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Evaluating Active Faulting and Geohazards in the Yakutat Bay Region of Southeastern Alaska

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Contents

Abstract

On September 10th the largest of four earthquakes (Mw 8.2) that occurred in southeast Alaska on 1899 produced a 6 m tsunami and may have produced as much as 14 m of co-seismic uplift. This earthquake had an epicenter somewhere near Yakutat or Disenchantment Bays. These bays lie at the transition between the Fairweather Fault (the Pacific-North American strike-slip plate boundary), and the Yakutat Terrane-North American subduction zone. The deformation front of this subduction zone is thought to include the eastern fault in the Pamplona Zone offshore, the Malaspina Fault onshore, and the Esker Creek Fault near Yakutat Bay. The 10 September 1899 event could have taken place on a Yakutat-North American megathrust that daylights in Yakutat or Disenchantment Bay. Alternatively, the 10 September 1899 earthquake could have originated from the Fairweather-Boundary and Yakutat faults, transpressive components of the Fairweather strike-slip system present in the Yakutat Bay region, or from thrusting along the Yakutat and Otemaloi Faults on the southeast flank of Yakutat Bay.

Characterizing fault slip during the Alaskan earthquakes of 1899 is vital to assessing both subduction zone structure and seismic hazards in the Yakutat Bay area. Each possible fault model has a different implication for modern hazards. These results will be used to update seismic hazard and fault maps and assess future risk to the Yakutat Bay and surrounding communities. During Aug. 6-17th, we anticipate acquiring high-resolution, marine multichannel seismic data aboard the USGS vessel Alaskan Gyre in Yakutat and Disenchantment Bays to search for evidence of recent faulting and directly test these competing theories for the 10 September 1899 event. This survey uses the University of Texas Institute for Geophysics' mini-GI gun, 24-channel seismic streamer, portable seismic compressor system, and associated gun control and data acquisition system to acquire the data. The profiles have a nominal common midpoint spacing of 1.625 m and a vertical resolution of ~1 m. Additionally, where water depths are sufficiently shallow enough, we use a Knudsen single transducer pole mounted chirp with a vertical resolution of ~10 cm. Estimated sediment accumulation rates from cores acquired in 2004 and 2008 within Disenchantment Bay will be used to quantify fault throw where it is seismically imaged. Our new seismic data will be incorporated with recent advances in the understanding of Yakutat Terrane-North America collision and deformation to determine the overall fault structure and seismogenic/tsunamigenic potential of southeast Alaska.

Field Work Details

Dates: August 7 - August 17, 2012

Port of Origin: Whittier, Alaska

Port of Termination: Seward, Alaska

Personnel:
Sean Gulick, co-chief scientist, University of Texas Institute for Geophysics (UTIG)
Peter Haeussler, co-chief scientist, United States Geological Survey (USGS)
Greg Snedgen, captain, USGS
Steffen Saustrup, seismic technician, UTIG
Maureen LeVoir, graduate student watchstander, UTIG

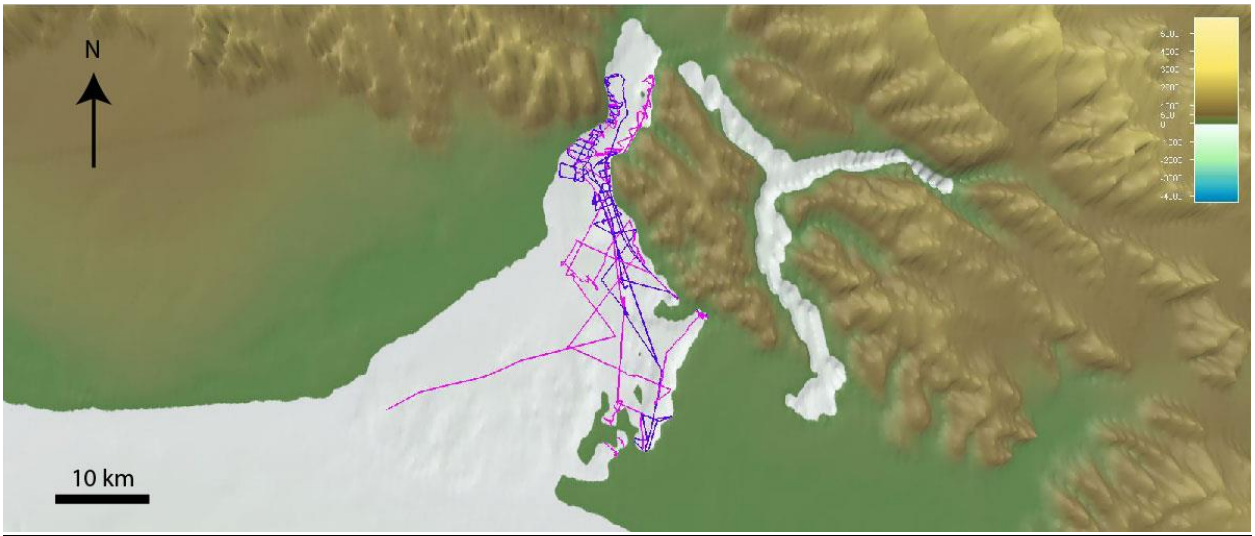
Objectives

The goals of the UTIG-USGS NEHRP survey of Yakutat and Disenchantment Bays are to investigate the mapped underwater faults that are suggested to have moved during the 10 September 1899 Mw 8.1 earthquake and tsunami. These include the Otemaloi Fault near Redfield Cove in eastern Yakutat Bay, the Yakutat Fault thought to either cross Knight Island and then proceed west to cross the mouth of Disenchantment Bay or to run the shoreline north of Knight Island up to Logan Beach, and the Esker Creek-Bancas Point Faults that are thought to enter Disenchantment Bay south and north of Bancas Point, respectively. Secondarily we will also examine the seafloor and subsurface features to determine what may be slumping related to the earthquake, structural related to convergent or transform tectonics including the coseismic rupture in 1899, or glacial due to the repeated advances and retreats of the Hubbard and Malaspina Glacier systems.

Synopsis of Survey

Despite the issues with the generator, we in the end acquired 48 seismic profiles for ~153 km and 140 chirp profiles. These data show that glacial features dominate the subsurface in Yakutat and Disenchantment Bay. A few minor faults were observed near Haenke Island and Esker Creek but no major faults cross or trend any significant distance into these Bays. Future work will thus require merging these data with existing deeper penetrating seismic data, multibeam data, remote sensing data, and geologic studies in order to produce a new map of the tectonic deformation in the Yakutat region and an assessment of the implications of the September 10th, 1899 earthquake and tsunami.

Survey trackline map (MCS – pink; Chirp – purple)



<u>Daily Log of Operations</u>

Aug. 3rd- UTIG Equipment retrieved by Haeussler and brought to USGS warehouse. UTIG crew arrived in Anchorage.

Aug. 4th- Equipment picked up from warehouse and supplies purchased in Anchorage. Crew and equipment driven to Whittier and loaded onto the R/V *Alaskan Gyre*. Lab setup was started.

Aug. 5th- Lab setup completed and chirp tested.

Aug. 6th- Electrician delayed until afternoon to rewire *Gyre* generator to three phase power; also gale in the Gulf of Alaska would prevent leaving during that evening. Decision was to delay departure until Aug. 7th. GI gun towing arrangement sorted and gun tested. GPS on the source buoy failed to work. Saustrup rewired using a replacement GPS antenna. Foodstuffs were purchased in Anchorage and delivered to vessel. Rewiring completed by late afternoon and successful test of running the *Gyre* compressor and both UTIG compressors.

Aug. 7th- All gear secured to vessel and packed down for the transit to Yakutat due to rough weather expected. This effort included putting the Mega Max compressor into the fish hold along with the two streamers and tying down all items as well as building supports under the compressor. Left dock at ~1700 due to a slightly more favorable weather forecast. Seas in Prince William Sound were less than 1 ft.

Aug. 8th- On transit with ~4 ft seas and made good time.

Aug. 9th- On transit but seas increased to ~6 ft and thus arrival in Yakutat Bay was delayed.

Arrived in Yakutat Bay late afternoon and steamed to near Knight Island to set up gear on deck and re-set up lab. Acquired our first seismic line 1201 but no chirp from southern end of the easternmost passage in Yakutat Bay to as far north as Kooisk Point. Recovered MCS gear and transited to Chicago Cove to anchor for the night.

Aug. 10th- Acquired Line 1202 and coincident Chirp data from north end of easternmost passage in Yakutat Bay past Knight Island and south to past Kooisk Point overlapping line 2012. Then acquired Line 1203 west into Yakutat Bay. Acquired Lines 1204 through 1211 within Yakutat Bay and crossing into southernmost Disenchantment Bay. No observations of clear faulting on any profiles but many superb images of glacial deposits and effects. Anchored near Knight Island.

Aug. 11th- On transit to Disenchantment Bay the generator ceased working. Captain diagnosed that it as a seized up water pump do to the bearings and a part would have to be flown in from Portland, Oregon. This delivery could not occur until Monday August 14th at the earliest. Decided to just deploy chirp and survey regions of possible faulting within Disenchantment Bay. Ice was very thick in the bay and it would not have been possible to acquire MCS data anyway. Acquired chirp data near Bancas Point as calved ice from Hubbard Glacier allowed. Ice jousted when needed to keep the larger bergs from striking the chirp head. Ice closed in enough that is was slow going to get back to our anchorage near Knight Island.

Aug. 12th- Transited to southern Disenchantment Bay and surveyed near Esker Creek and then crossed the Bay to survey from Point Latouche south to Logan Beach. Transited to near Redfield Cove and surveyed Line 1201 to get coincident data. Anchored in Doggie Inlet.

Aug. 13th- Transited to Yakutat to take on water and fuel and get information about the water pump's arrival. Discovered pump would not arrive until morning flight on August 15th and thus after getting some supplies left port to resume gathering chirp data. Acquired chirp data north of Doggie Island and then south to near Redfield Cove and Broken Oar Cove. Anchored south of Doggie Island.

Aug. 14th- Acquired chirp data between Doggie Island and Gregson Island, then through to Johnstone Passage to Puget Cove. Launched skiff for Haeussler and Saustrup to return to Yakutat and collect the water pump and a new belt for the generator. Acquired data up Puget Inlet and into shallow water regions south. Retrieved skiff, crew and parts. Commenced generator repairs while anchored. Tested generator and compressors and all in working order. Transited to north of Johnstone Passage and acquired Line 1212 north past Kriwoi, Krutoi and up to the kelp beds west of Knight Island. Pulled gear and transited to Disenchantment Bay. Acquired profiles 1213-1215 investigating near Point Latouche. Anchored behind Knight Island.

Aug. 15th – Left anchorage at 0500 and transited to upper Disenchantment Bay. Ice was clear on the east side of Haenke Island but too heavy north of the Island. Deployed seismic and chirp and acquired profiles between Haenke Island and east coast of Disenchantment Bay. These were Lines 1216 to 1233. Continued this pattern down to Point Latouche before being able to shoot a profile (Line 1234) across the Bay. We then acquired profiles in a zig zag pattern on the west flank of Disenchantment Bay from south to north in the Bancas Point area. We then acquired a single tie line (Line 1244) down west side of the Bay in the deep water ends of those profiles. We then acquired two lines in the Esker Creek area with the second one crossing Disenchantment Bay to Logan Beach area. The final profile line 1248 crossed from Logan Beach back into Yakutat Bay. We then pulled all gear and broke it down and stowed it for transit. Started transit back to Seward at 2100.

Aug. 16th - All gear repacked in order to separate shipments for Chile and Austin. LeVoir processed most of the seismic data to the first pass following the flows Saustrup set up. Worked on cruise report.

Aug. 17th – Continued transit to Seward.

Equipment Deployed and Acquisition Setup

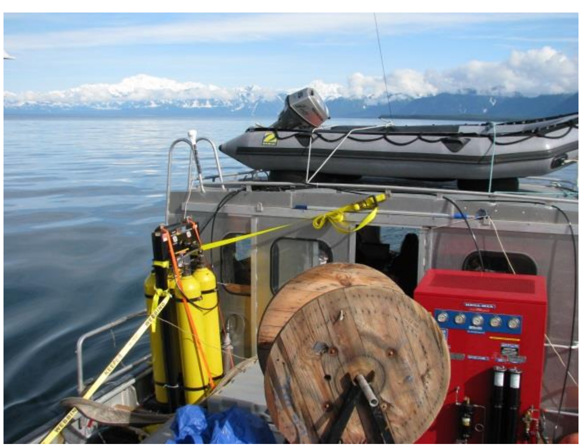
R/V Alaskan Gyre

The Alaskan Gyre (below) is 50-foot coastal seiner that has been converted into a versatile research vessel. There is a main deck comprising the lab, work area, and indoor living area with a bunking area. There is a smaller upper deck above the living area containing the bridge and some storage space. Inside the belly of the boat, there is a “fish hold” area that is used for storage and also contains three bunks. The Alaskan Gyre is designed for working in inside waters and coastal water of the open ocean and has a fiberglass hull which limits its ability to cruise in heavy ice. The vessel can safely and efficiently accommodate many types of scientific sampling. An onboard SCUBA compressor is available for dive operations. A "deck lab" encloses the aft third of the stern work deck. There are several options for the deck lab: 1) completely enclosed, 2) forward wall removed and 3) completely removed. A number of instruments have been successfully deployed from the Alaskan Gyre including: CTD, side scan sonar, towed sonic tracking hydrophones, gravity core, ADCP, Eckman grab sampler, Shipeck dredge, Tucker trawl, plankton nets, long-line fisheries sampling, pot fisheries sampling (Dungeness, shrimp, Tanner crab, and king crab), drop camera sleds, and multichannel seismic acquisition equipment. A variety of electronic navigation equipment is onboard including a GPS chartplotter, depth sounder, and radar. The vessel is an excellent observation platform and has been used for surveys of sea birds and marine mammals as well as marine geology.

For this seismic experiment, the lab area was used for active seismic acquisition and monitoring equipment, as well as gear storage. Four laptop computers were used during survey (navigation, seismic acquisition, chirp acquisition, and acquisition log). Raw MCS and chirp data and 1st-run processed MCS data were stored on a combination of external and internal drives and backed up to DVD media.

UTIG High-Resolution Multichannel Seismic System

Equipment aboard the *Alaskan Gyre* was set up in the lab and on the main deck outside the lab. A schematic representation (to scale) of the equipment setup and layout is at the end of this report. Below find descriptions of each part of the UTIG MCS system. Example MCS data can be found in processing section near the end of this report.



2 24-channel streamers (1 active, 1 backup): The seismic receiver is a Beam Systems, Inc.® (Pearland, TX),100m (75 m active), 24-channel, oil-filled, analog cable (left). 72 hydrophones (Teledyne Model T-2) are grouped three to a channel, group spacing is 3.125 m. The cable is 1.6 inch in diameter, liquid filled (Isopar M fluid). Nominal tow depth is 1 m or less. The cable can is easily deployed directly from the wooden shipping reel by hand, or can be wound around any available winch drum for mechanical deployment/recovery. A second, identical streamer is kept as a spare. On the *Alaskan Gyre*, one streamer was set up on the main deck on top of the fish hold, deployed from the port side, and the spare was kept inside the fish hold.

Sercel Mini GI 15/15-30/30 in^3: The mini-GI source (right) can be configured in harmonic or true GI mode, with each chamber at 15, 20, or 30 in^3 (total volume of 30, 40, or 60 in^3). Firing pressure is nominally 2000 psi, up to 3000 psi. Source frequency band at 15/15 in3 is ~60-400 Hz, with virtually no air bubble pulse. The GI gun was deployed from the main deck of the *Alaskan Gyre*, starboard side. The airgun was lifted into the water by the line from the *Gyre's* winch which remained in the water during operation, and towed by a line attached near the lab. The GI gun was configured to be 15/15 in^3 (total of 30 in^3) and was fired behind the vessel approximately even with the first channel of the streamer.

2 UTIG Electric Compressors (25 and 11 and scfm) and Alaskan Gyre air compressor: Three air compressors were used aboard the *Gyre*. During operation, as many compressors as possible were used simultaneously to fill the air tanks as the GI gun fired.

UTIG provided two air compressors. Air was provided by either (or both) of two Max-Air® (Kerrville, TX) electric compressors: the Mega-Max 6000 (3-phase power, 25.2 scfm, see Figures 7, 8); and the Max-Air 90 (single-phase power, 10.8 scfm, see left). Air is stored at 5000 psi and regulated down to firing pressure (2000 psi) through a manifold and receiver system. Either compressor can be located indoors or on deck, provided the deck area is well ventilated and at least partially protected from the elements. Compressor operation is automated and relatively quiet compared to gasoline- or diesel-powered compressors.

Two compressor motors (50-cycle and 60-cycle) are currently available for the larger compressor (left) depending on the power source available. This compressor is wired with a soft-start circuit, greatly reducing the power spike at start-up. The dimensions of the large compressor are as follows: 39”(W) x 36” (D) x 59” (H); Weight: 830 lbs (377 kg). In North America, the power is 60-cycle, 3-phase, 208/230/460 volts, 20 horsepower. On the *Alaskan Gyre*, the large compressor was set up on the port side, aft end of the main deck outside the lab. In transit, it was covered in a tarp to prevent contact with seawater; in operation and in calmer waters, it was covered with a plywood “roof” to avoid rain and other weather interference.

The more portable Max-Air 90 compressor (right) is suitable for platforms with space or power constraints. It's power specifications and dimensions are as follows: 60-cycle, single phase, 220 volts, 7.5 HP; Dimensions: 40"(W) x 20" (D) x 28.5" (H); Weight: 336 lbs (153 kg). On the *Alaskan Gyre*, the small compressor was located and operated with the *Gyre*'s compressor from within the fish hold area inside the boat.

Air Receiver: Compressed air is stored at 5000 psi in a pressure-regulated, vertical 4-pack cylinder rack (left). Air from the receiver is regulated down to a lower pressure (normally 2000 psi) for firing the sound source. Its dimensions are: 25" (W) x 25" (D) x 73" (H); Weight: 860 lbs (391 kg). On the *Alaskan Gyre*, the air tanks were operated from the starboard, aft end of the main deck right outside of the lab.

Firing controller: The source is controlled by a Real Time Systems® (Fredericksburg, TX) HotShot firing controller (below, right; also see lab setup photo under *Alaskan Gyre* vessel description). This controller is capable of firing and synchronizing up to 4 Bolt airguns or 2 GI guns. Firing is triggered by an internal clock or an external signal. The HotShot shotbox requires 110 VAC power. On the *Alaskan Gyre*, the firing controller was located and operated in the lab area.

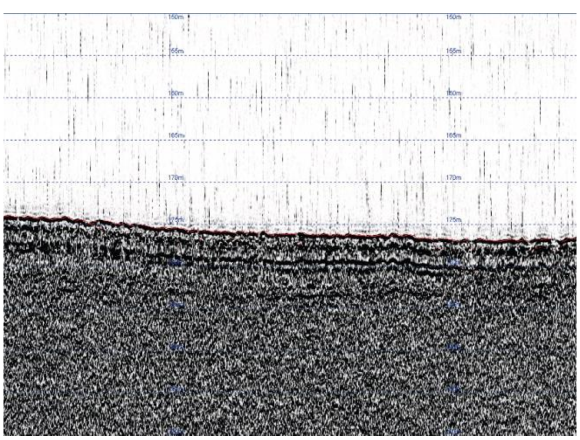
Geode seismic recorder: Analog signals from the cable are digitized and recorded using a Geometrics® Geode 24-channel seismic recorder, and accompanying Geometrics® SGOS software running on a laptop. The Geode requires 12-volt battery (car battery or similar). Data are stored on disk in either SEG-2 or SEG-Y format. Commonly, 1 second of data is recorded. The geode was also set up and operated in the lab of the *Alaskan Gyre*, on the same table as the shot box firing controller.

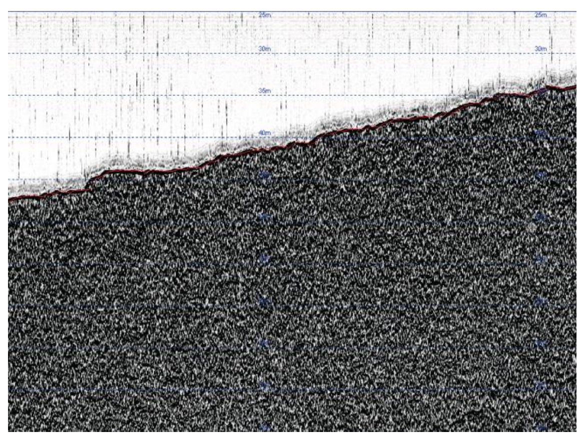
GPS system: Navigation data are acquired from a portable GPS antenna or copied from the vessel's own GPS system (NMEA), if such is available. Charts and real-time navigation can be displayed on a laptop using commercial software; in this case, Fugawi (www.fugawi.com). Navigation data are also stored on disk and written into the SEG-Y trace headers. An additional navigation display may be located on the bridge, if necessary for steering the vessel. The *Alaskan Gyre* had three GPS units set up. One on top of the port side, foremost corner of the lab roof, right above the Chirp and used for Chirp position; another on the sleeve of the airgun buoy, used for airgun position; and a third atop the starboard side, foremost corner of the lab roof, used for navigation.

UTIG Pole-Mounted Chirp

Portable Knudsen 3.5 kHz System: UTIG owns and maintains an integrated sonar system for use in conducting **C**ompressed **H**igh **I**ntensity **R**adar **P**ulse (CHIRP) subbottom profiling of the upper sediment layers of the ocean bottom or various fresh water systems. This highly portable

chirp (3.5 kHz center-frequency) profiling system (left) capable of being deployed on the smallest of vessels, including skiffs, dories, or other similar craft (left). The system consists of a portable version of the the Knudsen® 320 series echosounder and a single MASSA 3.5 kHz transducer, all of which is powered by a single 12 volt battery. The system can generate bottom and sub-bottom image from 3 – 200 m water depth in moderate-to-calm seas (i.e., swells no greater than 1 m). Data are displayed real-time using Knudsen Engineering® software. The Knudsen system generates SEG-Y files recognized by most seismic data processing packages. The system also comes with a GPS navigation unit that stamps the position at each shot point in the SEG-Y header. On the *Alaskan Gyre*, the Chirp system was rigged to a system of pipes and attached with rope to the main deck just outside the port side, foremost corner of the lab. See below for two screenshots of underway Chirp data.





At-Sea Processing of MCS Data

Preliminary processing of the MCS data was done while at sea aboard the *Alaskan Gyre* using Paradigm's FOCUS software. Below is a summary of the preliminary processing flow and plans for second-pass processing.

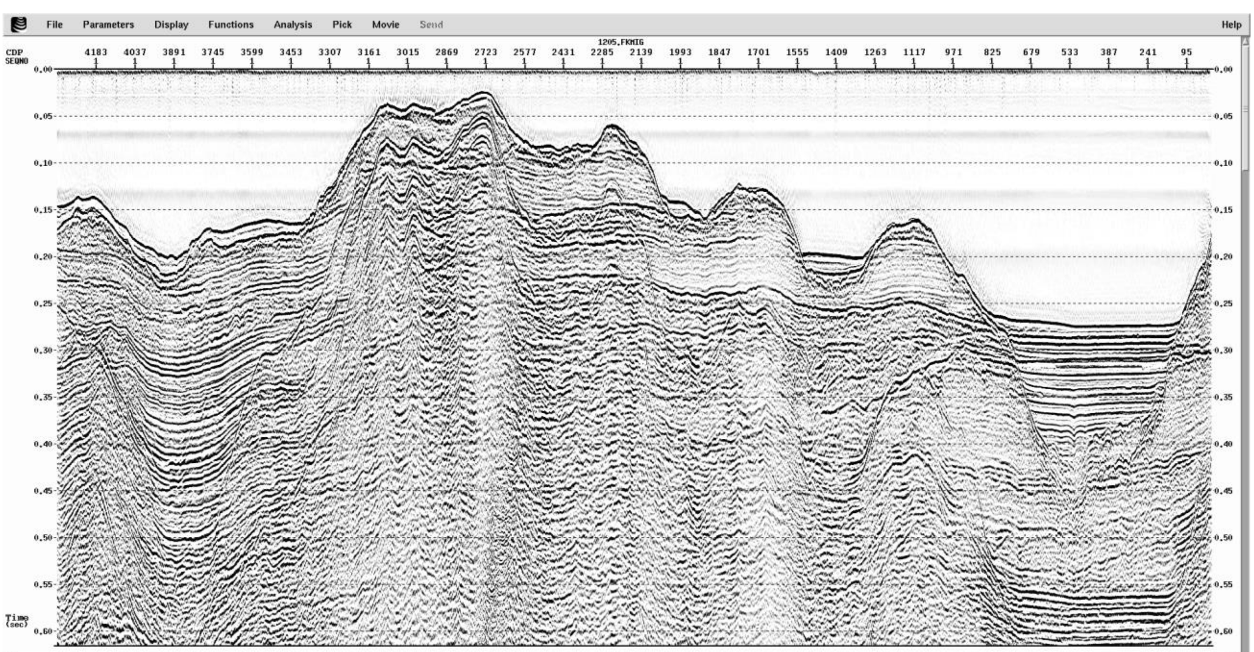
Preliminary processing flow:

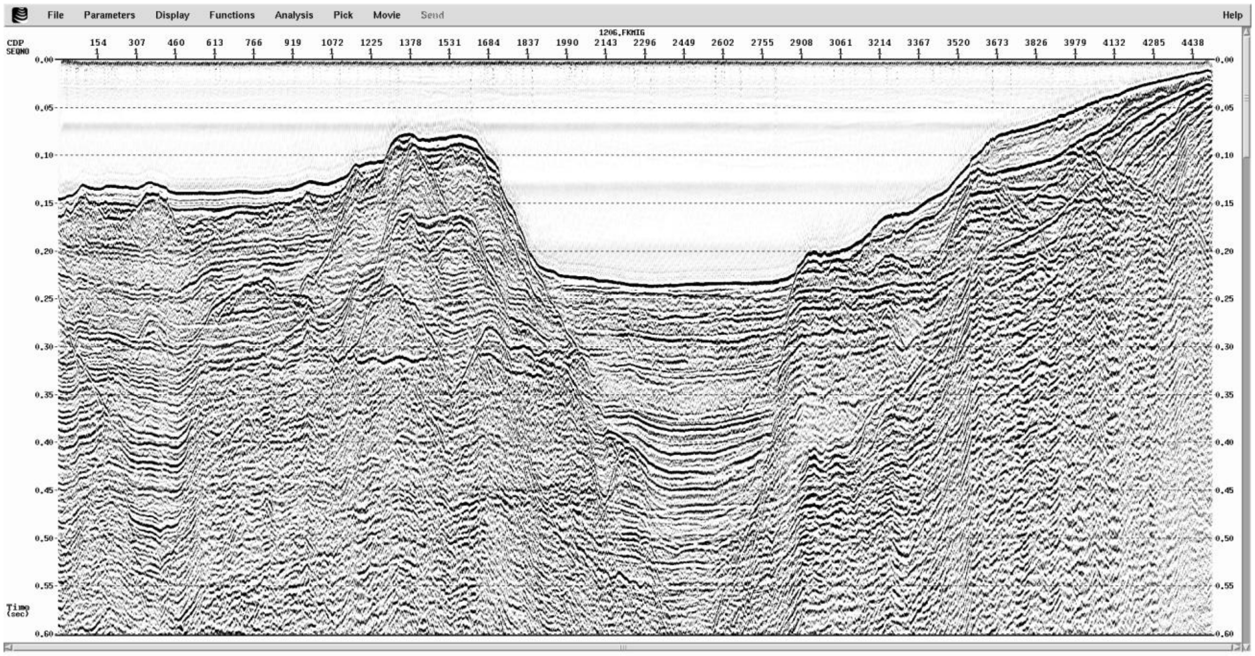
Reformat to FOCUS format
Reverse Polarity (streamer is wrong polarity)
Bandpass Filter 40-500 Hz
Geometry definition (nominal 12m shot spacing, 3.125m CDP spacing)
Time-Varying Gain (Spherical Divergence based on a nominal velocity function)
Later Trace Balance
CDP sort (nominal fold 6)
NMO correction (based on an example velocity picked from the first line)
Offset Muting
Stack
F/K Migration (1450 m/s)

Planned second-pass processing improvements:

Actual geometry using navigation data
Predictive Deconvolution
Velocity picking
Multiple attenuation

Examples of preliminary processed data (below top, line 1205; below bottom, line 1206):

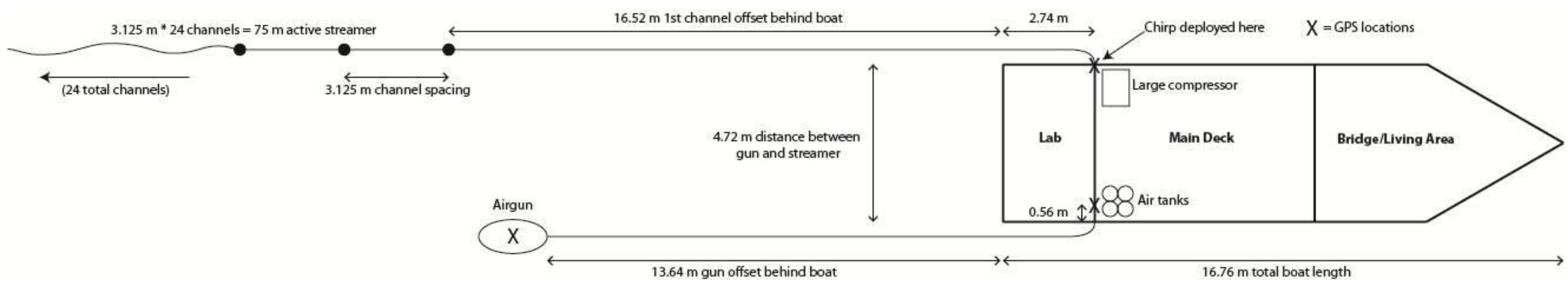




Summary of multichannel seismic lines:

Line	Filename	Local start date/time	Local end date/time	First shot	Last shot	Shot interval	Notes/ Description
1201	18.SGY	8/10/12 932	8/10/12 949	18	243	8s	1st good shot 32
1202	244.SGY	8/10/12 932	8/10/12 949	244	414	6s	1st good shot 245
1202a	415.SGY	8/10/12 949	8/10/12 1024	415	752	6s	Same line, changed record length to 2s. Is last shot 752? Not clear in log
1203	753.SGY	8/10/12 1024	8/10/12 1114	753	1263	6s	
1204	1264.SGY	8/10/12 1127	8/10/12 1327	1264	1416	6s	
1205	1417.SGY	8/10/12 1127	8/10/12 1327	1417	2496	6s	
1206	2497.SGY	8/10/12 1331	8/10/12 1424	2497	3623	6s	
1207	3624.SGY	8/10/12 1448	8/10/12 1631	3624	4057	6s	
1208	4058.SGY	8/10/12 1633	8/10/12 1747	4058	4786	6s	
1209	4787.SGY	8/10/12 1759	8/10/12 1821	4787	4850	6s	Is this last shot correct?
1210	4983.SGY	8/10/12 1859	8/10/12 1926	4983	5256	6s	
1211	5257.SGY	8/10/12 1933	8/10/12 1958	5257	5510	6s	
1212	5514.SGY	8/14/12 1455	8/14/12 1642	5514	6593	6s	1st good shot 5535
1213	6594.SGY	8/14/12 1843	8/14/12 1848	6594	6653	6s	Streamer caught up in gun, line aborted; 1st good shot 6601
1214	6654.SGY	8/14/12 1902	8/14/12 1947	6654	7116	6s	Reshoot of 1213, 1st good shot 6658
1215	7117.SGY	8/14/12 1953	8/14/12 2005	7117	7251	6s	1st good shot 7134
1216	7254.SGY	8/15/12 833	8/15/12 843	7254	7361	6s	Northernmost line in Dis. Bay, 1st good shot 7260

1217	7363.SGY	8/15/12 845	8/15/12 859	7363	7494	6s	
1218	7495.SGY	8/15/12 902	8/15/12 909	7495	7563	6s	
1219	7564.SGY	8/15/12 910	8/15/12 913	7564	7593	6s	
1220	7594.SGY	8/15/12 914	8/15/12 918	7594	7642	6s	
1221	7643.SGY	8/15/12 919	8/15/12 930	7643	7748	6s	
1222	7749.SGY	8/15/12 931	8/15/12 936	7749	7797	6s	
1223	7798.SGY	8/15/12 937	8/15/12 938	7798	7805	6s	
1224	7806.SGY	8/15/12 938	8/15/12 951	7806	7928	6s	
1225	7929.SGY	8/15/12 954	8/15/12 1001	7929	7992	6s	
1226	7993.SGY	8/15/12 1001	8/15/12 1005	7993	8028	6s	
1227	8029.SGY	8/15/12 1006	8/15/12 1024	8029	8204	6s	
1228	8205.SGY	8/15/12 1027	8/15/12 1031	8205	8253	6s	
1229	8254.SGY	8/15/12 1033	8/15/12 1044	8254	8395	5s	
1230	8396.SGY	8/15/12 1045	8/15/12 1052	8396	8478	5s	
1231	8479.SGY	8/15/12 1054	8/15/12 1106	8479	8629	5s	
1232	8630.SGY	8/15/12 1107	8/15/12 1114	8630	8724	5s	
1233	8725.SGY	8/15/12 1117	8/15/12 1138	8725	8980	5s	
1234	8981.SGY	8/15/12 1143	8/15/12 1222	8981	9450	5s	Wiggly line, SE Disenchantment Bay
1235	9451.SGY	8/15/12 1227	8/15/12 1243	9451	9608	6s	Wiggly line, NW Disenchantment Bay; changed from 5s to 6s early in line
1236	9609.SGY	8/15/12 1246	8/15/12 1306	9609	9824	6s	
1237	9825.SGY	8/15/12 1315	8/15/12 1329	9825	9965	6s	
1238	9966.SGY	8/15/12 1332	8/15/12 1342	9966	10067	6s	
1239	10067.SGY	8/15/12 1345	8/15/12 1406	10067	10277	6s	
1240	10278.SGY	8/15/12 1408	8/15/12 1415	10278	10356	6s	
1241	10357.SGY	8/15/12 1416	8/15/12 1427	10357	10463	6s	
1242	10464.SGY	8/15/12 1428	8/15/12 1431	10464	10492	6s	
1243	10493.SGY	8/15/12 1434	8/15/12 1453	10493	10679	6s	
1244	10680.SGY	8/15/12 1454	8/15/12 1535	10680	11093	6s	Long line
1245	11094.SGY	8/15/12 1538	8/15/12 1555	11094	11254	6s	
1246	11255.SGY	8/15/12 1555	8/15/12 1608	11255	11378	6s	
1247	11379.SGY	8/15/12 1608	8/15/12 1709	11379	11944	6s	Crossing Bay, 1st good shot 11387
1248	11945.SGY	8/15/12 1710	8/15/12 1836	11945	12743	6s, 7s	Last line, long line S through Bay



Vessel Layout Schematic

Publications

Gulick, S., LeVoir, M., Haeussler, P., Saustrup, S. (2012), Tectonic Origin of the 1899 Yakutat Bay Earthquakes, Alaska, and Insights into Future Hazards (talk), AGU 2012 Fall Meeting, San Francisco, CA.

An additional publication (first author LeVoir) is currently in progress as these new seismic data are improved and integrated with other geophysical datasets for analysis. The paper will propose a new tectonic model for Yakutat Bay using a multidisciplinary approach. These new data will also serve as the foundation for an undergraduate honors thesis studying the glacial history of the Hubbard Glacier within the lower Disenchantment and Yakutat Bays. This undergraduate thesis, though not originally a goal of the proposal, represents broader impacts of the funded research.