CRUISE REPORT

STEEP: ST. Elias Erosion/tectonics Project
Marine Reflection and Refraction Survey
R/V *Marcus G. Langseth*
September 10 – October 6, 2008
Astoria to Astoria

Cruise Participants

Science Party

Sean Gulick, UTIG – Chief Scientist
Gail Christeson, UTIG – Co-Chief Scientist
Beatrice Magnani, CERI – Co-Chief Scientist in training
Adam Barker, U Washington – Watchstander
Seth Campbell, U Maine – Watchstander
Ryan Elmore, UTIG – Watchstander
Ben Hooks, U Maine – Watchstander
Bobby Reece, UTIG – Watchstander
Lindsay Worthington, UTIG – Watchstander
Anatoly Miranov, UTIG – OBS Technician
John Gerboc, UTIG – Systems Administrator

LDEO Captain & Crew

Jim O'loughlin – Master

Matthew Bakis – Chief Mate
Chris Zimmerman – 2nd Mate
Nicholas Gasper – 3rd Mate
Al Karlyn – Chief Engineer
Matthew Tucke – 1st Engineer
Thomas DeWhirst – 2nd Engineer
Ryan Vetting – 3rd Engineer
Sal Oboza – Bosun
Inocencio Rimando – AB
George Cerano – AB
Ping Paragas – AB
Nicky Applewhite – OS
Jeromie Webster – OS
Henry Fuller – Steward
Ricky Rios – Cook
Jack Schwartz – Electrician
Rudolfo Florendo – Oiler
Fernando Uribe – Oiler
Travis Green – Oiler

LDEO Technical Support
Robert Steinhaus – Tech In Charge
Bern McKiernan – Assistant Tech In Charge/Acquisition Watch Leader
Robbie Gunn – Sound Source Watch Leader
Tom Spoto – Sound Source
Jenny White – Sound Source
David Martinson (NCS SubSea) – Navigation Watchleader
Ryan Eaton – Acquisition Watchstander
Mike Tatro – Acquisition Watchstander
Michael Zang – Chief IT

Marine Mammal Observers
Meike Holst – Lead Observer
Claudio Fossati – Lead PAM Observer
John Nicholas – Observer
Bradley Dawe – Observer
Brendan Hurley – Observer

Background

This is a multi-disciplinary study to address the evolution of the highest coastal mountain range on Earth - the St. Elias Mountains of southern Alaska and northwestern Canada. This orogen has developed over the past few million years as the Yakutat block, a continental-oceanic terrane, has attempted subduction beneath the eastern end of the Aleutian arc-trench system. The ~500 km-long, 150 km-wide St. Elias mountain range is the product of the dynamic balance between rapid uplift induced by crustal convergence and rapid exhumation by a regional system of large, fast-moving temperate glaciers. Most

sediments are deposited either on a broad shelf or in deepsea fans and provide a complete record of the tectonic, climatic, erosional, and eustatic events that have accompanied the orogeny. The overarching goal of the project is to develop a comprehensive model for the St. Elias orogen that accounts for the interaction of regional plate tectonic processes, structural development, and rapid erosion. The focus of the study is on the partitioning of deformation within the system from upper mantle flow to near-surface faulting and exhumation. The study will investigate the geodynamics of oblique collision under a set of conditions that will allow the PIs to address several important and fundamental questions:

Mt. St. Elias towering ~6000 m over the Gulf of Alaska coastline. STEEP seeks to examine the tectonic and climatic interactions that have produced the highest coastal mountains on Earth.

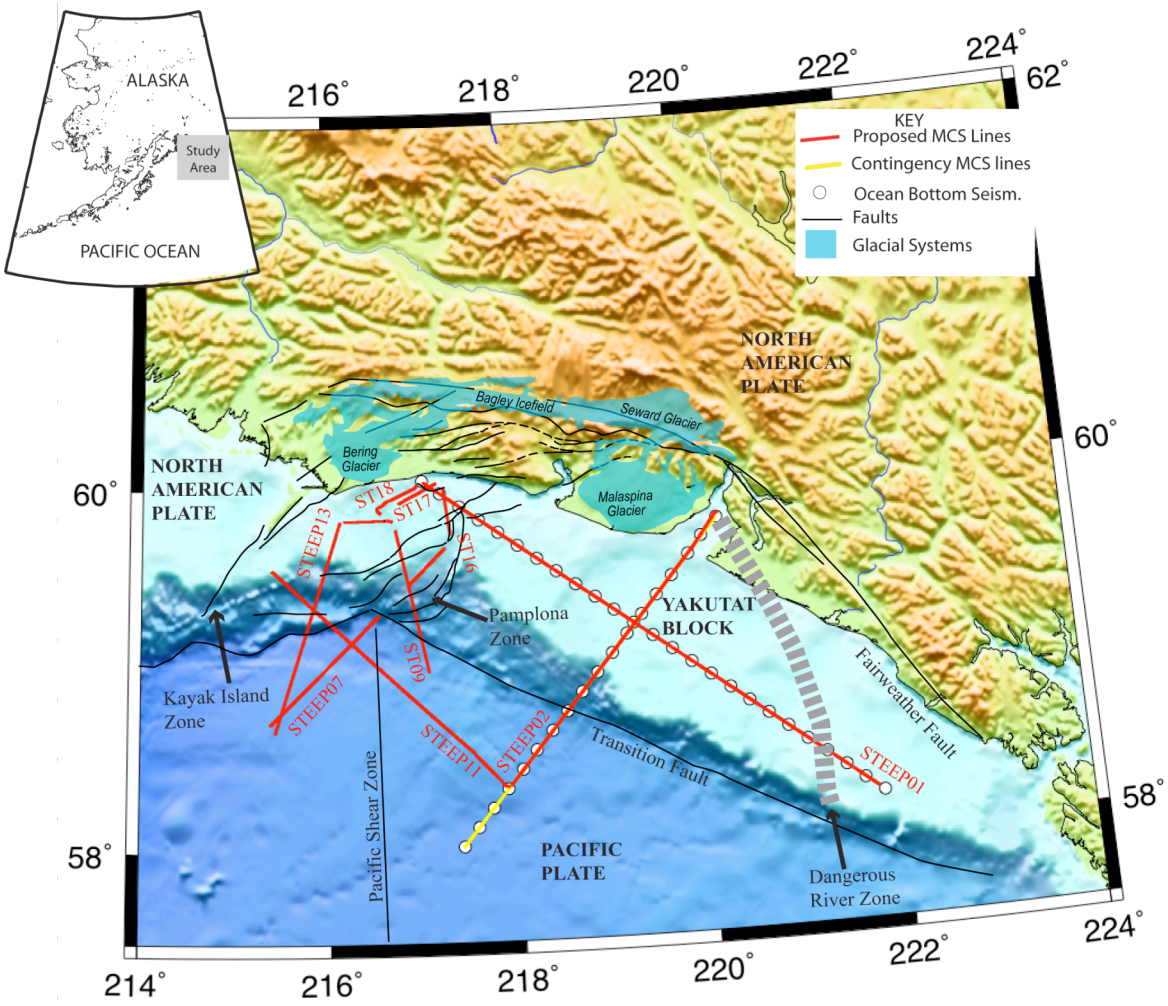
1. Has intense Quaternary glacial erosion redistributed mass in the orogen sufficiently to change regional deformational patterns, and has focused erosion along deep glacial valleys been sufficient to localize crustal strains?
2. How is deformation partitioned into lithospheric shortening and uplift versus lateral extrusion of the detached crust, and does intense erosion influence this partitioning?
3. Is the orogeny driven primarily by subduction of a buoyant oceanic plateau or by collision of a small microcontinental block attached to allochthonous ocean crust?

Addressing these questions has broad implications for understanding the geodynamics of oblique collision in general, the role of different mechanisms in development of far-field orogenic effects, and the control of erosion on development of slip partitioning during

oblique convergence. The project also has general implications for how subduction or accretion of small continental terranes versus oceanic plateaus contribute to deformation of the continents, and ultimately the fate of these fragments in construction of the crustal collage which is typical of virtually all continents.

Marine Seismic Objectives

The primary objectives for the marine seismic portion of STEEP include are threefold: 1) to image the offshore primary faults within and on the boundaries of the Yakutat Block, 2) to measure the velocity and thickness of the Yakutat crust, and 3) to image the sedimentary cover on the Yakutat Shelf and the sediments that make up the proximal part of the Surveyor Fan. The seismic reflection part of the experiment seeks to accomplish goals #1 and #3, while the seismic refraction component seeks to accomplish goal #2.



STEEP study area showing the acquired MCS lines, OBS sites, major faults and glaciers of bounding or within the Yakutat Block.

Faults that are targeted by the offshore component of STEEP include: the Dangerous River Zone, the Pamplona Zone, the Khitrov Fault Zone, the Pacific Shear Zone, the Transition Fault, and the Kayak Island Fault Zone. For each of these faults we seek to map their location, type of deformation, and history of deformation in order to examine

the tectonic response of the Yakutat Block and adjacent Pacific Plate to flat slab subduction.

The type and thickness of the Yakutat Block is unknown and yet this basic data are key to understanding the tectonic evolution of the margin. The Ocean Bottom Seismometer (OBS) transects (STEEP01 and STEEP02) are designed specifically to accomplish this goal by determining depth to Yakutat basement and moho and velocity structure of the crust.

The stratigraphic goals of the reflection data are to map key glacial erosion surfaces on the shelf that can be later dated by scientific ocean drilling and to map the sequences within the Surveyor Fan to track mass flux from the orogen. This stratigraphy can later be dated through ties with existing industry wells and hopefully future IODP drilling.

MCS Operations

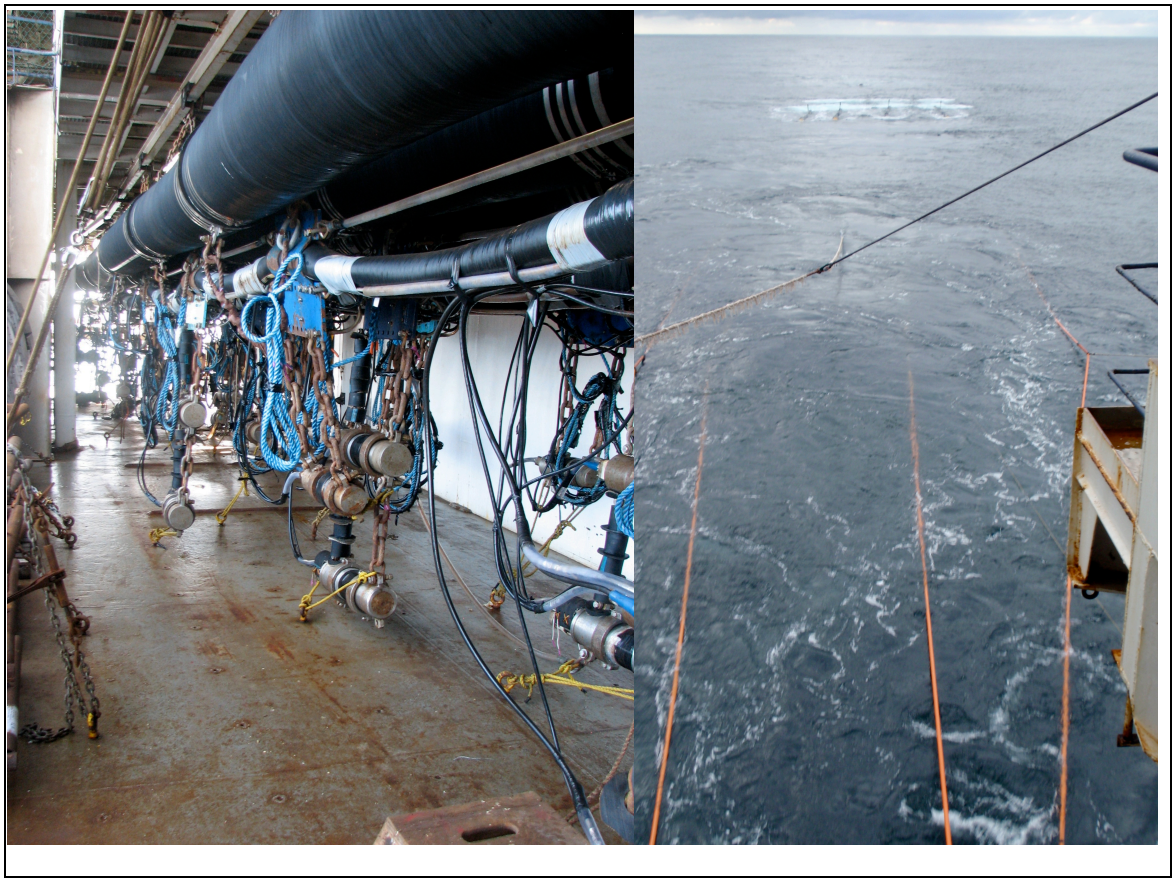
Summary

Multichannel Seismic (MCS) data collection used 8 km of LDEO's solid streamer with a total of 640 channels. Receivers are located within the streamer every 12.5 m and thus the Common Depth Point spacing is 6.25 m. The 40 Bolt airguns were deployed in 4 linear arrays with the full source being 36 guns at 6600 cubic inches in volume. Four 180 cu. in. guns served as hot spares. Data was acquired in demultiplexed SEGD format at 2 ms and was recorded for 16 seconds. The shot spacing was 50 m during the MCS and MCS/OBS profiles. Below is a table summarizing the MCS lines acquired during MGL0814. We recorded ~1250 km of MCS and accomplished over 90% of our imaging objectives. This included imaging the Dangerous River Zone, the Transition Fault, the Pamplona Zone, and the sedimentary record contained on the shelf and in the Surveyor Fan.

STEEP MCS Acquisition Table

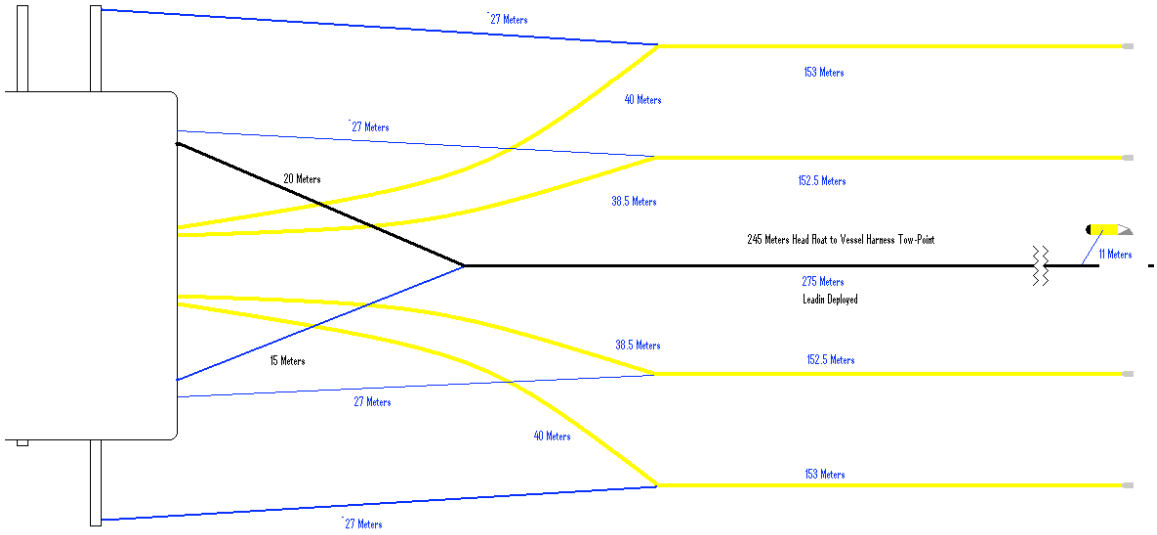
Line Number				
STEEP09	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 1, E: 2	711	2510	1799
	First CMP	Last CMP	Total Line Length	
	652	15647	93.71875	
STEEP13	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 4, E: 6	1007	3727	2720
	First CMP	Last CMP	Total Line Length	
	652	23047	139.96875	
STEEP15	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 3, E: 3	996	1585	589
	First CMP	Last CMP	Total Line Length	
	652	5999	33.41875	
STEEP07	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 7, E: 9	922	2830	1908
	First CMP	Last CMP	Total Line Length	

	652	16543	99.31875	
STEEP07a	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 10, E: 10	2690	2726	36
	First CMP	Last CMP	Total Line Length	
	na	na		
STEEP07b	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 11, E: 11	3338	3990	652
	First CMP	Last CMP	Total Line Length	
	652	6503	36.56875	
STEEP16	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 12, E: 12	1042	1645	603
	First CMP	Last CMP	Total Line Length	
	652	6103	34.06875	
STEEP19	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 14, E: 14	990	1088	98
	First CMP	Last CMP	Total Line Length	
	652	2071	8.86875	
STEEP17	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 13, E: 13	1036	1561	525
	First CMP	Last CMP	Total Line Length	
	652	5471	30.11875	
STEEP18	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 15, E: 15	996	1484	488
	First CMP	Last CMP	Total Line Length	
	652	5199	28.41875	
STEEP01a	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 16, E: 18	1031	3176	2145
	First CMP	Last CMP	Total Line Length	
	652	18447	111.21875	
STEEP01b	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 19, E: 23	3448	7679	4231
	First CMP	Last CMP	Total Line Length	
	660	35143	215.51875	
STEEP02	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 24, E: 28	953	5152	4199
	First CMP	Last CMP	Total Line Length	
	660	34767	213.16875	
STEEP11	Start/End Tape Number	First Shot Point	Last Shot Point	Total Shots
	S: 29, E: 32	361	4305	3944
	First CMP	Last CMP	Total Line Length	
	652	32823	201.06875	
			Total All Lines	
			1245.44375	



Linear airgun arrays shown onboard and towed behind the vessel. The arrays were spaced 6 m apart and totaled 40 guns of which 36 were active for a total of 6600 cu. inc.

Solid streamer used during STEEP08. Dark patches are the hydrophones and yellow parts are the foam encased wires, fiberoptics, and streamer members.



Streamer and gun configuration during MGL0814.

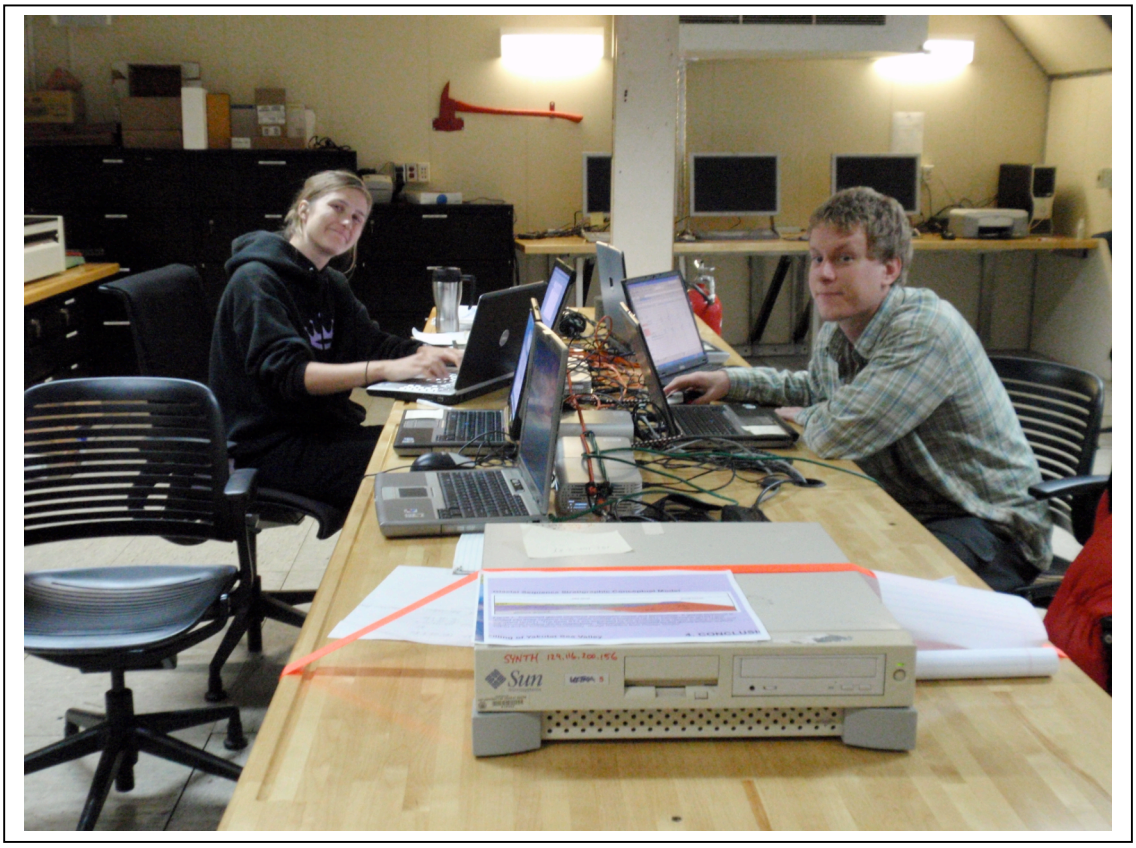
Onboard Quality Control and Preliminary Processing

During data collection the Watchstanders observed the streamer depth, the general noise levels on the streamer and shot gather, the condition of the guns, and alerted the science technician on duty as to any issues that occur including communications from the bridge or marine mammal observers. Detailed reports on problems encountered on all the lines are discussed both in the Chief's Scientist Daily Log and on the Observer Log Sheets (Appendix 1). The Technician-In-Charge Daily Reports are in Appendix 2.

Control room instrument displays with watchstanders observing data collection.

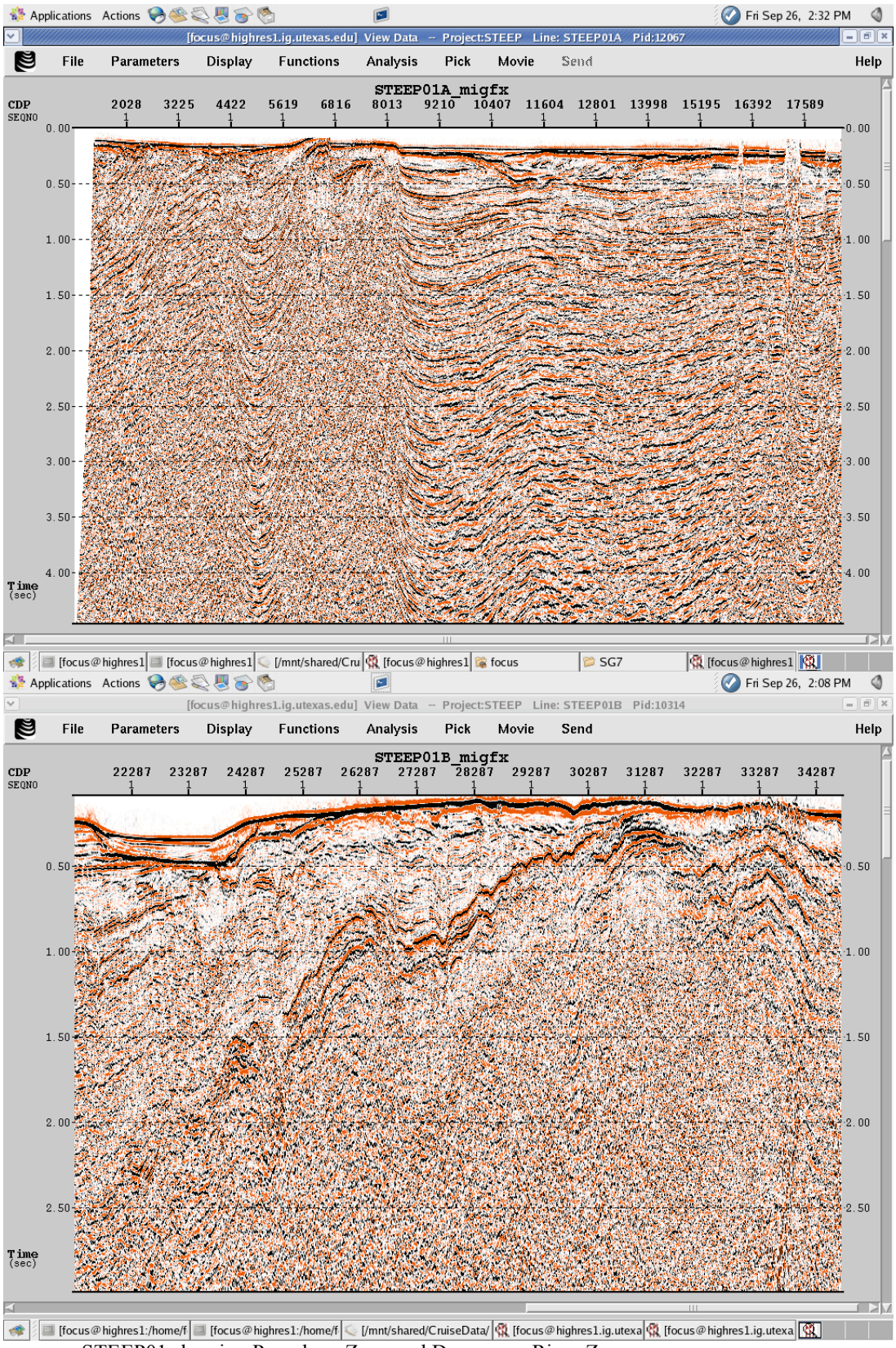
Immediately following the ending of a MCS line, the raw segd data was copied to a USB hard disk. The individual shot files were then concatenated into a single file for importing into our processing software, Paradigm Geophysical's FOCUS. Within FOCUS we defined a basic marine geometry for each profile using 12.5 m receiver spacing, 50 m shot spacing, 164 m near offset, and 6.25 m CDP spacing. We then read in the segd data, resampled to 4 ms, applied a bandpass filter of 3-8-60-80 Hz, recovered amplitude loss due to spherical divergence with a time-squared gain, conducted multichannel predictive deconvolution with 64 ms lag and 364 ms operator length, sorted the data into common midpoint gathers, and wrote them out in FOCUS format. We then performed a velocity analysis and picked mutes every 500 CDPs. Using these functions we conducted normal moveout on the CDPs and an outside mute before stacking the 80 fold data. Using a smoothed velocity field (5000 m by 500 ms) we conducted a finite

difference migration with a maximum dip of 65 degrees. Examples portions of each profile are shown below.

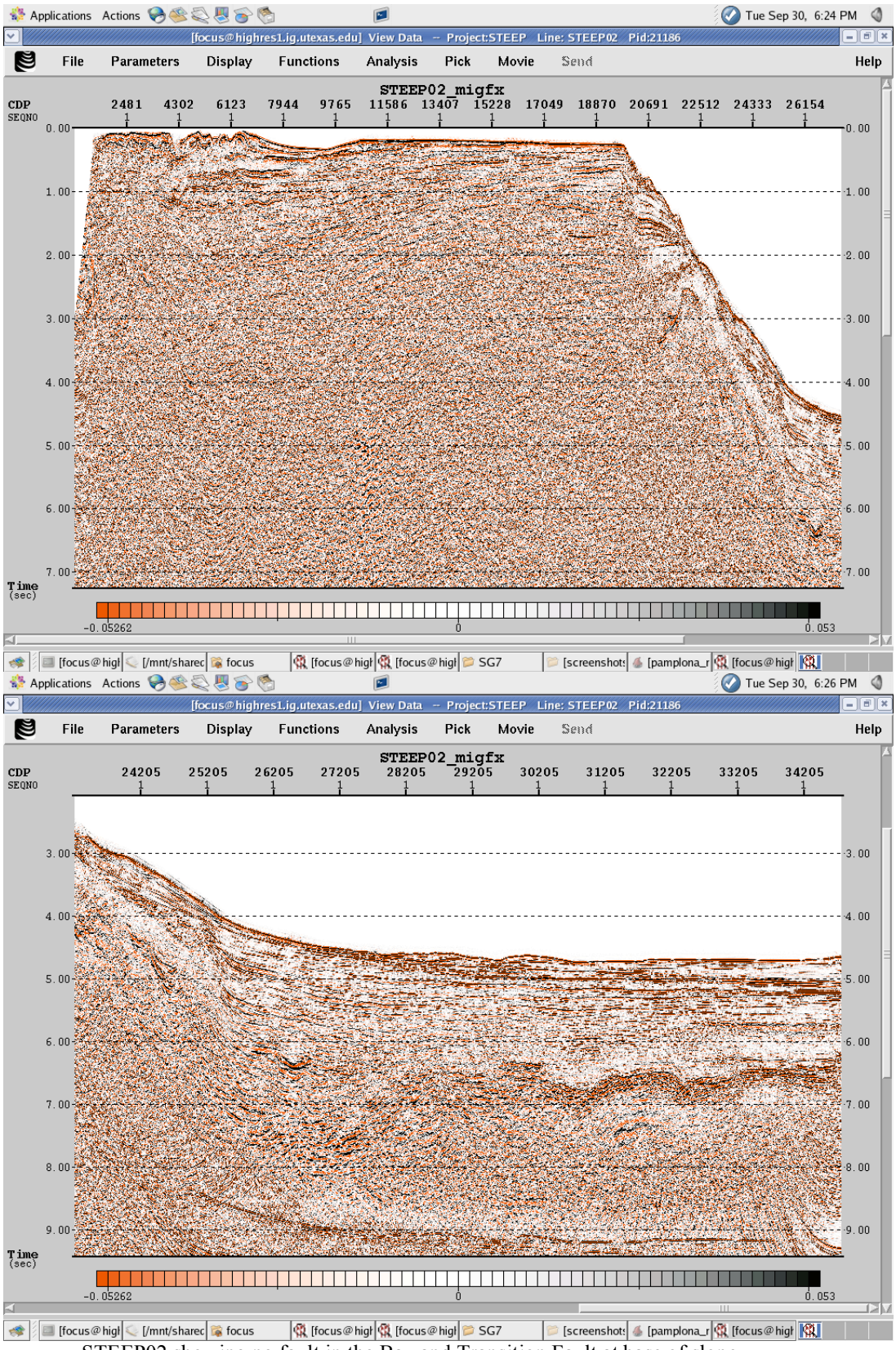


Processing station with a Sun workstation serving licenses to Linux laptops.

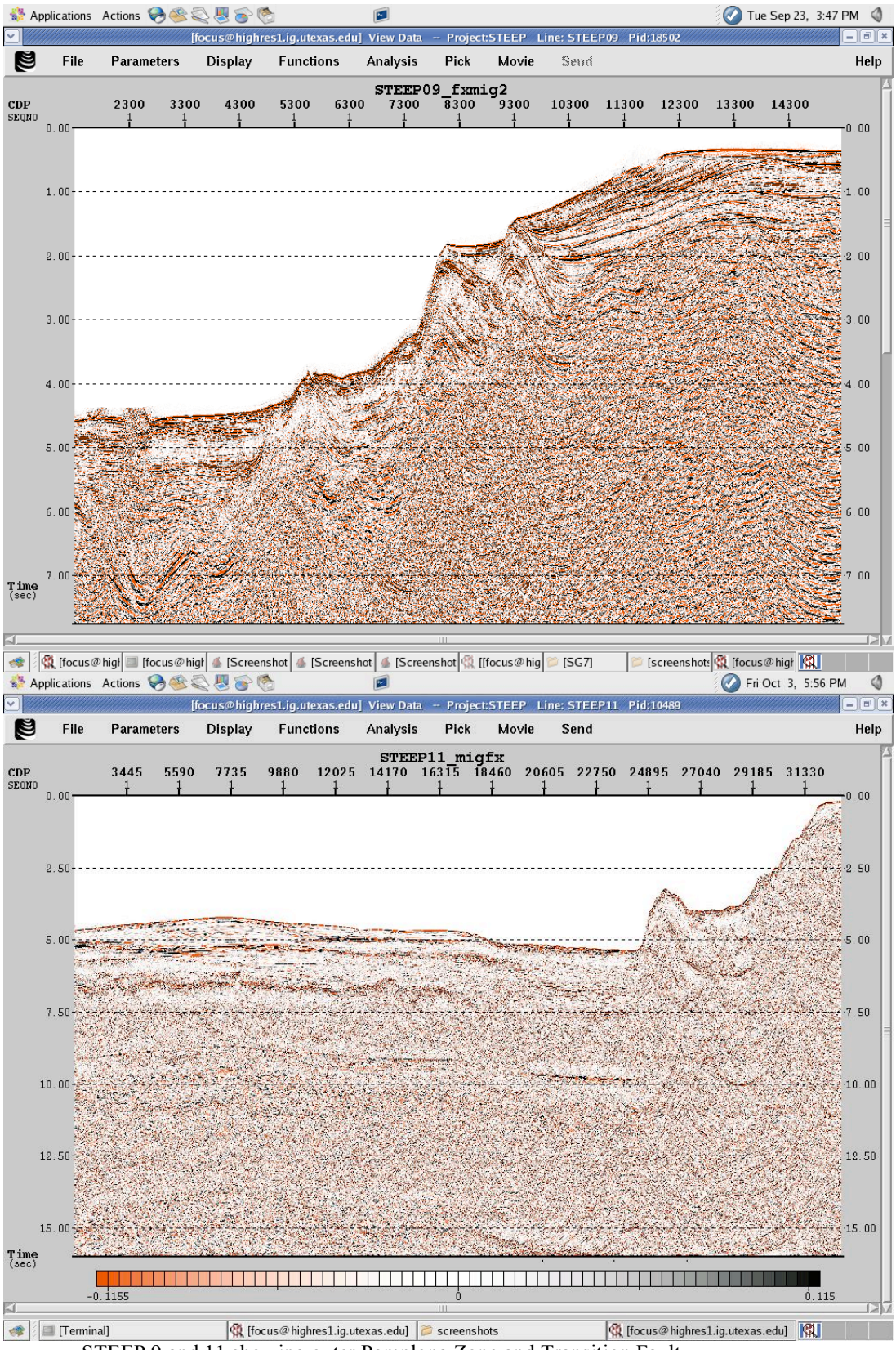
Future processing plans include using 3D geometry and the processed p190 files to place all midpoints in their true 3D location while processing the line as a 2D line. Deconvolution will be improved upon, velocities and mutes picked at a finer spacing, and a improved migration will be sought. For select lines we may use pre-stack migration methods.



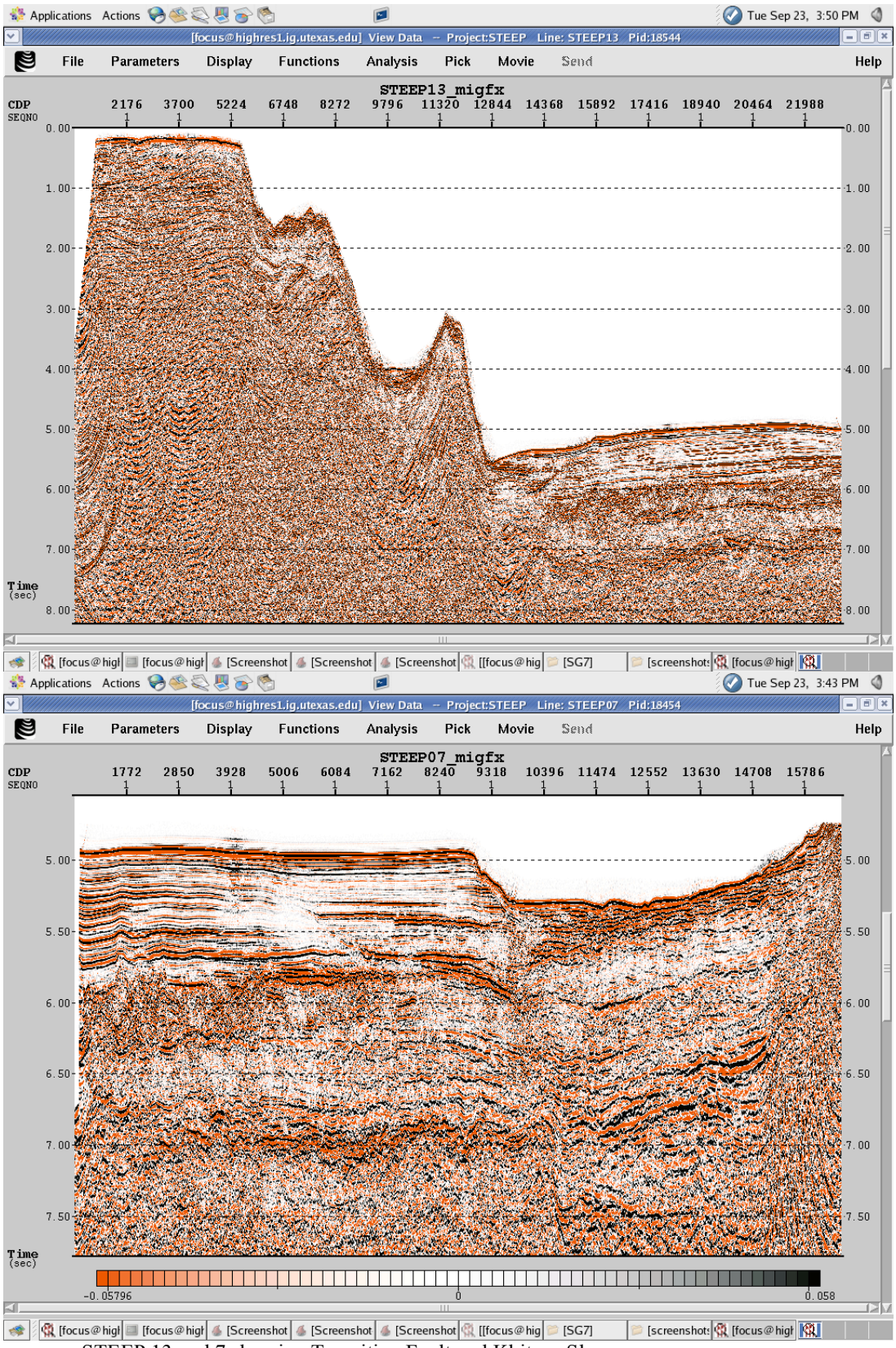
STEEP01 showing Pamplona Zone and Dangerous River Zone.



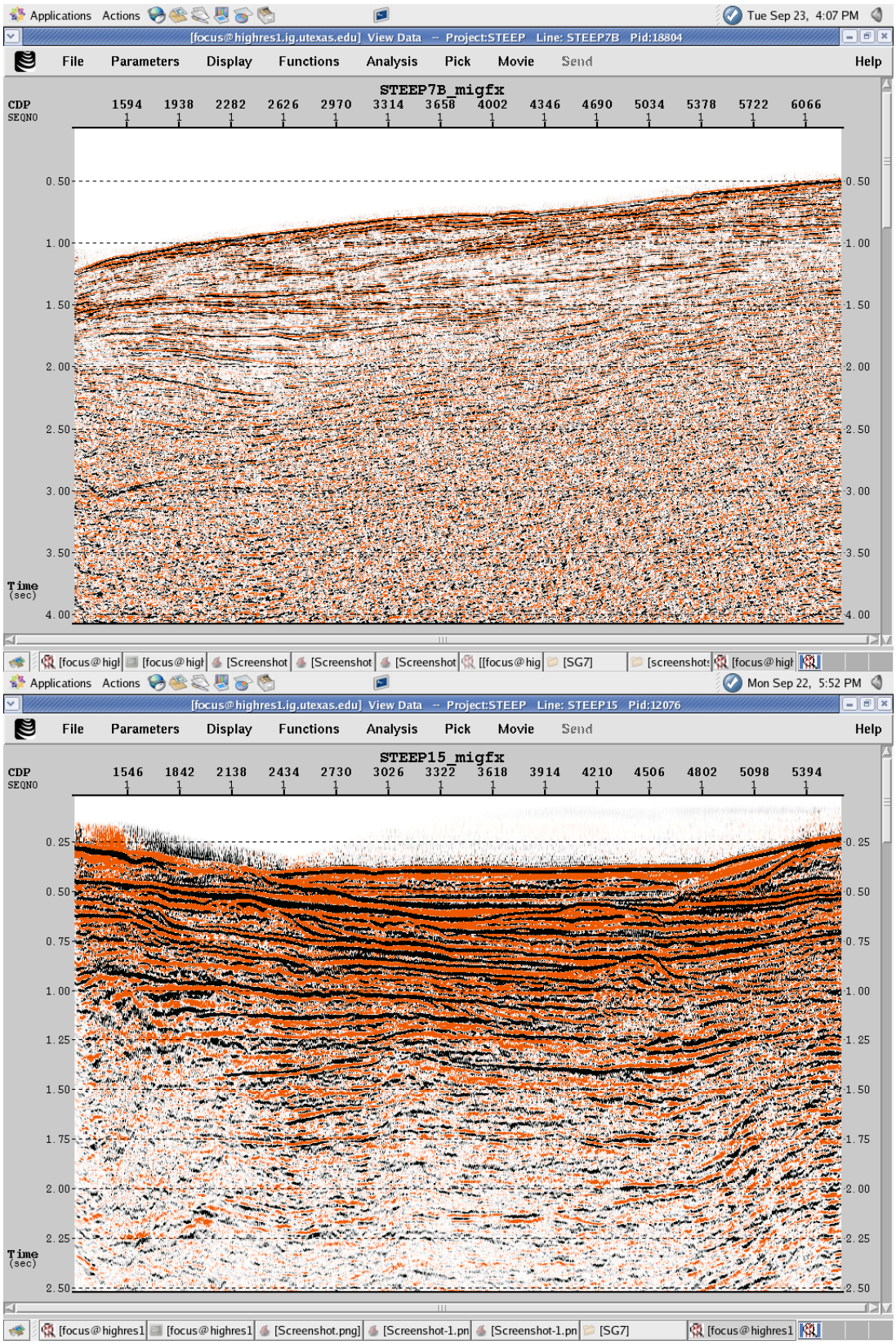
STEEP02 showing no fault in the Bay and Transition Fault at base of slope.



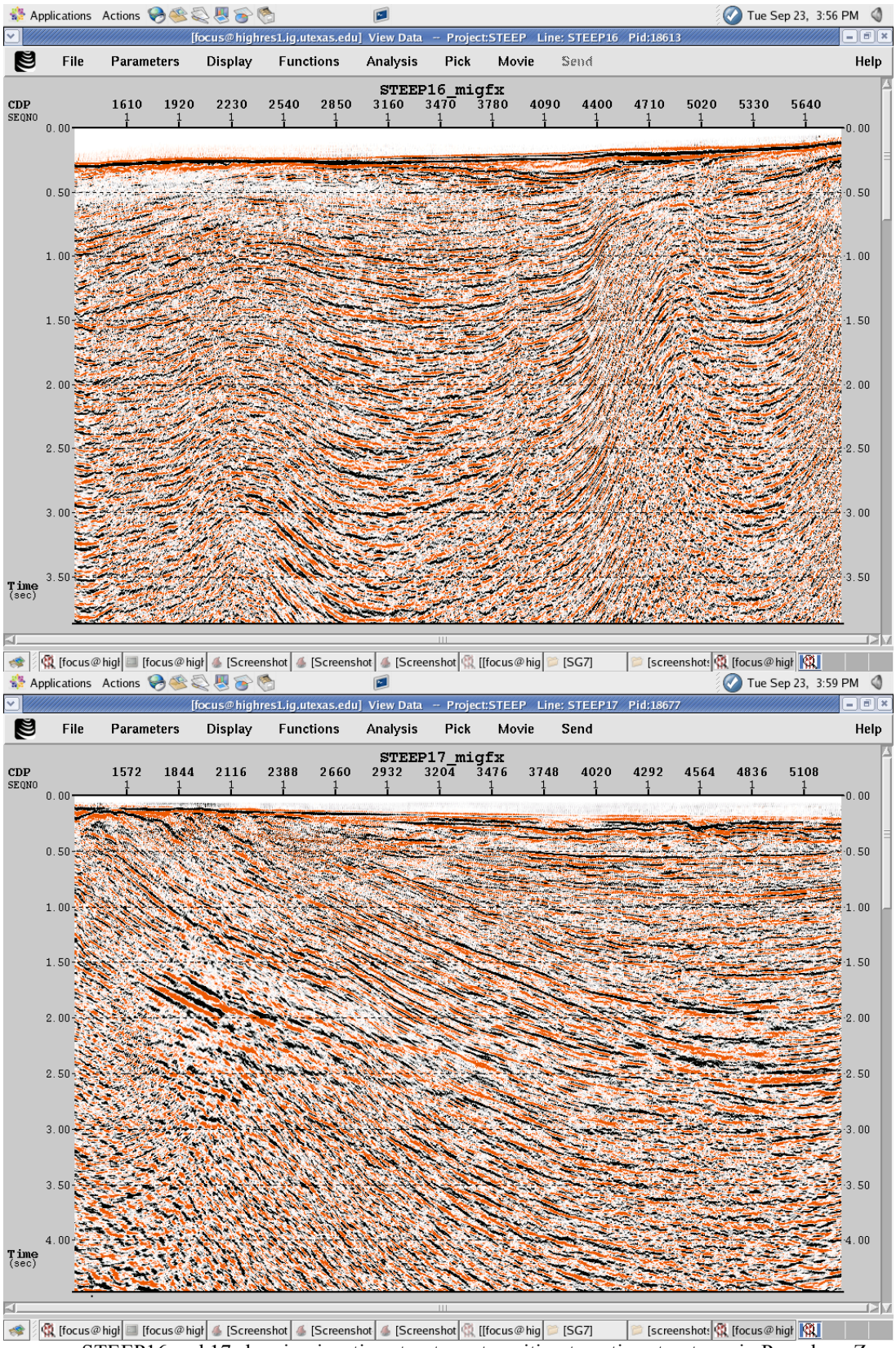
STEEP 9 and 11 showing outer Pamplona Zone and Transition Fault.



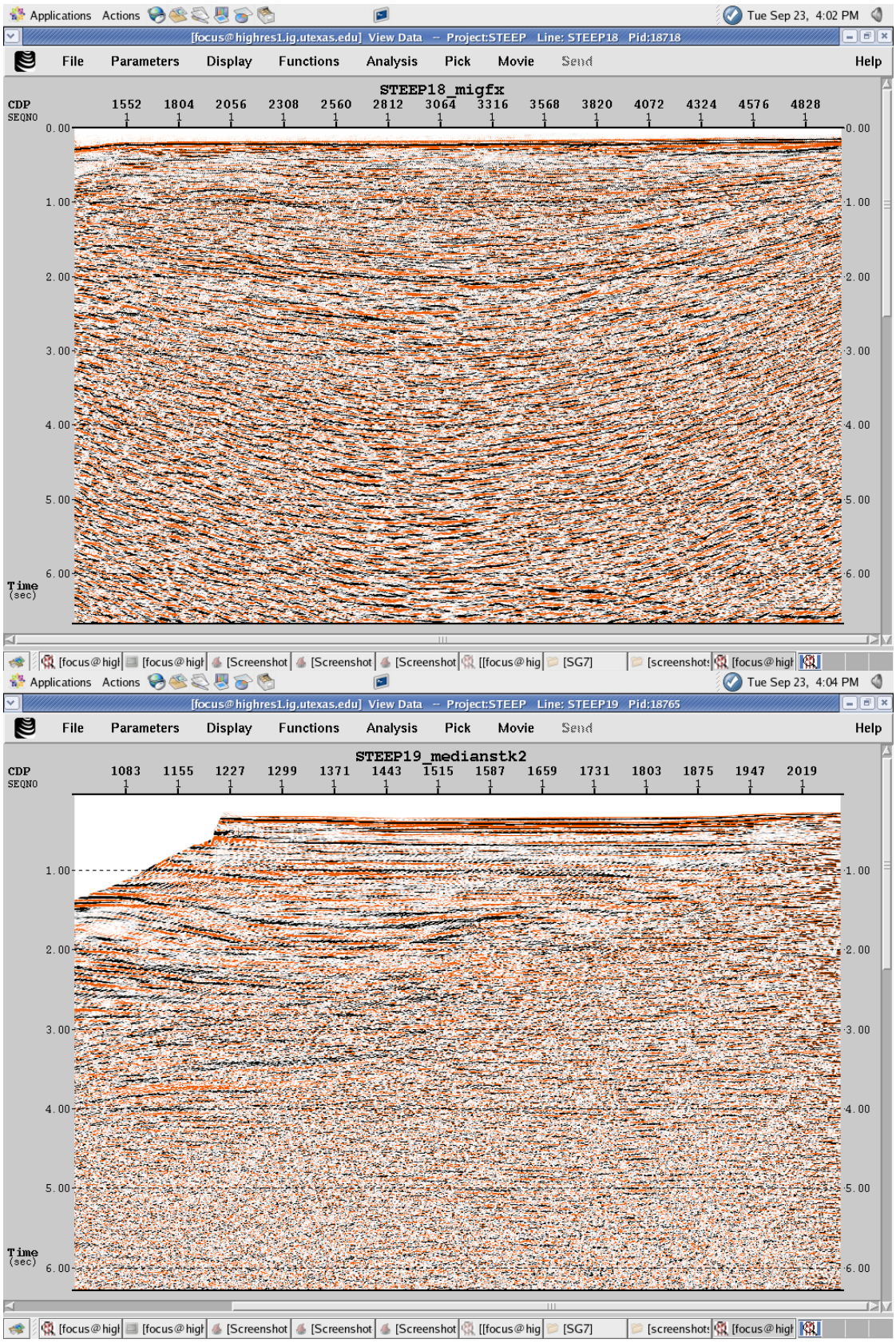
STEEP 13 and 7 showing Transition Fault and Khitrov Slope.



STEEP7B and 15 showing glacial strata on shelf near Bering Trough.



STEEP16 and 17 showing inactive structures transiting to active structures in Pamplona Zone.

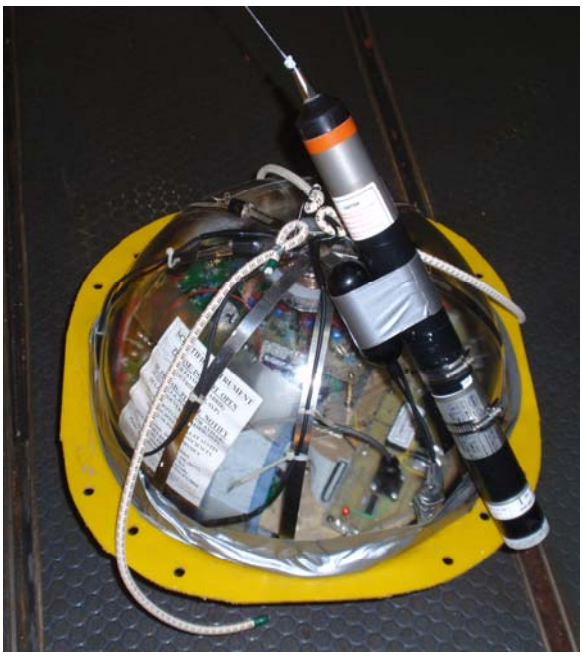


STEEP18 and 19 showing lack of faults away from near shore structure.

OBS Operations

Summary

Ocean Bottom Seismometers (OBSs) were deployed at a spacing of 15 km along two wide-angle profiles. 25 OBSs were deployed on STEEP01, with 21 of these instruments recovered by acoustic release, 2 recovered at the end of the cruise by their backup timed release, and 1 instrument was discovered during the cruise by the Kodiak Island Coast Guard station. 1 instrument was not recovered, and 1 instrument was recovered via its radio beacon 10 km from deployment position. Upon recovery most of the instruments had water inside their glass pressure spheres - the cause of this was ultimately attributed to the butyl tape. For the second deployment this tape was not used; instead instruments were sealed using a sealing tape provided by GeoPro. 18 OBSs were deployed on STEEP02, with 17 instruments recovered by acoustic release; 1 station did not release either by acoustic or backup release.



Original UTIG OBS prior to deployment.

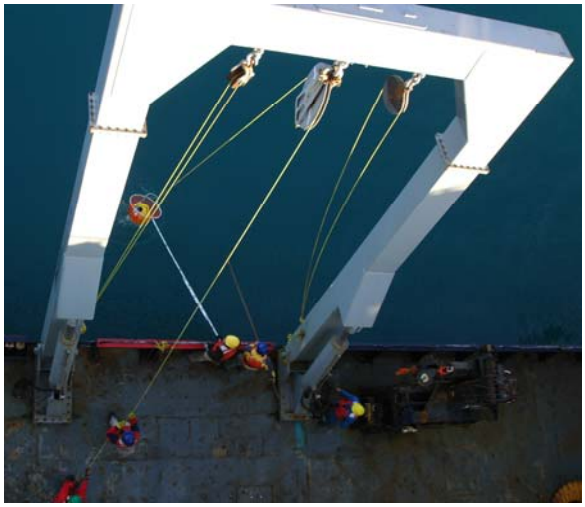
New GeoPro OBS after recovery.

Two types of OBSs were deployed during the cruise: the original UTIG OBS, and a new OBS purchased from GeoPro in Germany. The newer GeoPro OBS has many advantages over the UTIG OBS: it is quicker to prepare for deployment, it uses a smaller anchor frame that takes up less deck space, deployment was easier because of the attached rope, and recoveries were less stressful because of the ability to range to the instrument and acknowledge that it had released from the seafloor. The primary disadvantage of the GeoPro OBS was that its radio was not on a frequency that could be received by the bridge unit, nor could it be heard on the handheld radio until it was in visual sight. An additional disadvantage is its slower rise time from the seafloor - approximately 45 m/min compared to 60 m/min for the UTIG OBS.

Preparing OBS for deployment in the dry lab.

OBS staging area in the wet lab. Sign on flag reminds us to turn on the radio beacon prior to deployment.

OBS deployment.



OBS recovery.

OBSs were prepared by Anatoly Miranov and John Gerboc, with assistance by Gail Christeson and Beatrice Magnani; during STEEP02 some spheres were sealed by Sean Gulick and the watchstanders. OBSs were prepared in the dry lab and staged in the wet lab. The wet lab opens onto the main deck via a hangar door, thus allowing us to attach anchors prior to bringing the instruments onto deck. OBS deployments were made from the main deck using the starboard crane.

On OBS recoveries a transducer was lowered over the starboard side main deck adjacent to the dry lab, and the appropriate acoustic release signal was sent. Recoveries were made using the OBS net attached to a rope over the starboard A-frame block. The only difficulties encountered using this system was that occasionally the rope would come out of the block.

Timing Parameters for OBS Operations

Prior to the cruise historical timing parameters were used to estimate time length of OBS operations: ship transit speed of 10 knots, 20 minutes per deployment and recovery for ship

maneuvering and speed changes, release wire burn time of 10 minutes, and instrument rise time rates of 60 m/min.

On STEEP01 25 instruments were deployed over a time period of 24 hours, which was 2 hours faster than expected (average time for extra maneuvering/speed changes was closer to 12 minutes per instrument). 21 of the 25 STEEP01 instruments were recovered via acoustic release over a time period of 35 hours, which was 3.5 hours slower than expected. The extra time was spent attempting to release 4 instruments that did not surface, and in chasing down the errant instrument that was found via radio beacon 10 km from deployment position. Since the acoustic release signal should not travel 10 km we suspect that this instrument released early; this recovery proved the effectiveness of the RDF radio beacon.

On STEEP02 18 instruments were deployed over a time period of 17 hours - this was slightly faster than the expected deployment time even though there was a delay of 90 minutes waiting for a pilot at the entrance to Yakutat Bay. 17 of the 18 STEEP02 instruments were recovered over 37 hours, which was 5 hours longer than expected. The longer time period resulted from a combination of the slow GeoPro instrument rise times which added up quickly in deep water, repeated attempts to release OBS 214, and a long delay of several hours waiting for the pilot at the entrance to Yakutat Bay (delay was lengthened when the Langseth rescue boat sent to get the pilot had to be towed back to the ship by the harbormaster because of engine problems).

Approximately 24 hours at the end of the cruise were spent attempting to recover OBSs 214, 108, 121, and 122 on their backup timers. We were succesful in recovering OBSs 108 and 122.

STEEP01 OBS Deployment/Recovery Table

OBS	**Unit** **Depth**	**Latitude** *Deployment* *Recovery*	**Longitude** *Deployment* *Recovery*	**Time** *Deployment* *Recovery*	**Comments**
101	GeoPro 1 67 m	60.04832 60.04815	-142.93368 -142.97105	9/15/2008 13:34 9/23/2008 17:56	
102	UT 92-2 113 m	59.97497	-142.74158	9/15/2008 12:39	Recovered by Kodiak Island Coast Guard Station
103	GeoPro 2 110 m	59.90073 59.90053	-142.53333 -142.55066	9/15/2008 11:49 9/23/2008 15:17	
104	UT 92-7 103 m	59.82630 59.83248	-142.32600 -142.34144	9/15/2008 11:00 9/23/2008 13:44	
105	GeoPro 3 125 m	59.75173 59.75512	-142.11965 -142.12878	9/15/2008 10:08 9/23/2008 12:11	
106	UT 93-4 133 m	59.67685 59.68000	-141.91383 -141.92545	9/15/2008 9:14 9/23/2008 11:00	
107	GeoPro 4 131 m	59.60153 59.60355	-141.70942 -141.71660	9/15/2008 8:16 9/23/2008 9:44	
108	UT 94-7 146 m	59.52620 59.52202	-141.50673 -141.51595	9/15/2008 7:22 10/02/2008 1:29	Recovered on backup release
109	GeoPro 5 202 m	59.45022 59.45010	-141.30400 -141.30772	9/15/2008 6:24 9/23/2008 6:15	

110	UT 94-8	59.37425	-141.10200	9/15/2008 5:32	
	259 m	59.37645	-141.10413	9/23/2008 5:04	
111	GeoPro 6	59.29747	-140.90130	9/15/2008 4:32	
	157 m	59.29915	-140.90452	9/23/2008 3:43	
112	UT 94-10	59.22102	-140.70133	9/15/2008 3:39	
	154 m	59.29957	-140.78733	9/23/2008 2:44	10 km from deployment position; found by radio beacon
113	GeoPro 7	59.14348	-140.50228	9/15/2008 2:34	
	138 m	59.14307	-140.50977	9/22/2008 23:40	
114	UT 94-11	59.06598	-140.30448	9/15/2008 1:42	
	155 m	59.06598	-140.30450	9/22/2008 22:22	
115	GeoPro 8	58.98792	-140.10738	9/15/2008 0:47	
	145 m	58.98817	-140.10675	9/22/2008 21:04	
116	UT 94-12	58.90967	-139.91055	9/14/2008 23:46	
	151 m	58.91040	-139.90967	9/22/2008 19:47	
117	GeoPro 9	58.83198	-139.71502	9/14/2008 22:45	
	162 m	58.83185	-139.71407	9/22/2008 18:39	
118	UT 94-13	58.75300	-139.52117	9/14/2008 21:35	
	163 m	58.75315	-139.51920	9/22/2008 17:30	
119	GeoPro 10	58.67397	-139.32763	9/14/2008 20:37	
	250 m	58.67422	-139.32683	9/22/2008 16:17	
120	UT 94-15	58.59448	-139.13465	9/14/2008 19:10	
	145 m	58.59615	-139.13216	9/22/2008 15:06	
121	GeoPro 11	58.51500	-138.94283	9/14/2008 18:05	
	99 m				No recovery
122	UT 94-16	58.43555	-138.75140	9/14/2008 16:59	
	92 m	58.43918	-138.75476	10/02/2008 16:00	Recovered on backup release
123	GeoPro 12	58.35504	-138.56125	9/14/2008 15:50	
	110 m	58.35673	-138.56125	9/22/2008 9:22	
124	TW 4	58.27477	-138.37207	9/14/2008 14:45	
	135 m	58.27700	-138.37183	9/22/2008 8:10	
125	GeoPro 13	58.19400	-138.18283	9/14/2008 13:20	
	140 m	58.19460	-138.18397	9/22/2008 6:51	

STEEP02 OBS Deployment/Recovery Table

OBS	**Unit** **Depth**	**Latitude** *Deployment* *Recovery*	**Longitude** *Deployment* *Recovery*	**Time** *Deployment* *Recovery*	**Comments**
201	TW-4	59.77005	-139.73549	9/25/2008 1:02	
	142 m	59.77004	-139.73636	9/28/2008 2:40	
202	GeoPro 13	59.66931	-139.91251	9/24/2008 22:26	
	108 m	59.66283	-139.91905	9/28/2008 1:17	
203	UT 94-15	59.57938	-140.06943	9/24/2008 21:34	

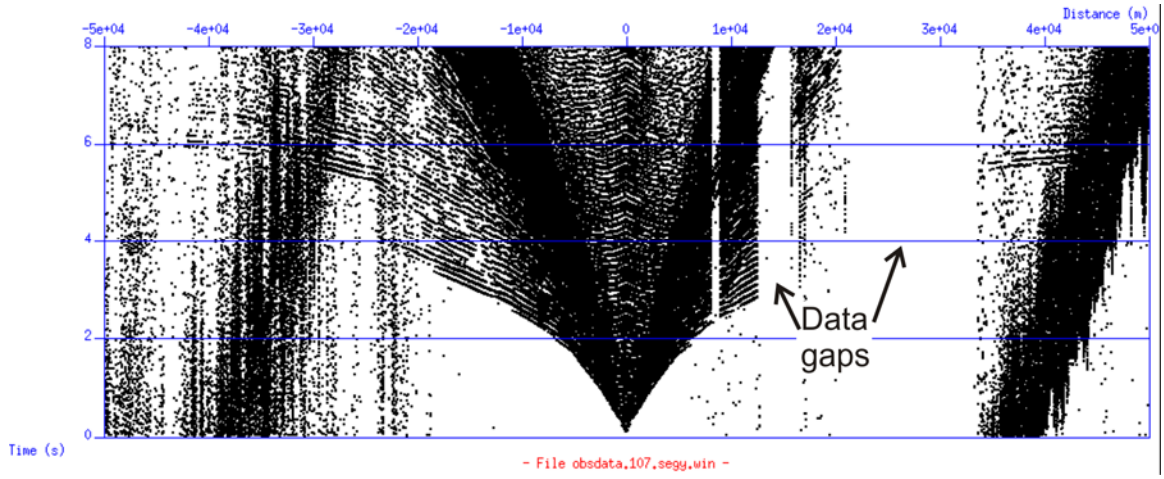
	125 m	59.57932	-140.07128	9/27/2008 20:35	
204	GeoPro 10	59.46710	-140.26268	9/24/2008 20:17	
	238 m	59.46833	-140.27043	9/27/2008 19:02	
205	UT 94-13	59.36600	-140.43602	9/24/2008 19:20	
	145 m	59.36678	-140.43975	9/27/2008 17:49	
206	GeoPro 9	59.26433	-140.60813	9/24/2008 18:23	
	146 m	59.26482	-140.60963	9/27/2008 16:30	
207	UT 94-12	59.16257	-140.77981	9/24/2008 17:14	
	88 m	59.16282	-140.78169	9/27/2008 15:13	
208	GeoPro 12	59.06033	-140.94975	9/24/2008 16:17	
	190 m	59.06062	-140.95311	9/27/2008 13:57	
209	GeoPro 8	58.95833	-141.11870	9/24/2008 15:22	
	652 m	58.95963	-141.12611	9/27/2008 12:27	
210	TW-9	58.85566	-141.28734	9/24/2008 14:20	
	1920 m	58.85592	-141.29447	9/27/2008 10:53	
211	GeoPro 7	58.75304	-141.45503	9/24/2008 12:45	
	3078 m	58.75812	-141.47317	9/27/2008 8:57	
212	GeoPro 6	58.64962	-141.62318	9/24/2008 11:42	
	3457 m	58.65294	-141.62344	9/27/2008 5:48	
213	UT 93-4	58.54640	-141.80343	9/24/2008 10:46	
	3492 m	58.54801	-141.79230	9/27/2008 3:14	
214	GeoPro 4	58.44290	-141.95078	9/24/2008 9:49	
	3511 m				No release
215	GeoPro 3	58.33919	-142.11459	9/24/2008 8:50	
	3513 m	58.34375	-142.12185	9/26/2008 21:22	
216	UT 92-7	58.23550	-142.27688	9/24/2008 7:53	
	3649 m	58.34375	-142.12185	9/26/2008 18:31	
217	GeoPro 2	58.13143	-142.43847	9/24/2008 7:01	
	3785 m	58.133117	-142.43755	9/26/2008 16:19	
218	GeoPro 1	58.02712	-142.59870	9/24/2008 5:56	
	3726 m	58.027722	-142.59663	9/26/2008 13:31	

Data Issues

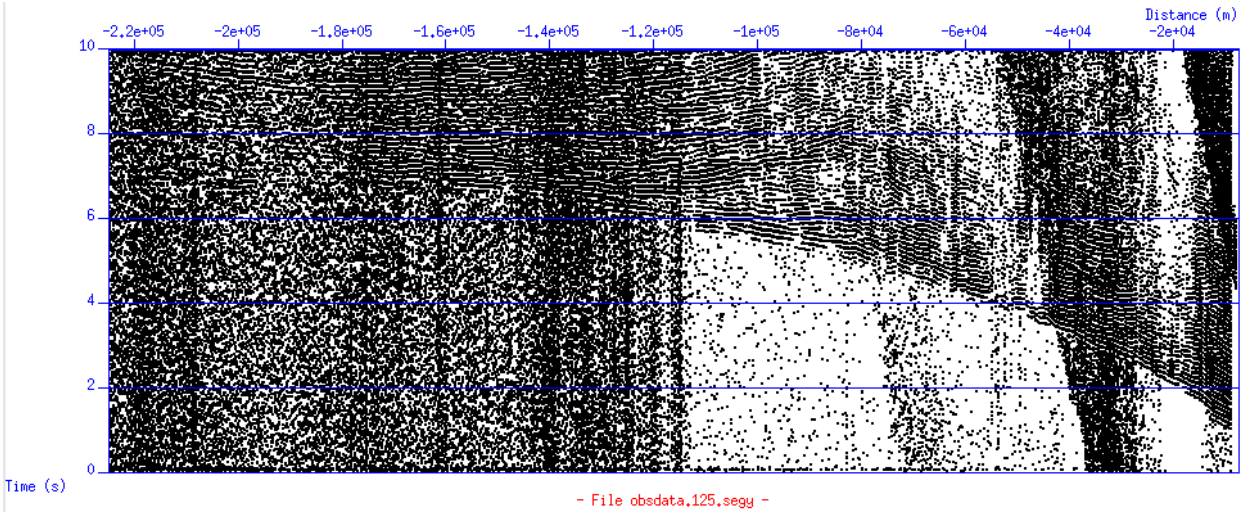
OBS	Comments
102	Recovered by Coast Guard, flash card corroded
104	Bad data vertical and hydrophone
108	Bad hydrophone, poor vertical
110	Bad hydrophone, poor vertical
112	Bad data vertical and hydrophone
114	Bad hydrophone
116	Poor hydrophone
118	Could not read flash card
120	Bad data vertical and hydrophone
124	Bad vertical
216	Bad bit on flash card?

Sample Record Sections

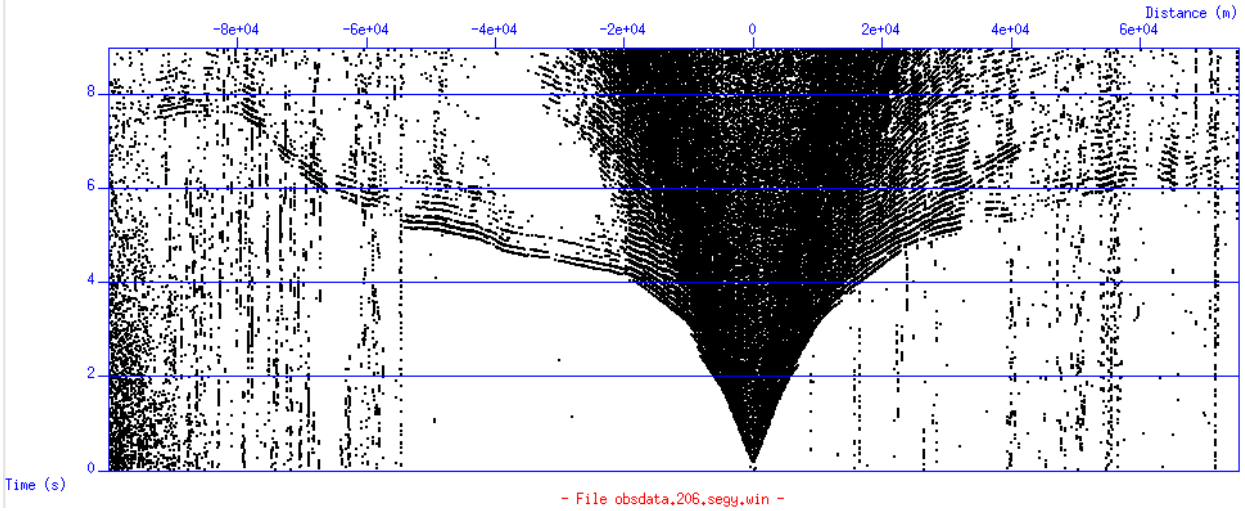
Below we show some sample record sections from the GeoPro OBSs on STEEP01 and STEEP02. At sea we had problems processing the UTIG OBS data, which was diagnosed as an error in the linux version of the OBSTOOL software.



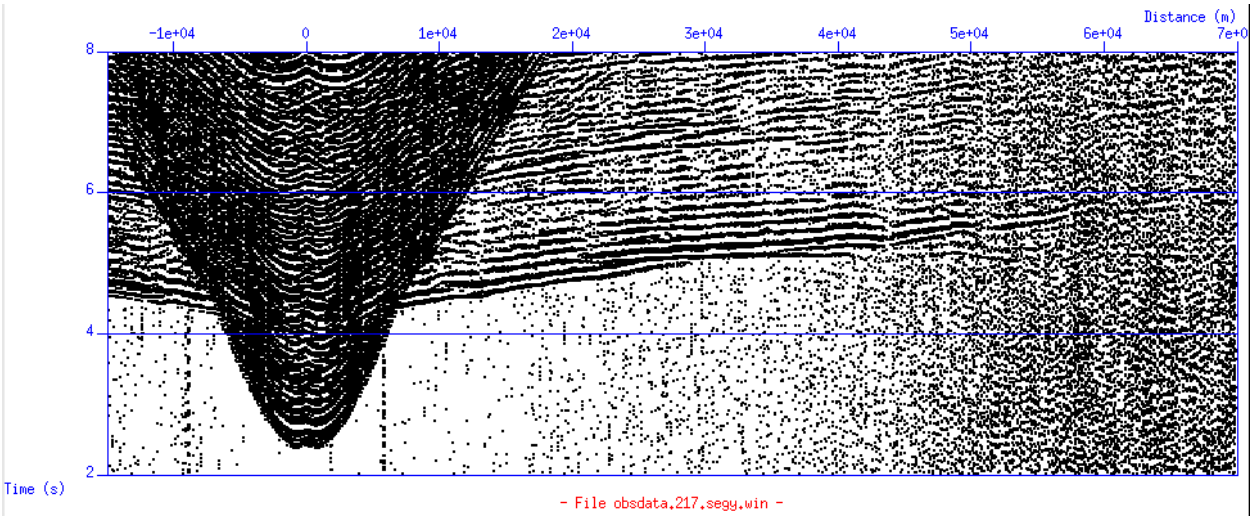
Data recorded by OBS 107, near western/central portion of STEEP01 profile. A short data gap occurred because of a marine mammal sighting, and a larger gap because of air compressor failure. Shot spacing is 50 m.



Data recorded by OBS 125, at eastern end of STEEP01 profile. Notice clear arrivals at offsets >200 km. Shot spacing is 50 m.



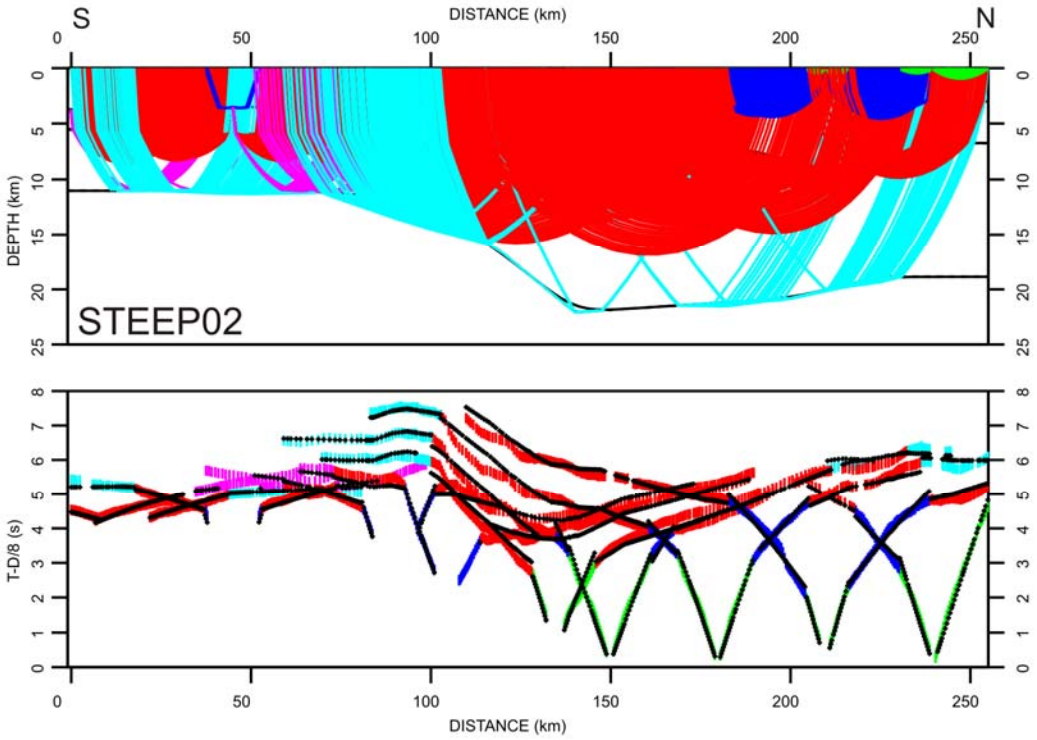
Data recorded by OBS 206, near northern end of STEEP02 profile. Shot spacing is 150 m.



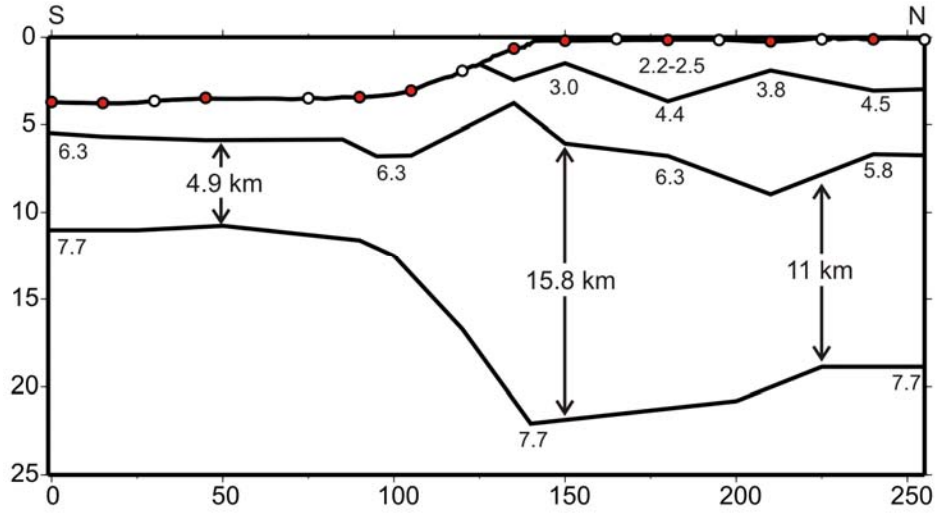
Data recorded by OBS 217, near southern end of STEEP02 profile. Shot spacing is 150 m. Note PmP triplication at ~30 km offset, and Pn arrivals 30-60 km offset.

Preliminary STEEP02 Velocity Model

Arrivals were picked on the STEEP02 GeoPro OBS instruments, and a preliminary velocity model was created during the cruise using Colin Zelt's Rayinvr code. This preliminary model suggests that the Yakutat block is thicker than oceanic crust and thinner than continental crust, and is consistent with a oceanic plateau origin for the block.



Ray-tracing of preliminary STEEP02 velocity model.



Preliminary STEEP02 velocity model. Only data from the GeoPro (red circles) instruments were used for model creation.

Shipboard Geophysics

Summary

In addition to seismic reflection and refraction data, we collected multibeam bathymetry, subbottom profiler, magnetics, and gravity data during all lines and transits. The equipment specifics are a Kongsberg EM120 deep water multibeam, a Geometrics 882 magnetometer, a Bell Aerospace BGM-3 Gravimeter The bathymetry data was ping edited during the cruise using Caris software and will be gridded and integrated with existing bathymetry postcruise. We collected a total of 5 XBT drops, the sound-velocity profiles of which are used to calibrate the bathymetry data. The Knudson 3.5 kHz subbottom profiler data were written out as SEGY for future use. The magnetics data were archived for future processing and modeling. The gravity data which were logged every second are being corrected using base station ties at LDEO and will be sent to the PIs postcruise.

Chief Scientist Daily Log

09/10-09/12

We sailed from Astoria, Oregon around 11:30 on the 10th of September for a 4-day transit to the field area. Seas slightly rough once we crossed the bar and a number of the scientists and students were ill. Most were recovered within 8-12 hours. OBS technicians spent the first part of the transit getting the wet/dry lab set up and starting to prep instruments.

09/13

Due to Hurricane Ike coming ashore in Galveston, Texas, Chief Science Officer Robert Steinhouse is disembarking to go home to repair damages to his house in Texas City. He disembarked at the entrance to Dixon Strait at 18:30. OBS Technicians, Anatoly Mironov and John Gerboc, with the assistance of co-chief scientist Gail Christeson and chief-scientist-in-training Beatric Magnani, stated final preparations for OBS to be launched on 09/14. Prepping the first OBS (UTIG style) took four hours, and thus there was concern about having them ready in time for deployment. The OBS team however seems to be increasing their pace. The Geoprobe style OBS take less time to prep. Since the deployment plan will be alternating styles of OBS the team is prepping them in order. Watches are scheduled to start at 0400 on 09/14 local time and the first OBS deployment is expected at 0600. News from the land operations is that PI Harm van Avendonk and IRIS tech Willie Zamora are unable to fly by helicopter to install the instruments due to poor visibility. Plan is to continue offshore operations at pace and if the land instruments are not installed by the time the OBS and MCS deployments are completed than an non-OBS line will be acquired prior to starting STEEP01.

09/14

OBS deployments start at 05:30. At the start of deployments the OBS team had seven instruments ready and throughout deployments there were able to keep up and even sometimes get ahead. Deployments were done roughly every hour. OBS (UTIG style) 114 and 118 inadvertendly were launched without their radio beacons on so those two OBS will have to be recovered with the aid of the strobe light alone. All other OBS were

launched without incident and efficiently. Land team has been still unable to fly due to visibility. Co-chiefs devised a new plan to shoot MCS only for ~36 hours in order to give the land team more time to get the instruments deployed.

09/15
OBS deployments were completed at 05:30 and streamer operations started. Two kilometers of Streamer 2 were deployed along with the tail buoy to the aft. One section changed out along with one can. All six kilometers from Streamer 1 were deployed changing out 1 can and one section. Discovered some of the supposedly refurbished cans were in fact old bad cans that may never have been sent for repair. Streamer operations completed at 20:00. Plan is to steam south and turn inline with STEEP09 such that we cross the waypoint sufficiently after daybreak tomorrow for the required 30 minute MMO observation window.

09/16
Gun deployments went slower than expected due to the complexities of changing the string separation from 8 to 6 m and thus it was clear operations could not start at daybreak. At 06:30 lead sound source technician noted that the float on the streamer was too close to the gun strings suggesting that the near offset (length of the tow leader) was incorrect. After calculating it using GPS it turned out the length was off by 50 m. We opted to break off of the run in for STEEP09, turn back south, and do deck operations while heading south. We removed the Chinese finger, let 50 m more of leader out, and replaced the Chinese finger. This brought the near offset to 164 m. Then the gun string deployment was completed by mid morning as we turned back onto STEEP09. We started acquiring STEEP09 on the run-in at SP 711 at ~11:00. Shortly after starting the line we had a power down due to a Dall's Porpoise sighting at 11:36. We ramped up again at 1954 and we reacquiring data with the full array by 12:17 at shot 911. Line completed at 22:40 local. We turned to port on an inside turn and called the transit line STEEP15. STEEP15 was started at 22:49 local at SP 996.

09/17
STEEP15 completed at 02:04 local at SP 1585 with a port turn onto STEEP13. STEEP13 started at 02:16 local at SP 1007. From 03:01 to 03:38 streamer was towed at 12 m instead of 9 m to keep it level. STEEP13 was complete at 18:53 local at SP 3727. Outside turn to starboard and start of STEEP07. STEEP07 started at 22:52 local at SP 922.

09/18
During the course of the line STEEP07 three different guns (SIG04, SIG20, and SIG22) were turned off due to consistent misfires and the spare 180 cu in guns on Strings 1 and 2 were turned on. At 08:49 and 09:20 local string 3 were briefly powered down for quick maintenance to tow point/rope. Due to rough weather streamer came to near surface at ~10:30 local time and would not come back down. Also due to rough weather the PAM wrapped itself first around String 2 and then the streamer leader. The magnetometer wrapped itself around String 4 and we freed it and brought it on deck. Decided to end STEEP07 at 11:54 local, SP 2830 and turn around in hopes of getting streamer to

submerge. Chose to turn to starboard in hopes of freeing PAM from streamer however during the turn PAM ceased working. At 16:04 local and SP 2690 we started STEEP07a with the streamer mostly at depth. However quickly the streamer resurfaced and we ended the line with no useful data at SP 2726. Continued along the STEEP07 transect trying to get the streamer to sink. At 21:10 local the front of the streamer was down and line STEEP07B was started at SP 3338. Fought to keep the streamer down for the line which only occasionally worked.

09/19
Decided to end the line at 02:22 local. Plan was to turn into the sea and see if conditions would be safe enough to recover String 2. Conditions however were not safe enough and so instructed the bridge to find a more northerly or northwesterly heading that was a smoother ride and if the cable came down we would start acquiring data again. Turned out that due north resulted in a smoother ride and the S-turn brought the front of the cable down. We were able to get the at least half of the cable down and thus decided to shoot a line along the north heading that crosses STEEP01. This line was called STEEP16 and started at 03:44 local. STEEP16 shot with the streamer at ~14 although near birds 12 and 13 it frequently tried to come up but still better than on the previous two lines. STEEP16 ended at 07:27 due to shallow water and turned to port to shoot STEEP17 crossing STEEP01 in a western orientation and setting up to turn onto the line. PAM was easily recovered by hand and therefore must have freed itself during the night. Gun maintenance was done during the line, including pulling in String 2 and repairing two guns (360 and 220 cu in, respectively). STEEP17 was ended at 10:47. Stayed on same course while String 2 was deployed. Turned to starboard onto STEEP19, which was started at 12:30 local. STEEP19 completed at 13:52 local with a starboard turn to STEEP18 which heads towards the start of STEEP18 but stays over 3 nm from the shoreline. STEEP18 started at 13:53 local. Birds, which had been at 14 m for all of STEEP19, were brought up slowly during STEEP18 0.5 m at a time to 11.5 m by 15:39. Magnetometer was redeployed and logging by 17:48 local. STEEP18 ended at 18:04. Turned starboard onto STEEP01 which started at 18:17. Streamer slowly brought up to 9 m by 20:01 local as we shot down STEEP01.

9/20
STEEP01 speed over ground very slow for the first third although the streamer well behaved. Marine mammal siting at 8:57 local which caused a ~7 minute powerdown (SPs 2880-2896) and thus we were able to go right back to full power on the guns at 09:04 local. Compressor failure at 09:56 at SP 2966. We left on one gun and once the compressor was back up we ramped up. Ramp up complete by 10:38 at SP 3112. Compressor failure again at 11:05. Decided to end the line once we realized the repair of the valve would take some time. STEEP01 restarted at 12:10 local with ramp up complete at 12:54 local. SOL officially therefore at SP 3448 and time 12:55.

9/21
Shooting the second part of STEEP01. Power down for marine mammal at 13:55 at SP7679. Ramp up started at 14:12, SP 7732. Missed shots 7728-7731. Marine mammal sighted again and given the issue how long the re-ramp up would have taken and the

proximity to the end of the line we chose to end the end at 14:25, SP 7766. Maggie recovered at 14:34, Airguns at 15:27, and Streamer at 20:51 local times. Started recovering OBS. First OBS (#125) recovered at 22:37.

9/22
Continuing to recover OBS along STEEP01. Successfully recovered OBS 124 and 123. Had to abandon OBS 122 and 121 due to no response. There was some question of the power to the deck unit in the following OBSs, which were recovered successfully, so we will return to these two at the end of the experiment. Also successfully recovered OBS 120-113. OBS 112 was not found on recovery (UTIG type) however as we prepared to transit to next site, the OBS was heard on the RHF 10 km away! Found and recovered this OBS. OBS 111-109 all successful.

9/23
Recovering OBS: 108 never appeared as was abandoned. 107-103 were recovered successfully. 102 was also abandoned and 101 successful. XBT done at 10:15 local. Transit to southern end of STEEP02. OBS deployments on STEEP02 started at 21:56 local.

9/24
OBS deployments on STEEP02 continuing. Entered the bay between OBS 204 and 203 and went over a 22 m sill. Brought pilot onboard after OBS 202 was dropped. Airguns were deployed by 19:29 with a marine mammal gun started well before sunset. Ramp up complete by 20:35 and STEEP02 OBS only started at 21:12 after we turned. Maggie deployed by 21:21 local.

9/25
Continued shooting STEEP02 OBS. Turned off String 4 Gun 8 (60 cu in) at 08:26 local; not allowed to turn on spare due to 6600 cu in limit.

09/26
Finishing shooting STEEP02 OBS. Maggie off at 01:01 and on deck at 01:07 local. EOL STEEP02 OBS at 01:07. PAM onboard at 01:12 local. All guns recovered by 02:45 local and transiting to site of OBS 218. OBS 218-215 recovered successfully. OBS 214 never responded to transducer. Weather quite rough (4 m seas) and thus wondering if signal is not reaching OBS. Decided to abandon recovery of OBS 214 and return at automatic release. OBS 213-212 recovered.

09/27
Continuing to recover STEEP02 OBS. OBS 211-204 all recovered. Drove over sill into Yakutat bay 0.1 nm to the west to survey depths at 11:44 local (+5 ft tide). OBS 203 recovered. Rescue boat launched to go collected Robert Steinhaus and Pilot at 13:28. Pilot onboard at 15:44. OBS 202 and 201 recovered. OBS recoveries complete by 18:40. Steamed out of Bay and start streamer deployment at 22:45 local.

09/28

Continuing streamer and gun deployment. Finished deploying 2 km of Streamer 2 at 12:29 local. Streamer optics problem at 1:11 local that appeared to be at Can 15. Tried numerous different cans at position 15 and tried removing streamer section to the head of Can 15. Checked S/N for can that would not power up and discovered we were on can off. Put back on the streamer section and original can at 15 and pulled back into previous can. Upon inspecting the streamer aft of can 15 one ferrel was noted to be missing at 03:55 local. Ferrel replaced at head of section 14 and streamer powered up successfully at 04:18. At 06:14 local a bad coil was discovered in bird position 5. Coil on streamer section towards head was also bad. Changed out streamer section at 06:56 local, which was completed by 07:38 local; all birds talking. Started a slow turn to port to prevent going to the Bay too soon. Streamer deployed up through Bird 2 when the section with torn skin was reached. Changed this streamer section from 08:24 to 08:57 local. Ship turn back to starboard to head back to point of entry into Bay. Discussion with the LDEO ship operations occurred at 09:00 local and permission was received to follow plan for acquiring data in Yakutat Bay. Turning to port to line up to enter Bay at 11:01 local. Streamer deployment completed at 11:41 local. Deployed gun strings 1 and 2 by 12:32 local. Crossed sill at 12:48 local and set birds to 6 m depth due to westward crab from current outside the Bay and crossed sill on eastern side of gap. Once sill crossed lack of current inside the Bay reduced the crab angle. All guns deployed by 14:17 local and streamer returned to 9 m depth. Maggie deployed at 14:40 and PAM deployed at 14:52 local. Turned to starboard to line up for 180 degree turn onto line at 03:07 local. Otter spotted and thus delayed start of mitigation gun. Mitigation gun started at 16:46. Ramp up started at 16:54 and 180 degree turn started at 16:58 local. Ramp up complete at 17:24 local, halfway around turn. Starting line STEEP02 MCS 17:41 while still in turn to make sure we cross the water depth change in case this is location is the Dangerous River Zone fault. Lined up by 17:47 on STEEP02 MCS with shot points correctly numbering. Pilot off by 18:39 local. Turn ended at 18:47 local. Raised birds to 6m at 21:40 local and crossed the sill leaving the Bay at 21:49 local. Returned birds to 9m at 22:26 local.

09/29
Continuing to shoot STEEP02 MCS. All well until compressor failure at 12:18 local, SP 2017. Airguns restarted 12:21 local, SP 2021. Started turning to starboard towards STEEP11 at 1840. EOL STEEP02 at 18:41 local. Line was ended within turn and STEEP11 was started at 18:47 local. Turn was complete at 19:13 with streamer straight at 20:19, SP 616. Sank birds to 10 m at 21:36 due to rough weather; sank birds again to 12 m at 22:27.

9/30
Continuing to shoot STEEP11. Raised birds to 10 m at 01:46 as weather seemed to moderate although still too rough to use normal depths. Powered down String 2 gun 8 at 7:38 due to no fires- volume now at 5720 cu in. Streamer rising towards surface due to weather worsening at ~8:08; set bird depths to 13 m but only the front is down. Speed up driving by line tension to try and bring streamer down. Raised tension to 4500 lbs at 08:24 and succeeded in bring it down starting at 08:22; left streamer at 13 m to avoid problem. Weather moderating and streamer brought up to 11 m at 12:05 local. Mammal power down at 14:22. Missed shots 3542-3644; mitigation gun only 3645-3668. Guns

returned to full volume at 14:27, SP 3669. At 17:44 local the Maggie brought on board. EOL STEEP11 at 17:55. PAM on deck at 17:56 local. All guns onboard by 19:08 local. Streamer onboard by 23:05 local. Starting transit to OBS 214 to be there in time for its automatic release.

10/01
Arrived at OBS 214 at 09:46 local. Tried talking to it with the deck unit but it was never clear that we were receiving true responses. After ~45 minutes of trying and ~35 minutes after the automatic release surface time we gave up and transited on to OBS108 at 10:51 local. On the way to OBS108 site, the bridge heard the OBS on the surface via the RHF at 17:19 local. OBS 108 onboard by 17:29. Heading to OBS 121.

10/02
Arrived at OBS 121 at 03:30 slowing down. Transducer in the water at 04:04 and sending signal to OBS 121. Never received any responses that made very much sense. Brought transducer back on board at 04:16 local. Plan was to wait until the automatic release at 0600. OBS never was observed at the surface nor were any attempts to communicate with it reliable. Abandoned OBS at 06:50 and headed to OBS 122. 1.3 nm from the site OBS was heard on radio. Recovered OBS 122 at 16:00. Deck secured and started transit to Astoria.