multichannel seismic data (MCS) was conducted using the R/V Langseth version of the Paradigm software package Echos (v2015.5). For each MCS line raw data were read in, nominal geometries assigned, and brute stacks created. For select lines, additional processing including: gap deconvolution, velocity analysis, and Kirchhoff migration was applied. All navigation files (P190) were read into Paradigm and quality controlled (QC'ed) for any navigation errors.

We exported raw shot files to SEGY format, with navigation information written into the headers from the QC'd P190 files. We also exported the "final" stack for lines depending of level of processing either brutestack, velocity stacks or near-offset stacks.

Below is a detailed description of the processing steps taken onboard. We summarize the general steps applied to the data to produce the brute and migrated stacks. We also outline the additional processing steps and QC methodology for the streamer navigation files.

1. Read in raw shot data (SEGD format)

Raw shot files are written in SEGD format with a .RAW extension and organized into tape folders onboard R/V Langseth. Each shot is one SEGD file which contains the shot record for each channel and meta data such as: shot point number, time of the shot, latitude, longitude, seafloor depth, and others. Reading the raw data into Echos takes two steps.

a. Record SEGD format

This job required a single raw SEGS file as input to generate a text file of SEGD format in the Interactive SDB.

Example job: segd_format.dat

```
*JOB
*CALL   SEGD                    8058
RECORD  1

TAPEOPT -tapefile /home/sciparty/segd/TAPE0004.REEL/R001446_1627272921.RAW
WRITE   format_raw_PM03
*END
```

b. Read in SEGD data

This job requires the above created format file and a list of all SEGD shot files to read in. A csh script (attached below) is used to create the list of .RAW files.

Example job: segd_load.dat

```
*JOB
*CALL   SEGD                    8058
FHDRDEF
SHOT        GENERAL 73          BYTE
WDEPTH        AUX    1713    4     ASCII
RECORD  1           INCR    2046
```

```
READ    format_raw_PM03
TAPEOPT -flist /home/sciparty/CruiseData/public/processing/Flist_TAPE_1_6
*CALL   DSOUT   OVERWRT
LABEL   PM03all_shots
*END
```

2. Apply nominal geometry

For onboard processing we define a simplified geometry where we assume no streamer feathering and set the nearest source-receiver offset of 220 m, shot spacing of 50 m, and receiver spacing of 12.5 m. The number of channels on the 15 km streamer was 1200. The data are then sorted into CDP gathers.

Example job: nominal_geometry.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_shots
PKEYLST
5885    7938
*CALL   MARINE  2253    1200    1       220     12.5    50
5885    32
*CALL   GEOMLD  6.25    10000
*CALL   SORT    400     600000
KEYS
cdp
offset
*CALL   DSOUT
LABEL   PM03_cdps
*END
```

3. Filter and edit data

Here we filter the data to remove low frequency swell noise and spikes. We also remove bad channels from the dataset.

Example job: nominal_geometry.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_cdps
PKEYLST
5885    8138
*CALL   EDIT    chan
ALL
13      24      56      301     519     529     541     549
756     813     829     861     877     885     886     979
1185
*CALL   FILTER                  FREQ
BANDSL
            3       7       200     250
*CALL   DSOUT
```

```
LABEL   PM03_cdps_bp3-7-200-250
*END
```

4. Brute stack

In this job we generate a brute stack making an assumption of velocities (using approximate water velocity) and only use the near 20 traces to avoid stacking improperly flattened reflection in the NMO correction and to avoid feathering artifacts. We also apply a Kirchhoff time migration assuming water velocities.

Example job: brutestack.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_cdps_bp3-7-200-250
PKEYLST
1219    18842
*CALL   VFNDEF  cdp                     OVERWRT
VFLABEL
V1480
VFUNC   1219
0      1480    17000   1480
VFUNC   18842
0      1480    17000   1480
*CALL   GAIN
SPHDIV
*CALL   NMO     NMOAPP
VEL
V1480
*CALL   MUTE
STRETCH 45
V1480
*CALL   STACK   NORMAL              20
*CALL   MIGTX   17624   6.25
VEL
V1480
*CALL   DSOUT
LABEL   PM03_bp3-7-200-250_brute-20
*END
```

a. Optional: Brute stack including deconvolution

To quickly process the final lines and to also remove the source signature from the resulting reflection data, we defined another brute stacking process utilizing deconvolution, filtering, and Kirchhoff migration. Below is this job. In the next sections we will detail the parameters used for this example.

Example job: brutestack-20_v1480_migtx.dat

```
*JOB
*CALL   DSIN
```

```
LABEL   PM03_cdps
PKEYLST
1219    18842
*CALL   FILTER
BANDSL
          3      7      200    250
*CALL   DECONA  cdp    seqno
KEYDEF  13231   1      2
GAP     124            24
180    1250    180    1250    0      17000   0      17000
*CALL   FILTER
BANDSL
          3      7      200    250
*CALL   VFNDEF  cdp                    OVERWRT
VFLABEL
V1480
VFUNC   1219
0      1480    17000   1480
VFUNC   18842
0      1480    17000   1480
*CALL   GAIN
SPHDIV
*CALL   NMO     NMOAPP
VEL
V1480
*CALL   STACK   NORMAL             20
*CALL   MIGTX   17624   6.25
VEL
V1480
*CALL   DSOUT   OVERWRT
LABEL   PM03_brute-20_v1480_migtx_DECON
*END
```

5. Optional: Gap deconvolution

Many of the seismic lines in this region exhibit very hard seafloor reflections with little acoustic penetration resulting in lines with very strong multiples and with a “ringing” effect due to the source signature not being a true delta function. Below we use DECONA to define a window about the direct arrival and use this source signature to predictively deconvolve the source from all traces. This removes most of the “ringing” effect and allows us to better pick velocities.

Example job: decon.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_cdps_bp3-7-200-250
PKEYLST
2660    18660
*CALL   DECONA  cdp    seqno
KEYDEF  11000   3      4
```

```
GAP     60          60
150     1300    150     1300    1       17000   1       17000
*CALL   DSOUT
LABEL   PM03_cdps_bp3-7-200-250_DECON
*END
```

6. Optional: Velocity analysis

To create a better seismic image, and to begin building an acoustic geologic model of the subsurface, we apply stacking velocity analysis. Utilizing the interactive velocity picking capability in Paradigm, we read in every 500 CDPs (this can change for lines or regions within lines that have more complex geologies) and create supergathers of up to 4. These velocities can then be used to better stack and migrate the seismic sections as shown below. Also during this process mutes are defined to remove any unflattened reflections and to remove the refraction data.

Example job: veldef.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_cdps_bp3-7-200-250_DECON
RANGE   2660    18660   4       500
 #*CALL   AGC    500
*CALL   VELDEF         MODIFY
VEL
PM03_vel
*END
```

7. Optional: Velocity stack

After defining stacking velocities, we apply the NMO correction using the defined velocities and mute. We also apply correction for spherical divergence and amplitude scaling to attenuate any additional noise.

Example job: stack.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_cdps_bp3-7-200-250_DECON
PKEYLST
2660    18660
*CALL   GAIN
SPHDIV
*CALL   NMO
VEL
PM03_vel
*CALL   MUTE
VFMUTE
PM03_mute
*CALL   AMPSCAL 31              cdp
GATES
            150     2
```

```
*CALL   FILTER
BAND
          3     7      200     250
*CALL   STACK
*CALL   DSOUT
LABEL PM03_bp3-7-200-250_velstack_DECON
*END
```

8. Optional: Kirchhoff time migration

Finally, we apply Kirchhoff time migration to the post stack data using our picked velocities to create a more realistic seismic section.

Example job: kirchmig.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_bp3-7-200-250_velstack_DECON
PKEYLST
2660    18660
*CALL   MIGTX   16001   6.25
VEL
PM03_vel
*CALL   DSOUT
LABEL   PM03_bp3-7-200-250_velstack_DECON_kmig
*END
```

9. Load P190 navigation

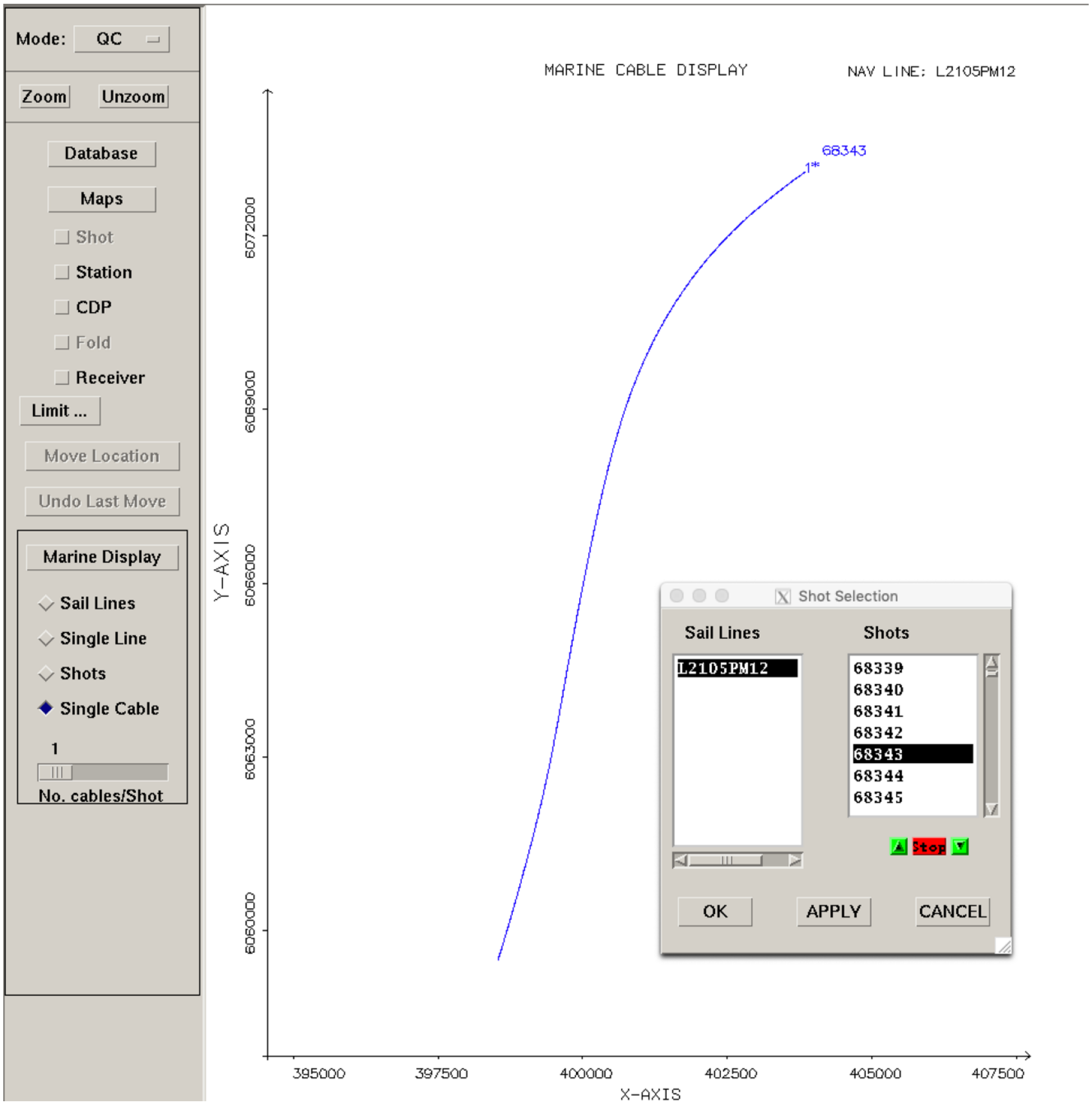
For each seismic line, a processed navigation file is delivered to the ship in UKOOA P190 format. The navigation data stored in the file uses the differential GPS on the vessel, gun strings, and tail buoy, and the compasses in each bird to define the streamer geometry. The navigation data was processed by technical staff off-ship but delivered onboard after processing. Each P190 file is read into Paradigm and converted into the internal FMT format. This navigation data can then be QC'ed and the locations read into the seismic headers for off-ship processing.

Example job: navload.dat

```
*JOB
*CALL   NAVDSK  UKOOA90 1200    3      12
FILE    /home/sciparty/CruiseData/processed/seispos/Seq001_MGL2105PM03.P190
*CALL   NAVPRNT ALL
*CALL   NAVWRT  1      3000    1200
FILE    /home/sciparty/CruiseData/public/processing/PM03/PM03.fmt
*END
```

10. QC P190 navigation

The onboard science party quality controlled each seismic navigation file using the Paradigm 3D Geometry utility (figure below). This utility allows us to interactively display the navigation for each shot. This allowed us to check the shot locations, streamer feathering, and position for each line to identify any navigation issues. To do this, we load the previously generated FMT formatted navigation data. Then select QC mode and “single cable” to define the proper geometries. Finally select “Marine Display” to view the streamer location, and view each shot in succession.



Example navigation display using Geometry 3D

11. Merge navigation with shot data

After applying the quality control to the navigation data, we read the locations into Paradigm to be exported for off-ship processing. Note water depth is not read into the headers here since this was already done during the SEGD import.

Example job: navhdr.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_shots
PKEYLST
```

```
68301   71600
*CALL   GEOMLD  6.25    10000
NOUPDAT
wdepth
NAVFILE
/home/sciparty/CruiseData/public/processing/PM03/PM03.fmt
#*CALL   SORT    400     600000
KEYS
cdp
offset
*CALL   DSOUT
LABEL   PM03_shots_w_nav
*END
```

12. Export to SEGY format

Finally, we export the Paradigm data to SEGY format for off-ship processing. The job below is for navigated shot data, but similar (but slightly modified) versions can be used for CDP and stacked data. Note some header values are reused with the addition of some header math to output the correct values.

Example job: shot_segy_save.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_shots_w_nav
PKEYLST
5885    7338
*CALL   GOUT                PRESTK        chan
TAPEOPT -tapefile /home/sciparty/echos_exports/PM03.shots.segy
DEFINE  CHAN    1      4      INT
DEFINE  ENSNO   5      4      INT
DEFINE  SHOT    9      4      INT
DEFINE  CHAN    13     4      INT
DEFINE  FFID    17     4      INT
DEFINE  CDP     21     4      INT
DEFINE  SEQNO   25     4      INT
DEFINE  CABLE   29     2      INT
DEFINE  CABLE   31     2      INT
DEFINE  CABLE   33     2      INT
DEFINE  OFFSET  37     4      INT
DEFINE  RDEPTH  41     4      INT
DEFINE  WDEPTH  45     4      INT
DEFINE  SELEV   49     4      INT          12
DEFINE  SHT_X   73     4      INT
DEFINE  SHT_Y   77     4      INT
DEFINE  REC_X   81     4      INT
DEFINE  REC_Y   85     4      INT
DEFINE  CABLE   89     2      INT
DEFINE  YEAR    157    2      INT
```

```
DEFINE  DAY     159    2      INT
DEFINE  HOUR    161    2      INT
DEFINE  MINUTE  163    2      INT
DEFINE  SECOND  165    2      INT
DEFINE  CABLE   167    2      INT    4
DEFINE  MID_X   181    4      INT
DEFINE  MID_Y   185    4      INT
*END
```

Example job: cdp_segy_save.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_cdps_bp3-7-200-250_DECON
PKEYLST
2660   18660
*CALL   GOUT                 PRESTK  CDP    SEQNO
TAPEOPT -tapefile /home/sciparty/echos_exports/PM03.cdps.2600-18600-100.segy
DEFINE  CHAN    1      4      INT
DEFINE  ENSNO   5      4      INT
DEFINE  SHOT    9      4      INT
DEFINE  CHAN    13     4      INT
DEFINE  FFID    17     4      INT
DEFINE  CDP     21     4      INT
DEFINE  SEQNO   25     4      INT
DEFINE  SPIDX   29     2      INT
DEFINE  SPIDX   31     2      INT
DEFINE  SPIDX   33     2      INT
DEFINE  OFFSET  37     4      INT
DEFINE  WDEPTH  45     4      INT
DEFINE  SELEV   49     4      INT          12
DEFINE  STIM    73     4      INT
DEFINE  STIM    77     4      INT
DEFINE  STIM    81     4      INT
DEFINE  STIM    85     4      INT
DEFINE  SPIDX   89     2      INT
DEFINE  YEAR    157    2      INT
DEFINE  DAY     159    2      INT
DEFINE  HOUR    161    2      INT
DEFINE  MINUTE  163    2      INT
DEFINE  SECOND  165    2      INT
DEFINE  SPIDX   167    2      INT    4
DEFINE  STIM    181    4      INT
DEFINE  STIM    185    4      INT
DEFINE  SPIDX   189    4      INT
DEFINE  CDP     193    4      INT
*END
```

Example job: stack_segy_save.dat

```
*JOB
*CALL   DSIN
LABEL   PM03_bp3-7-200-250_velstack_DECON_kmig
PKEYLST
2660    18660
*CALL   GOUT                  POSTSTK CDP
TAPEOPT -tapefile /home/sciparty/echos_exports/PM03.vstack.kmig.segy
DEFINE  CHAN    1      4      INT
DEFINE  ENSNO   5      4      INT
DEFINE  SHOT    9      4      INT
DEFINE  CHAN    13     4      INT
DEFINE  FFID    17     4      INT
DEFINE  CDP     21     4      INT
DEFINE  SEQNO   25     4      INT
DEFINE  CHSET   29     2      INT
DEFINE  CHSET   31     2      INT
DEFINE  CHSET   33     2      INT
DEFINE  OFFSET  37     4      INT
DEFINE  WDEPTH  45     4      INT
DEFINE  SELEV   49     4      INT        12
DEFINE  INVALID 73     4      INT
DEFINE  INVALID 77     4      INT
DEFINE  INVALID 81     4      INT
DEFINE  INVALID 85     4      INT
DEFINE  CHSET   89     2      INT
DEFINE  YEAR    157    2      INT
DEFINE  DAY     159    2      INT
DEFINE  HOUR    161    2      INT
DEFINE  MINUTE  163    2      INT
DEFINE  SECOND  165    2      INT
DEFINE  CHSET   167    2      INT    4
DEFINE  INVALID 181    4      INT
DEFINE  INVALID 185    4      INT
*END
```

CSH script to make list of raw SEGD files.

```
#!/bin/csh

if ($#argv < 1) then
  echo " "
  echo "Usage:  Flist_script.csh firstreel (lastreel)"
  echo "For example:  Flist_script.csh 001 0010"
  echo "Note: Provide lastreel unless there is only one reel."
  echo " "
  exit(1)
```

```
endif

#
set CRUISEID = "MGL2105"   # Cruise ID
set SEGDDIR = "/home/sciparty/segd"   # SEGD output
set FLIST_DIR = "/home/sciparty/CruiseData/public/processing"
#
#
set FIRST = $1     # First reel number
if ($#argv < 2) then
  set LAST = $FIRST
  set FILE = $FLIST_DIR/"Flist_TAPE_"$FIRST
  echo "Output to " $FILE
else
  set LAST = $2     # Last reel number
  set FILE = $FLIST_DIR/"Flist_TAPE_"$FIRST"_"$LAST
  echo "Output to " $FILE
endif
set REEL = $FIRST

if (-f ./temp)rm temp

#echo $REEL $FIRST $LAST
while ($REEL <= $LAST)
echo $REEL >> temp
@ REEL++
end

awk '{printf("%03d\n", $1);}' temp > temp2

if (-f ./temp3)rm temp3

foreach REEL( `awk '{print $1}' temp2 ` )

echo " "
#echo "Working on :" $REEL

ls -d $SEGDDIR/TAPE*$REEL.REEL
echo " "
ls  $SEGDDIR/TAPE*$REEL.REEL/R* >> temp3
end

awk '{i++; print (i, substr($1,1,77))}' temp3 > $FILE
```

```
rm temp
rm temp2
rm temp3

echo "ALL FILES DONE."
```

Appendix E – Multibeam bathymetry data

We acquired multibeam bathymetry data during the survey once we entered the permitted work area. There were some technical problems starting the multibeam instrument, so we were delayed collecting data for ~18 hrs after shooting began.

The multibeam system on the Langseth is a hull mounted 1x1 degree Kongsberg EM-122_109 multibeam system with 432 beams athwartships per ping, transmitting at a frequency of 12.0 kHz with maximum possible angular coverage of 150 degrees. For this cruise the system was set with an angular swath width.

At ~1800 m water depth, the ping interval was 7.69 s. We surveyed at ~3.8-4.5 kts and transited without guns and streamer at ~10 kts. Maximum beam angles were set at 65 degrees. The swath width is ~2-5x the water depth. Sound velocities were updated every 1-3 days from XBT profiles acquired during the survey (sound velocity profile = SVP). Normal incidence correction for backscatter was 6 degrees. Dual Swath and Ping Modes were set to Auto. Sound velocity at the transducer was from sensor or from SVP in bad weather because air bubbles can cause incorrect readings at the sensor. The acquisition software is the Kongsberg Seafloor Information System.

Potential data artifacts and noise come from the 3.5 kHz sub-bottom profiler and high-frequency noise from the guns mechanical action. These artifacts need to be addressed in hand editing of the swath data.

Table X.1. Roll and pitch bias for Langseth sonars

	Roll	Pitch	Heading
TX Transducer	0.1603	-0.0772	359.99
RX Transducer	0.1603	-0.0772	0.00
Attitude, COM2/UDP5	-0.54	-0.23	0.43
Attitude COM3/UDP6	0.00	0.00	0.00
Stand-alone heading			-0.20

X.1 Multibeam Processing

We undertook initial processing of the multibeam bathymetry data acquired during our cruise using MB-System (Caress and Chayes, 2006). Processing steps, commands, scripts and ‘cookbook’ are included here. The basic onboard processing flow for multibeam data consists of the following steps:

1) Copying and converting the raw data: The data from the EM122 are written in a read-only format that must be converted before edits can be applied. The command for copying and editing is mbcopy.
2) Automatic processing: An automatic processing routine flags spikes and excessive slopes using mbclean. The mbclean script also writes parameter files for pitch and roll (see Table X.1.).
3) Manual processing: We used mbedit to flag bad pings by hand.
4) Gridding the data for mapping and interpretation using mbgrid.

We hand edited most of the multibeam data collected during the cruise. Each member of the science party participated in data processing and gridding the files.

Standard Processing Flow and Onboard "Cookbook"

01_mbcopy.csh → copies raw files and converts to mbsystem format

02_mbclean.csh → automatic, first edits and parameter for pitch and roll

mbedit → manual processing program to hand pick bad pings for removal

03_mbprocess.csh → apply edits from mbclean and mbprocess

04_mbgrid.csh → make grd file and gmt script for display and interpretation

1. Copy and convert raw files

The data from Langseth's EM122 are written out in a format interpreted by MB-System as 58. This is a 'read-only' format, so the files must be converted to another format before edits can be applied. This format is mb59 for EM sonars. mbcopy is the command that does this conversion.

As a team, we will process one day of data at a time. The job below will grab and convert one day of bathy data from EM122 internal format to mbsystems format for processing. It will also make a directory and put the files in that directory.

Places to edit the job are highlighted below.

JOB: 01_mbcopy.csh

USEAGE: > csh 01_mbcopy.csh

SCRIPT:

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

```
set month = 07
set day = 21

foreach file (/home/sciparty/CruiseData/raw/multibeam/MGL2105/2021/07/$day/*.all)
    set file59 = `echo $file  | sed s/_/" "/g | awk '{print $2$3}'`
    mbcopy -I $file -F58/59 -O ./data_$month$day/"$file59".mb59
end
```

2. Automatic editing

Now you have your data files in the correct format, in a directory called data_7021, for the example above. The next step is automatic cleaning and setting the pitch and roll bias. These biases are fixed for the Langseth: ROLL = 0.1603 and PITCH = -0.0772. This job will also create a file list to be used in mbprocess.

You will need to edit the highlighted fields.

JOB: 02_mbclean.csh

USEAGE: > csh 02_mbclean.csh

SCRIPT:

```
#!/bin/csh

# automatic cleaning routine

# first create a list of the files

set day = 0723 #MMDD - change this accordingly

ls ./data$day/*.mb59 > files.$day

mbclean -C60/2 -S60/3/2 -I files.$day -F-1 -M2

# Notes on the flags:
# -C  defines the maximum slope accepted between beams - 2 is the unit (1 = radian; 2 = degrees) -60/2 means 60 degrees
# -S  defines what qualifies as spikes - same convention as C the unit (1 = radian; 2 = degrees) -60/2 means 60 degrees
# spikes can be identified only acrosstrack (1) along track (2) or in both directions (3)
# -M defines the mode for cleaning - 1 flags only furthest beam - 2 flags two beams associated with slope, 3, 4, 5, etc
# -F format - negative value means list of files
```

-G can be used to flag data where depth is different from median beam -G0.8/1.2 will limit beams with depth bewtween 0.8xmedian_beam and 1.2xmedian_beam

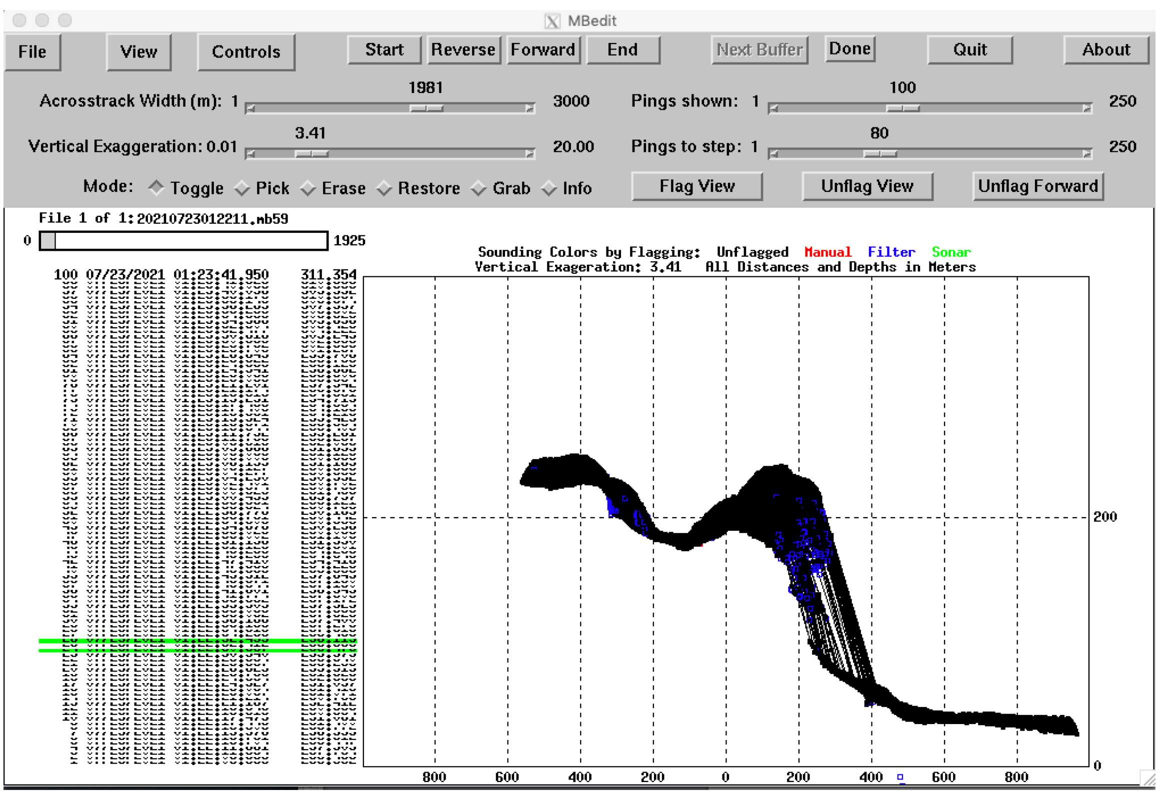
set pitch and roll bias. mbset reads these into parameter files
On Langseth: Roll = 0.1603
Pitch = -0.0772

mbset -I files.$day -F-1 -PROLLBIASMODE:1 -PROLLBIAS:0.1603 -PPITCHBIASMODE:1 -PPITCHBIAS:-0.0772

Mode 1 applies bias to port and starboard equally.

3. mbedit

This is a GUI to hand edit the anomalous pings. For batch processing a day at a time, we can try to get through quickly—my rule of thumb is to look at around 100 pings at a time, vertical exaggeration of about 10 and try to smooth it out a bit. Everyone will have a slightly different style here.



4. Process the data

The command mbprocess will apply the edits to your data and create a processed file in the data directory called filename.m59.

Change highlighted entry accordingly.

JOB: 03_mbprocess.csh

USEAGE: > csh 03_mbprocess.csh

SCRIPT:

```
#!/bin/csh

# mbprocess to actually clean the data using the flagged data generated by 02_mbclean and mbedit.
# this program generates files with the same name and a p before the extension (i.e. p.mb59)in
# the same directory as the data files

set day = 0722 #MMDD

# Apply prcoessing. This script will apply processing from any automatic edits flagged via mblean and manual edits flagged via mbedit. Each time mbclean parameters are updated or more manual edits are made, this script should be re-run.

mbprocess -I files.$day -F-1
```

5. Grid the data for mapping

Now we are ready to plot the processed data!! mbgrid will make a .grd file that can be read by the gmt program for plotting the data on a map. The script 04_mbgrid.csh makes a day directory in the /bathy/grids directory and will place the .grd file. The script will also create a .cmd file, which is a gmt bash script that will create a map.

JOB: 03_mbprocess.csh

USEAGE: > csh 04_mbgrid.csh

SCRIPT:

```
#!/bin/csh

# create a grd file that can be read in GMT
```

first create list with the processed files

set day = 0722 #MMDD

mkdir ./grids/$day

sed s/.mb59/p.mb59/g files.$day > processed_files.$day

mbgrid -A2 -I processed_files.$day -E100/100 -O ./grids/$day/processed_$day -N

-A2 means bathymetry data are given negative values
-E50/50 is the resolution of the grid - this example would be 50m/50m
-O is for the name of the output file (0721_processed will become 0721_processed.grd)
-N is to ensure that missing data are filled with NaN to be ignored

6. Making a map

To make a basic map, navigate into the bathy/grids/$day directory and open the .cmd script. This script needs to be run twice:

- The first time, uncomment the line that starts with mbm_grdplot
- Next, edit the –L flag to show your map title, everything needs to be within " " marks. It should read something like: -L"July 22 – Bathy Grid: Depth (m)"
- In the variable definitions, make sure they look like this (with the correct month and day):
    - PS_FILE=./processed_0722.grd.ps
    - CPT_FILE=./processed_0722.grd.cpt
    - DATA_FILE=./processed_0722.grd

After editing the .cmd file, it should run and show you a map. Usage:

- bash *.cmd

Now, we can play around with different parameters in the gmt script. You will run this command again, but now LEAVE the mbgrid line commented out.

One parameter to play with:

To create a hill shade and more texture on the bathymetry map, you can make an intensity file (for example: intensity_0722.grd) by running the command:

gmt grdgradient ./processed_0722.grd –Gintensity_0722.grd –A0/270 –Ne0.6

The –A defines the azimuth for shading—could be worth testing different parameters, most shaded topo or bathy images tend to be illuminated from the north so an angle between 315 and 45 might be worth testing—above I use 270 as it is the default in the gmt manual pages. You can type in man grdgradient for further discussion. You can also add the above to the .cmd script. Add your intensity file to the INTENSITY_FILE variable in the script, then add the following after grdimage is called:
-I$INTENSITY_FILE

So that would now read:

```
gmt grdimage $DATA_FILE -I$INTENSITY_FILE -J$MAP_PROJECTION$MAP_SCALE \
        -R$MAP_REGION \
```

You can also comment out the grdcontour command to just look at the intensity.

If you want to make many maps to compare them, you will also need to edit the PS_FILE variable each time you run the script.

Appendix F – Gravity tie information

BGM3 ship-to-shore gravity tie report

Bahlau, vessel: R/V Langseth

Release Date: 2021/07/15 22:41:24 UTC

Sensor: S213
Software version: 1.2
Port/Pier/Berth: Pier 91 - Seattle

Gravity station number	A
Station name	University Of Washington - Marine Dock MSB AA
mGal at pier	980732.07
Tie start time UTC	2021/07/15 21:41:04.117
Samples used	3600
Land tie used	Yes
Water height to pier 1	18 ft 1 in
Water height to pier 2	18 ft 2 in
Water height to pier 3	17 ft 10 in
Average of filtered counts	25155.667659195
Filter length	361
Scale factor	5.096606269
NEW BIAS	**852525.23**

Table 1: Gravity tie information

BGM3 land tie report

Bahlau, Jensfold, Gaytan, vessel: Marcus G. Langseth

Release Date: 2021/07/15 20:59:57 UTC

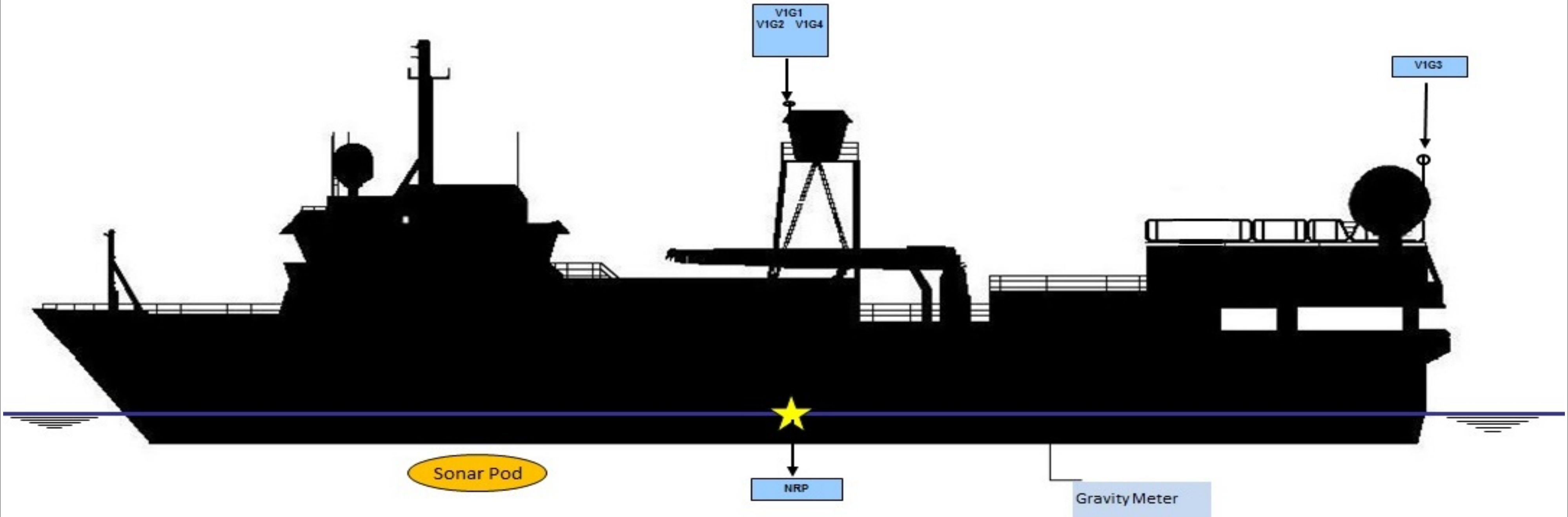
Sensor: S213
Land meter: G-237
Land meter temperature: 49
Software version: 1.2
Reference station: B
Reference station name: MSB AA
Reference station number: MSB AA
Reference mGal: 980729.78
Reference latitude: 0
Reference longitude: 0
New station: A
New station mGal: 980732.07309556
New station latitude: 47.631033
New station longitude: -122.380867
Notes:

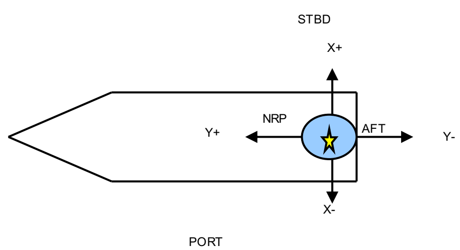
Appendix G – Offsets, file formats and underway data

Company: L-DEO - Lamont - Doherty Earth Observatory
Vessel: Marcus G. Langseth
Client: Worthington/NSF

Project: MGL2105
Area: Queen Charlotte Fault
Start Date: 15-Jul-21

R/V Marcus G. Langseth - Vessel Sensor Offsets



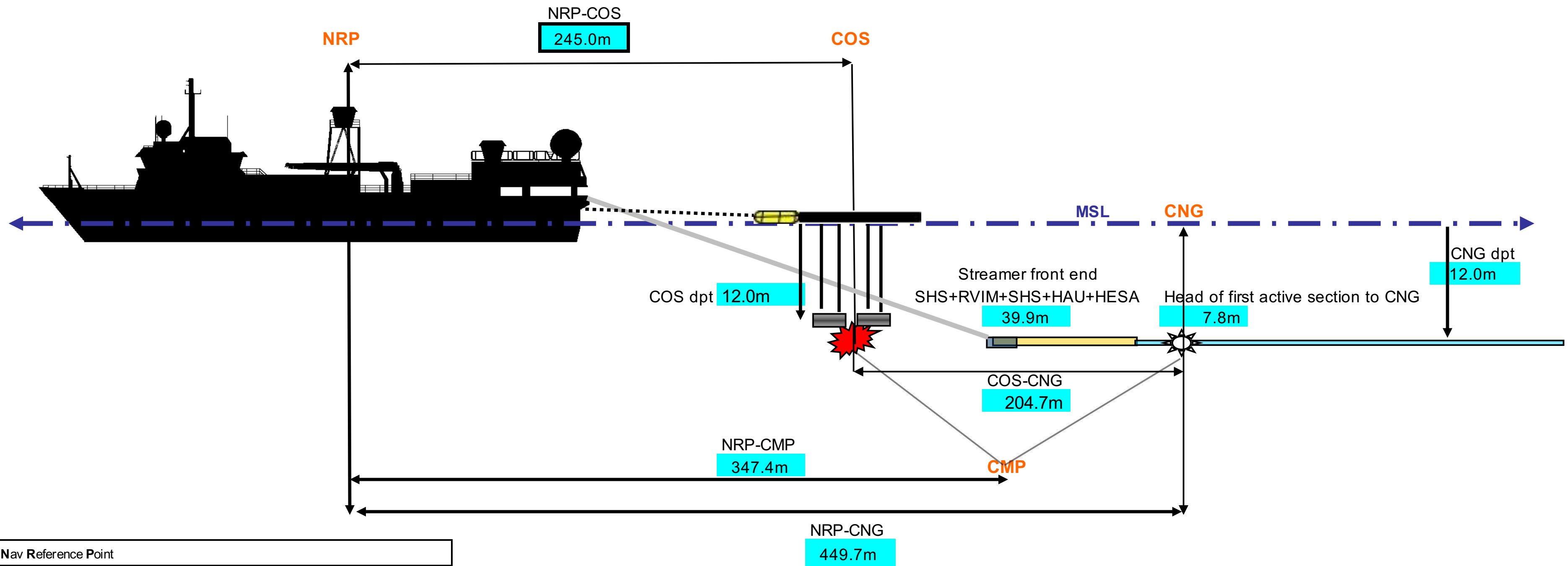


Negative values are above water line

All measurements in meters

		STBD/PORT (X)	FORE/AFT (Y)	UP/DOWN (Z)
NRP	NAVIGATION REFERENCE POINT	0.00	0.00	0.00
V1G1	C-Nav 3050	0.00	0.00	-16.90
V1G2	SeaPath 200	0.00	1.50	-16.90
V1G3	C-Nav 2000	-2.10	-29.20	-14.50
V1G4	Pos MV	-1.30	1.20	-16.90
V1R1	PosNet	-1.30	0.00	-16.90
Sonar Pod	EM122 Knudsen ADCP	0.00	20.20	7.49
	EM122 Center Beam offset (in Spectra)	0.00	13.4	7.49
MRU	Seapath MRU	2.30	14.16	-4.30
BGM	Bell Gravity Meter	0.00	-13.10	1.10

R/V Marcus G. Langseth - Towing Offsets



NRP	Nav Reference Point			
COS	Centre of Source			
CNG	Centre of Near Group	Trace #	1	Of S1
CMP	Common Mid-Point			
MSL	Mean Sea Level			
NRP-Stern	29.5m			
NRP-COS	245.0m			

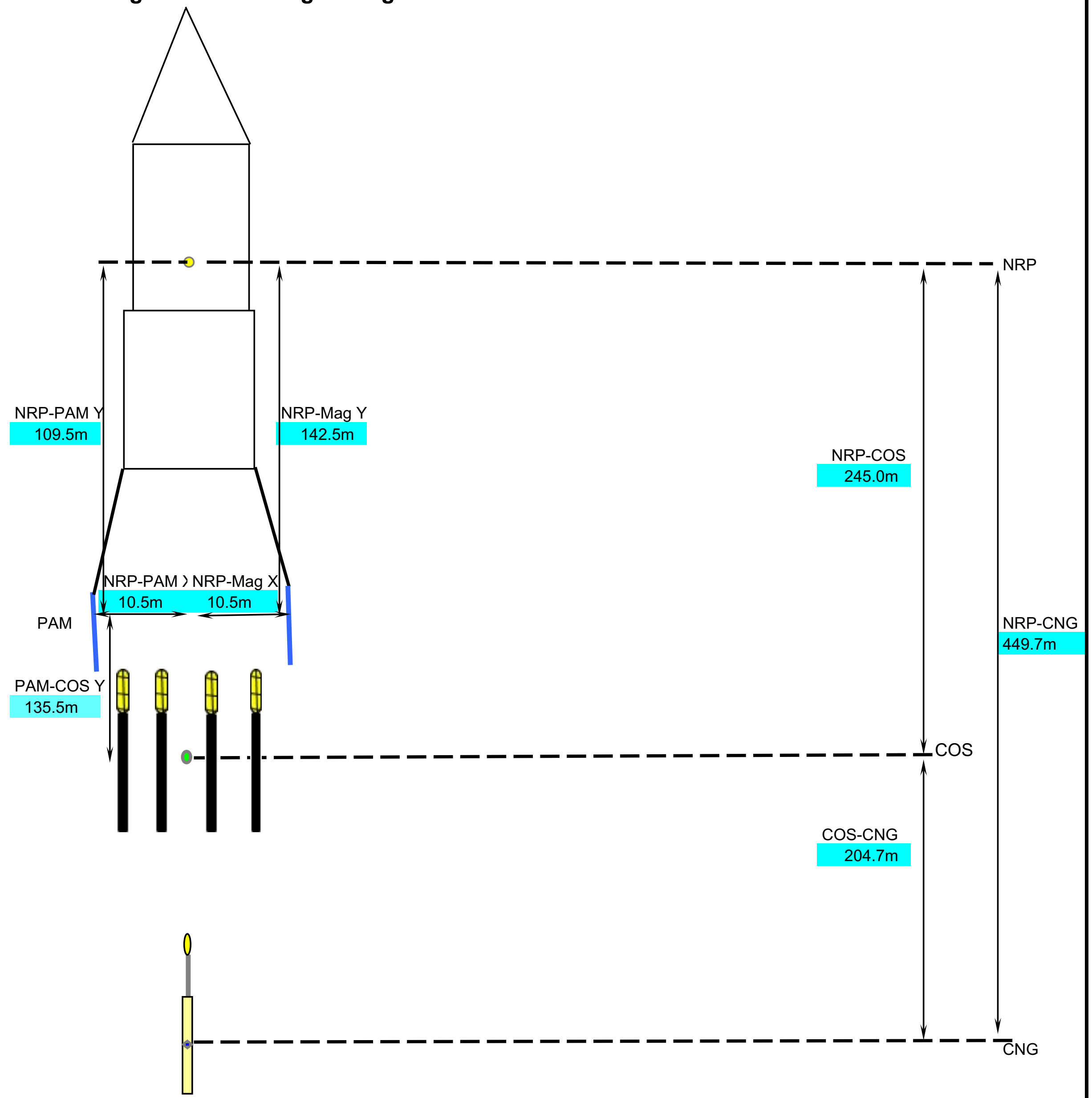
All measurements in meters

Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Towing Configuration

	# Streamers	Length	Channels	Spacing
SEAL	1	15000	1200	12.5m

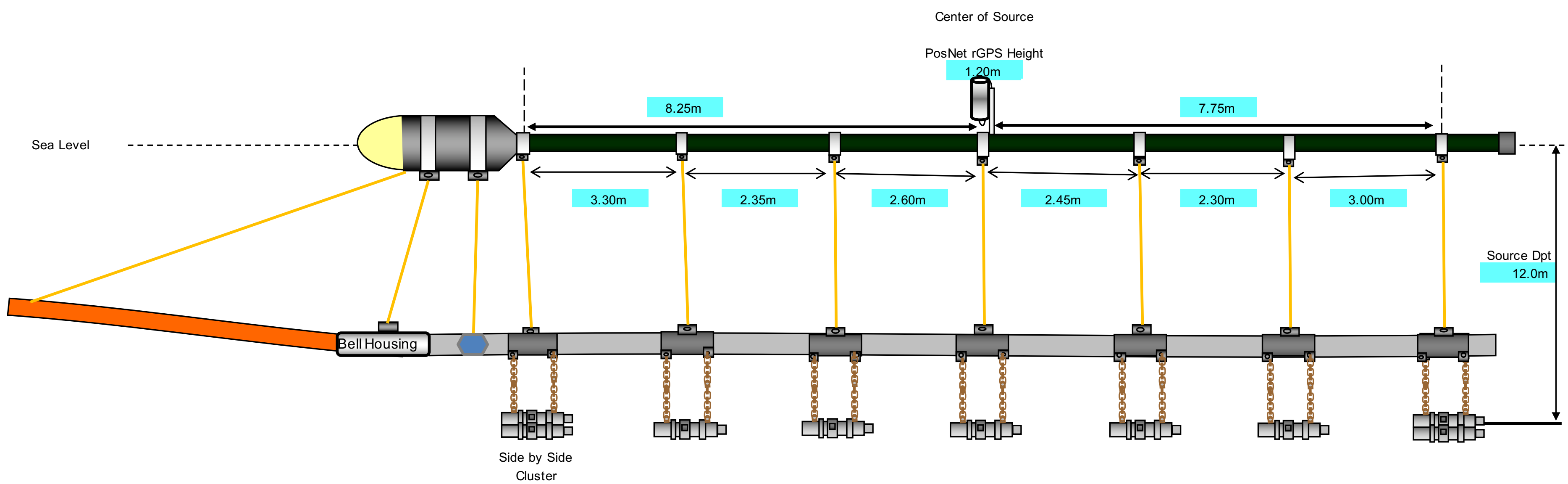
# Gun Strings Used	4	Vol (in^3)	6600



NOT to Scale

Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Gun Array Offsets



Center of Source

Air Manifold

Gun volumes by number		
Gun	Volume	Status
Gun 1	360 cu. in.	Primary
Gun 2	360 cu. in.	Primary
Gun 3	40 cu. in.	Primary & Mitigation
Gun 4	180 cu. in.	Primary
Gun 5	90 cu. in.	Primary
Gun 6	120 cu. in.	Primary
Gun 7	60 cu. in.	Primary
Gun 8	220 cu. in.	Primary
Gun 9	220 cu. in.	Primary

Array total volume (without spares) is 6600 cu. in. Total volume/string (without spare) 1650 cu. in.
Guns (1 & 2) & (8 & 9) in a horizontal cluster.
Gun clusters have 0.75m between guns and hang 0.95m from center of hanger
Horizontal Clusters are 1m from gun port to gun port
Single guns hang from hanger 1.15m
All gun volumes, numbering, locations, and offsets were inspected and verified by Chief Source Mechanic.

All measurements in meters
NOTE: drawing not to scale

Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Gun Configuration

Center of Source

Gun Clusters

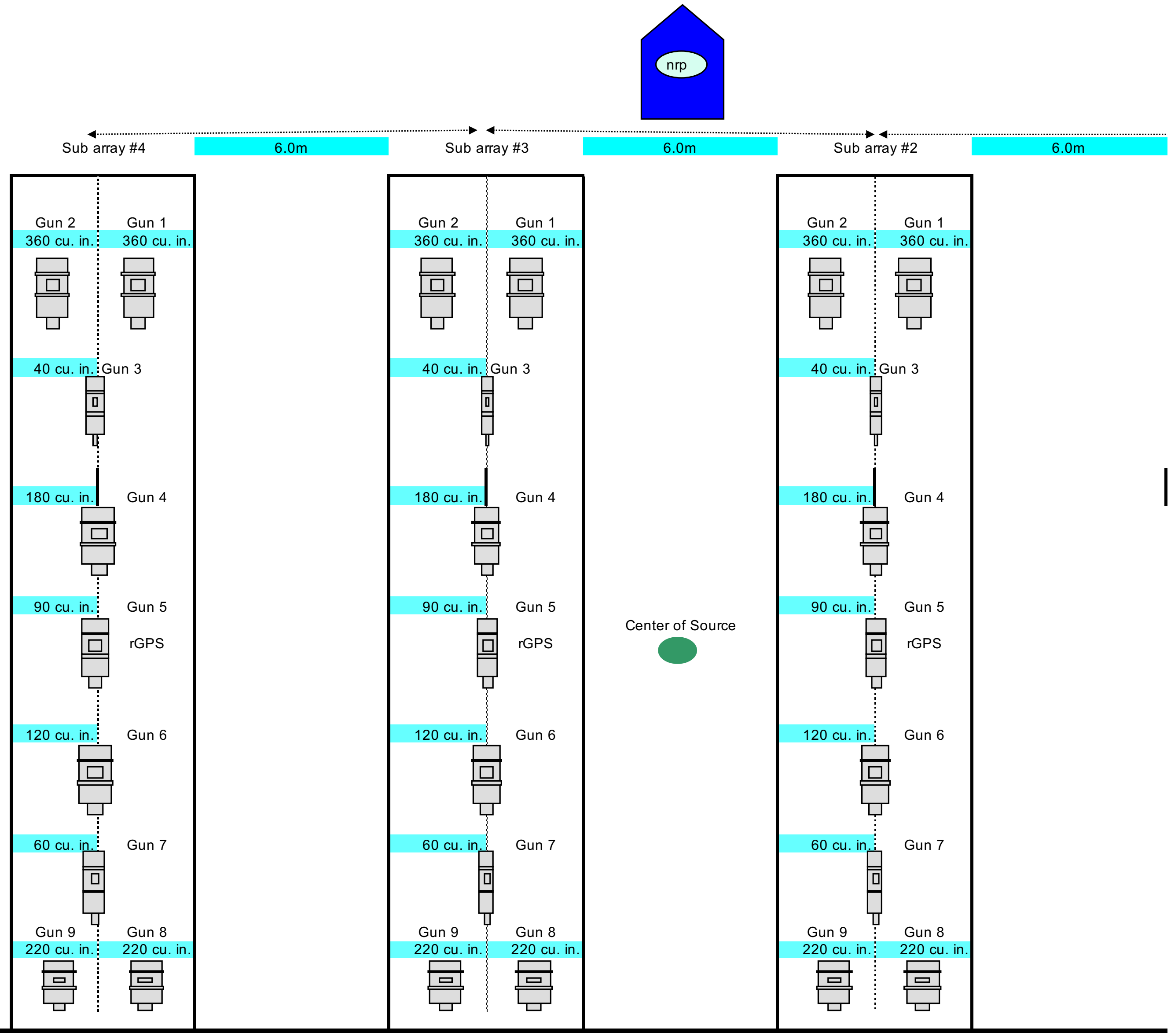
Guns 1 & 2 horizontal array

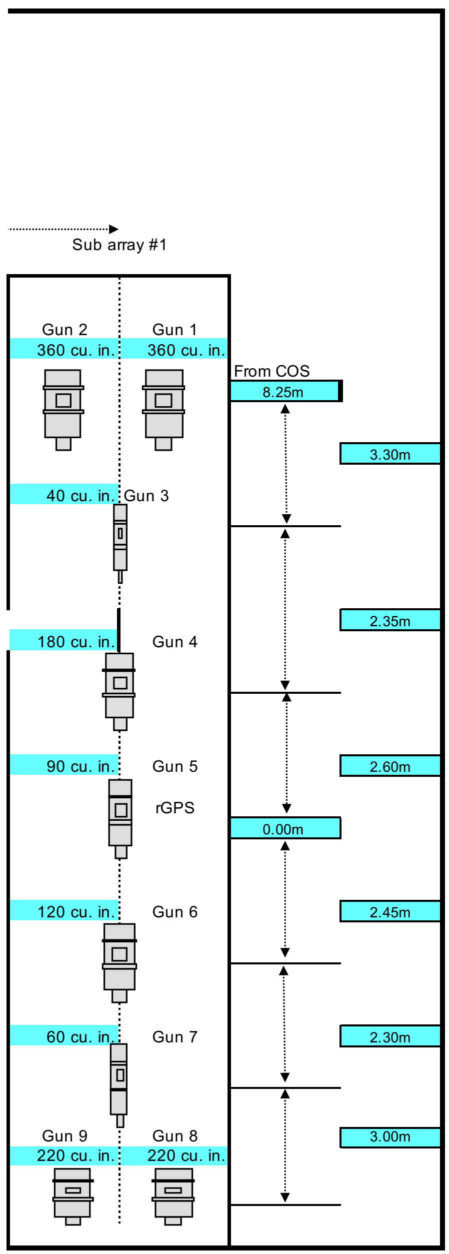
Guns 9 & 10 horizontal array

Gun Offsets relative to Center of String

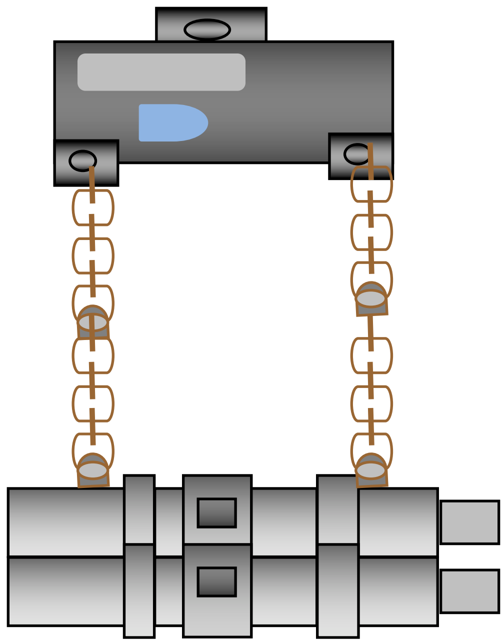
	X	Y
Gun 1	0.50m	8.31m
Gun 2	-0.50m	8.31m
Gun 3	0.00m	5.03m
Gun 4	0.00m	2.60m
Gun 5	0.00m	0.00m
Gun 6	0.00m	-2.74m
Gun 7	0.00m	-5.09m
Gun 8	0.50m	-8.21m
Gun 9	-0.50m	-8.21m

All measurements in meters




Sub array #1
Gun 2
360 cu. in.
Gun 1
360 cu. in.
From COS
8.25m
3.30m
40 cu. in.
Gun 3
2.35m
180 cu. in.
Gun 4
90 cu. in.
Gun 5
2.60m
rGPS
0.00m
120 cu. in.
Gun 6
2.45m
60 cu. in.
Gun 7
2.30m
Gun 9
220 cu. in.
Gun 8
220 cu. in.
3.00m

Gun Plate



Center of ports between guns 1 and 2 is the reference point

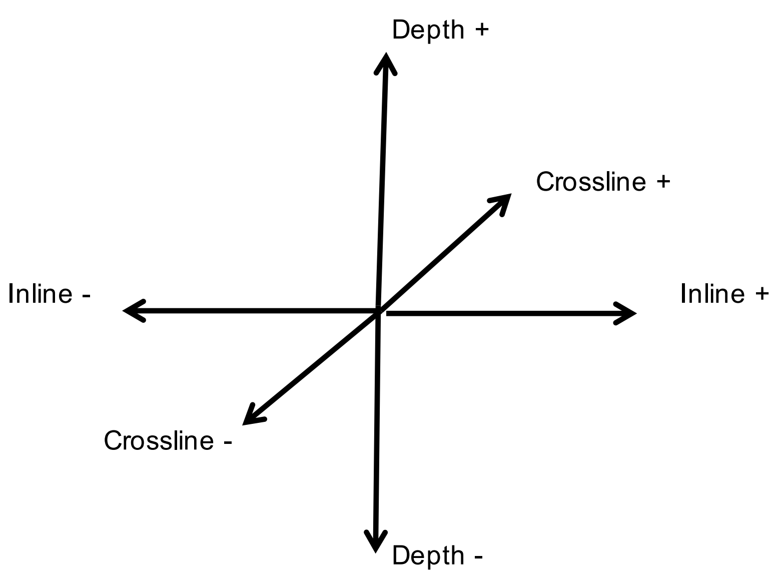


Plate
1
2
3
4
5
6
7

Plate
1
2
3
4
5
6
7

Plate
1
2
3
4
5
6
7

Plate
1
2
3
4
5

6
7

Distances in Meters

Hydrophone Offsets

Gun String 1			
Phone	Inline	Crossline	Depth
	N/A	N/A	N/A
1	3.18	0.00	0.95
2	5.34	0.00	0.91
	N/A	N/A	N/A
	N/A	N/A	N/A
3	10.48	0.00	0.90
	N/A	N/A	N/A

Gun String 2			
Phone	Inline	Crossline	Depth
	N/A	N/A	N/A
1	3.05	0.00	0.93
2	5.48	0.00	0.96
	N/A	N/A	N/A
	N/A	N/A	N/A
3	10.50	0.00	0.92
	N/A	N/A	N/A

Gun String 3			
Phone	Inline	Crossline	Depth
	N/A	N/A	N/A
1	3.18	0.00	0.96
2	5.22	0.00	0.97
	N/A	N/A	N/A
	N/A	N/A	N/A
3	10.61	0.00	0.90
	N/A	N/A	N/A

Gun String 4			
Phone	Inline	Crossline	Depth
	N/A	N/A	N/A
1	3.50	0.00	0.96
2	5.53	0.00	0.97
	N/A	N/A	N/A
	N/A	N/A	N/A

Depth Transducer (

Gun String 1		
Plate	DT	Inline
1	1	0.00
2		N/A
3	2	5.68
4		N/A
5		N/A
6		N/A
7	3	16.28

Gun String 2		
Plate	DT	Inline
1	1	0.00
2		N/A
3		N/A
4	2	8.00
5		N/A
6		N/A
7	3	16.08

Gun String 3		
Plate	DT	Inline
1	1	0.00
2		N/A
3	2	5.49
4		N/A
5		N/A
6		N/A
7	3	15.58

Gun String 4		
Plate	DT	Inline
1	1	0.00
2		N/A
3	2	5.59
4		N/A
5		N/A

3	10.59	0.00	0.90
	N/A	N/A	N/A

6		N/A
7	3	15.58

Offsets

1

Crossline	Depth
N/A	1.20
N/A	N/A
N/A	1.08
N/A	N/A
N/A	N/A
N/A	N/A
N/A	1.23

2

Crossline	Depth
N/A	1.23
N/A	N/A
N/A	N/A
N/A	1.20
N/A	N/A
N/A	N/A
N/A	1.30

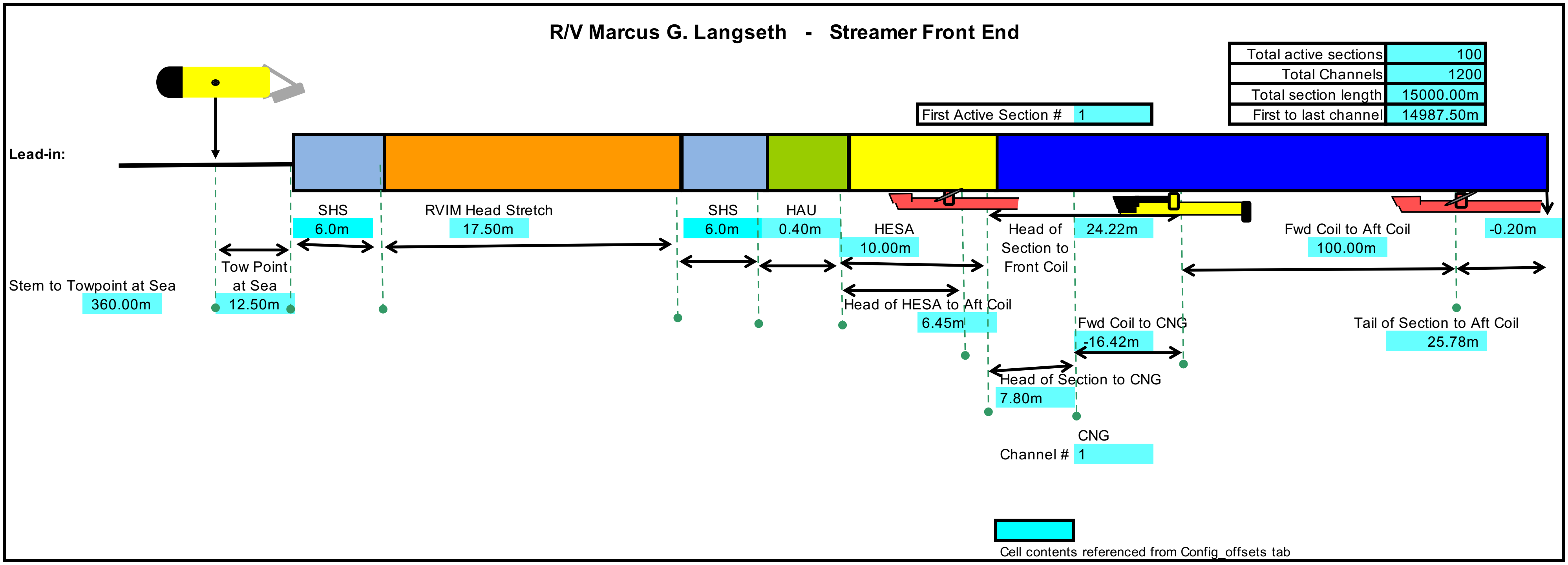
3

Crossline	Depth
N/A	1.23
N/A	N/A
N/A	1.10
N/A	N/A
N/A	N/A
N/A	N/A
N/A	2.37

4

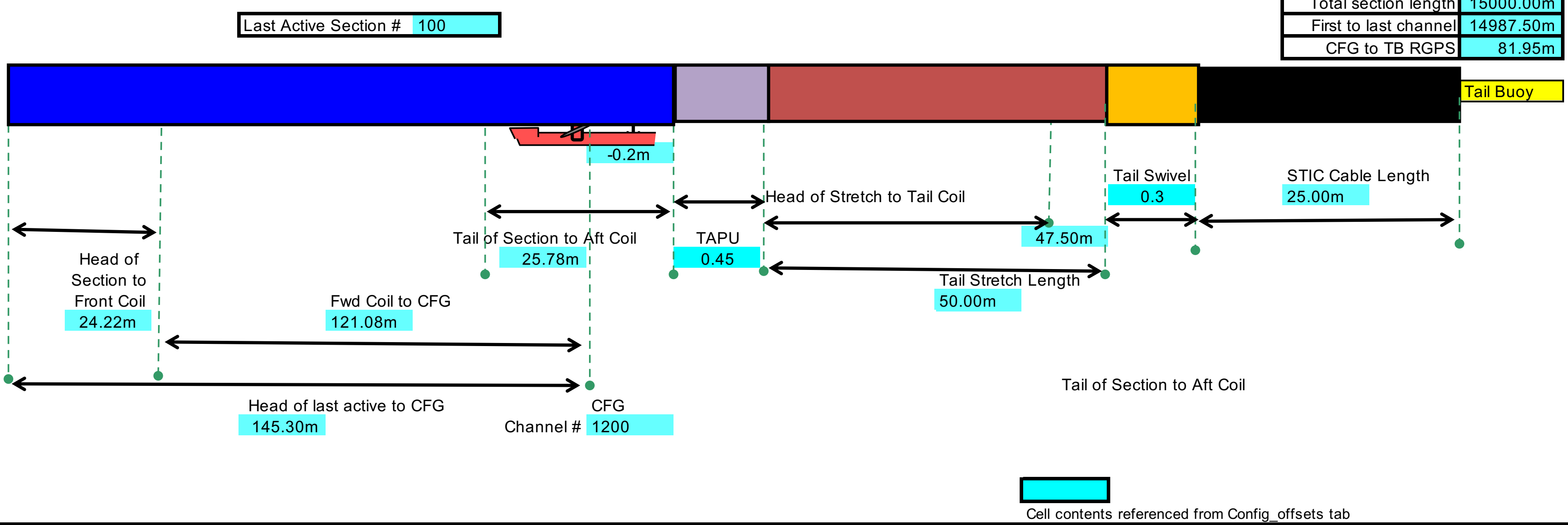
Crossline	Depth
N/A	1.23
N/A	N/A
N/A	1.10
N/A	N/A
N/A	N/A

N/A	N/A
N/A	2.23


R/V Marcus G. Langseth - Streamer Front End
Total active sections 100
Total Channels 1200
Total section length 15000.00m
First to last channel 14987.50m
First Active Section # 1
Lead-in:
SHS
6.0m
RVIM Head Stretch
17.50m
SHS
6.0m
HAU
0.40m
HESA
10.00m
Head of Section to Front Coil
24.22m
Fwd Coil to Aft Coil
100.00m
-0.20m
Stern to Towpoint at Sea
360.00m
Tow Point at Sea
12.50m
Head of HESA to Aft Coil
6.45m
Fwd Coil to CNG
-16.42m
Tail of Section to Aft Coil
25.78m
Head of Section to CNG
7.80m
CNG
Channel # 1
Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Streamer Tail End

Total active sections	100
Total Channels	1200
Total section length	15000.00m
First to last channel	14987.50m
CFG to TB RGPS	81.95m



R/V Marcus G. Langseth - Streamer Complete

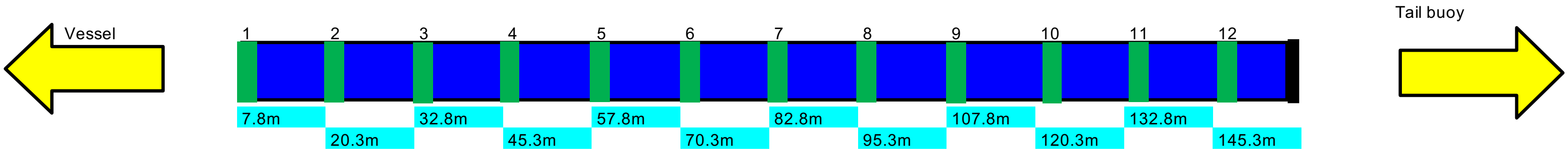
Total active sections	100
Total Channels	1200
Total section length	15000.00m
First to last channel	14987.50m

Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Hydrophone Offsets

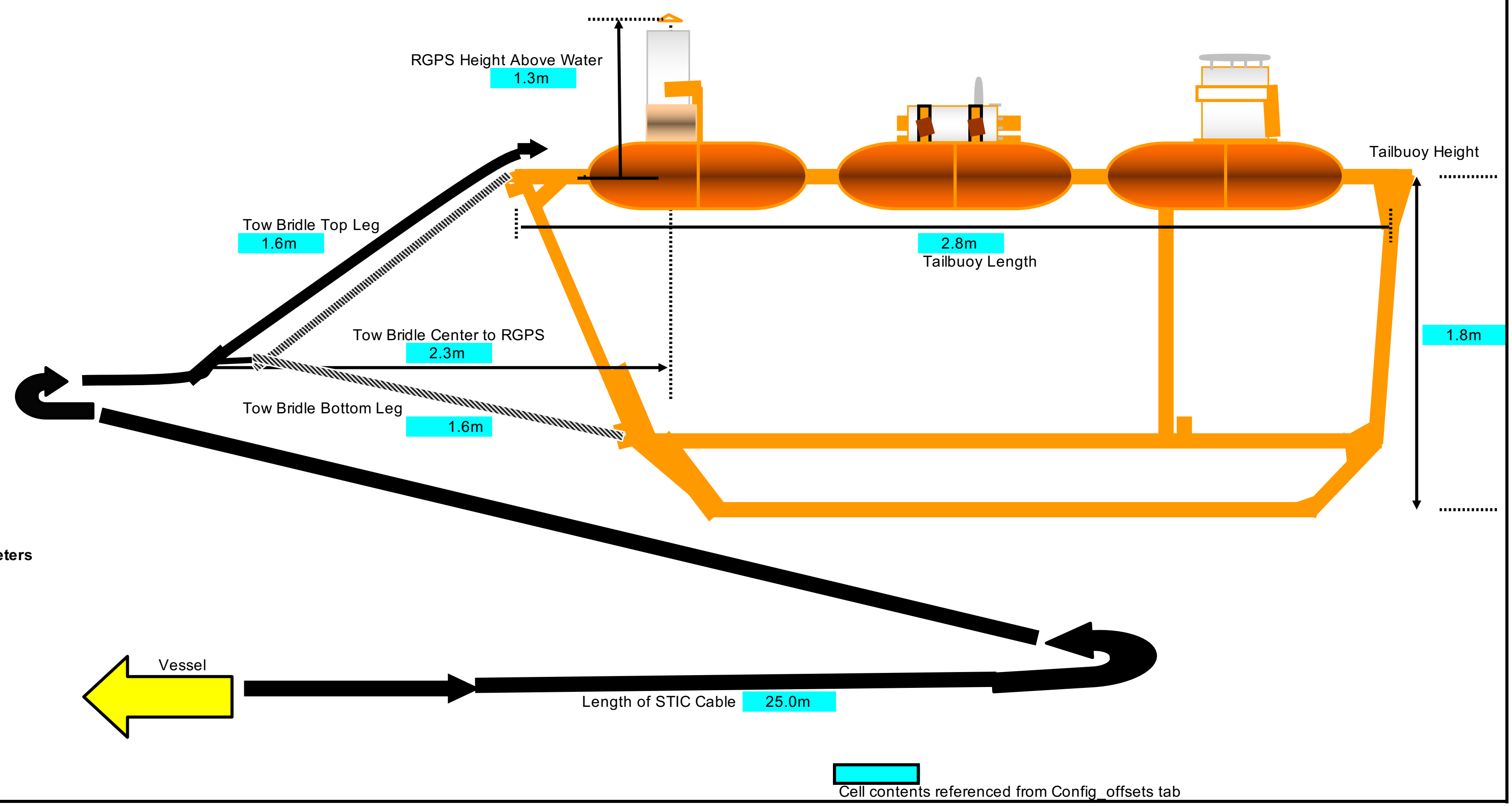
Sercel 150meter SSAS

Number of SSAS Sections	100
Channels per active section	12
Total channels	1200



Cell contents referenced from Config_offsets tab

R/V Marcus G. Langseth - Tailbuoy



All measurements in meters

Job Specific	
NRP to COS Y	245
NRP to COS X	0
Source Depth	12
Streamer Depth	12
# streamer sections	100
# channels	1200
CNG Channel #	1
CFG Channel #	1200
#MCS Streamers	1
lead-in: stern to tow point at sea	360
MCS Streamer Sep.	0
Gun volume total	6600
Volume per string	1650
# of guns used	36
# Gun Strings	4
gun string separation	6
PAM Y from stern	80
PAM X - (outside of stern rail)	3
Stern to MAG Y	113
Stern to MAG X - (outside of stern rail)	3

Derived Offsets (formula)	
NRP to CMP	347.35
COS-CNG	204.7
CNG-CFG	-14987.5
NRP-Mag Y	142.5
NRP-Mag X	10.5
NRP to tail buoy RGPS	15494.9
Total Length of Streamer sections	15000
PAM-COS Y	135.5
PAM-COS X	10.5
NRP-PAM Y	109.5
NRP-PAM X	10.5
NRP-CNG	449.7

Derived Offsets (formula)	
Towing Offsets Tab	
NRP-COS	245
NRP-CNG	449.7
NRP-CMP	347.35
COS-CNG	204.7
CNG Channel #	1
NRP-Stern	29.5
Distance from Head of first section to CNG	7.8
Source Depth	12
Streamer Depth	12
Front End Length	39.9

Derived Offsets (formula)	
Towing Configuration TAB	
NRP-COS	245
NRP-CNG	449.7
COS-CNG	204.7
NRP-Pcable CNG	0
COS-Pcable CNG	0
P-Cable Streamer Sep	0
NRP-PAM Y	109.5
NRP-PAM X	10.5
PAM-COS Y	135.5
PAM-COS X	10.5
# Gun Strings	4
gun volume	6600
Gun separation	6
# 2D Streamers	1
2D Streamer Ch Spacing	12.5
Number 2D Channels	1200
2D Streamer Length	15000
2D Streamer Sep	0
NRP-MAG X	10.5
NRP-MAG Y	142.5

Derived Offsets	
Acoustic Overhead TAB	
G1T1	-9.15
G2T1	-9.15
G3T1	-9.15
G4T1	-9.15
S1T1	-16.95
S1T2	-167.28
S1T3	-12322.92
S1T4	-12472.6
S1T5	1
S1T6	0
S1T7	0
S2T1	0
S2T2	0
S2T3	0
S2T4	0
S2T5	0
S2T6	0
S2T7	0
S3T1	0
S3T2	0
S3T3	0
S3T4	0
S3T5	0
S3T6	0
S3T7	0
S4T1	0
S4T2	0
S4T3	0
S4T4	0
S4T5	0
S4T6	0
S4T7	0
Front to TB	15075
S1T1-S1T2	150.33
S1T3-S1T4	149.68
S1T4-S1T5	100.777

Derived Offsets (formula)	
Gun array offsets	
Bracket distance 1-2	0
Bracket distance 2-3	3.3
Bracket distance 3-4	2.35
Bracket distance 4-5	2.6
Bracket distance 5-6	2.45
Bracket distance 6-7	2.3
Bracket distance 7-8	3
SourceGPS-COS Y	0
COS - Acoustic Y	-5.47
rGPS height above water	1.2
G1 Volume	360
G2 Volume	360
G3 Volume	40
G4 Volume	180
G5 Volume	180
G6 Volume	90
G7 Volume	120
G8 Volume	60
G9 Volume	220
G10 Volume	220
G-Depth 1	0.95
G-Depth 2	0.95
G-Depth 3	1.15
G-Depth 4	0.95
G-Depth 5	0.75
G-Depth 6	1.15
G-Depth 7	1.15
G-Depth 8	1.15
G-Depth 9	0.95
G-Depth 10	0.95
G10 to Acx Z	1.4
G10 to Acx X	-0.5
Surface to Acx	13.4
Fwd bracket to COS	8.25
Aft bracket to COS	7.75

Derived Offsets	
Streamer Front End	
Stern-towpoint at sea	360
towpoint at sea to end of lead-in	12.5
SHS Length	6
rvim length	17.5
HAU/STU length	0.4
HESA Lgth	10
Fwd Coil to Aft Coil	100
Head to First RX	7.8
Fwd Coil to CNG	-16.423
Head to Fwd Coil	24.223
Tail to Aft Coil	25.777
CNG Channel #	1
Center of streamer to Acx transducer	-0.2
First Section #	1
# channels	1200
section length	15000
# sections	100
channel spacing	12.5
First to last	14987.5
HESA Head to aft coil	6.45

Derived Offsets	
Streamer Tail End	
Head to Fwd Coil	24.223
Tail to Aft Coil	25.777
Head to CFG	145.3
Coil to Coil	100
TAPU Lngth	0.45
Tail Stretch Length	50
Tswivel Lngth	0.3
STIC Length	25
Last active	100
# channels	1200
# sections	100
total section length	15000
First to last	14987.5
Stretch Coil	
Center of streamer to Acx transducer	-0.2
channel spacing	12.5
CFG #	1200
Fwd coil to CFG	121.077
CFG to TBRGPS	81.95
Stretch head to fwd coil	2.5
Stretch head to aft coil	47.5

Derived Offsets	
Streamer complete	
#Sections	100
# Channels	1200
First to last	14987.5
Total section length	15000

Derived Offsets	
Hydrophone Offsets	
Channel 1	7.825
2	20.325
3	32.825
4	45.325
5	57.825
6	70.325
7	82.825
8	95.325
9	107.825
10	120.325
11	132.825
12	145.325
# channels	12
# Active's	100
Total Channels	1200

Derived Offsets	
Tailbuoy offsets	
RGPS height above water	1.3
TB length	2.8
TB height	1.83
RGPS-ACX	1
Bridle-RGPS	2.25
Top Leg	1.55
Bottom Leg	1.6
STIC	25
ACX below water line	1.3

Guns						
Source GPS-COS Y	0				G1 X	0.5
					G1 Y	8.31
Bracket distance 2-3	3.3				G2 X	-0.5
Bracket distance 3-4	2.35				G2 Y	8.31
Bracket distance 4-5	2.6				G3 X	0
Bracket distance 5-6	2.45				G3 Y	5.03
Bracket distance 6-7	2.3				G4 X	0
Bracket distance 7-8	3				G4 Y	2.6
COS - Acoustic Y	-5.47		G10 to Acx Z	-0.5	G5 X	0
rGPS height above water line	1.2		G10 to Acx Y	1.4	G5 Y	2.6
G1 Volume	360		G-Depth 1	0.95	G6 X	0
G2 Volume	360		G-Depth 2	0.95	G6 Y	0
G3 Volume	40		G-Depth 3	1.15	G7 X	0
G4 Volume	180		G-Depth 4	0.95	G7 Y	-2.74
G5 Volume	180		G-Depth 5	0.75	G8 X	0
G6 Volume	90		G-Depth 6	1.15	G8 Y	-5.09
G7 Volume	120		G-Depth 7	1.15	G9 X	0.5
G8 Volume	60		G-Depth 8	1.15	G9 Y	-8.21
G9 Volume	220		G-Depth 9	0.95	G10 X	-0.5
G10 Volume	220		G-Depth 10	0.95	G10 Y	-8.21

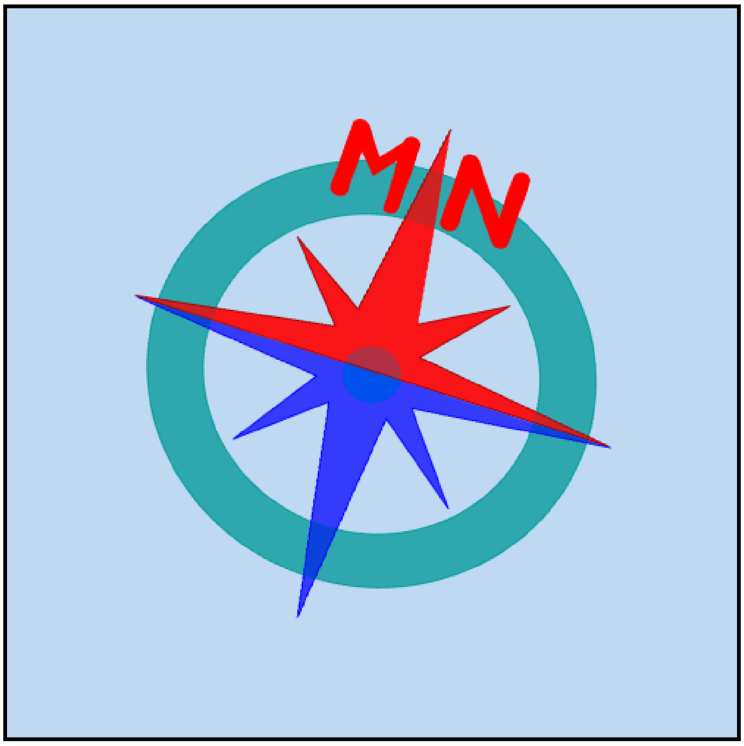
Fixed Positions Streamer	
NRP to Stern	29.5
tow point at sea to end of lead-in	12.5
STU/module length	0.4
Coil to coil	100
head of section to coil	24.223
tail of section to coil	25.777
channel spacing	12.5
NRP to Port/STBD Rail	7.5
Head to First RX	7.8
Head to Last RX	145.3
Channels per section	12
Center of section to Acx transducer	-0.2
First Section Number	1
HAU/HAPU Length	0.4
SHS Length	6
RVIM length	17.5
HESA Length	10
Active Section Length (SSAS)	150
TES tail stretch length	50
STIC	25
TES Fwd Coil	2.5
TES Aft Coil	47.5
HESA Aft Coil	6.45

Acoustics referenced to CNG or COS	
G1T1	-9.15
G2T1	-9.15
G3T1	-9.15
G4T1	-9.15
S1T1	-16.95
S1T2	-167.28
S1T3	-12322.92
S1T4	-12472.6
S1T5	1
S1T6	0
S1T7	0
S2T1	0
S2T2	0
S2T3	0
S2T4	0
S2T5	0
S2T6	0
S2T7	0
S3T1	0
S3T2	0
S3T3	0
S3T4	0
S3T5	0
S3T6	0
S3T7	0
S4T1	0
S4T2	0
S4T3	0
S4T4	0
S4T5	0
S4T6	0
S4T7	0

Tailbuoy offsets	
RGPS height above water	1.3
TB length	2.8
TB height	1.83
RGPS-ACX	1
Bridle-RGPS	2.25
Top Leg	1.55
Bottom Leg	1.6
STIC	25
ACX below water line	1.3

Declination

Date	2021-07-19
Latitude	54° 8' 53.66" N
Longitude	133° 59' 19.45" W
Elevation	0.0 km GPS
Model Used	IGRF2020
Declination	17° 47' E changing by 0° 8' W per year



Compass shows the magnetic bearing of the magnetic north (MN)

Magnetic declination is the angle between true north and the horizontal trace of the local magnetic field. In general, the present day field models such as the IGRF and World Magnetic Model (WMM) are accurate to within 30 minutes of arc for the declination. However, local anomalies exceeding 10 degrees, although rare, do exist.

Document created: 2021-07-09 02:41 UTC

Help: How to interpret results Questions: geomag.models@noaa.gov

AML Oceanographic - Micro-X SV-Xchange Sensor Data

The AML SV-Xchange Sound Velocity probe outputs the directly measured time-of-flight of an acoustic ping from a single sensor
The SV-Xchange sensor is output in the following serial sentence format:

FILE NAME: ***MGL-svuss01.y****d****

svuss01 2015:233:00:00:47.0489 1542.106
svuss01 yyyy:ddd:hh:mm:ss.ssss xxxx.xxx

Item	Definition	Units
xxxx.xx	Sound Velocity (Directly measured in meters per second)	m/s

NOTE:
1) Powering on the sensor outputs the Sensor information and Calibration Dates

Example:

```
Micro.X Sound Velocity Version 1.06 SN:010234
AML Oceanographic Ltd.
SV.Xchange Sensor SN:204749, Calibrated 06/30/15
```

POS/MV Position and Orientation System for Marine Vessels

POS/MV outputs data using the NMEA 0183 format at rates of up to fifty sentences per second. The following seven different sentence formats are available.

- 1. $INGGA-Global System Position Fix Data
- 2. $INHDT-Heading - True data
- 3. $INVTG-Course over ground and Ground speed data
- 4. $INGST-GPS pseudorange noise statistics
- 6. $PRDID-Attitude data
- 7. $INZDA-Time and date

$INGGA, hhmmss.sss, llll.lllll, a, yyyyy.yyyyy, b, t, nn, v.v, x.x, M,,,c.c,rrrr*hh

$INGGA-Global System Position Fix Data

Item	Definition	Value	Units
$INGGA	Header	$INGGA	
hhmmss.sss	UTC time of position	n/a	Hours/Minutes/Seconds.decimal. Two fixed digits of hours. Two fixed digits of minutes. Two fixed digits of seconds. Three digits for decimal fractions of a second.
llll.lllll	Latitude	-90 to +90	DegreeslMinutes.decimal. Two fixed digits of degrees Two fixed digits of minutes Five digits for decimal minutes.
a	N (north) or S (south)	N or S	
yyyyy.yyyyy	Longitude	-180 to +180	Degrees/Minutes.decimal. Three fixed digits of degrees. Two fixed digits of minutes. Five digits for decimal minutes.
b	E (east) or W (west)	E or W	
		0 = Fix not available or	

t	GPS Quality Indicator	invalid 1 = CIA standard GPS; fix valid. 2 = DGS mode; fix valid. 3 = PPP mode; fix valid. 4 = RTK fixed 5 = RTK float 6 = free inertial	
nn	Number of satellites used in fix	0 to 32	
v.v	Horizontal dilution of precision		
x.x	Altitude of the IMU above or below the mean sea level. A negative value indicates below sea level.	n/a	Metres
M	Units of measure = metres	M	
Null	Null		
Null	Null		
c.c	Age of differential corrections in records since last RTCM-104 message.	0 to 99.9	Seconds
rrr	DGPS reference station identity	0000 to 1023	
*hh	Checksum	00 - FF	
/CR/LF	Carriage return and line feed	/CR/LF	

Note that, in the case of the HDOP, IMU altitude and age of differential connections, POS/MV adds leading digits as required (i.e. if the value exceeds 9.9). Also, note that commas separate all items, including null fields. The information is valid at the location of the vessel frame.

$INHDT, x.x, T*hh

$INHDT-Heading - True data

Item	Definition	Value	Units
$INHDT	Header	$INHDT	
x.x	True vessel heading in the vessel frame	o to 359.99	degrees
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

$INVTG, x.x, T,, M, n.n, N, k.k, K*hh

$INVTG-Course over ground and Ground speed data

Item	Definition	Value	Units
%INVTG	Header	$INVTG	
x.x	True vessel track in the vessel frame	0 to 359.99	degrees
T	True	T	
null	Not supported	null	
M		M	
n.n	Speed in the vessel frame	n/a	Knots
N	Knots	N	
k.k	Kilometres	K	
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

Note that, in the case of the track and the speed fields, POS/MV adds the leading digits as required (i.e. if the value exceeds 9.9). ALso, note that commas separate all items in the including null fields.

$INGST, hhmmss,sss,,smjr.smjr,smnr.smnr, o.o, l.l, y.y, a.a *hh

$INGST-GPS pseudorange noise statistics

Item	Definition	Value	Units
$INGST	Header	$INGST	
hhmmss.sss	UTC time of position	n/a	Hours/Minutes/Seconds.decimal. 2 fixed digits of hours. 2 fixed digits of minutes. 2 fixed digits of seconds. Three digits for decimal fractions of a second.
null	Not supported	null	
smjr.smjr	Standard Deviation of semi-major axis of error ellipse	n/a	Metres
smnr.smnr	Standard deviation of semi-minor axis of error ellipse	n/a	Metres
o.o	Orientaion of semi-major axis ellipse	0 to 359.9	Degrees from true north

l.l	Standard deviation of latitude	n/a	Metres
y.y	Standard deviation of longitude	n/a	Metres
a.a	Standard deviation of Altitude	n/a	Metres
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

Note that, in the case of all fields POS/MV adds leading digits as required (i.e. if the value exceeds 9.9). Also, note that commas separate all items, including null fields. The information is valid at the location of the vessel frame.

Note that commas separate all items

Two attitude data strings are available. The strings are identical except for the definition of roll and pitch angles. One string uses Tate-Bryant angles and the

other uses TSS angles. Use the POS/MV Controller program to set the required angle convention.

$PRDID, PPP.PP, RRR.RR, xxx.xx*hh

$PRDID-Attitude data

Item	Definition	Value	Units
$PRDID	Header	$PRDID	
PPP.PP	Pitch	-90.00 to +90.00	Degrees
RRR.RR	Roll	-90.00 to +90.00	Degrees
xxx.xx	Sensor heading	0 to 359.99	Degrees
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

Note that commas separate all items

Two attitude data strings are available. The strings are identical except for the definition of roll and pitch angles. One string uses Tate-Bryant angles and the

other uses TSS angles. Use the POS/MV Controller program to set the required angle convention.

$INZDA, hhmmss.ss, DD, MM, YYYY,, *hh

$INZDA-Time and date

Item	Definition	Value	Units
$INZDA	Header	$INZDA	
			Hours/Minutes/Seconds.decimal.

hhmmss.sss	UTC time	n/a	2 fixed digits of hours 2 fixed digits of minutes 2 fixed digits of seconds Three digits for decimal fractions of a second
DD	Day of month	01 to 31	
MM	Month of year	01 to 12	
YYYY	Year		
Null	Null		
Null	Null		
*hh	Checksum	n/a	/CR/LF

BGM-3 Gravimeter Data

The BGM-3 Gravimeter outputs the gravitational force in the following serial sentence format:

FILE NAME: ***MGL-vc01.y****d*****

vc01 2015:234:00:00:53.7862 04:024326 00
vc01 yyyy:ddd:hh:mm:ss.ssss xx:yyyyyy ff

Item	Definition	Units
xx	Output Frequency	Hz
yyyyyy	Raw Counts	n/a
ff	Sensor Status (00 – Null) See manual for other Error Codes.	n/A

CNAV GPS receiver data

CNAV outputs data in NMEA 0183 compatible format. Currently* the following sentence types are enabled:

- $GPVTG-GPS Velocity, Track made good and Ground speed data (computed by the CNAV GPS receiver).
- $GPGGA-Gobal Positioning System Fix data (computed by the CNAV GPS receiver).

  *Note: there are other sentence types available from CNAV. Please consult the software manual for more options.

$GPVTG, xxx.x, T,, M, m.mm, N, n.nn, K*hh

$GPVTG Sentence Fields

Item	Definition	Units
xxx.x	Course over ground (COG)	Degrees from True North
T	Indicates course relative to True North	n/a
M	COG	Degrees from Magnetic North
m.mm	Speed over ground (SOG)	Nautical miles per hour (knots)
N	Indicates that the speed over ground is in knots	n/a
n.nn	SOG	km/h
K	Indicates that the SOG is in km/h	n/a /td>
*hh	Checksum (hexadecimal representation)	n/a

$GPGGA,hhmmss.ss, ddmm.mmmmm, a, ddmm.mmmmm, a, x, xx, x.x, xx.xx, M, xx.xx, M, x.x, xyy*hh

$GPGGA Sentence Fields

Item	Definition	Units
hhmms.ss	UTC time of position	Hours/Minutes/Seconds.decimal.
ddmm.mmmmm	Latitude	Degrees/Minutes.decimal.
a	Direction of Latitude N = North S = South	n/a
ddmm.mmmmm	Longitude	Degrees/Minutes.decimal
a	Direction of Longitude E = East	n/a

	W = West	
x	GPS Quality indicator 0 = fix not valid 1 = GPS Autonomous fix 2 = GcGPS Corrected Fix	n/a
xx	Number of GPS satellites used in solution fix	n/a
x.x	Horizontal Dilution of Precision (HDOP)	n/a
xx.xx	C-NAV GPS receiver antenna altitude reference to Mean Sea Level (MSL)	n/a
M	Altitude units--M indicates meters	n/a
xx.xx	WGS-84 Geoidal separation distance from MSL based on the NIMA/NASA EGM96 15-minute (Earth Gravity Model)	Meters
M	Geosoidal separation units--M indicates meters	n/a
x.x	Age of GcGPS corrections used in solution fix	n/a
xyy	C-NAV GPS receiver reference identification	x is downlink satellite communication beam in use yy is the GPS correction signal mode/type being used
*hh	Checksum (hexadecimal representation) followed by CRLF terminator pair	n/a

CNAV 3050 GPS receiver data

CNAV 3050 outputs data in NMEA 0183 compatible format. Currently* the following sentence types are enabled:

- $GPVTG-GPS Velocity, Track made good and Ground speed data (computed by the CNAV GPS receiver).
- $GPGGA-Gobal Positioning System Fix data (computed by the CNAV GPS receiver).

  *Note: there are other sentence types available from CNAV. Please consult the software manual for more options.

$GPVTG, xxx.x, T,, M, m.mm, N, n.nn, K*hh

$GPVTG Sentence Fields

Item	Definition	Units
xxx.x	Course over ground (COG)	Degrees from True North
T	Indicates course relative to True North	n/a
M	COG	Degrees from Magnetic North
m.mm	Speed over ground (SOG)	Nautical miles per hour (knots)
N	Indicates that the speed over ground is in knots	n/a
n.nn	SOG	km/h
K	Indicates that the SOG is in km/h	n/a /td>
*hh	Checksum (hexadecimal representation)	n/a

$GPGGA,hhmmss.ss, ddmm.mmmmm, a, ddmm.mmmmm, a, x, xx, x.x, xx.xx, M, xx.xx, M, x.x, xyy*hh

$GPGGA Sentence Fields

Item	Definition	Units
hhmms.ss	UTC time of position	Hours/Minutes/Seconds.decimal.
ddmm.mmmmm	Latitude	Degrees/Minutes.decimal.
a	Direction of Latitude N = North S = South	n/a
ddmm.mmmmm	Longitude	Degrees/Minutes.decimal
a	Direction of Longitude E = East	n/a

	W = West	
x	GPS Quality indicator 0 = fix not valid 1 = GPS Autonomous fix 2 = GcGPS Corrected Fix	n/a
xx	Number of GPS satellites used in solution fix	n/a
x.x	Horizontal Dilution of Precision (HDOP)	n/a
xx.xx	C-NAV GPS receiver antenna altitude reference to Mean Sea Level (MSL)	n/a
M	Altitude units--M indicates meters	n/a
xx.xx	WGS-84 Geoidal separation distance from MSL based on the NIMA/NASA EGM96 15-minute (Earth Gravity Model)	Meters
M	Geosoidal separation units--M indicates meters	n/a
x.x	Age of GcGPS corrections used in solution fix	n/a
xyy	C-NAV GPS receiver reference identification	x is downlink satellite communication beam in use yy is the GPS correction signal mode/type being used
*hh	Checksum (hexadecimal representation) followed by CRLF terminator pair	n/a

Furuno DS-50 Doppler Speedlog Data

The FURUNO DS-50 is a highly advanced, precision Doppler Speed Log incorporating FURUNO's advanced computer technology. The DS-50 provides accurate display of speed over a wide range from dead slow to 40 kt. Speeds are detected relative to ground or water both fore/aft and athwart ship.

The speed logger data from the Furuno DS-50 is output in the following sentence formats:

FILE NAME: ***MGL-slog01.y****d****

$VDVHW,90.0,T,95.0,M,11.07,N,20.50,K*47
$VDVHW,x.x,T,y.y,M,n.n,N,s.s,K*hh

Item	Definition	Units
x.x	Vessel Heading	Degrees True
T	Units	n/a
y.y	Vessel Heading	Degree Magnetic
M	Units	n/a
n.n	Speed of vessel relative to water	Knots
N	Units	n/a
s.s	Speed of vessel relative to water	Km/hour
K	Units	n/a
*hh	Checksum	n/a

$VDVLW,0005293.53,N,0005293.53,N*5F
$VDVLW,xxxxx.xx,N,yyyyy.yy,N*hh

Item	Definition	Units
xxxxx.xx	Total cumulative distance of vessel travel	knots
N	Units	n/a
yyyyy.yy	Distance recorded since reset of DS-50 unit	knots
N	Units	n/a
*hh	Checksum	n/a

$VDVBW,011.04,000.09,A,011.04,000.09,V*46
$VDVBW,xxx.xx,yyy.yy,A,zzz.zz,ttt.tt,V*hh

Item	Definition	Units
xxx.xx	Longitudinal water speed	knots
yyy.yy	Transverse water speed	knots

A	**Status: water speed, A=data valid, V=data invalid**	**n/a**
zzz.zz	**Longitudinal ground speed**	**knots**
ttt.tt	**Transverse ground speed**	**knots**
V	**Status: ground speed, A=data valid, V=data invalid**	**n/a**
***hh**	**Checksum**	**n/a**

FE700 Navigational Echosounder data

The FE700 Navigational Echosounder outputs data in the following formats

- $PFEC - unspecified
- $SDDBT - Depth Below Transducer
- $SDDBS - Depth Below Surface

$PFEC ,aaaa,x,x*hF

PFEC sentence format

Item	Definition	Units
aaaa	unspecified	unspecified
x	unspecified	unspecified
x	unspecified	unspecified
*hF	unspecified	unspecified

$DBT,x.x,f,x.x,M,x.x,F*hh

SDDBT sentence format

Item	Definition	Units
x.x	Water depth	feet
f	f = feet	n/a
x.x	Water depth	meters
M	M = meters	n/a
x.x	Water depth	fathoms
F	F = fathoms	n/a
*hh	Checksum	n/a

$DBS,x.x,f,x.x,M,x.x,F*hh

SDDBS sentence format

Item	Definition	Units
x.x	Water depth	feet
f	f = feet	n/a
x.x	Water depth	meters
M	M = meters	n/a
x.x	Water depth	fathoms
F	F = fathoms	n/a
*hh	Checksum	n/a

Geometrics G-882 Cesium Marine Magnetometer Data

The G-822 Cesium Marine Magnetrometer converts the cesium Larmor signal (70 kHz to 350 kHz) into magnetic field strength in nano-Teslas (20,000 nT to 100,000 nT) by using a CM-221 counter module. The G-882 outputs magnetic field strength in the following serial sentence format:

FILE NAME: ***MGL-mag01.y****d****

mag01 2015:114:00:17:32.7965 $ 49034.313,0781,0876
mag01 yyyy:ddd:hh:mm:ss.ssss $ xxxxx.xxx,aaaa,bbbb

Item	**Definition**	**Units**
xxxxx.xxx	Magnetic Field Strength (nano Teslas)	nT
aaaa	A/D channel 0 (9999 full scale, 0 to +5 volts) *Not Used	n/a
bbbb	A/D channel 1 (9999 full scale, 0 to +5 volts) *Not Used	n/a

Kongsberg EM122 Multibeam – Center Beam Depth Data

The EM122 multibeam depth datagram from a single beam echo sounder are output for logging in the following NMEA 0183 DPT serial sentence format:

FILE NAME: ***MGL-bath02.y****d****

bath02 ***2015:233:00:14:27.1279*** ***$KIDPT,4840.83,5.60,12000.0*73***
bath02 ***yyyy:ddd:hh:mm:ss.ssss*** ***$KIDPT,xxxx.xx,z.zz,rrrrr.r*##***

Item	*Definition*	*Units*
KIDPT	**Talker identifier and sentence formatter**	**n/a**
xxxx.xx	**Seafloor bottom depth from transducer face**	**Meters**
z.zz	**Offset of transducer from waterline of vessel calculated using heavy compensation from Kongsberg Seapath 200 MRU**	**Meters**
rrrrr.r	**Maximum range scale in uses by system**	**Meters**
***##**	**Checksum**	***hh**

SEAPATH 200 Intertial Navigation System

SEAPATH outputs data in NMEA format using the following sentence formats:

- 1. $INGGA-Global System Position Fix Data
- 2. $INHDT-Heading - True data
- 3. $INVTG-Course over ground and Ground speed data
- 4. $INZDA-Time and date

$INGGA, hhmmss.sss, llll.lllll, a, yyyyy.yyyyy, b, t, nn, v.v, x.x, M,,,c.c,rrrr*hh

$INGGA-Global System Position Fix Data

Item	Definition	Value	Units
$INGGA	Header	$INGGA	
hhmmss.sss	UTC time of position	n/a	Hours/Minutes/Seconds.decimal. Two fixed digits of hours. Two fixed digits of minutes. Two fixed digits of seconds. Three digits for decimal fractions of a second.
llll.lllll	Latitude	-90 to +90	DegreeslMinutes.decimal. Two fixed digits of degrees Two fixed digits of minutes Five digits for decimal minutes.
a	N (north) or S (south)	N or S	
yyyyy.yyyyy	Longitude	-180 to +180	Degrees/Minutes.decimal. Three fixed digits of degrees. Two fixed digits of minutes. Five digits for decimal minutes.
b	E (east) or W (west)	E or W	
t	GPS Quality Indicator	0 = Fix not available or invalid 1 = CIA standard GPS; fix valid. 2 = DGS mode; fix valid. 3 = PPP mode; fix valid. 4 = RTK fixed 5 = RTK float 6 = free inertial	
nn	Number of satellites used in fix	0 to 32	
v.v	Horizontal dilution of precision		
x.x	Altitude of the IMU above or below the mean sea level. A negative value indicates below sea level.	n/a	Metres
M	Units of measure = metres	M	

Null	Null		
Null	Null		
c.c	Age of differential corrections in records since last RTCM-104 message.	0 to 99.9	Seconds
rrr	DGPS reference station identity	0000 to 1023	
*hh	Checksum		
/CR/LF	Carriage return and line feed	/CR/LF	

$INHDT, x.x, T*hh

$INHDT-Heading - True data

Item	Definition	Value	Units
$INHDT	Header	$INHDT	
x.x	True vessel heading in the vessel frame	o to 359.99	degrees
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

$INVTG, x.x, T,, M, n.n, N, k.k, K*hh

$INVTG-Course over ground and Ground speed data

Item	Definition	Value	Units
$INVTG	Header	$INVTG	
x.x	True vessel track in the vessel frame	0 to 359.99	degrees
T	True	T	
null	Not supported	null	
M		M	
n.n	Speed in the vessel frame	n/a	Knots
N	Knots	N	
k.k	Kilometres	K	
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

$INZDA, hhmmss.ss, DD, MM, YYYY,, *hh

$INZDA-Time and date

Item	Definition	Value	Units
$INZDA	Header	$INZDA	

hhmmss.sss	UTC time	n/a	Hours/Minutes/Seconds.decimal. 2 fixed digits of hours 2 fixed digits of minutes 2 fixed digits of seconds Three digits for decimal fractions of a second
DD	Day of month	01 to 31	
MM	Month of year	01 to 12	
YYYY	Year		
Null	Null		
Null	Null		
*hh	Checksum	n/a	
/CR/LF	Carriage return and line feed	/CR/LF	

UDP Datagrams

In addition to the serial logs, each data stream is broadcast over the local ship's network via UDP.

```
UDP MESSAGES

33103 (C-Nav World DGPS +RTCM)
 cnav    2008:013:02:15:33.7076  $GPGGA,021533.00,2710.75894,N,09511.75255,W,2,7,1.3,10.86,M,-26.31,M,10,0108*5D
 cnav    2008:013:02:15:33.7276  $GPVTG,166.4,T,,M,3.74,N,6.93,K*69

33104 (Applanix POS/MV INS)
 posmv   2008:013:02:15:01.7342  $INGGA,021501.498,2710.78491,N,09511.75611,W,1,10,0.8,-1.51,M,,,,*11
 posmv   2008:013:02:15:01.7344  $INHDT,171.2,T*20
 posmv   2008:013:02:15:01.8504  $INVTG,168.1,T,,M,3.9,N,7.3,K*70
 posmv   2008:013:02:15:01.9667  $INGST,021501.498,,1.2,1.1,75.1,4.0,4.0,6.1*6C
 posmv   2008:013:02:15:02.0849  $PASHR,021501.498,171.25,T,0.38,-1.11,0.02,0.068,0.068,1.906,1,1*39
 posmv   2008:013:02:15:02.0850  $INZDA,021501.0000,13,01,2008,,*78

33106 (Simrad Seapath 200 INS)
 seapath 2008:013:02:14:15.7873  $INZDA,021415.73,13,01,2008,,*78
 seapath 2008:013:02:14:15.9036  $INGGA,021415.73,2710.833433,N,09511.767381,W,2,10,0.8,-28.43,M,,M,0.8,0291*79
 seapath 2008:013:02:14:15.9036  $INVTG,169.86,T,,M,4.0,N,,K,D*02
 seapath 2008:013:02:14:15.9037  $INHDT,170.23,T*12

33111 (Simrad GC-80 aka "Tokamak" gyrocompass)  NOTE: NOT Sperry MK027
 gy01    2008:013:02:16:10.7810  $HEHDT,170.1,T*28
 gy01    2008:013:02:16:10.7812  $HEROT,002.86,A*17
 gy01    2008:013:02:16:11.5544  $PTKM,HEALM,0000,0,G1*09

33121 (Furuno DS50 speedlog)
 slog01  2008:013:02:16:53.9002  $VDVHW,,T,,M,04.10,N,07.59,K*49
 slog01  2008:013:02:16:54.0185  $VDVBW,004.08,-00.47,A,004.08,-00.47,V*46
 slog01  2008:013:02:16:54.0186  $VDVLW,0000966.85,N,0000966.85,N*5F

33602 (Simrad EM120 centerbeam depth)
 bath02  2008:014:17:22:01.2949  $KGDPT,1143.40,0.0,12000.0*4e

33701 (RMYoung 26700)
 wx01    2008:013:02:18:26.9205    3.0   2.8   4.2   6.3  58  58   5   0.0   0.0   0.0   0.0 355 355   0  21.1  21.0  20.9  21.1  7  7  7 1015.0

33711 (RMY relative wind to the DP autopilot)
 mwv01   2008:013:02:19:00.9197  $INMWV,57.0,R,4.4,N,A*08

33611 (Bell BGM-3 gravimeter)
 vc01    2008:013:02:19:30.9852  01:024904 01
```

LDEO PCO2 + CNav + TSG + WX01 + SBE38 Systems

PCO2 merge is a combination of outputs of various serial data in the following sentence format:

yyyyjjj.jjj aaaa.aa bb.bb cccc.cc ddd.dd e.ee fff.f gggg.gg hh i k, llll.llllllm, nnnnn.nnnnnno, pp.pppp, q.qqqqq, rr.rrrr, ss.s, ttt, uu.u, vvvv, w.ww, xxx.x, yy.yyyy

PCO2 Data

Item	Definition	Value	Units
yyyyjjj.jjj	pco2 Computer Date/Time	n/a	Year/Julian Day.decimal Four fixed digits of year. Three fixed digits of julian day. Five fixed digits for decimal fractions of a julian day.
aaaa.aa	CO2 Raw Signal	n/a	mVolts
bb.bb	CO2 Analyzer Cell Temperature	n/a	Celcius
cccc.cc	PCO2 Barometer	n/a	mbar
ddd.dd	VCO2	n/a	ppm
e.ee	Equilibrator Water Temp	n/a	Celcius
fff.f	pCO2	n/a	uatm
gggg.gg	Flow Controller	n/a	mVolts
hh	Flow Meter	n/a	cc/min
i	Sample ID #	0 to 16	integer
k	Sample ID	Equil, Atmos, Nitrogen, CC18798, CA07163, CC15551, or CC63668	alphanumeric
llll.llllllm	CNav Latitude	0 to 90, N/S	degrees/minutes.decimal/direction
nnnnn.nnnnnno	CNav Longitude	0 to 180, E/W	degrees/minutes.decimal/direction
pp.pppp	TSG Internal Temperature	n/a	Celcius
q.qqqqq	TSG Conductivity	n/a	S/m
rr.rrrr	TSG Salinity	25 to 40	ppm
ss.s	WX01 Bird 1 Wind Speed 60 sec avg	n/a	knots
ttt	WX01 Bird 1 Wind Direction 60 sec avg	0 to 360	degrees
	WX01 Temperature		

uu.u	Instantaneous	n/a	Celcius
vvvv	WX01 Ship Barometer Instantaneous	n/a	mbar
w.ww	CNav Speed Over Ground / Speed Made Good	0 to 15	knots
xxx.x	CNav Course Made Good	0 to 360	degrees
yy.yyyy	SBE38 Temperature Probe	n/a	Celcius

LDEO PCO2 System

PCO2 outputs data in the following sentence format:

yyyyjjj.jjj aaaa.aa bb.bb cccc.cc ddd.dd e.ee fff.f gggg.gg hh i k

PCO2 Data

Item	Definition	Value	Units
yyyyjjj.jjj	pco2 Computer Date/Time	n/a	Year/Julian Day.decimal Four fixed digits of year. Three fixed digits of julian day. Five fixed digits for decimal fractions of a julian day.
aaaa.aa	CO2 Raw Signal	n/a	mVolts
bb.bb	CO2 Analyzer Cell Temperature	n/a	Celcius
cccc.cc	PCO2 Barometer	n/a	mbar
ddd.dd	VCO2	n/a	ppm
e.ee	Equilibrator Water Temp	n/a	Celcius
fff.f	pCO2	n/a	uatm
gggg.gg	Flow Controller	n/a	mVolts
hh	Flow Meter	n/a	cc/min
i	Sample ID #	0 to 16	integer
k	Sample ID	Equil, Atmos, Nitrogen, CC18798, CA07163, CC15551, or CC63668	alphanumeric

OBSIP Shotlog Format

Each OBSIP shotlog contains a header followed by shot records:

```
#obsipshotfile v1.0
#shotnumber date time sourceLat sourceLon shipLat shipLon waterDepth sciTag
0001280 2009-08-27 05:08:49.807873  48.495334 -129.201444  48.494097 -129.203017 2530.6 MGL0910_05
0001279 2009-08-27 05:12:33.961869  48.491860 -129.204474  48.490060 -129.205425 2526.4 MGL0910_05
0001278 2009-08-27 05:16:36.302883  48.488608 -129.206115  48.486807 -129.206944 2530.3 MGL0910_05
0001277 2009-08-27 05:19:51.053880  48.485157 -129.209212  48.483406 -129.209755 2526.1 MGL0910_05
0001276 2009-08-27 05:24:01.863875  48.480813 -129.212088  48.479293 -129.213152 2516.1 MGL0910_05
```

Shot records are in the following format:

```
0001276 2009-08-27 05:24:01.863875  48.480813 -129.212088  48.479293 -129.213152 2516.1 MGL0910_05
sssssss yyyy-mm-dd hh:mm:ss.ssssss  xx.xxxxxx  yyy.yyyyyy  vv.vvvvvv  www.wwwwww dddd.d llllllllllllllll
```

OBSIP record format

Item	Definition	Units
sssssss	shot number	n/a
yyyy-mm-dd	date	ISO8601 format
hh:mm:ss.ssssss	time	ISO8601 format
xx.xxxxxx	source lat	degrees, WGS84
yy.yyyyyy	source lon	degrees, WGS84
vv.vvvvvv	vessel lat	degrees, WGS84
ww.wwwwww	vessel lon	degrees, WGS84
dddd.d	depth	meters
llllllllllllllll	linename	n/a

Seabird Electronics SBE-45 Thermosalinograph Station Data

* Includes SBE-38 Remote Temperature Sensor Data

The Thermosalinograph data from the Seabird SBE-45 integrated temperature and conductivity unit is output in the following sentence formats that includes the Seabird SBE-38 Remote Temperature Sensor located at the Uncontaminated Seawater System intake in the bow of the RV Marcus G. Langseth.

FILE NAME: ***MGL-tsgraw.y****d****

tsgraw 2015:234:00:04:28.6392 t1= 27.7779, c1= 5.75784, s= 36.1196, sv=1541.693, t2= 27.6301
tsgraw yyyy:ddd:hh:mm:ss.ssss t1= tt.tttt, c1= cc.ccccc, s= ss.ssss, sv=vvvv.vvv, t2= tt.tttt

Item	**Definition**	**Units**
T1	Temperature from SBE 45 - TSG	°C, ITS-90
C1	Conductivity from SBE 45 - TSG	S/m
S	Salinity calculated from T1 and C1 by SBE 45	psu
SV	Calculated sound velocity based on S (or T1 and C1) from the SBE 45 and Temperature (T2) from the SBE 38. Using the Chen-Millero calculation.	Chen-Millero, m/sec
T2	Temperature from SBE 38 – Remote Temperature (USS)	°C, ITS-90

Gyroscope data

The gyroscope serial data is output in the following sentence formats:

- PTKM,HEALM -- Unspecified
- HEHDT -- Heading - True
- HEROT -- Rate Of Turn

$PCICM,HEALM,xxxx,x,xx*hh

ALM sentence format

Item	Definition	Units
xxxx	unspecified	n/a
x	unspecified	n/a
*hh	unspecified	n/a

$HEHDT,xxx.x,T*hh

HDT sentence format

Item	Definition	Units
xxx.x	Heading true	degrees
T	T = true	n/a
*hh	Checksum	n/a

$HEROT,-xxx.x,A*hh

HEROT sentence format

Item	Definition	Units
xxxx.x	Rate of turn	Degrees per minute, Note: "-" means bow turns to port
A	A = data valid	n/a
*hh	Checksum	n/a

Streamer Tension Unit Data

STU outputs data in the following sentence format:

aaa bbb cc dd ee f g hhhh iiii jjjj kkkk l m nnnn oooo pppp qqqq r s tttt uuuu vvvv wwww x y zzzz !!!! @@@@ ####

STU Data

Item	Definition	Value	Units
aaa	na	n/a	n/a
bbb	Julian Day	1 to 366	day
cc	Hour	0 to 24	integer
dd	Minutes	0 to 60	integer
ee	Seconds	0 to 60	integer
f	# 1 ID	1	integer
g	# 1 Channel #	0	integer
hhhh	# 1 Peak Tension	n/a	lbs
iiii	# 1 Average Tension	n/a	lbs
jjjj	# 1 Delta Tension	n/a	n/a
kkkk	# 1 Temperature	n/a	Celcius
l	# 2 ID	1	integer
m	# 2 Channel #	1	integer
nnnn	# 2 Peak Tension	n/a	lbs
oooo	# 2 Average Tension	n/a	lbs
pppp	# 2 Delta Tension	n/a	n/a
qqqq	# 2 Temperature	n/a	Celcius
r	# 3 ID	1	integer
s	# 3 Channel #	2	integer
tttt	# 3 Peak Tension	n/a	lbs
uuuu	# 3 Average Tension	n/a	lbs
vvvv	# 3 Delta Tension	n/a	n/a
wwww	# 3 Temperature	n/a	Celcius
x	# 4 ID	1	integer
y	# 4 Channel #	3	integer
zzzz	# 4 Peak Tension	n/a	lbs
!!!!	# 4 Average Tension	n/a	lbs

@@@@	# 4 Delta Tension	n/a	n/a
####	# 4 Temperature	n/a	Celcius

Vaisala WXT-520 Meteorological Station Data

The meteorological data from the Vaisala WXT-520 integrated weather station is output in the following sentence formats:

FILE NAME: ***MGL-vaisala.y****d******

$WIMWV,105,R,3.8,N,A*32
$WIMWV,x.x,R,y.y,N,A*32

Item	Definition	Units
x.x	Wind direction value: Wind direction is given in relation to the devices north-south axis.	Degrees
R	Wind direction unit (R = relative)	n/a
y.y	Wind speed value	Knots
N	Wind speed unit (knots	n/a
A	Data status: A = valid, V = Invalid	n/a

$WIXDR,A,105,D,0,A,105,D,1,A,105,D,2,S,3.7,N,0,S,3.8,N,1,S,3.9,N,2,C,27.2,C,0,C,28.4,C,1,H,70.5,P,0,P,1013.5,H,0,V,0.00,M,0,Z,0,s,0,R,0.0,M,0,V,0.0,M,1,Z,0,s,1,R,0.0,M,1,R,1.7,M,2,R,0.0,M,3*6D

$WIXDR,A,xxx,D,0,A,xxx,D,1,A,xxx,D,2,S,x.x,N,0,S,x.x,N,1,S,x.x,N,2,C,xx.x,C,0,C,xx.x,C,1,H,xx.x,P,0,P,xxxx.x,H,0,V,x.xx,M,0,Z,0,s,0,R,x.x,M,0,V,x.x,M,1,Z,0,s,1,R,x.x,M,1,R,x.x,M,2,R,x.x,M,3*6D

Item	Definition	Units
A	**Transducer id 0 type (Wind Direction)**	**n/a**
xxx	Transducer id 0 data (min wind direction)	Degrees
D	Transducer id 0 units (degrees, min wind direction)	n/a
0	Transducer id for min wind direction	n/a
A	Transducer id 1 type (wind direction)	n/a
xxx	Transducer id 1 data (average wind direction)	Degrees
D	Transducer id 1 units (degrees, average wind direction)	n/a
1	Transducer id for average wind direction	n/a
A	Transducer id 2 type (wind direction)	n/a
xxx	Transducer id 2 data (max wind direction)	Degrees
D	Transducer id 2 units (degrees, max wind direction)	n/a
2	Transducer id for max wind direction	n/a
S	**Transducer id 0 type (wind speed)**	**n/a**
x.x	Transducer id 0 data (min wind speed)	Knots
N	Transducer id 0 units (Knots, min wind speed)	n/a

0	Transducer id for min wind speed	n/a
S	Transducer id 1 type (wind speed)	n/a
x.x	Transducer id 1 data (average wind speed)	Knots
N	Transducer id 1 units (Knots, average wind speed)	n/a
1	Transducer id for average wind speed	n/a
S	Transducer id 2 type (wind speed)	n/a
x.x	Transducer id 2 data (max wind speed)	Knots
N	Transducer id 2 units (Knots, max wind)	n/a
2	Transducer id for max wind speed	n/a

C	**Transducer id 0 type (Temperature)**	**n/a**
xx.x	Transducer id 0 data (Temperature)	Celcius
C	Transducer id 0 units (C, Temperature)	n/a
0	Transducer id for Temperature	n/a
C	**Transducer id 1 type (temperature)**	**n/a**
xx.x	Transducer id 1 data (Tp internal temperature)	Celcius
C	Transducer id 1 units (C, Tp internal temperature)	n/a
1	Transducer id for Tp internal temperature	n/a
H	**Transducer id 0 type (Humidity)**	**n/a**
xx.x	Transducer id 0 data (Humidity)	% Reletive Humidity
P	**Transducer id 0 units (%, Humidity)**	**n/a**
0	Transducer id for Humidity	n/a
P	**Transducer id 0 type (Pressure)**	**n/a**
xxxx.x	Transducer id 0 data (Pressure)	hPA
H	Transducer id 0 units (hPa, Pressure)	n/a
0	Transducer id for Pressure	n/a

V	**Transducer id 0 type (Accumulated rainfall)**	**n/a**
x.xx	Transducer id 0 data (Accumulated rainfall)	millimeters
I	Transducer id 0 units (mm, Accumulated rainfall)	n/a
0	Transducer id for Accumulated rainfall	n/a
Z	**Transducer id 0 type (Rain duration)**	**n/a**
xx	Transducer id 0 data (Rain duration)	seconds
s	Transducer id 0 units (s, Rain duration)	n/a
0	Transducer id for Rain duration	n/a
R	**Transducer id 0 type (Rain intensity)**	**n/a**

x.x	Transducer id 0 data (Rain intensity)	mm/hr
M	Transducer id 0 units (mm/h, Rain intensity)	n/a
0	Transducer id for Rain intensity	n/a
V	**Transducer id 1 type (Hail accumulation)**	**n/a**
x.x	Transducer id 1 data (Hail accumulation)	hits/cm2
M	Transducer id 1 units (hits/cm2, Hail accumulation)	n/a
1	Transducer id for Hail accumulation	n/a
Z	**Transducer id 1 type (Hail duration)**	**n/a**
x	Transducer id 1 data (Hail duration)	seconds
s	Transducer id 1 units (s, Hail duration)	n/a
1	Transducer id for Hail duration	n/a
R	**Transducer id 1 type (Hail intensity)**	**n/a**
x.x	Transducer id 1 data (Hail intensity)	hits/cm2h
M	Transducer id 1 units (hits/cm2h, Hail intensity)	n/a
1	Transducer id for Hail intensity	n/a
R	**Transducer id 1 type (Rain peak intensity)**	**n/a**
x.x	Transducer id 1 data (Rain peak intensity)	mm/h
M	Transducer id 1 units (mm/h, Rain peak intensity)	n/a
2	Transducer id for Rain peak intensity	n/a
R	**Transducer id 1 type (Hail peak intensity)**	**n/a**
x.x	Transducer id 1 data (Hail peak intensity)	hits/cm2
M	Transducer id 1 units (hits/cm2, Hail peak intensity)	n/a

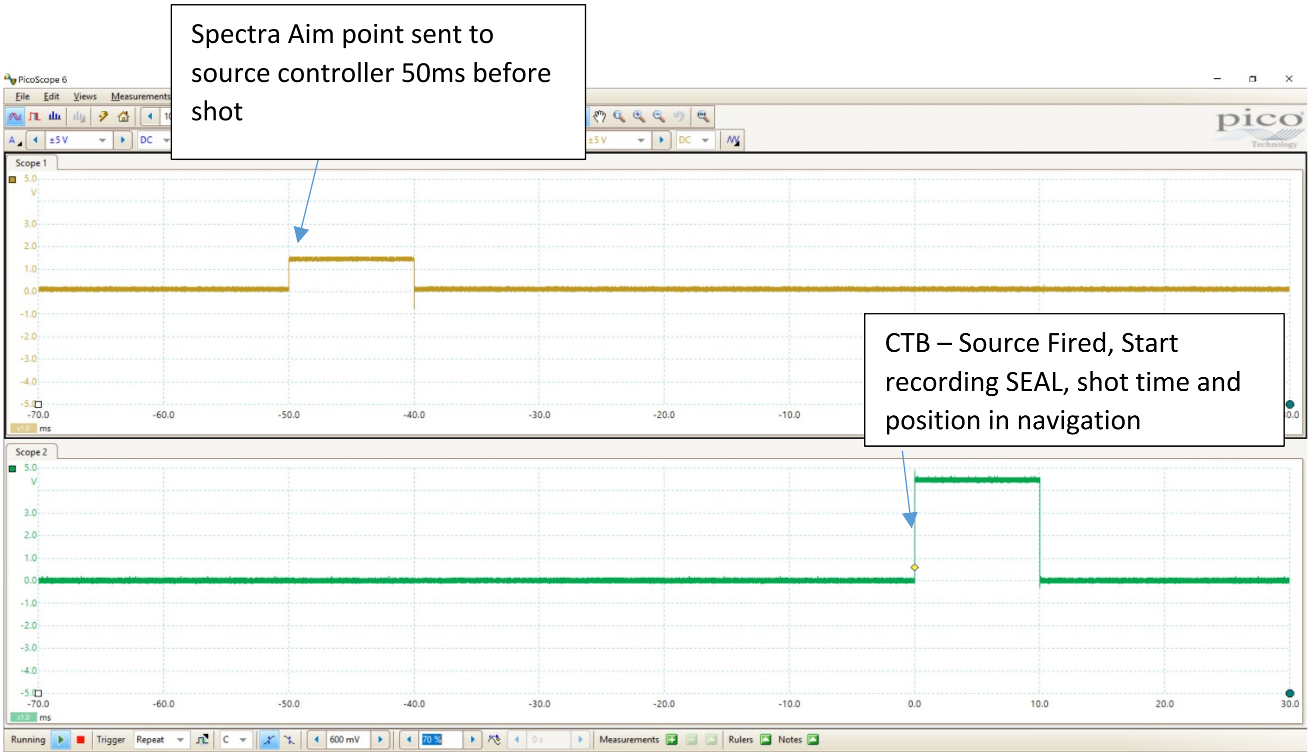
Vane Tension Load Cell Units Data
(Omega DP41-S High Performance Strain Gauge Indicators)

The Omega DP41-S Strain Gauges are directly linked to the Port and Starboard Seismic Streamer Barovane Tension Load Cells, the units are calibrated and output voltages to the Omega unit for conversion into Pounds (Lbs.) The Vane Tension Load data is output in the following serial format:

FILE NAME: ***MGL-vanep.y****d*** / MGL-vanes.y****d******

vanep 2015:171:23:59:59.9061 029096.
vanep yyyy:ddd:hh:mm:ss.ssss xxxxxxx.

Item	Definition	Units
xxxxxx	Strain force measured by load cell (pounds) to the nearest whole number	lbs



The spectra navigation system predicts the shot point using the defined shot point interval (50m). When coming up to a predicted shot point, spectra will send a trigger (50ms before predicted shot) to the source controller (GunLink 2000). GunLink then waits a set time (50ms) before firing the guns.

When the source fires a CTB signal is sent to SEAL to begin recording and Spectra to record the shot fired time and position.