FAIM

Far-offset Airgun Imaging of the Mantle

Cruise Report EW-0106 R/V *Maurice Ewing*

San Juan, Puerto Rico to Saint George, Bermuda

May 31 – June 30, 2001

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*** WARNING ***

This report contains graphic depictions of beautiful and unique seismic data that may be overexcite some sensitive readers.

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SUMMARY

This report documents R/V *Maurice Ewing* cruise EW-0106, an expedition aimed at seismically imaging oceanic lithosphere upper mantle using airguns and ocean-bottom seismometers (OBSs). This experiment was funded by NSF grant OCE-0002417.

This cruise took place in June of 2001 in a region approximately 200 nautical miles south of Bermuda, on the edge of the Sargasso Sea. The experiment tested new applications of old technology (using airguns to image the mantle) and old applications with new technology (using the new Scripps L-CHEAPO 2000 OBSs in a refraction experiment), and so there was a sense of excitement to accompany the generally very calm seas typical of this part of the world in the spring. In the end, both tests were successful. The new instruments performed extremely well, with 100% instrument recovery on 20 deployments (5 more than had been requested), and 100% data recovery on all but one instrument. Even more importantly, the data are excellent and very exciting. Our results should pave the way for future active-source seismic experiments focused on directly imaging upper-mantle lithospheric properties.

<u>Scientific Goals.</u> The scientific goals of this experiment involve inferring oceanic mantle dynamic processes from the seismic structure of the upper mantle. At a mid-ocean ridge, upwelling mantle undergoes two processes that should fundamentally alter its seismic structure: melting and corner flow. Decompression melting of upwelling mantle begins at some depth between 50 and 100 km (we don't know where, exactly) and continues to some depth near the crust mantle boundary. The mantle is made of different minerals, and these mineral start melting at different depths and melt at different rates. The extracted melt, which forms the crust, thus has a different chemical composition than the mantle. Mantle that has had melt extracted from it, residual mantle, thus has a different chemical composition than it did before melting; it is depleted in the crustal components and will thus also have a different seismic velocity. In theory, we should be able to relate seismic velocity to degree of melting. The relationship is not direct, however, because of the effects of corner flow. Upwelling mantle must "turn the corner" from vertical to horizontal flow as the plates spread apart. The strain involved in turning the corner tends to align the olivine grains in the mantle rock. Olivine is the predominant mantle mineral, and because olivine is an anisotropic mineral, the corner-flow process will impart a particular seismic signature to the mantle, causing it to propagate seismic energy faster in one direction than the other.

How these two processes, melting and corner flow, actually work at a spreading center remain major unknowns that reflect our incomplete knowledge of a number of fundamental things, such as the temperature of the mantle, the latent heat of melting, the mode of melting, deformational mechanisms under various conditions (wet, dry, with and without melt), and so on. It is likely, however, that these process leave behind vertical seismic structure — some kind of layering — that is characteristic of the processes. Mantle upwelling directly beneath the spreading axis will melt over the entire melting interval, and so this mantle will be quite depleted in crustal minerals. Mantle that rises off-axis begins turning the corner before it has risen through the entire melt

column and so is less depleted. In general, melt depletion should decrease with depth in the upper mantle. Mantle upwelling beneath the spreading axis undergoes major strain as it makes a sharp turn near the surface, ending up somewhere near the top of the mantle, just beneath the crust, as it spreads off axis. Mantle rising off axis begins turning deeper and more smoothly, and so it ends up deeper below the crust, and it is not strained as much by the corner flow. Thus there should be both compositional and anisotropic vertical gradients in the residual mantle, off axis, that are characteristic of the patterns of melting and flow at a mid-ocean ridge. The goals of this experiment are to image these seismic gradients within old oceanic lithosphere, enabling us to infer mantle dynamic processes at a spreading center.

Technical Goals and Shooting Strategy. Our scientific goals require recording of seismic energy from closely spaced shots at source/receiver distances of many hundreds of kilometers. The only practical and safe way of doing such an experiment is with airguns, but airgun shots have never been recorded at these source/receiver offsets over oceanic lithosphere. A fundamental technical goal of this experiment is thus figuring out how airgun technology can be used to image mantle structure. Sound energy travels much slower in water than in the crust or mantle, so it is common for water-borne energy from a previous shot to arrive at a recording instrument at the same time as energy from the shot of interest. When this happens, the desired signal is buried in the high amplitude water-borne energy, which is called previous-shot noise. Our main technical premise is that long time intervals between shots will enable all of the seismic energy traveling in the water column, generated by one shot, to propagate beyond the recording array before the next shot goes off. A main component of our experiment thus boils down simply to waiting a very long time between shots.

The velocity structure of the upper mantle is very poorly know, and a reasonable assumption is that the vertical velocity gradient is small. This implies that seismic energy propagating from the surface through the mantle and back to the seafloor will travel much farther horizontally than vertically. For example, seismic energy that has penetrated 40 km into the mantle may travel 800 km horizontally before it reaches the seafloor. For this reason, we need to record shots at very large shot-to-receiver distances. It would take seismic energy traveling along that path through the mantle about 1.5 minutes to go from the shot to the receiver 800 km away. The energy from that same shot traveling through the water, however, would take about 10 minutes to reach the instrument. We therefore would need to wait 10 minutes between shots if we want to ensure that no noise from a previous shot clouds our seismic recordings. In addition, if the velocity gradient is small, the amplitude of the seismic energy that has traveled through the mantle is predicted to be quite small. Thus, even if previous shot noise is dealt with, some strategies are needed to increase the signal-to-ambient noise ratio of the data.

The two most obvious and effective strategies for increasing the S/N ratio are maximizing source strength and stacking multiple shots at a single location. The first of these strategies involves selecting a collection of guns that maximizes the volume for the source array while maintaining an acceptable source signature. The second strategy is somewhat more complicated because of the competing goals of (i) large source/receiver offsets, (ii) multiple shots at shot points, and (iii) a close spacing between shot points, and also because the optimal number of shots to stack is uncertain. A close spacing between shot points is as important as noise free data when recording a refraction profile, because the trace-to-trace coherence between signals is the primary means of identifying seismic events. If traces are too far apart, then lateral heterogeneities, such as seafloor roughness, can disrupt that coherence to such an extent that it is not possible to confidently identify seismic phases. A seismic ship must keep moving, or risk tangling the airguns, and will cover a distance of ~1 km in the time it takes for the waterborne energy to clear most of the 800 km array. The shooting strategies we considered and used are discussed in the Science Operations section of this report.

The data collected during this experiment demonstrate the effectiveness of airguns for upper-mantle studies, and provide a wealth of information on how such an experiment can be optimized. We thus feel that our technical goals have been achieved. Our scientific goals follow from this technical success, and our initial assessment of the seismic data suggests that a great deal will be learned about the mantle dynamic processes occurring at mid-ocean spreading centers from a careful examination of these data.

Science Complement

<u>Science Party</u>

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<u>Ship's Science</u>

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John DiBernardo	PSSO	Cover photo, far right
John Byrne	Gunner	Cover photo, 2nd from right
Ropate Maiwiriwiri	Gunner	Cover photo, 4th from right
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Dave Wolford	2nd Mate	
Richard Thomas	3rd Mate	
Matthew Tucke	1st A/Engineer	
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Matos, Francisco	Electrician	
Smith, John	Steward	
Taylor, Kelly	Cook	
Moqo, Luke	Utility	
Tomas, Kelly	A/B	
Bailey, James	A/B	
Mecketsy, Meredith	A/B	
Ruegg, Bryan	A/B	
Walker, Wakefield	A/B	
Sypongco, Arnold	O/S	
Uribe, Fernando	Oiler	
Florendo, Rodlofo	Oiler	
Wyatt, Richard	Oiler	

Narrative

May 29 (Tue)

All of the science party are in San Juan. We had planned on staying on board, but the party from the previous cruise (a hydrosweep test cruise, Panama-San Juan) is still on board, and we book rooms in a nearby Hotel where the Scripps folks have been staying. The 10-box Georgia Tech shipment (primarily 4 computers) is delivered to the ship late in the day. We set up the 2 Unix machines, verify that they have survived the trip, and head to the hotel by 16:30. We have a relaxing swim at the beach.

May 30 (Wed)

Complete setting up and securing the computers in the main lab. The Scripps' OBS van is scheduled to be delivered at 10:00, but doesn't arrive until nearly 16:00. The ship's crew are dealing with several issues all day, including the main fantail hatch, which leaks, and an engine part which has to be machined in San Juan. The 1st mate and the deck crew remain on board until 19:00 to help us unload the OBS van. All of the Scripps' boxes, 5 of 8 instrument racks, the anchors, and 5 of 8 float racks are craned down by 19:00. The crew was willing to stay and finish, but we stopped at 19:00 nevertheless to allow everyone to have a nice last night in port.

May 31 (Thu)

Received word early that the "refurbished" hatch would arrive at 08:15, and so we began craning down the remainder of the OBS gear at 07:30. All gear was down by the time the hatch arrived at 08:50. The starboard A-frame crane was used to stack the instrument racks two high, and these pairs were bolted together and positioned along the starboard waist deck as four pairs all laterally bolted together and strapped to the deck with ratchet straps through eye bolts. Three float racks were similarly secured on the fantail lengthwise just starboard of the A-frame. Each instrument was removed from the rack, and release mechanisms were installed and the electrical connectors to the mechanisms were connected. The anchors were secured on two pallets of 12 each starboard of the streamer reel, secured again with ratchet straps to eye bolts in the deck. All OBS and other science gear was secure by 13:45. The pilot arrived at the scheduled time of 14:30, and we set sail under partly cloudy skies and a brisk wind out of the northeast.

June 1 (Fri)

A quiet day of steaming through very calm seas. Science party settles in, and everyone is feeling well.

June 2 (Sat)

Another day of transit in calm seas. Several movies are watched. Arrive at the first point around 23:00 and conduct the first "rosette" test of 12 acoustic releases housed in a single frame lashed to an OBS anchor deployed using the starboard A-frame. Water depth was 5170m, and the rosette was lowered to 4800 m. The EdgeTech transducer had been mounted in the ships hull well while in port, and the signal, which has to propagate through a steel plate, is somewhat weak from this well. In particular, it was noticed that the return signal was noticeably weakening with depth. At 4800m, all of the releases responded to commands, but release #5 appeared "flaky". The EdgeTech deck unit was clipped in to the ships hull-mounted 12 kHz transducer, and the signal strength problem went away. A burn command was issued to the 12^{th} release, and upon recovery was found to have burned on a single release command. Also upon recovery, the winch wire was found to have a tightly tangled crimp at about 20m of wire out. This was no doubt due to the fast winch rates that were used early on in the decent when the wire-line did not yet have sufficient weight.

June 3 (Sun JD154/155)

An OBS (*Sam*) was quickly assembled on deck and deployed for a short test line, again from the starboard waist deck with the A-frame. We pinged to this instrument as it fell and landed on the bottom and found that it had a descent rate of ~52m/minute – similar to previous test deployments prior to this cruise. Assured that the instrument was happy, we proceeded to a point ~40 km to the SSW and deployed an array of 4 airguns off the aft gun booms in the same configuration planned for primary shooting.

The test line consisted of shooting from 40-km range toward the instruments, and included a single 360 degree circle at near 30 km range. The test shooting is designed to test several things: 1) that the instruments perform at depth; 2) that the firing system can handle long shot times; and 3) that the guns most likely to tangle on tight turns (the aft guns) can handle turns of up to 10 degrees per minute. The line was shot in excellent weather. Gun tangling was not a problem, but the Chief gunner Johnny DiBernardo decided to rig the center guns 10 and 11 closer to the centerline of the ship as a result of the test circle. It was also found out that the Spectra seismic acquisition software did not like shooting circles on standard point-to-point lines. When the system realized we had crossed back on ourselves and were proceeding back in toward the origin waypoint, it stopped firing. Firing could be restarted by reversing the line. This process is a bit of a pain, and new mode of shooting needs to be found for shooting the circles.

We stopped shooting, pulled the guns, and issued the release command for *Sam_test* 18:43Z (14:43L). A double ping from *Sam_test* seven minutes later indicated that the instrument had been released. The rise rate was ~50m/minute. The instrument was sighted on the surface at 20:31Z, and was on deck by 20:53. We then began the second rosette test while data was being extracted from Sam_test and the instrument was prepared for redeployment in the same spot.

From Dave Willoughby's Progress Report #1: "The data logger appeared to work flawlessly, and all the shots that we checked looked good. The greatest amplitude was about ±1,000,000 counts on the hydrophone for the near shots, and the lowest was about ±12,000 counts on the seismometer for the most distant shots (full scale is just over ±5,000,000 counts). These signal levels were low enough that Dan and Jim decided that it would be best to raise the gains on all the instruments from X8 and X64 to X32 and X256 on the hydrophone and seismometer channels, respectively. Clipping of the water wave on near shots is not a concern, and raising the gain will ensure that the more critical shots at the longest ranges will still be well resolved."

The first instrument, *Sam*, of the main experiment was deployed at 21:38L and was on the bottom at 23:19 local, bringing a long first day to an end.

June 4 (Mon JD155/156)

The issue of clearance to work in Bermudan waters had come up in port on Wed May 30 when the captain asked for bounding points of the science operations. He noted that we didn't have clearance to work in Bermuda waters and that a majority of the proposed work would be conducted within the 200 nautical mile limit of Bermuda. Contact with Lamont revealed that the office there had been confused by the ship-time request form, which, under the field for clearance, indicated a "N" followed by "Bermuda", whereas the form should have included a "Y" followed "Bermuda". The Lamont office immediately began moving the clearance permit through the system, including expediting things at the U.S. State Department, which ultimately obtains the official clearance from their counterpart office in London, and making direct contact with the relevant Bermuda authorities responsible for making the de facto decision to permit the work.

By Friday June 1, we had informal assurance from John Diebold at Lamont that the Bermudan Deputy Governor's Office and the Bermuda Department Agriculture and Fisheries had no problem with the proposed survey and would be issuing a permit very soon. However, these assurances were not sufficient for the captain to allow us to begin conducting science operations of any kind in Bermudan waters. We were frustrated but optimistic about the soon-to-arrive clearance, and rearranged the deployment plan and pattern such that after the first deployment, *Sam*, we sail to the western end of the line, deploy the westernmost instruments, and then deploy a pair of instruments another 123 km west of these - effectively shifting the line westward by one recording station. This change cost ~10 hours and was premised on the likelihood of receiving the clearance by Tuesday or Wednesday, at which point all of the western instruments outside of the 200-nautical-mile-radius Bermuda-EEZ circle would be complete. We steamed to the western end of line and deployed *harp* and *guinness*.

On Mon June 4 a fax was received from Lamont. This fax was a copy of a faxed memo that had been sent on Friday from John A. Barnes, Director of Bermuda Agriculture and Fisheries, to Peter O'Brian of the Bermuda Deputy Governor's Office indicating that the Department Agriculture and Fisheries *"would have no objections to the above proposed cruise to do geological research"*. This memo represented the most important step in permitting process, and the memo was meant to provide a response to the London office's inquiry (in advance of the London office's actual inquiry) on Bermuda's position vis a vis issuing clearance for the proposed science work. Before showing the fax to the science party, the captain called the Paul Ljundgren (Lamont marine superintendent) to ascertain whether this fax represented an "official" clearance. Ljundgren replied via fax that that the memo did not represent an official clearance as the official clearance had to come from London. The chief scientist tried to make the case for proceeding with operations to the captain based on the following points:

1) There was no probable scenario in which clearance from London would not come through.
2) We had de facto permission from the relevant authorities of Bermuda.

3) We were in any event working at the outermost edge of Bermuda's EEZ.

4) We were in fact already working with Bermuda on this experiment, having a seismometer deployed in the vault of Bermuda Harbor radio, the coordinating branch of the Bermuda coast guard, whose station chief was recentering our seismometers once a week.

5) There was absolutely no negative consequence that could be envisioned resulting from beginning our deployments in the EEZ a day or two in advance of receiving "official" clearance.

These arguments did not persuade the captain, who would still not allow us to deploy instruments within the EEZ.

The science party is dispirited by the situation, because there is no way to gauge how long the beauracratic process in Washington/London will take, but it is clear that valuable science time will be pointlessly wasted while the final technicalities are taken care of on shore. Instead of completely flushing this time down the toilet, we decide to acoustically follow all of the instruments to the bottom as we deploy them. Doing this, we can deploy all of the instruments west of the EEZ line and steam to the first deployment site within the EEZ. There we plan to wait, holding station, until Friday for an "official" clearance. If no clearance has arrived at that point, a fallback experiment layout to the west will be undertaken.

June 5 (Tue JD156/157)

Deployed *pauli* and *urquell* 143 km west of original western end of transect, watching each instrument fall to the bottom. Begin 280-km transit east to next site.

June 6 (Wed JD157/158)

Deployed *dixie* and *420*. These instruments were originally intended to be deployed 2 km within what the bridge determined to be the boundary of Bermuda's EEZ. We relocated these instruments 6 km westward along the transect. At 10:00L the chief scientist calls shore to try to inquire about the details of the permitting process, what was being done, and to make suggestions for expediting the process. At 11:30L we receive a fax from John Diebold that is a copy of an e-mail sent from W. Thomas Cocke, Office of Oceans Affairs, the U.S. Department of State. That fax/e-mail reads: *"Hi John. I'm sending this e-mail to facilitate your operational problems involving obtaining permission for EWING to conduct research in Bermuda. Since you hold a permit from the local authorities in Bermuda indicating they support your research, and are notifying the Foreign and Commonwealth Office in London of such, I see no problem with commencing research activities. My surmise is that FCO will issue an approval at some future point, and then you are covered by the official process. The only problem that might occur, is that FCO would deny the request in London, which seems unlikely, or they would have done so already. In the unlikely event of denial, our office will first try to convince FCO to revise their position, and if unsuccessful, notify you to cease your research in Bermuda waters. The only non-routine issue in this request is the timing. UK has been very supportive of U.S. research activities. Good luck with your research. Best regards, Tom."..* The captain is now willing to allow operations within the Bermuda EEZ. For all subsequent deployments, we verify that the instrument is falling, following it to 500-m depth before disabling the transducer. Deployed *abita, mamba, asahi, cass* and *pete*.

June 7 (Thu JD158/159)

Deployed *bud, foster, bass, tecate*, and *carib*. All of the deployments through *carib* have been carried out in fine weather and with a luxuriously monotonous lack of problems or incidents in either checkout or deployment. Checkout of the next two instruments to be deployed – the final two – reveals problem with three instruments in a row. Despite their near exhaustion, the Scripps team quickly assemble two healthy instruments, and *sierra* and *molson* are deployed. Guns deployed, start shooting 20:00L (02:00Z). Begin shooting the first circle at 23:53L (JD159 03:53Z).

June 8 (Fri JD159/160)

Winds begin to pick up to a steady 20 knots throughout the day. Increase to 25-30 overnight. Seas building to 6-8 feet. Shoot Circles 1-5. The bridge crew is doing a fine job of steaming the circles and appear to be proud of themselves. We receive word that the official clearance from London has been received.

June 9 (Sat JD160/161)

Winds steady at 25-30 throughout the day. Seas 8-12 feet; an unpleasant ride, but only one incidence of gun tangling. Shoot Circles 6-11.

June 10 (Sun JD161/162)

Winds calm somewhat to generally below 20 knots, and seas are around 6-8 feet. Weather is ugly with fog and rain. Wind slowly calms throughout the day. Enthusiasm for shooting circles is quickly eroding amongst the bridge crew. The term "circle jerk" is repeated often throughout the day. Shoot Circles 12-17.

June 11 (Mon JD162/163)

Weather is significantly improved. They day begins with gray skies, fog and light rain, but the wind is mostly below 10 knots and the seas are calm with swell of 1-2 feet.

June 12 (Tue JD163/164)

Finish circles at 0400L, shoot Line 1b, Line2, begin Line 3. Shooting on distance works fine. Cloudy and rainy most of the day, but sea state is good.

June 13, 14, 15 (Wed JD164/165, Thu JD165/166 Fri JD166/167)

Shoot Line 3. Weather is dominated by a high-pressure ridge. Seas are calm with little to no wind. We steam into a current while shooting Line 3. Our maximum speed can be no greater than 5.2 knots over the ground to maintain an appropriate shot rate at the fixed 1 km spacing, and our speed through the water can be no greater than 5 knots because of the stress on guns, floats, etc. Steaming east on Line 3, we work against a current and make no more than about 4.5 knots over the ground, ultimately losing several hours in the schedule.

June 16 (Sat JD167/168)

Shoot Line 4. The turn onto Line 4 is complete by 03:00L. We have been shooting by time while making turns (beginning with the turn onto Line 3), and the turns have been taking about 1 hour.

June 17-21 (Sun-Thu JD168/169 - 172/173)

Shoot Lines 5-6 and most of Line 7. A blur of perfect weather and virtually hassle-free shooting. Apart from a few gun issues, the most significant glitch we have encountered was the realization on Thursday 21 that the Spectra system has not been generating logs since Line 1b. This is because it must be told to begin logging at the start of each line, and we haven't been doing this. In addition, we have only intermittent "Ewing" logs, which is the seismic log recorded by Octopus. Nevertheless, there is a continuous shot-time log,, and, in places where the Ewing log is missing,, there is ample ancillary information that will enable us to assign positions to the shots for which we only have times.

June 22 (Fri JD173/174)

Begin shooting western circle set. Small snafu with the shot interval at the beginning of western circle set #1, shots 1-6. Otherwise, very problem free shooting.

June 23 (Sat JD174/175)

Finish shooting western circle set at JD174 10:10Z. Pull guns and head for *pauli*. *Pauli*, *urquell*, *guinness*, and *dixie* are recovered with no problems at all. We send a release command to 420 from 3 km away while *dixie* is rising. We get a release acknowledgement from *420* but no "double ping", indicating the instrument has pulled off the bottom. We recover *dixie*, and after some confusion issue the backup release command to *420*. The instrument releases and is soon on the surface. We discover that *dixie* has not recorded data.

June 24-25 (Sun-Mon JD175/176/177)

Ridiculously good weather continues. *Abita*, *mamba*, *asahi, cass, foster, bass, tecate, carib*, *molson,* and *sierra* are all recovered without incident in a smooth blur of steaming and deck opps.

June 26 (Tue JD177/178)

The deck crew, happy to be doing something other than painting, eagerly assists in the somewhat involved operation of loading the Scripps van. Instrument and float racks are filled on deck and maneuvered to beneath the starboard waist J-frame. The instruments are raised to C-Deck and then lifted by the port crane to a ramp outside the van, from where they're moved via pallet jack into position. The entire van is loaded by noon, with the exception of single racks for *sam*, *pete* and *bud*. *Sam* is recovered in the afternoon.

Since recoveries have gone so well, we have a fair amount of time left - even assuming we have problems with pete and bud. We decide to put the streamer out and shoot MCS data along a line connecting pete and bud. The streamer goes out in what must certainly be record time, 3.5 hours. Shooting begins on FAIMMCS Line (FAIM 1).

June 27 (Wed JD178/179)

Strong currents (though calm seas) have the streamer at a 45 degree angle to port (tailbuoy to the west, steaming north). We have been looking at the wide angle data, and there is cause for excitement. We were very discouraged to see almost nothing on *pauli* and *guinness*, but *foster*, *cass* and *tecate* have some very exciting data!

June 28 (Thur JD179/180)

Finish shooting MCS, streamer and guns secured by 13:00Z, JD179. *Pete* is recovered without incident, steam toward *bud*. It's clear that we will have about an extra day if all goes well with *bud's* recovery. We are tempted to shoot all the way into Bermuda. There is scientific value in having shots recorded by the seismometers at BDA (the piers beneath Bermuda Harbor Radio) as we approach the island; and Lizarralde was annoyed with the captain's strong resistance to our putting the streamer out on the pretense of lack of time. Obviously we had plenty of time. In the end, we feel the karma swirling around us. We have had an extremely successful cruise, and we decide to simply go in to port a day early. Hectic backing up and packing commences.

June 29 (Fri JD180)

We're met by the harbor pilot at 2 pm local time. A beautiful run in to the harbor at St. George brings a remarkable cruise to a fitting end.

SCIENCE OPERATIONS

The science operations during this cruise mainly involved OBS operations and shooting. We also acquired a ~150-km-long MCS profile near the end of the cruise. Several decisions were made during the first few days of the cruise that concerned the deployment and array pattern and the shooting strategies. Aspects of these decisions are described in the Narrative, and so the discussion of them here will be brief. This experiment involved very little real-time incoming data. Once the instruments were in the water and shooting had commenced, the experiment proceeded in a relatively relaxed mode of simply monitoring the firing of the shots.

Shooting Strategy. The initial shooting strategy involved firing shots around circles, where the center of the circles were 6 km apart along an 800-km portion of the IPOD/USGS geophysical transect.. Each circle would have a radius of ~1km, the tightest circle the ship could steer. The idea is that these shots, as many as 30 per circle, would be stacked into a single trace - with S/N enhancement on the order of $N^{1/2}$, where N is the number of shots stacked. With OBSs deployed in pairs, with the instruments of the pairs spaced 3 km apart, we could assume the paired instruments were effectively in one spot and merge the profiles of a pair into a single profile with a nominal stacked-shot spacing of 3 km. The actual instrument layout is shown in the experiment map of Figure 1. Tables 1 and 2 give details on deployment times, clock corrections, and deployment and re-located positions for the OBS instruments.

We conducted a test of the circle shooting strategy during the test deployment of instrument *sam*. The offset of the circle center was at ~45 km. A strong Pn phase was observed, but the trace-to-trace time shift of this phase was substantial around the circle due to the rough nature of the basement, and the amplitude and phase characteristics of the Pn arrival varied considerably. Tests onboard to automatically determine static corrections for stacking based on cross-correlation of this strong phase were not particularly promising. We became concerned that stacking of shots fired around a circle would be particularly difficult at farther offsets. We thus reconsidered the shooting strategy and opted for a plan that involved both circle shots and shots on distance.

The Ewing has the ability to shoot on distance. It is possible to fire a shot every 1 km with sufficient time between shots to allow the previous shot energy to propagate nearly the entire 800 km of the array. The strategy is to shoot at particular locations along the transect, then turn around and shoot at those same locations steaming in the other direction, then turn around again, etc. The advantages of this approach are that no static corrections are needed for these co-located shots, and the trace spacing for each instrument is 1 km. The disadvantage of this approach is that it is more time consuming, and it would not be possible to stack nearly as many traces per shot. We opted for a strategy that incorporated both circles and shots on distance. The shooting pattern that was shot is illustrated in Figure 2. For the co-located shots, there are regions where we have 7 fold, 5 fold, 3 fold, and single-fold stacks. Information on the circle shots is given in Table 3.

Array Geometry. The layout of the instruments and the overall shooting pattern was substantially impacted by the time wasted due to clearance issues. (See Narrative for discussion.) Basically, the line was shifted westward by ~125 km and 1-2 days of shooting time was lost.

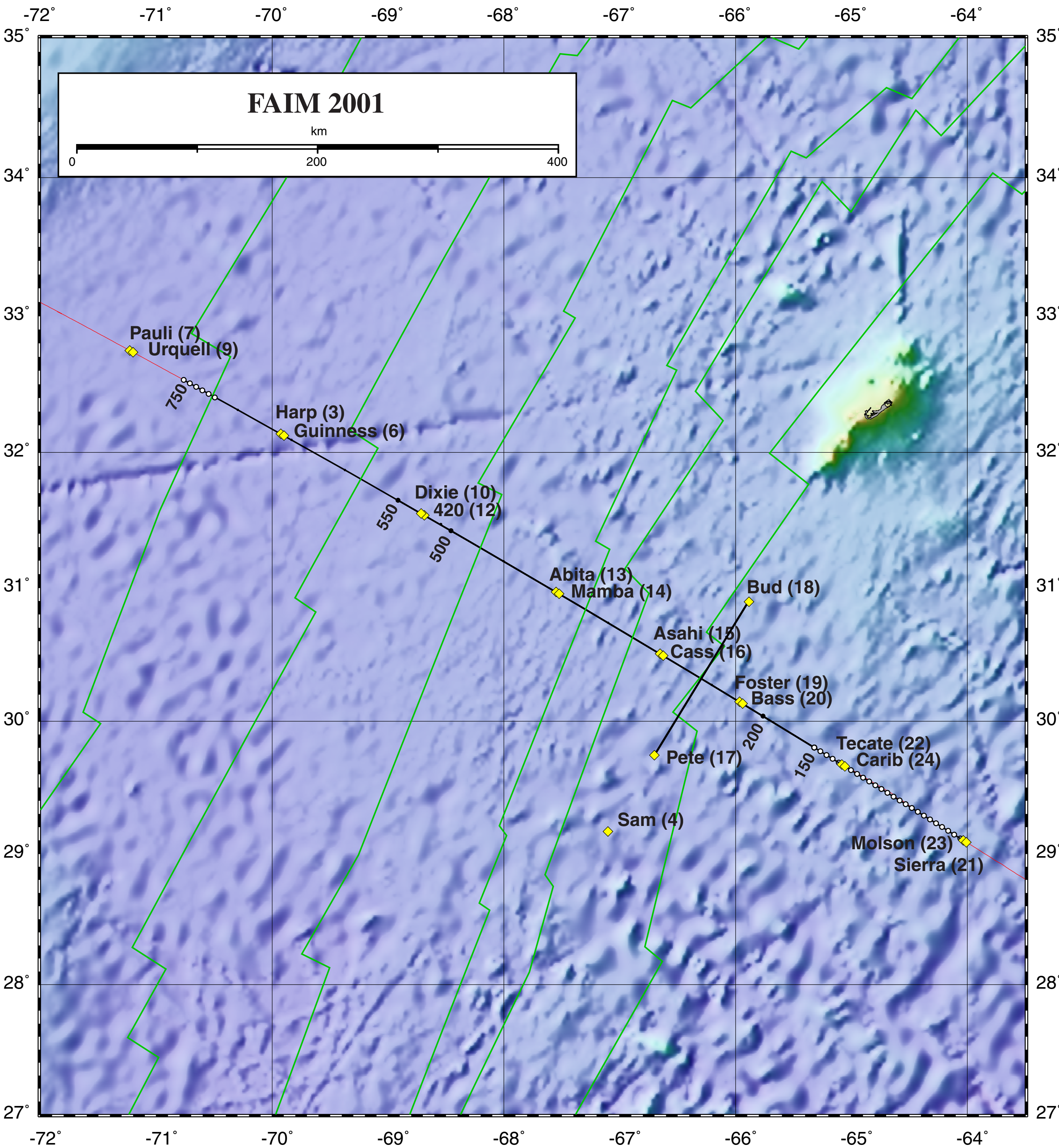
MCS Data. Instrument recovery on the main line, Line 1, proceeded ahead of schedule and without complications - which are synonymous since the recovery schedule is padded with contingency time. Halfway through the recovery we thus decided to leave *pete* and *bud* down until last with the idea of shooting a line between these instruments. After recovering the final Line-1 instrument, we proceeded to *sam*, recovered *sam*, and deployed the streamer while heading to *pete*. The 6-km streamer went out in what must be a record time of ~3 hours. Still, the first shot was fired on this line, Line 2, ~4 km beyond *pete*. Oh well. We shot Line 2 on distance with a shot separation of 300 m, giving a nominal PSN window of 140 km.

The MCS brute stack for Line 2 is shown with the other data record sections. The Bermuda swell is apparent, rising towards the north, and two small-offset fracture zones appear to be crossed by this transect.

Line Names. Our naming "convention" for lines is not great. Officially, Line 1a is that portion of the main transect covered by the eastern circle set. Line 1b is the westward continuation prior to the first switchback of on-distance shooting. Every switchback then gets a new number. The portion of the transect covered by the western circle set also gets a line number. Along the main transect, then, there are 9 separate lines (Line 1a, 1b, 2, 3, 4, 5, 6, 7, 8), with Line 1a and Line 8 being circle shots, and Lines 2b-7 being switcbacks along the main transect for co-located shots fired on distance. The perpendicular line shot between *pete* and *bud* we called FAIMMCS Line. Not particularly inspired. These are the line names (Line 1a-8, FAIMMCS Line) that appear in the "line name" column of the Ewing shot time files.

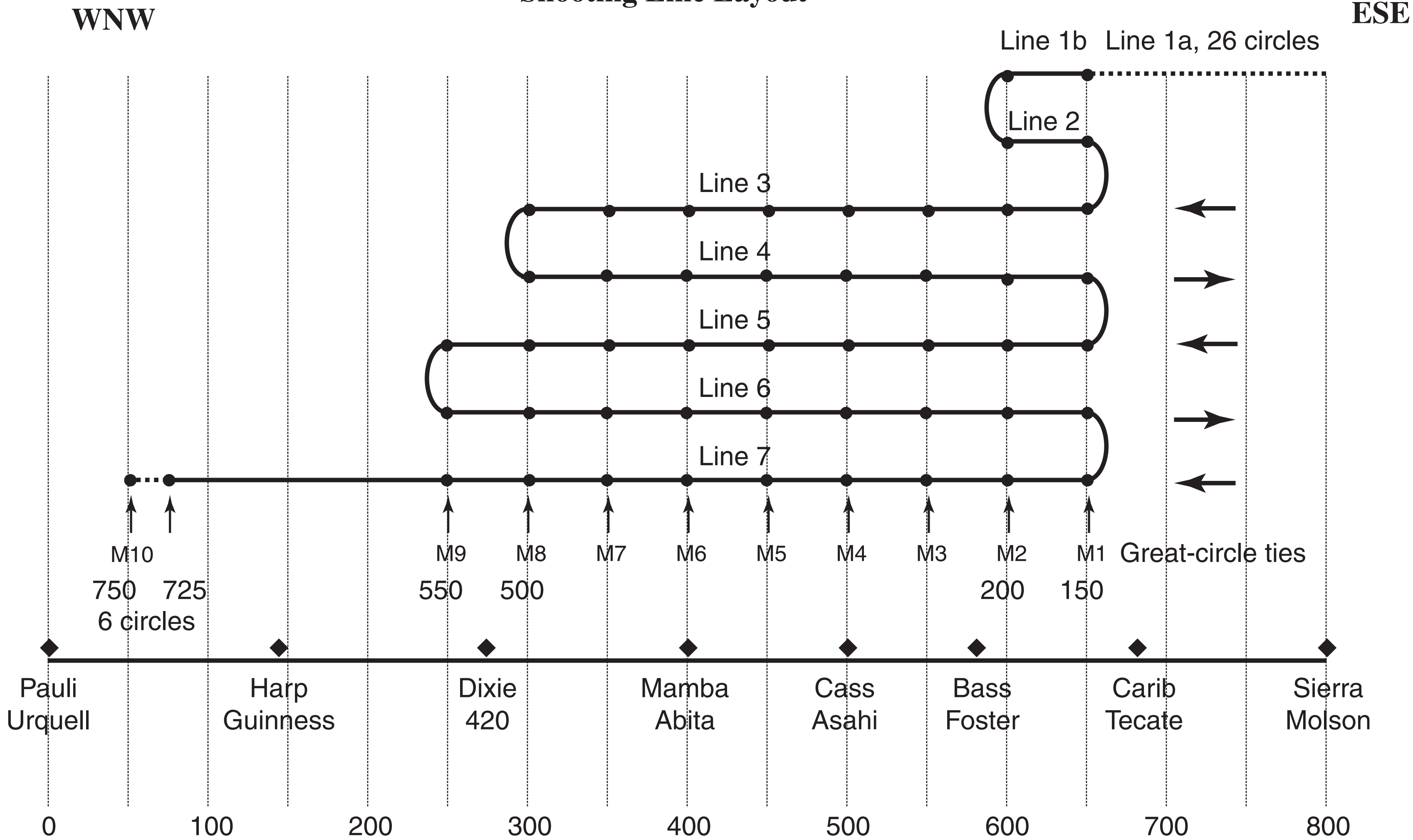
Since all of the shots from Lines 1a-8 lie along a single transect and have been stacked into single profiles for each instrument, we "unofficially" refer to this main transect as Line 1. We refer to the transect between *pete* and *bud* as Line 2.

The IPOD/USGS Line. The main transect, Line 1, was shot along the IPOD/USGS line, a transect along which MCS data were recorded in 1977. This line follows a great-circle path. The ship's steering system follows rum lines, however, and it was necessary to supply waypoints every 50 km to ensure that we stayed on the IPOD great-circle path. We have the IPOD MCS data in pre-stack form, purchased as 41 CD's from the USGS. A considerable amount of Sang Kim's time at sea was spent trying to figure out the navigation of those data. This task is complete, and these data provide us with a means for estimating basement depth beneath the seafloor - the roughness of which is the primary static observed in the record sections.



FAIM 2001
km
0
200
400
-72°
-71°
-70°
-69°
-68°
-67°
-66°
-65°
-64°
35°
34°
33°
32°
31°
30°
29°
28°
27°
Pauli (7)
Urquell (9)
750
Harp (3)
Guinness (6)
Dixie (10)
420 (12)
550
500
Abita (13)
Mamba (14)
Bud (18)
Asahi (15)
Cass (16)
Foster (19)
Bass (20)
200
Pete (17)
Tecate (22)
Carib (24)
150
Sam (4)
Molson (23)
Sierra (21)

Shooting Line Layout



Schematic of shooting pattern along the main IPOD transect. Each new line number represents a switchback and change of direction. Shooting direction is indicated by arrows. Points labelled M were waypoints given to the bridge to maintain an approximate great-cicle path (the ship could only stear a rum line). Numbers along the bottom are distances from pauli in kilometers.

L-CHEAPO 2000 OPERATIONS ON EW0106

Report of the OBSIP Team (Willougby lead)

In June 2001, Scripps L-CHEAPO 2000 data loggers from the National Science Foundation's West Coast Ocean Bottom Seismology Instrument Pool (OBSIP) were deployed for scientific purposes for the first time. Previous deployments had been limited to test cruises off San Diego.

The ship was loaded and departed from San Juan, Puerto Rico on May 31. One instrument was deployed on June 2, airgun shots were recorded and the instrument recovered and the data examined on June 3. This test led to raising the amplifier gain on most of the instruments. Before and after this test deployment, secure tests of all the acoustic transponder/releases and of the transceiver used on deck were conducted.

A series of nineteen deployments then began on June 4, and continued through June 7. Since their purpose was to record airgun shots for a refraction survey of the mantle, the instrument array was rather large, with the main northwest-southeast line approximately 800 km in length, and a cross-line consisting of 3 additional instruments, about 225 km long. Instrument deployment locations and details are shown in Table 1.

An assortment of airgun lines were then shot by the Ewing and the first seventeen instruments were recovered between June 23 and June 26, with the remaining two brought aboard by June 29. All but one of the instruments recorded data for the entire duration of its deployment.

The instrument racks and lab equipment were stored in the container while still at sea. This cruise concluded with the arrival of the ship in St. George, Bermuda on June 29.

Lab and Deck Setup

The lab equipment and most of the units in the system of racks for storing instrument frames and float assemblies was unloaded from the container on 'B' deck and transferred to the fantail on 'D' deck using the ship's cranes while in port. Several crewmembers assisted in rigging and operating the cranes and moving the racks around on deck. Even with the extra help, this operation consumed three hours after the container was secured on deck and its start was delayed by the late arrival of the container because of problems with paperwork that had not been completed by the forwarding agent.

A stand for instrument assembly and for holding instruments on recovery was located under the A- frame on the waist deck on the starboard side. Four stacked pairs of instrument frame racks were strapped in place just aft of the A-frame with about a foot between the racks and the rail. Three float racks were located further aft on the fantail. Five more float racks were left in the container because of concerns about retaining adequate work space on the fantail, but these concerns proved unfounded and three of them were craned down to the fantail while at sea. This was made relatively easy by exceptionally calm seas throughout most of the trip. Two stacks of anchors were also tied down on the fantail.

Lab equipment was packed in Zarges' ® boxes, which were brought down to the fantail and stored in the dry lab on the port side. All the boxes were lowered using the ship's crane in two lifts using cargo nets. Five data logger pressure case stands, two laptop computers and other pieces of test equipment were set up on the large 4-foot by 24-foot workbench along the outboard side of the lab. This proved to be a generous workspace; an adequate arrangement could probably be set up in a slightly smaller area. But a major reduction in available space would be much less convenient and would hamper efficiency.

Dismantling and container stowage of the instrument and support equipment were accomplished in two stages. All but one of the loaded storage racks were craned up to and arranged in the container after the first sixteen instrument recoveries had been completed, while in transit to shoot another airgun line using the last two instruments and the ship's multichannel hydrophone streamer as receivers. The remaining racks and the boxes of lab equipment were moved up to the container on the last day at sea after the last two instruments were recovered.

The deck transfer and storage operations required about two hours, and were facilitated by extremely calm seas. In rough weather this operation would seriously compromise the safety of both personnel and equipment, though if it had been possible to locate the container on the deck from which deployment and recovery operations are conducted, both the setup and dismantling procedures would have been much easier.

Another alternative would be to perform these unloading and loading operations in port at the beginning and end of the cruise, though this may require port stops longer than the two days scheduled at each end of this experiment. When large arrays of more than 30 instruments are to be deployed, shipping will require two or more containers. Most research vessels have limited space for securing multiple containers, so unpacking and setting up the deck arrangements in port will be necessary in these cases.

Acoustics

A line-powered acoustic transceiver was used to range to the instruments and generate commands for ranging for nearly all operations with the instruments in the water. A battery-powered unit was tested once in this capacity and worked equally well, but was usually employed only for testing the instrument transponders on deck prior to deployment.

Initially, the transceiver in the lab was connected to the transducer supplied by the manufacturer, which was mounted in the ship's transducer well. This worked adequately, but ranging to instruments near the seafloor was sometimes intermittent, so the transceiver was connected to the ship's 12 kHz hull transducer instead. This arrangement yielded outstanding performance; the only missed ranges usually occurred when the instrument was on or near the surface, where intermittent contact is to be expected. The inferior performance of the manufacturer's transducer is probably not related to its design, but to the Ewing's rather unusual mounting arrangement in the well, in which a semi-rigid plate is actually placed between the transducer and the seawater. This almost certainly causes some attenuation of both the outgoing and reply signals.

Before and after the initial test deployment, a frame containing 12 of the acoustic transponders used in the instruments was lowered on a wire to a depth that was a few hundred meters above the seafloor to test the watertight integrity and operational performance of each unit. All of the transponders worked properly once the surface transceiver was connected to the ship's hull transducer.

Checkout, Assembly and Deployment

To prepare each instrument for deployment, the data logger pressure case was removed from the instrument frame while the frame was still stored in the rack. Two people then carried each anchor, instrument frame and float frame to the assembly stand under the A-frame. While one member of the technical staff assembled the release system and checked out the acoustic transponder on deck, another tested and prepared the data logger for deployment. A third staff member served to assist and expedite either operation as needed.

The data logger checklist consists of a single page that includes current and voltage tests, a short suite of electronics tests, and the setting of experiment parameters using a terminal. The instruments were set to record hydrophone and seismometer data at 125 samples per second. While the instrument is designed so that it should not be necessary to open a working data logger unless a failure occurs, all the pressure cases were opened in order change a jumper to raise the amplifier gains to the values determined during the test deployment. With the third person available for assistance, this caused minimal delay. Both the mechanical assembly and deck testing, and the data logger checkout in the lab were usually completed in about 30 minutes.

Despite the fact that all the instruments had been inspected and tested in the lab before shipping, three of the them failed to operate properly during the checkout procedure and their pressure cases had to be opened for repairs. Each failure was from a different cause. One instrument emitted visible smoke from a burning resistor; this was the result of a short circuit caused by a power capacitor failure. A second instrument had a failure on the analog-to-digital converter board, and on a third instrument, it was not possible to synchronize the Seascan time base with the GPS clock properly. A spare data logger was substituted for the first of these, which then served to provide a spare A-to-D board and Seascan time base for the other two.

Deployment was uneventful. A "tugger" winch was used to deploy the instruments from the starboard A-frame, with a "pelican hook" to release the instrument from the winch wire once it was in the water. Again, calm sea conditions made this a very simple operation. The first few instruments were followed to the bottom using the acoustic ranging system, then their acoustic transponders were disabled once they were on the bottom. The instruments required about 100 minutes to descend to a depth of approximately 5000 meters, yielding a descent rate of about 50 meters per minute. Once the reliability of the acoustics system had been established, the transponders on the remaining instruments were disabled after they had descended to about 500 meters to allow the ship to proceed without delay to the next deployment site.

Recovery Procedures

All but one of the instruments released its anchor and ascended to the surface after only one acoustic command. A backup release command sent to the remaining instrument successfully caused it to begin its ascent. Nearly all the releases required about eight minutes of burn time before the instrument lifted off from its anchor; one took nearly fifteen minutes for reasons that have not been determined. Most of the instruments were deployed in pairs separated by about three kilometers, and the usual procedure was to wait to release the second instrument until the first instrument had been brought aboard. During one daylight recovery, we attempted to release the second instrument when the first was about halfway between the seafloor and the surface. This instrument failed to release using its primary release command. Despite the fact that the failure was probably not related to having two instruments in the water column simultaneously, this experiment was not repeated.

The instruments rose to the surface from a typical depth of 5000 meters in about 100 minutes, a rise rate of 50 meters per minute, approximately the same as the descent rate during deployment. GPS navigation allowed positioning of the ship so that the instruments were easily sighted when they broke the surface, at ranges of between 50 and 500 yards. Spotting the flashing light at night proved easier than seeing the flag in daylight.

Exemplary ship handling on the part of the Ewing's deck department personnel set a record of seven minutes between the time an instrument was located on the surface and when it was hauled aboard using the starboard A-frame. In the worst case, ship maneuvering required about a half-hour. A new procedure was instituted wherein a member of the science party was stationed on the bow to point and/or aim a flashlight at the instrument to indicate its position to the bridge after it disappeared from view under the forecastle; deck officers said this facilitated more efficient maneuvering. Once again, calm seas made finding the instruments on the surface and maneuvering the ship alongside relatively easy.

Once aboard, data logger status and clock were checked, the remaining data in the buffer transferred to the disk. Mechanical hardware was disassembled and stored in the racks.

Significant errors in the time marks were found in eight of the instruments. Further examination, however, revealed that the time marks in these instruments had "jumped" in a way that had a minimal effect on the data timing. Subsequent to this finding, the actual offset of the instruments' real time clocks at recovery was checked on fourteen of the instruments by comparing the output of the GPS clock with the timing of the ASCII characters read from the real time clock and displayed on the terminal. A fixed offset had to be subtracted from this measurement to obtain the actual time error. A summary of the time offset measurements is shown in Table 2. The problem with the instrument time marks is further discussed below in the "Instrument Problems" section of this report.

All but one of the instruments recorded between 2 and 3 million 512-byte blocks of data. The data from each instrument were then transferred to a FireWire disk drive and to a DAT tape. This procedure consumed about an hour for each instrument, but was sometimes hampered by failures of the laptop computers or peripherals that in a few cases required re-booting them several times. Eventually, the failure rate was minimized using an arrangement in which one laptop was served as a terminal for the instrument and the other was connected to the SCSI bus for transferring the data.

After the data storage and backup were completed, the files were transferred to Unix systems belonging to the Principal Investigators using the ship's local area network. This tied up the backup system for an additional twenty minutes for each instrument but allowed scientists to plot substantial numbers of record sections and evaluate the quality of the data during the instrument recovery phase of the operation.

Instrument Problems

Considering that the instruments were new and had only been briefly tested before being shipped to meet the research vessel in San Juan, performance and reliability were excellent. Three data loggers required repairs to solve problems discovered during checkout. One data logger failed to record data while deployed, and a timing problem that potentially affects all the data loggers was discovered. One acoustic transponder failed during testing and one failed to effect an anchor release until the second release circuit was activated. Each of the failures will be discussed below.

Data Logger failures:

• A capacitor on the power converter board short circuited the digital battery pack and burned up the current measuring resistor in series with its battery. The resistor limited the current and kept the battery pack fuse from blowing. Numerous failures of tantalum capacitors were noted when the instruments were powered up for the first time; this particular capacitor is the only one that failed after having passed all tests in the lab. This was an easy problem to find and except for the fact that no spare power converter boards or were brought aboard, it would have been easy to fix.

• One analog-to-digital converter board failed to display proper output and drew excess current during testing. The board was replaced by a spare. A failed regulator I.C. on the board is the suspected cause of the failure.

• One Seascan time base could not be synchronized with the GPS clock properly. The complete clock board and time base assembly was exchanged for a spare; the details of the failure were determined later.

• One instrument passed all tests during checkout but failed to record any data. When the instrument was recovered, screen messages indicated that the software was in the data acquisition mode, but that data were not being stored in the RAM buffer. During subsequent tests, this data logger performed flawlessly. At this time, no explanation for this failure has been found.

• Several data loggers displayed offsets as great as one-half second between the GPS clock second mark and the instrument Time Mark used to check timing errors on recovery. Further examination revealed that the Time Mark on these instruments would occasionally jump at random, but that the time stored in the real-time clock used as a source for the time stamp written at the beginning of each data block was relatively unaffected. Subsequent analysis revealed that this problem was caused by the outputs from the Seascan time bases being re-synchronized at random; because of the nature of the circuitry, this had a much greater effect on the time marks than on the real-time clock or analog-to-digital converter.

Careful examination of the clock board schematic revealed a jumper that was mislabeled on the drawing. With the jumper in the position that was used, the Time Rest input to the input was more noise susceptible than would otherwise be the case. However, subsequent testing has indicated that changing this jumper has not solved the problem. At this time, the cause remains to be determined.

After discovering the nature of this problem, measurement of the timing of the real-time clock output was checked following each recovery. In most cases this indicated that the timing offset was within the specification of 1 mS of offset for each day of deployment; the worst case was an offset of about 30 mS on one instrument.

Acoustic Release Problems:

• One transponder responded intermittently to commands when lowered on the testing frame the first time. This unit was tested on deck before and after lowering, and all functions worked perfectly. After the surface transceiver was connected to the ship's hull transducer it was lowered on the second deployment of the frame and again performed flawlessly.

• One instrument failed to release its anchor until the second release wire was activated. Upon recovery, the primary release system was tested and the release mechanism and burn wire carefully examined. No anomalies were found. The cause of the failure of the first release remains a mystery, as the burn wire and acoustic system both worked perfectly when tested after recovery. It is possible that the wrong code may have been entered into the command transceiver, and that the valid "command received" reply heard aboard ship was actually coming from the instrument that was already released.

Because of two instruments that were lost during earlier test deployments off San Diego, the release system had been modified to minimize the possibility of jamming the mechanism. All the release mechanisms and anchors were slightly modified from the original design. The frame modification consisted of a "skirt" that raised the entire instrument, including the release mechanism, eight inches higher above the anchor. All but four of the instrument frames deployed were modified in this fashion. The instrument that failed to release with the primary command was one of the four that were not modified, but careful examination of the mechanism revealed no evidence that its release mechanism had jammed. The three other unmodified instruments were released normally on the first command.

Personnel

The checkout and deployment team for this trip consisted of two very experienced engineers and one engineer who was recently hired, but who was already quite experienced in working with the instruments in the lab. Additional help was obtained from ship's crewmembers, scientists and students to operate the controls for the winch and A-frame and handle lines during the deployments and recoveries.

A team of three people is nearly essential for efficient preparation of the instruments, and for checkout, data backup and dismantling after recovery. However, the use of three experienced engineers is not necessary -- one of the three team members can be relatively inexperienced and trained on the spot.

One checkout team was sufficient for this cruise, despite the fact that deployments and recoveries continued round-the-clock. The fact that the instrument pairs were separated by transits that took between four and seven hours left plenty of time for naps, and the two-hour rise time after a release added even more idle time to that figure. Extremely calm seas and a very stable ship also contributed to the ease of the operation and minimized fatigue.

On cruises where more frequent deployments are planned, at least two three-man checkout teams will be necessary if deployments and recoveries are to continue 24 hours a day. On long cruises with several successive deployments and recoveries of large fleets of instruments, even two teams may not be sufficient. The fatigue that results from working twelve hours a day at sea is cumulative. It is notable in this regard that the Ewing encourages its seamen to work twelve-hour days and pays them overtime accordingly, but allows them to reduce their commitment to eight hours whenever they are tired.

Acknowledgments

The Scripps/IGPP technical staff on this trip consisted of engineers Crispin Hollinshead, Rod Milan, and David Willoughby. Chief Scientist Dan Lizarralde and Co-Principal Investigator Jim Gaherty provided excellent leadership and support and were fun and interesting to work with. The ship handling of Captain Mark Landow and the deck crew of the Maurice Ewing* was outstanding and contributed to efficient instrument deployments and recoveries. Chief Mate Stan Ziegler led deck operations and maintained safety during awkward transfers of equipment between decks at sea. Chief Engineer Al Kalyn kept the ship and its equipment running smoothly and Science Officer Joe Stennett provided capable assistance reflecting his many years of service aboard research vessels. And cooks John Smith and Kelly Thomas prepared delicious cuisine that made it a real challenge not to eat too much.

*Watching the deck officers conning the 240' ship to a position alongside the small instrument packages prompted one staff member to compare it with "coaxing an elephant to perform ballet by tickling it carefully and selectively with a feather."

Table 1: Clock checkout times pre-deployment and post-recovery. Where the offsets of the instrument clock are large or erratic, an offset was determined from the ASCII character string output form the instrument clock. It is the instrument clock that provides the time stamp for the disk headers. This ASCII offset has to be corrected for the "duration" of the ASCII character string. It has been determined that the erratic clock behavior was related to the particulars of the checkout procedure. The clocks are actually ok, and the jumping time is a random +/- 4ms jumpiness in the oscillator that gets translated into a 250ms jumpiness in apparent absolute time. The digitizer remains good to drift +/- 4ms, however. Also note, the dates are given in calendar days, whereas times are listed in Zulu. Bad form on the OBSIP guys part, but all days can be converted to Julian days by adding 151 to the date (e.g. 6/4/01 is JD155) since the times are Zulu.

Site Name	**D/L NO.**	**Deployment Time**	**Recovery Time**	**Time Tag (ms)**	**Offset (ms)**	**ASCII Offset**	**Corr. ASCII**	**Note**
harp	3	6/4/01 22:14	6/24/01 02:38	979.04	-20.96	------	------	OK
sam	4	6/3/01 23:33	6/27/01 05:55	985.61	-14.39	-3.98	-14.38	OK
guinness	6	6/5/01 01:07	6/24/01 05:05	903.55	-96.45	------	------	Time Jump?
pauli	7	6/5/01 10:32	6/23/01 14:51.50	21.85	21.85	------	------	OK?
urquell	9	6/5/01 12:06	6/23/01 17:32.50	29.59	29.59	------	------	OK?
dixie	10	6/5/01 22:48	6/24/01 13:47	19.65	19.65	------	------	No Data
"420"	12	6/6/01 04:54	6/24/01 16:22.50	522.82	------	------	------	
"420"	12	6/6/01 04:54	6/25/01 02:57	------	------	45.40	35.00	Time Jump
abita	13	6/6/01 10:27	6/25/01 00:24	770.13	------	42.30	31.90	Time Jump
mamba	14	6/6/01 10:53	6/25/01 02:45	30.54	30.54	40.90	30.50	OK
asahi	15	6/6/01 16:21	6/25/01 09:19	4.56	4.56	15.00	4.60	OK
cass	16	6/6/01 17:05	6/25/01 11:30.50	18.97	18.97	30.20	19.80	OK?
pete	17	6/6/01 20:58	6/28/01 21:40	20.22	20.22	31.00	20.60	OK
bud	18	6/7/01 04:34	6/29/01 06:30	480.12	------	18.50	8.10	Time Jump
foster	19	6/7/01 09:23	6/25/01 16:58.25	997.14	-2.86	7.80	-2.60	OK
bass	20	6/7/01 09:38	6/25/01 19:11.50	632.15	------	-5.46	-15.86	Time Jump
sierra	21	6/7/01 21:16	6/26/01 14:12.25	688.83	------	19.30	8.90	Time Jump
tecate	22	6/7/01 14:21	6/26/01 01:59.50	32.19	32.19	42.60	32.20	OK
molson	23	6/7/01 22:21	6/26/01 11:59.50	328.39	------	10.70	0.30	Time Jump
carib	24	6/7/01 15:09	6/26/01 04:16	542.29	------	48.60	38.20	Time Jump

Table 2: Deployment positions in deployment order, Relocated seafloor positions, Distance to pauli, and Depth

Name		Deployment Position		Seafloor Position		X to pauli (km)	Depth
sam	29° 10.000' N	67° 06.133' W	(29.1667, -67.1022)				5170m
harp	32° 08.199' N	69° 55.578' W	(32.1367, -69.9263)	**-69.934**	**32.136**	139.296	5419m
guiness	32° 07.412' N	69° 53.903' W	(32.1235, -69.8984)	**-69.905**	**32.123**	142.385	5384m
pauli	32° 44.842' N	71° 13.774' W	(32.7474, -71.2296)				5408m
urquell	32° 44.059' N	71° 12.073' W	(32.7343, -71.2012)				5415m
dixie	31° 32.959' N	68° 42.772' W	(31.5493, -68.7129)				5248m
420	31° 32.159' N	68° 41.178' W	(31.5360, -68.6863)	**-68.685**	**31.535**	274.894	5247m
abita	30° 58.035' N	67° 33.031' W	(30.9673, -67.5505)	**-67.554**	**30.967**	399.585	5174m
mamba	30° 57.170' N	67° 31.378' W	(30.9528, -67.5230)	**-67.526**	**30.954**	402.619	5133m
asahi	30° 30.353' N	66° 39.154' W	(30.5059, -66.6526)	**-66.655**	**30.507**	499.578	5058m
cass	30° 29.523' N	66° 37.520' W	(30.4921, -66.6253)	**-66.627**	**30.493**	502.680	5063m
pete	29° 44.667' N	66° 42.031' W	(29.7444, -66.7005)				5176m
bud	30° 53.625' N	65° 53.037' W	(30.8937, -65.8839)				4896m
foster	30° 08.810' N	65° 57.960' W	(30.1468, -65.9660)	**-65.968**	**30.147**	576.715	5005m
bass	30° 07.970' N	65° 56.369' W	(30.1328, -65.9395)	**-65.941**	**30.133**	579.743	4996m
tecate	29° 40.729' N	65° 05.445' W	(29.6788, -65.0908)	**-65.09**	**29.677**	676.176	5048m
carib	29° 39.522' N	65° 03.153' W	(29.6587, -65.0526)	**-65.05**	**29.657**	680.632	4926m
sierra	29° 05.001' N	64° 00.261' W	(29.0833, -64.0043)	**-64.012**	**29.086**	799.578	4967m
molson	29° 05.854' N	64° 01.833' W	(29.0976, -64.0305)	**-64.035**	**29.099**	796.917	4961m

Table 3: Circle shot data. Circle number, number of shots on the circle, number of turns, start and end times.

Circle No.	Shots	Turns	Start Time	End Time
East Circles				
1	29	5	159 03:53:30.000	159 08:06:00.00
2	27	5	159 08:59:00.000	159 12:45:00.00
3	28	5	159 13:30:00.000	159 17:33:00.00
4	27	5	159 18:17:00.000	159 22:12:00.00
5	27	5	159 22:56:00.000	160 02:51:00.00
6	29	5	160 03:35:00.000	160 07:48:00.00
7	26	5	160 08:23:00.000	160 12:09:00.00
8	28	5	160 13:02:00.000	160 17:06:00.00
9	23	4	160 17:41:00.000	160 21:00:00.00
10	23	4	160 21:35:00.000	161 00:54:00.00
11	23	4	161 01:29:00.000	161 04:48:00.00
12	24	4	161 05:23:00.000	161 08:51:00.00
13	23	4	161 09:26:00.000	161 12:45:00.00
14	22	4	161 13:29:00.000	161 16:39:00.00
15	23	4	161 17:14:00.000	161 20:33:00.00
16	22	4	161 21:08:00.000	162 00:18:00.00
17	24	4	162 00:53:00.000	162 04:21:00.00
18	23	4	162 04:56:00.000	162 08:15:00.00
19	18	3	162 08:50:00.000	162 11:24:00.00
20	17	3	162 11:59:00.000	162 14:24:00.00
21	18	3	162 14:59:00.000	162 17:33:00.00
22	17	3	162 18:08:00.000	162 20:33:00.00
23	17	3	162 21:08:00.000	162 23:33:00.00
24	18	3	163 00:08:00.000	163 02:42:00.00
25	18	3	163 03:17:00.000	163 05:51:00.00
26	18	3	163 06:26:00.000	163 09:00:00.00
West Circles				
W1	18	3	173 15:30:00.000	173 18:12:00.00
W2	16	3	173 18:47:00.000	173 21:03:00.00
W3	17	3	173 21:47:00.000	174 00:12:00.00
W4	17	3	174 00:56:00.000	174 03:21:00.00
W5	18	3	174 04:05:00.000	174 06:39:00.00
W6	11	2	174 07:14:00.000	174 08:46:00.00

Table 4: Streamer information for FAIMMCS Line.

MOD	SERIAL #	CAN #	SHIP OFFSET	CHANNELS	BIRD	COMMENTS	WEIGHT
TB			6344.3M			**TAIL BUOY AT 6345M**	
STIC	CABLE 25.3M		6319M TO 6344M				
1		**2151**				**POWER MODULE 12151**	
HS	30120-HS	50M	6269M TO 6319M				
TS	0697-30284TS	50M	6219M TO 6269M				
					1	**BIRD AT 6221M**	
AT	0498-30025	4M	6215M TO 6219M			**new**	
	31374	**RED**	6140M TO 6215M	**1 TO 6**			
2		**3538**			**2C**	**BIRD AT 6146M**	
	0298-31388	**ORNG**	6065M TO 6140M	**7 TO 12**			
	0996-30299	**RED**	5990M TO 6065M	**13 TO 18**		**new**	
3		**2734**			**3**	**BIRD AT 5996M**	
	1296-30808	**ORNG**	5915M TO 5990M	**19 TO 24**		**new**	
	1096-31330	**RED**	5840 TO 5915M	**25 TO 30**		**new**	
4		**2731**			**4C**	**BIRD AT 5846M**	
	0298-31385	**ORNG**	5765M TO 5840M	**31 TO 36**		SOME AIR	
	0298-31399	**RED**	5690 TO 5765M	**37 TO 42**			
5		**2754**			**5**	**BIRD AT 5696M**	
	31408	**ORNG**	5615M TO 5690M	**43 TO 48**			
	0298-31361	**RED**	5540M TO 5615M	**49 TO 54**			
6		**3607**			**6C**	**BIRD AT 5546M**	
	0298-31402	**ORNG**	5465M TO 5540M	**55 TO 60**			
	0298-31337	**RED**	5390M TO 5465M	**61 TO 66**			
7		**3189**					
	1096-30337	**ORNG**	5315M TO 5390M	**67 TO 72**		**new**	
	0298-31390	**RED**	5240m to 5315m	**73 to 78**			
8		**3606**			**7**	**BIRD AT 5246M**	
	0298-31346	**ORNG**	5165M TO 5240M	**79 TO 84**		FLAT	
	0298-31381	**RED**	5090M TO 5165M	**85 TO 90**			
9		**3107**					
	0298-31391	**ORNG**	5015M TO 5090M	**91 TO 96**			
	0298-31406	**RED**	4940M TO 5015M	**97 TO 102**		**new**	
10		**3395**			**8C**	**BIRD AT 4946M**	
	0298-31384	**ORNG**	4865M TO 4940M	**103 TO 108**			
	0198-31341	**RED**	4790 TO 4865M	**109 TO 114**			
11		**3599**					
	0198-31398	**ORNG**	4715M TO 4790M	**115 TO 120**			
	0298-31387	**RED**	4640M TO 4715M	**121 TO 126**			
12		**3597**			**9**	**BIRD AT 4646M**	
	0298-31378	**ORNG**	4565M TO 4640M	**127 TO 132**			

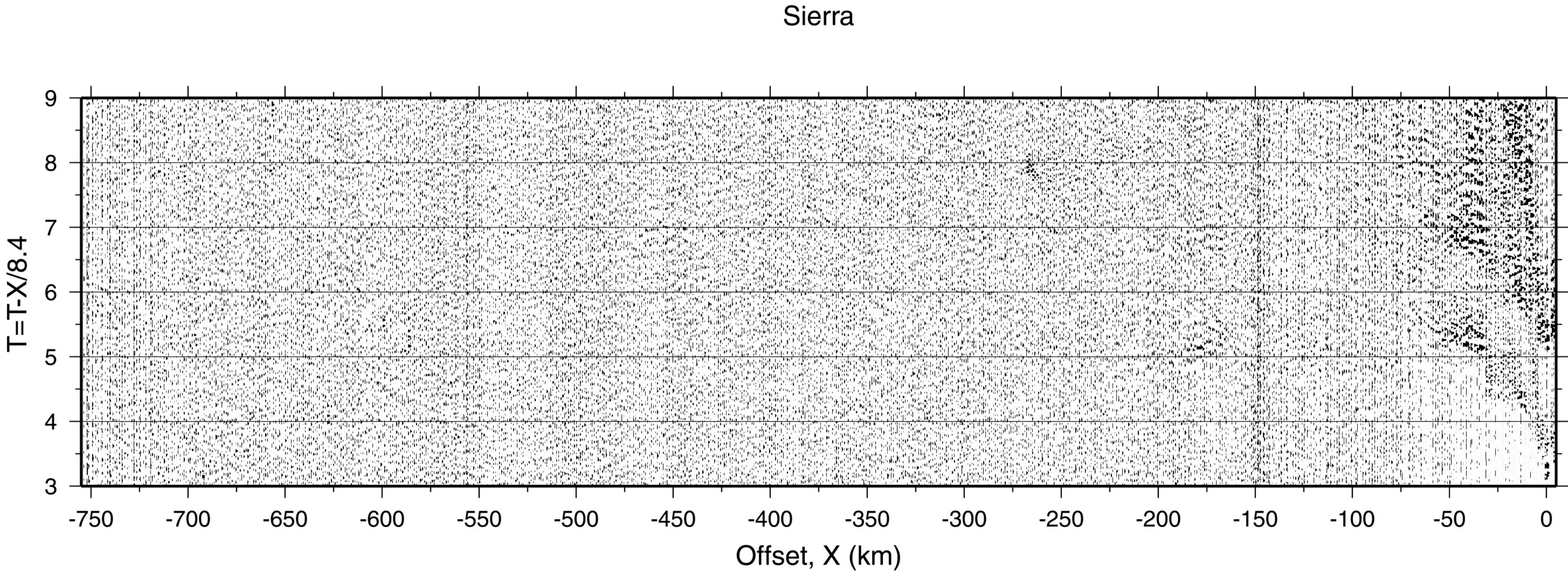
	0298-31369	**RED**	4490M TO 4565M	**133 TO 138**			
13		**3604**					
	0298-31396	**ORNG**	4415M TO 4490M	**139 TO 144**			
	0198-31335	**RED**	4340M TO 4415M	**145 TO 150**			
14		**2965**			**10C**	**BIRD AT 4346M**	
	0198-31362	**ORNG**	4265M TO 4340M	**151 TO 156**			
MOD	**SERIAL #**	**CAN #**	**SHIP OFFSET**	**CHANNELS**	**BIRD**	**COMMENTS**	**WEIGHT**
	0298-31373	**RED**	4190M TO 4265M	**157 TO 162**			
15		**2714**					
	0198-31334	**ORNG**	4115M TO 4190M	**163 TO 168**			
	0298-31405	**RED**	4040M TO 4115M	**169 TO 174**			
16		**2757**			**11**	**BIRD AT 4046M**	
	0298-31386	**ORNG**	3965M TO 4040M	**175 TO 180**		**new**	
	0397-31119	**RED**	3890M TO 3965M	**181 TO 186**			
17		**3031**					
	0198-31318	**ORNG**	3815M TO 3890M	**187 TO 192**			
	0198-31343	**RED**	3740M TO 3815M	**193 TO 198**			
18		**3602**			**12C**	**BIRD AT 3746M**	
	1296-30312	**ORNG**	3665M TO 3740M	**199 TO 204**			
	0996-30302	**RED**	3590M TO 3665M	**205 TO 210**			
19		**2940**					
	30804	**ORNG**	3515M TO 3590M	**211 TO 216**			
	0996-30327	**RED**	3440M TO 3515M	**217 TO 222**			
20		**2935**			**13**	**BIRD AT 3446M**	
	0197-31058	**ORNG**	3365M TO 3440M	**223 TO 228**			
	0298-31389	**RED**	3290M TO 3365M	**229 TO 234**			
21		**3184**					
	31329	**ORNG**	3215M TO 3290M	**235 TO 240**			
	0996-30279	**RED**	3140M TO 3215M	**241 TO 246**			
22		**2563**			**14C**	**BIRD AT 3146M**	
	0996-30291	**ORNG**	3065M TO 3140M	**247 TO 252**		**new**	
	31371	**RED**	2990M TO 3065M	**253 TO 258**			
23		**2507**					
	31350	**ORNG**	2915M TO 2990M	**259 TO 264**			
	31363	**RED**	2840M TO 2915M	**265 TO 270**			
24		**2567**			**15**	**BIRD AT 2846M**	
	0996-30300	**ORNG**	2765M TO 2840M	**271 TO 276**			
	0696-31347	**RED**	2690 TO 2765M	**271 TO 282**			
25		**2717**					
	31327	**ORNG**	2615M TO 2690M	**283 TO 288**			
	31383	**RED**	2540M TO 2615M	**289 TO 294**			
26		**2523**			**16C**	**BIRD AT 2546M**	
	0996-30304	**ORNG**	2465M TO 2540M	**295 TO 300**			

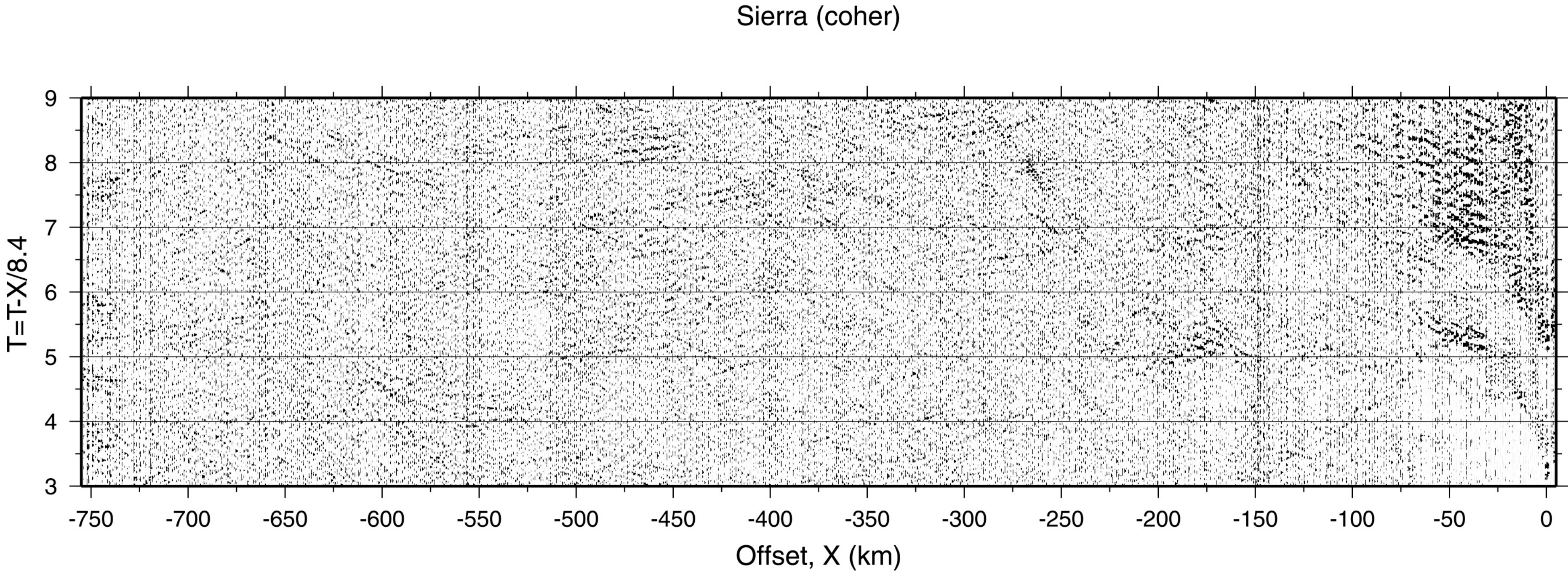
	0696-0138	**RED**	2390M TO 2465M	**301 TO 306**		**new**	
27		**3163**					
	0298-31372	**ORNG**	2315M TO 2390M	**307 TO 312**			
	0298-31365	**RED**	2240M TO 2315M	**313 TO 318**		**new**	
28		**2511**			**17**	**BIRD AT 2246M**	
	31326	**ORNG**	2165M TO 2240M	**319 TO 324**			
	30251	**RED**	2090M TO 2165M	**325 TO 330**			
29		**2570**					
	0298-31321	**ORNG**	2015M TO 2090M	**331 TO 336**		**new**	
	31433	**RED**	1940M TO 2015M	**337 to 342**		**new**	
30		**3172**			**18C**	**BIRD AT 1946M**	
	0597-31268	**ORNG**	1865M TO 1940M	**343 TO 348**			
MOD	**SERIAL #**	**CAN #**	**SHIP OFFSET**	**CHANNELS**	**BIRD**	**COMMENTS**	**WEIGHT**
	0996-30281	**RED**	1790 TO 1865M	**349 TO 354**			
31		**2505**					
	0996-30303	**RED**	1640M TO 1715M	**361 TO 366**			
32		**2554**			**19**	**BIRD AT 1646M**	
	1096-31346	**ORNG**	1565M TO 1640M	**367 TO 372**			
	30313	**RED**	1490M TO 1565M	**373 TO 378**			
33		**3182**					
	1096-30326	**ORNG**	1415M TO 1490M	**379 TO 384**		**new**	
	0697-31277	**RED**	1340M TO 1415M	**385 TO 390**			
34		**2506**			**20C**	**BIRD AT 1346M**	
	0198-31350	**ORNG**	1265M TO 1340M	**391 TO 396**		**new**	
	0696-10057	**RED**	1190M TO 1265M	**397 TO 402**			
35		**2462**					
	1096-30320	**ORNG**	1115M TO 1190M	**403 TO 408**		**BLKHDS THIN SECTION**	
	0996-31349	**RED**	1040M TO 1115M	**409 TO 414**			
36		**2747**			**21**	**BIRD AT 1046M**	
	0697-31282	**ORNG**	965M TO 1040M	**415 TO 420**			
	31413	**RED**	890M TO 965M	**421 TO 426**			
37		**3192**			**22C**	**BIRD AT 896M**	
	SS1-0696-0140	**ORNG**	815M TO 890M	**427 TO 432**			
	31400	**RED**	740M TO 815M	**433 TO 438**			
38		**3543**			**23**	**BIRD AT 746M**	
	0298-31410	**ORNG**	665M TO 740M	**439 TO 444**			
	31284	**RED**	590M TO 665M	**445 TO 450**			
39		**2728**			**24**	**BIRD AT 596M**	
	31436	**ORNG**	515M TO 590M	**451 TO 456**			
	31375	**RED**	440M TO 515M	**457 TO 462**		**new**	
40		**2485**			**25**	**BIRD AT 446M**	
	30314	**ORNG**	365M TO 440M	**463 TO 468**		**??????????**	
	31357	**RED**	290M TO 365M	**469 TO 474**		**????? 31377 ?????**	
41		**2970**				**BIRD AT 296M**	

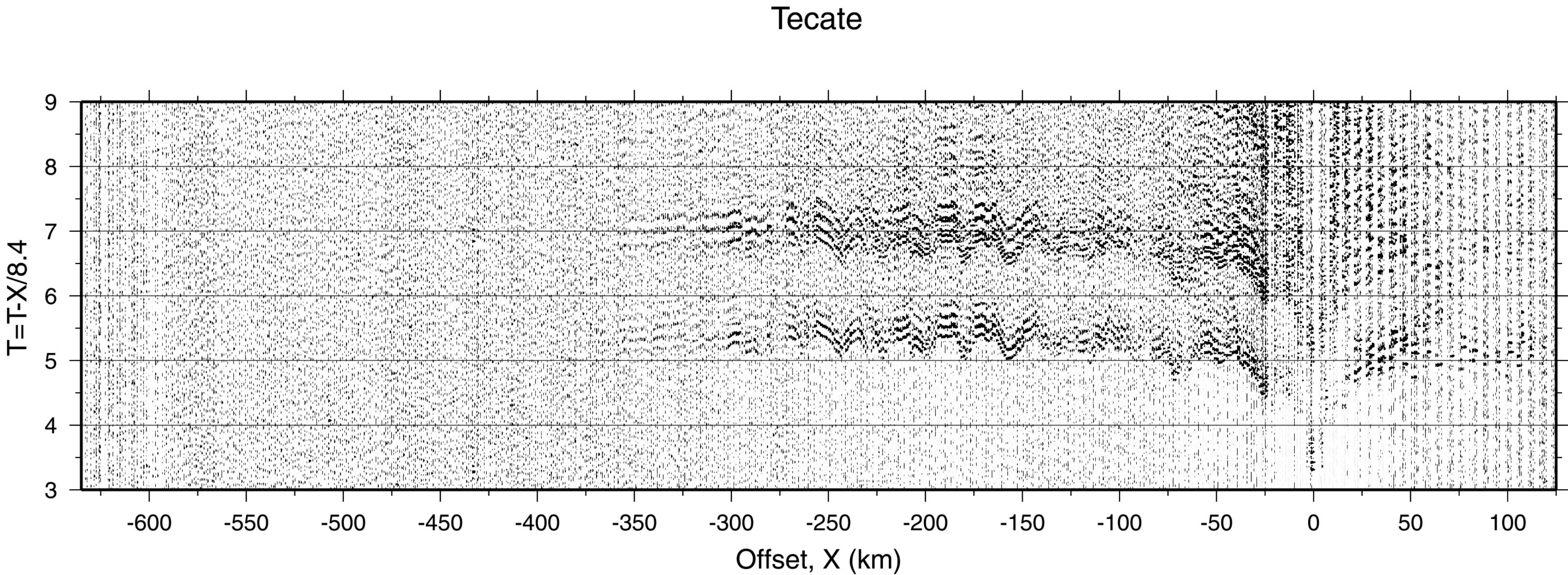
	0298-31360	**ORNG**	215M TO 290M	**475 TO 480**			
	30128HS		165M TO 215M	STRETCH			
42		**10284**	**PASSIVE CAN**				
	30134HS		115M TO 165M	STRETCH			
LDR	0498-30025		STERN TO 115M	LEADER		**FIBER OPTIC**	

RECORD SECTIONS

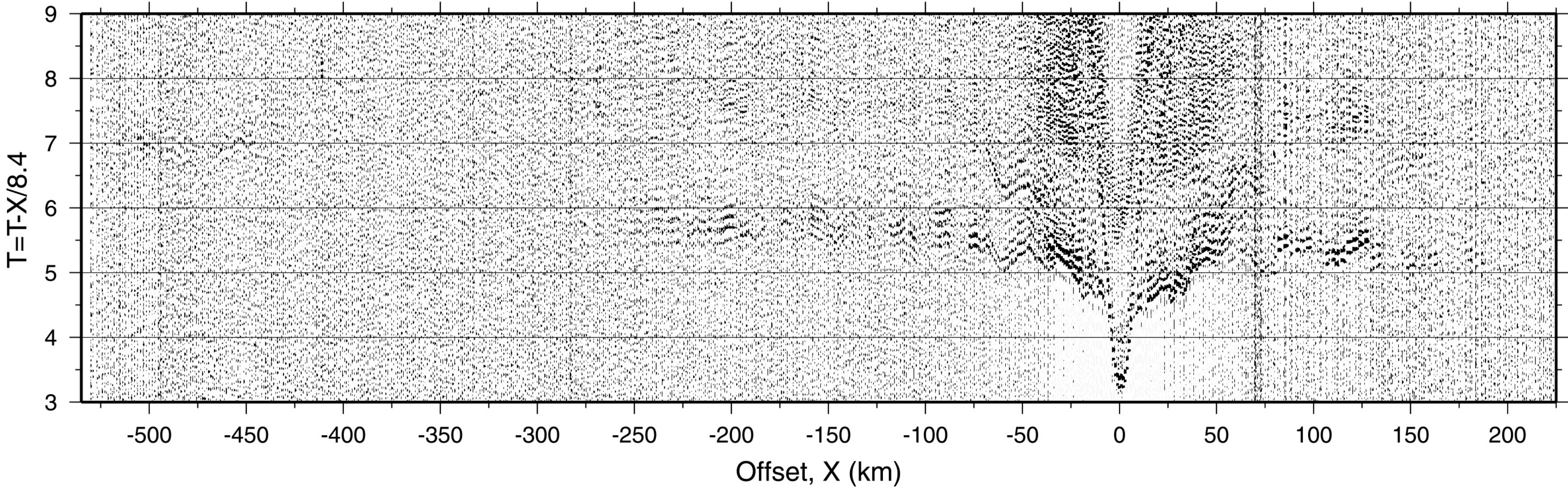
The following seismic sections include profiles for the inline instruments, Line 1. The profiles include the stacked, co-located shots and circle shots merged from the paired instruments. Traces have been normalized to the median value and, in some cases, multiplied by a range-dependent gain. Profiles for *pete* and *bud* for Line 1 shots are plotted as a function of angle relative to the line. Profiles for Line 2 are also shown for *pete* and *bud* ,and the MCS data for Line 2 are brute stacked with 50-m CDP bins using the inner 3 km of the streamer. Enjoy.

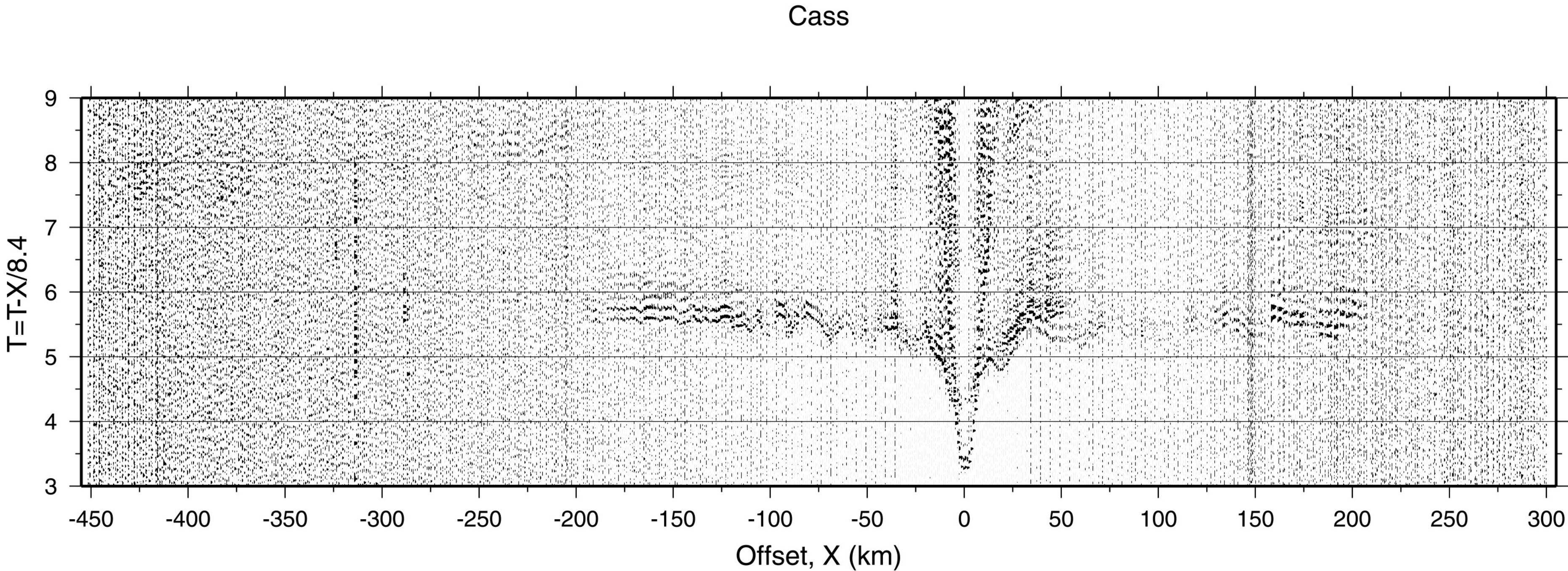

Sierra
T=T-X/8.4
9
8
7
6
5
4
3
-750
-700
-650
-600
-550
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
Offset, X (km)


Sierra (coher)
T=T-X/8.4
9
8
7
6
5
4
3
-750
-700
-650
-600
-550
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
Offset, X (km)

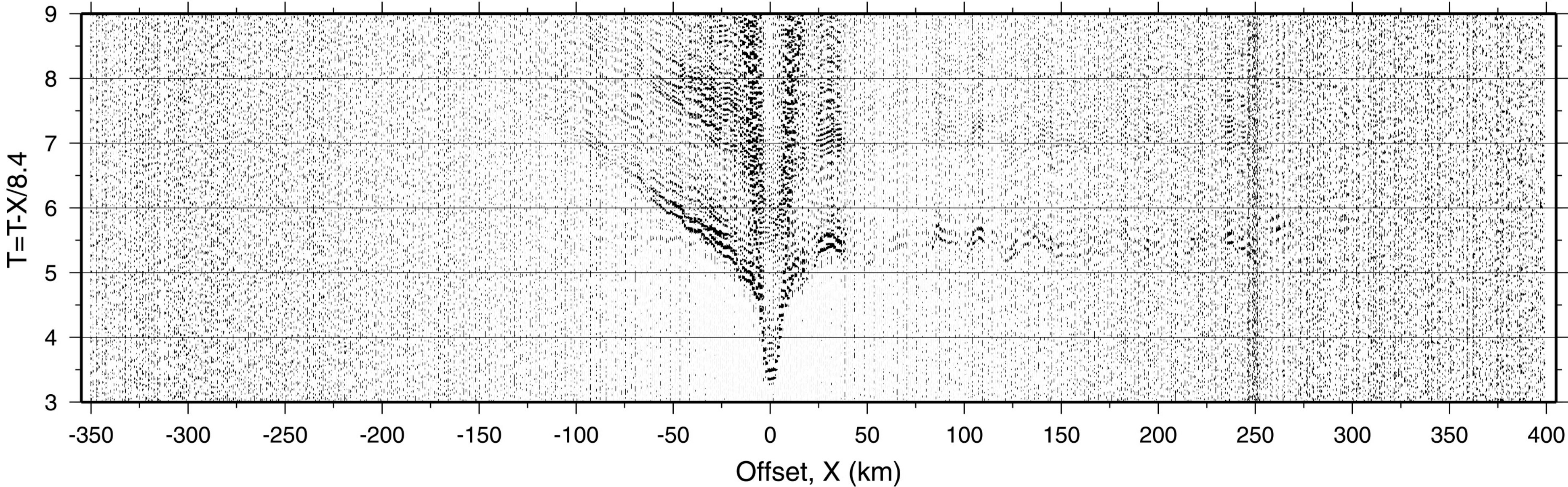

Tecate
T=T-X/8.4
9
8
7
6
5
4
3
-600
-550
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
Offset, X (km)

Bass

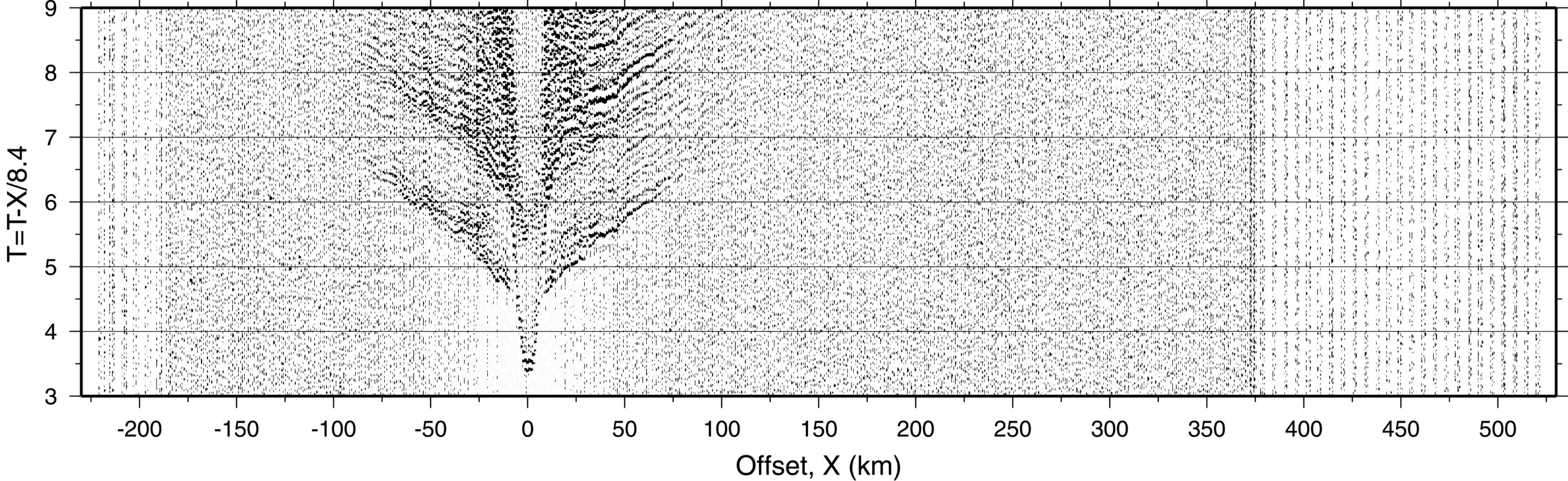

T=T-X/8.4
9
8
7
6
5
4
3
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
Offset, X (km)


Cass
T=T-X/8.4
9
8
7
6
5
4
3
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
300
Offset, X (km)

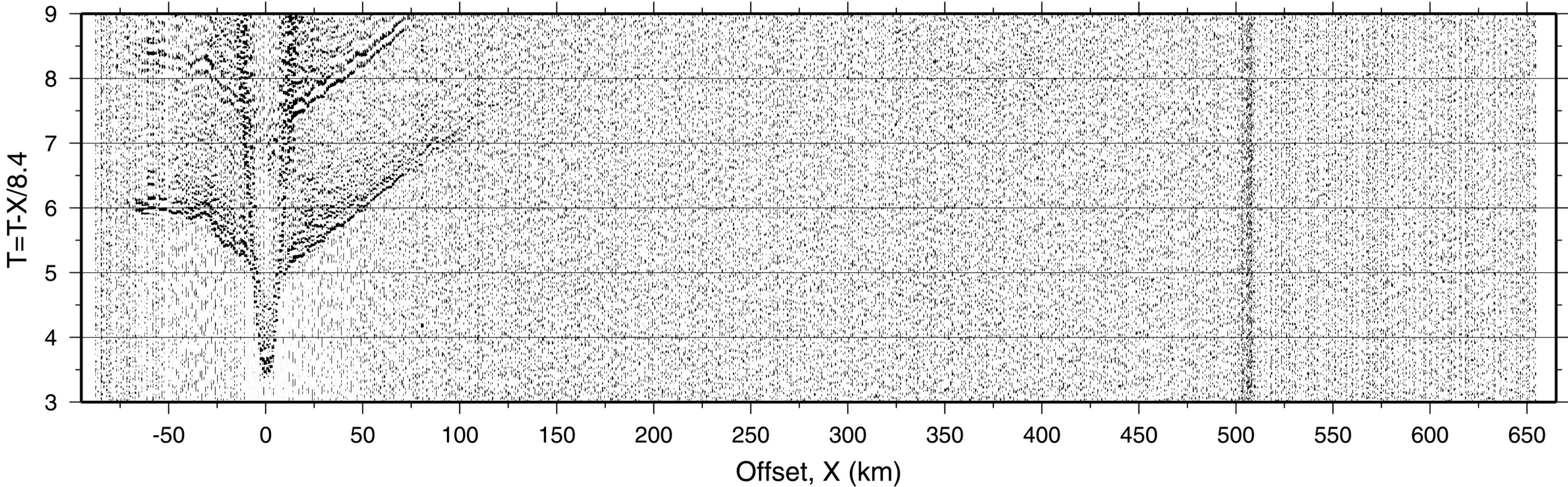
Abita


9
8
7
6
5
4
3
T=T-X/8.4
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
Offset, X (km)

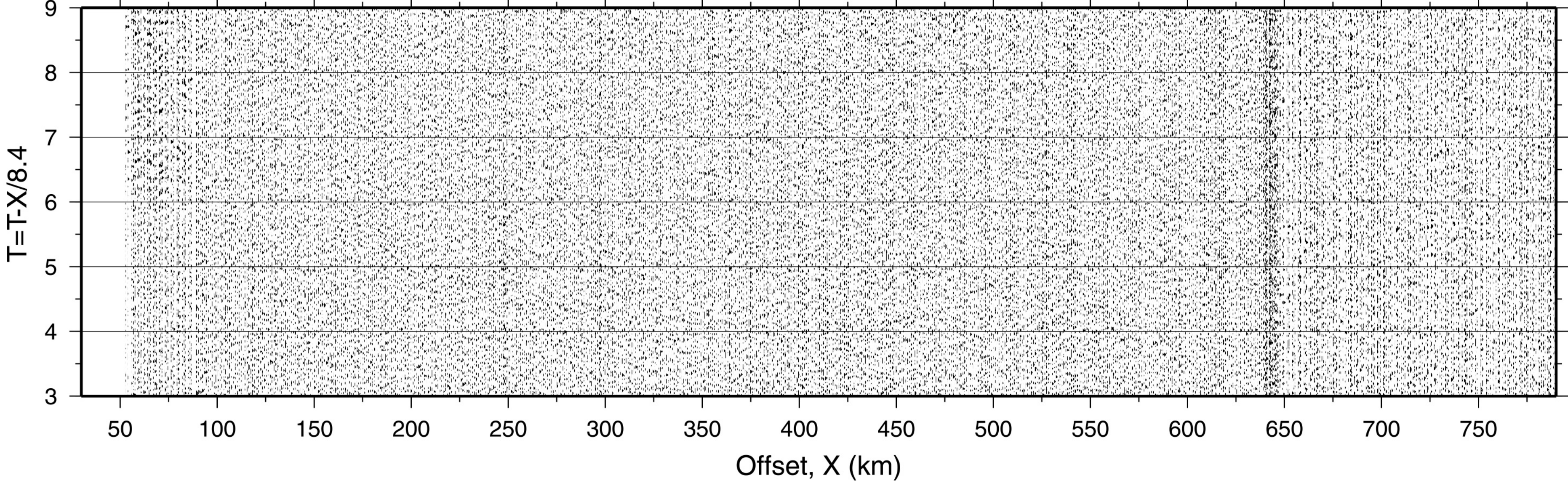
420


T=T-X/8.4
9
8
7
6
5
4
3
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
Offset, X (km)

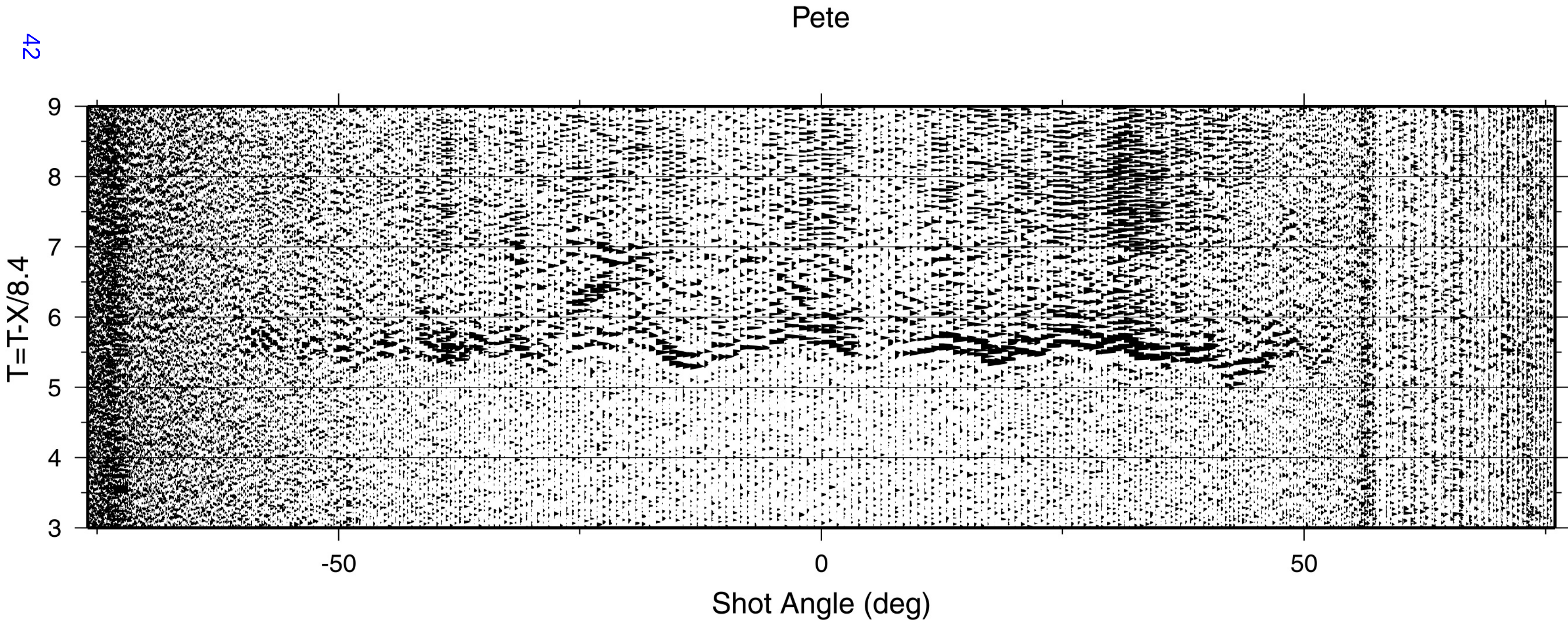
Harp


T=T-X/8.4
9
8
7
6
5
4
3
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Offset, X (km)

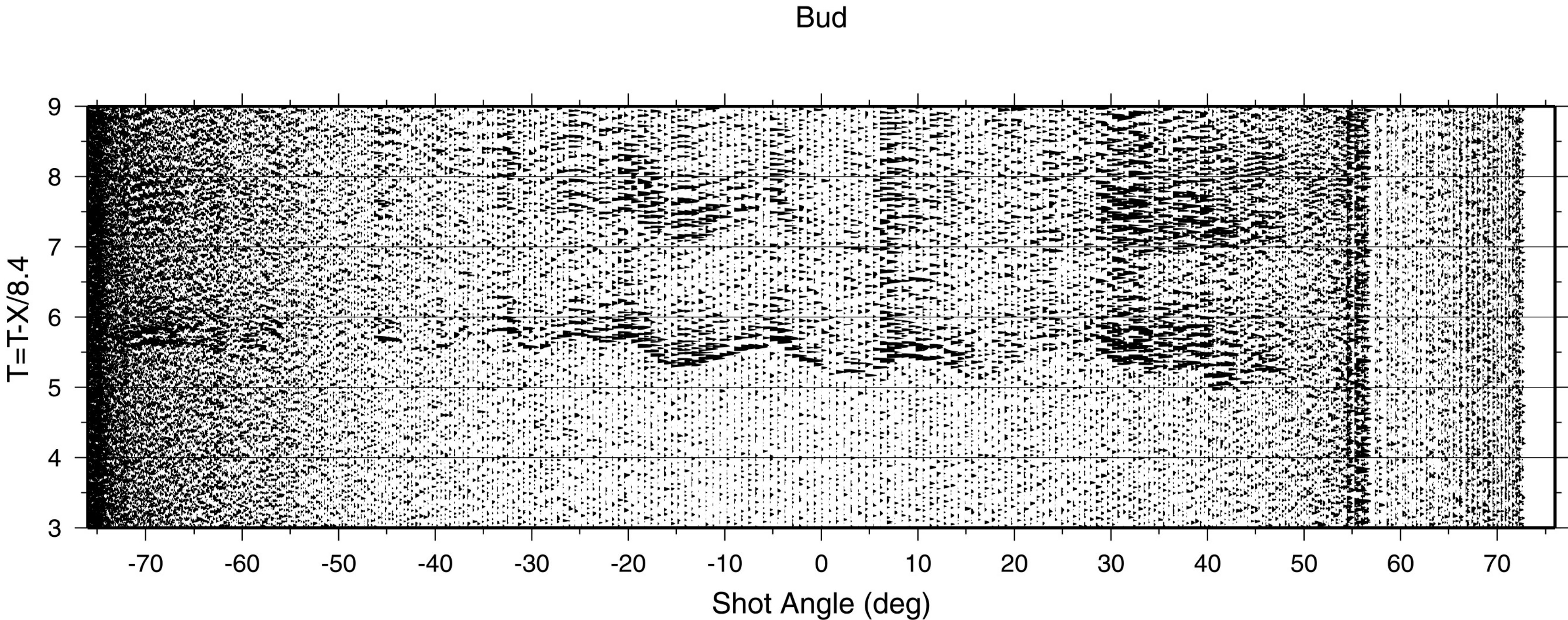
Pauli

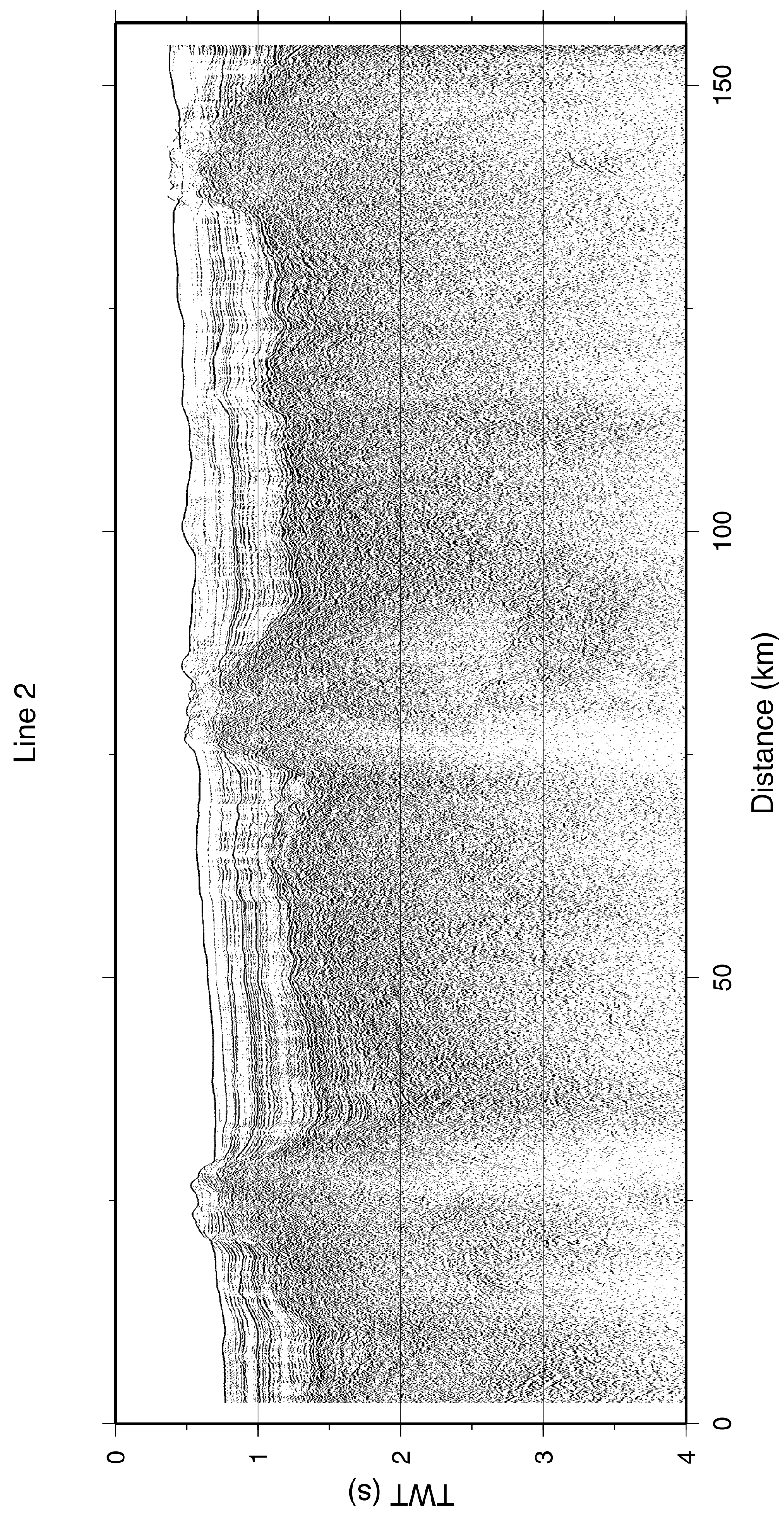


T=T-X/8.4
9
8
7
6
5
4
3
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
Offset, X (km)



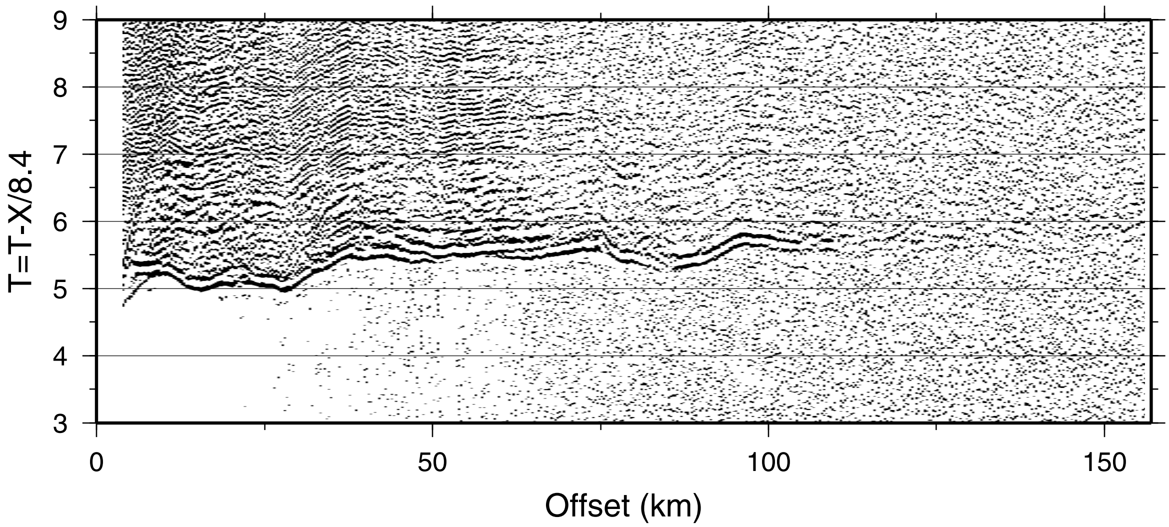
Pete
9
8
7
6
5
4
3
T=T-X/8.4
-50
0
50
Shot Angle (deg)


Bud
T=T-X/8.4
9
8
7
6
5
4
3
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
Shot Angle (deg)

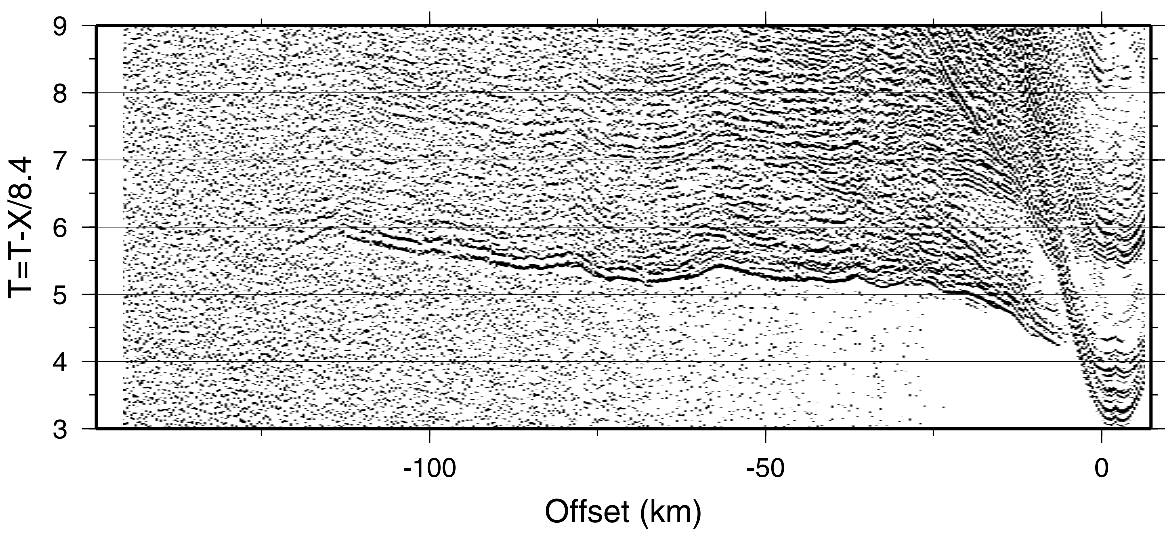


Line 2
TWT (s)
0
1
2
3
4
Distance (km)
0
50
100
150

Pete, Line 2



Bud, Line 2



EWING DATA REDUCTON SUMMARY

The R/V Ewing produces a cruise report and a data tape as part of their standard deliverables. The data tape will be submitted to the IRIS DMC as metedata for this cruise. The Ewing cruise report is part of the data tape, existing as a pdf file, and primarily includes information on the formats of various data files (e.g. shottime files, gravity data, hydrosweep bathymetry, etc.) We include extracted portions of the Ewing cruise report in this report, the *FAIM, EW-0106 Cruise Report.*

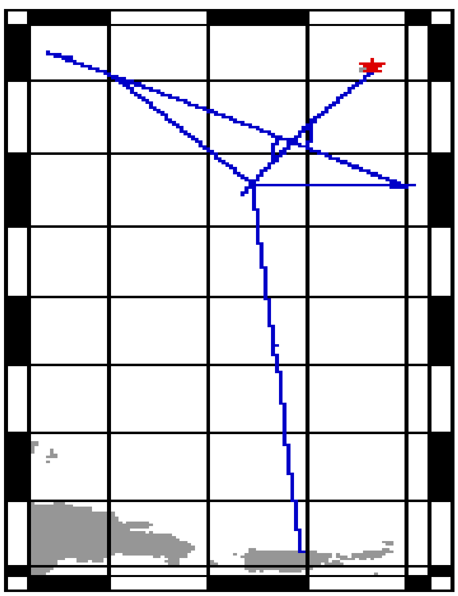
Lamont– Doherty Earth Observatory
Office of Marine Affairs
61 Route 9W
Palisades, NY 10969

Prepared By:Richard Oliver–Goodwin
richardo@ldeo.columbia.edu
845 365–8677

R/V Maurice Ewing Data Reduction Summary

EW−0106 San Juan, Puerto Rico − St. George, Bermuda

Date	Julian Date	Time	Port
May 31, 2001	151	14:30:00	San Juan, Puerto Rico
June 29, 2001	180	14:00:00	St. George, Bermuda



All data in this report is logged using GMT time and Julian days in order to avoid confusion with local time changes.

Spectra

Spectra logs data to files in UKOOA[1] P1/90 format and P2/94 Format. The file formats are included in separate PDF documents on the tape. The contents of these files contain all the parameters used during shooting each of the lines, as well as the positions of all the sensors. I have included perl scripts for extracting shot times and positions from the P1 and P2 files on the tape.

This was the third cruise running the Spectra navigation and seismic shooting system.

Positioning of Sensors

The Spectra system defines a reference point which is used as a reference to all points which need an offset (range and bearing to TB, for example). This reference point has been defined as the center of the ship's mast, at sea level.

Any documentation included herein that refers to the vessel reference or reference or master will be referring to this reference point.

However, daily navigation files that are not related to spectra (i.e. n., hb.n, mg.n, files) are referenced to the Tasmon P−Code GPS filtered positions.

Offset information can be found under the **Ship Diagrams** section of this document.

Data Reduction

Since spectra positions its shots precisely based on a Kalman filtering algorithm, we will assume that it has the correct shot location. However, as a fallback measure, I have also processed the shots using our normal navigation filtering.

Therefore you will find the following shotlog files:

- nb0.r Contains shot times and positions based on Spectra positioning.
- nb2.r Contains shot times and positions based on Spectra navigation
- ts.n Contains shot times and positions based on Ewing navigation

Please see the File Formats section for more information on these files.

1 United Kingdom Offshore Operators Association

Hydrosweep

This cruise was the maiden voyage of our Hydrosweep multibeam sonar DS−2 system. The upgraded 59 "hard" beam version of HSDS−2 worked reliably and produced significantly improved data..

There are, however, some unresolved issues:

1. When hydrosweep data acquisition is paused or stopped , the "draft" is reported as centerbeam depth.
2. When hydrosweep data acquisition is paused or stopped, the frequency of the udp broadcast increases to once per second creating files of considerable size.
3. Mbinfo reports data acquired during the above mentioned "pauses" as drops, so an accurate determination of total bathymetry counts cannot be made.

Gravity

There were no gravity data interruptions.

Seismic Acquisition

There were minor but chronic problems with the Syntron system incorrectly reporting air−gun auto fires. In an effort to investigate and correct these false reports, two shots were missed. Both shots (#178, #324) occurred during FAIMLine7.

Shot #401 on FAIMLine5 was also missed.

Streamer configuration files are included on the tape in Excel 97 format.

Data Logging

The R/V Maurice Ewing data logging system is run on a Sparc Ultra Enterprise Server. Attached are 48 serial ports via 3 16−port Digi International SCSI Terminal Servers. Generally, all data logged by the Ewing Data Acquisition System (DAS) is time stamped with the CPU time of the server, and broadcast to the Ewing network using UDP packet broadcasts. The CPU time of the server is synchronized once every half hour to a Datum UTC gps time clock.

GPS times are also time−tagged with cpu time, although the time of the GPS position is from the GPS fix itself.

The following tables describe the data instruments which performed logging during this cruise. The tables associated with the instruments describe logging periods and data losses for that instrument.

Time Reference

Datum StarTime 9390−1000

logging interval: 30 minutes
file id: tr2

Used as the CPU synchronization clock. This clock is polled once every half hour to synchronize the CPU clock of the data logger to UTC time. The logger (octopus) is responsible for updating the times of the other CPUs.

There were chronic problems with the Ewing time daemon, particularly at the end of the cruise.

Note that the Spectra system uses its own Trimble gps receiver for synchronizing its hardware to UTC time. This is the time the shot points are referenced to; not the CPU time.

Interruption s greater than 30 minutes are displayed in the following table

Log Date	LogDate	Comment
2001+151:02:41:30.185		Logging officially started
2001+151:02:41:30.185	2001+151:16:33:30.190	Data interruption
2001+159:03:33:29.729	2001+160:00:05:29.734	Data interruption
2001+176:20:35:29.737	2001+177:14:49:29.164	Data interruption
2001+177:14:49:29.164	2001+177:15:25:16.696	Data interruption
2001+177:15:29:30.068	2001+178:05:41:39.909	Data interruption
2001+178:05:41:39.909	2001+178:06:17:27.497	Data interruption
2001+178:06:17:27.497	2001+178:06:53:14.832	Data interruption
2001+178:06:53:14.832	2001+178:07:29:01.967	Data interruption
2001+178:07:29:01.967	2001+178:08:04:49.110	Data interruption
2001+178:08:04:49.110	2001+178:08:40:36.249	Data interruption
2001+178:08:40:36.249	2001+178:09:16:22.262	Data interruption

Log Date	LogDate	Comment
2001+178:09:16:22.262	2001+178:09:52:09.421	Data interruption
2001+178:09:52:09.421	2001+178:10:27:56.565	Data interruption
2001+178:10:27:56.565	2001+178:11:03:43.709	Data interruption
2001+178:11:03:43.709	2001+178:11:57:01.262	Data interruption
2001+180:14:00:00		Logging officially ends

Spectra

Spectra uses its own Trimble gps receiver for synchronizing its hardware to UTC time. This is the time the shot points are referenced to; not the CPU time.

GPS Receivers

GPS data is usually logged at 10 second intervals. The NMEA strings GPGGA and GPVTG are logged for position, speed, and heading fixes. This data was logged constantly throughout the cruise.

The Tasmon GPS was the primary GPS for this cruise.

Trimble Tasmon P/Y Code Receiver

logging interval: 10 seconds
file id: gp1

The Tasmon is the primary GPS receiver for the Ewing Logging system and the primary GPS for Spectra fixes. The accuracy is around 15 meters. There were no interruptions during this cruise.

Interruptions greater than 10 minutes are displayed in the following table

Log Date	LogDate	Comment
2001+151:02:43:08.612		Logging officially starts
2001+151:15:05:17.526	2001+151:16:51:48.880	Data interruption
2001+180:14:00:00		Logging officially ends

Trimble NT200D

logging interval: 10 seconds
file id: gp2

The Trimble is the secondary receiver for GPS data. Data is logged at 10 second intervals and is also used as an input to Spectra, although it is weighed at a lower value than the Tasmon receiver.

Interruptions greater than 10 minutes are displayed in the following table

Log Date	LogDate	Comment
2001+151:02:43:15.457		Logging officially started

Log Date	LogDate	Comment
2001+151:15:05:12.294	2001+151:16:56:23.902	Data Interruption
2001+180:14:00:00		Logging officially ends

Tailbuoy Garmin GP8

logging interval: 10 seconds
file id: tb1

The tailbuoy receiver was working during all lines with the exception of minor blackouts during deployment and turns.

Interruptions greater than 30 minutes are displayed in the following table

Log Date	Log Date	Comment
2001+178:10:55:40.302		Tailbouy logging starts
2001+179:13:05:44.549		Tailbuoy logging officially ends

Speed and Heading

Furuno CI−30 Dual Axis Speed Log
Sperry MK−27 Gyro

logging interval: 6 seconds
file id: fu

The Furuno and Gyro are combined to output speed, heading and course information to a raw Furuno file, as well as an NMEA VDVHW signal used as an input to various systems including steering and Spectra.

Interruptions greater than 30 minutes are displayed in the following table

Log Date	Log Date	Comment
2001+151:02:43:50.360		Logging officially starts
2001+151:15:05:18.686	2001+151:16:52:23.232	Data Interruption
2001+180:14:00:00		Logging officially ends

Gravity

Bell Aerospace BGM−3 Marine Gravity Meter System

logging interval: 1 second
file id: vc. (raw), vt. (processed)
drift per day: −0.456

The BGM consists of a forced feedback accelerometer mounted on a gyro stabilized platform. The gravity meter outputs raw counts approximately once per second which are logged and processed to provide real−time gravity displays during the course of the cruise as well as adjusted gravity data at the end of the cruise.

Interruptions greater than 10 minutes are displayed in the following table

Log Date	Log Date	Comment
2001+151:02:44:02.843		Official start date
2001+151:15:05:18.526	2001+151:16:52:54.059	Lost BGM output
2001+180:14:00:00		Logging officially ends

Bathymetry

Krupp Atlas Hydrosweep−DS−2

logging interval: variable based on water depth
file id: hb (centerbeam), hs (swath)

The hydrosweep full swath data is continuously logged for every cruise, and centerbeam data is extracted and processed separately. The centerbeam operates at a logging frequency dependent on the water depth.

The full swath data is not routinely processed, but can be processed with the MB−System software which can be downloaded for free. For instructions, use the website: http://www.ldeo.columbia.edu/MB−System.

MBSystem, version 4.6.10 is necessary to process data after Jan 1, 2000.

Note: During OBS deployment, the hydrosweep was routinely suspended to avoid interference with the standard wide beam profilers. As the new DS−2 system falsely reports paused or stopped periods of data acquistion, it has proved most difficult to distinguish periods of OBS deployment from "real" data interruptions..

Log Date	LogDate	Comment
2001+152:12:00:17.000		Logging officially starts
2001+180:14:00:00		Logging officially ends

Weather Station

RM Young Precision Meteorological Instruments, 26700 series

logging interval: 1 minute
file id: wx

The weather station is used to log wind speed, direction, air temperature, and barometric pressure. We log this information at 1−minute intervals.

Log Date	LogDate	Comment
2001+151:02:45:42.915		Logging officially starts
2001+151:15:05:00.682	2001+151:16:54:54.432	Data Interruption
2001+180:14:00:00		Official end logging

Seismic Lines

As this was the third cruise using Spectra to fire the guns and log the shot times, we are still in the process of learning all aspects of the system and integrating Spectra into the Ewing system.

The ability to shoot concentric circles in addition to traditional survey lines was critical to the success of this cruise. Since Spectra had no facility to use a circle as an aim point, we excercised a previously unused shooting mode, the "cycle test", to accomplish this. The "cycle test" mode is basically a testing mode, as the name might suggest, and required some massaging to perform as if "on−line". This has resulted in some compromises in shot logging.

The following items were of concern during this cruise:

1. The P2 and P1 formats do not store the shot time in millisecond range.
2. Where Spectra P2 and P1 logging normally continue without interruption, constant switching from "cycle test" mode to "normal" mode apparently required manual intervention. As a result, P1 and P2 files were not logged for FAIMLines 1b, 2, 3, 4, 5, 6, 7, and 8. Note: Since shottimes for all shots were logged via conventional Ewing system logging and P2 and P1 formats do not store times in millisecond range, data loss was minimized.
3. An incorrect "shot layback" parameter of −53.4 meters was entered in the Spectra System. This setting effectively shifted the ship offsets and severely compromised our efforts to shoot at identical positions on the forward and reversed lines.
4. SIOSEIS cannot handle the Spectra output header for SEG−D.

A system has been created where the Spectra header, data from the Digicourse cable output, data from the gun depths, and real−time data from the Ewing logging system are all used to create a Ewing standard SEG−D header readable by SIOSEIS to place on the 3490 tape for each shot.

Unfortunately, due to human error, I was unable to produce the Ewing standard SEG−D header for most of the shots of FAIMLine1a.

There are several files for each line reflecting the line status:

File	Description
ts.n	Shot time is merged with Ewing navigation to determine shot location
nb2.r	Navigation is from Spectra, and includes tailbuoy, tailbuoy range and bearing

Shot Files Table

Line Name	Times ()	Ewing(ts.n, nb2.r)		Spectra (shots.p1, shotlog.p2)		
		Shots	Missing	P1 Shots	P2 Shots	Missing
FAIMLine1a	159:03:53:28.980 163:09:35:28.980	001−679		0001−0679	0001−0679	
FAIMLine1b	163:09:44:35.794 163:15:18:31.304	001−051		None recorded	None recorded	
FAIMLine2	163:16:25:51.157 163:21:47:22.153	001−051		None recorded	None recorded	
FAIMLine3	163:22:53:44.572 165:00:01:27.839	001−351		None recorded	None recorded	
FAIMLine4	165:13:48:39.452 167:06:33:33.709	001−351		None recorded	None recorded	
FAIMLine5	167:07:38:00.631 169:02:53:59.740	001−400	401	None recorded	None recorded	
FAIMLine6	169:04:03:38.461 171:01:02:03.581	001−401		None recorded	Not recorded	
FAIMLine7	171:02:03:05.029 173:15:17:30.860	001−563	178, 324	None recorded	Not recorded	
FAIMLine8	173:15:30:50.980 174:08:44:20.980	001−109		None recorded	None recorded	
FAIMMCSLine	178:13:28:51.424 179:07:00:45.677	014−520		013 −520	013−520	
FAIMTestLine	165:12:41:28.980 165:13:09:28.980; 167:06:41:14.980 167:07:16:14.980; 169:03:09:32.980 169:03:44:32.980; 171:01:09:36.980 171:01:51:36.980;	001−005 001−006 001−006 001−007				

San Juan, Puerto Rico

EW0105 San Juan, Puerto Rico

Pier/Ship	Latitude	Longitude
	18 27.84N	66 06.36W

Pier 8

Reference	Latitude	Longitude
	18 27.8N	66 05.5W

Cruise Ship terminal

	Id	Julian	Date	Mistie	Drift/Day	Prev Mistie
Pre Cruise	EW0104	139	19. May 01	9.82	0.02	8.99
Post Cruise	EW0105	151	31. May 01	11.63	0.151	9.82
Total Days			12.00	1.81		

Time	Entry	Value	
1446	CDeck Level BELOW Pier	0.00	
1446	Pier 1 L&R Value	2332.11	L&R
1446	Reference L&R Value	2334.21	L&R
	Pier 2 L&R Value	2332.11	L&R
	Reference Gravity	978680.69	mGals
	Gravity Meter Value (BGM Reading)	978691.80	mGals
	Potsdam Corrected	0	1 if corrected

*Gravity meter is **5.5** meters below CDeck*

	Difference in meters between Gravity Meter and Pier				5.50	meters
Height Cor =	Pier Height*	FAA Constant				
	5.50	0.31			1.71	mGals/min

Difference in mGals between Pier and Gravity Meter

Pier (avg) −	Reference *	1.06 L&R/mGal		Delta L&R	
2332.11	2334.21	1.06		−2.23	mGals

Gravity in mGals at Pierside

Reference + Delta mGals [+ Potsdam]				Pier Gravity	
978680.69	−2.23	0.00		978678.46	mgals

Gravity in mGals at Meter

Pier Gravity+	Height Correction			Gravity@meter	
978678.46	1.71			978680.17	mGals

Current Mistie

BGM Reading	Calculated Gravity			Current Mistie	
978691.80	978680.17			11.63	mGals

St. George, Bermuda

EW0106 St. George, Bermuda

Pier/Ship	Latitude	Longitude
	32 22.71N	64 40.89W

Pier 8

Reference	Latitude	Longitude
	32 15.00N	64 41.67W

Tiger Bay Wharf

	Id	Julian	Date	Mistie	Drift/Day	Prev Mistie
Pre Cruise	EW0105	151	31. May 01	11.63	0.15	9.82
Post Cruise	EW0106	180	29. Jun 01	−1.60	−0.456	11.63
Total Days			29.00	−13.23		

Time	Entry	Value	
1850	CDeck Level BELOW Pier	−0.30	
1850	Pier 1 L&R Value	3417.80	L&R
1850	Reference L&R Value	3418.10	L&R
	Pier 2 L&R Value	3418.00	L&R
	Reference Gravity	979821.40	mGals
	Gravity Meter Value (BGM Reading)	979821.20	mGals
	Potsdam Corrected	0	1 if corrected

*Gravity meter is **5.5** meters below CDeck*

	Difference in meters between Gravity Meter and Pier				5.20	meters
Height Cor =	Pier Height*	FAA Constant				
	5.20	0.31			1.61	mGals/min

Difference in mGals between Pier and Gravity Meter

Pier (avg) −	Reference *	1.06 L&R/mGal		Delta L&R	
3417.90	3418.10	1.06		−0.21	mGals

Gravity in mGals at Pierside

Reference +	Delta mGals	[+ Potsdam]		Pier Gravity	
979821.40	−0.21	0.00		979821.19	mgals

Gravity in mGals at Meter

Pier Gravity+	Height Correction			Gravity@meter	
979821.19	1.61			979822.80	mGals

Current Mistie

BGM Reading	Calculated Gravity			Current Mistie	
979821.20	979822.80			−1.60	mGals

File Formats

For all formats, a **–** in the time field means an invalid value for some reason.

Streamer Compass/Bird Data — cb.r

This data is not processed, but can still be found in the "processed" data directory.

Shot Time	Line	Shot	Latitude	Longitude
2000+079:00:08:40.085	strike1	000296	N 15 49.6217	W 060 19.8019

2nd GPS Position Latitude	Longitude	Tailbuoy Position Latitude	Longitude
N 15 49.6189	W 060 19.8101	N 15 47.1234	W 060 20.1901

Furuno Gyro	Streamer Compasses & Heading
344.1	C01 2.3 C02 1.7 ...

Gun Depths — dg

Gun depths in tenths of meters. There will always be 20 gundepths even if only one gun was configured and shooting.

Shot Time	Gun Depths 1	2	3	4	5	6	7	8	9	...	20
2001+089:06:47:05.909	189	068	005	005	096	005	060	054	005	...	6

Raw Furuno Log — fu.s

This data has been smoothed and output 1 fix per minute.

CPU Time Stamp	Track	Speed	Hdg	Gyro
2000+166:00:01:53.091	–	4.4	140.5	148.3

Hydrosweep Centerbeam — hb.n

Hydrosweep data merged with navigation

CPU Time Stamp	Latitude	Centerbeam Longitude	Depth
2000+074:09:55:00.000	N 13 6.6206	W 59 39.3908	134.9

Merged Data — m

CPU Time Stamp	Latitude	Longitude	GPS Used	Set	Drift	Depth
2000+200:12:25:00.000	N 45 54.1583	W 42 47.1770	gp1	0.0	0.0	

Magnetic Total Intensity	Anomaly	Gravity FAA	GRV	EOTVOS	Drift	Shift
49464.7	55.5	22.2	980735.0	-8.4	-0.1	2.8

Temperature	Salinity	Conductivity
0.0	0.0	0.0

The gravity drift and shift are values that have been added to the raw gravity to make up for drift in the meter that has been lost in accordance with a gravity check at each port stop.

Temperature,Salinity and Conductivity will only be valid while logging a Thermosalinograph, which is not usually the case.

Magnetics Data mg.n

- A minus sign in the time stamp is flagged as a spike point, probably noise...
- Anomaly is based on the International Geomagnetic Reference Field revision 2000

```
CPU Time Stamp         Latitude     Longitude     Raw Value Anomaly
200+077:00:23:00.000 N 16 11.2918 W  59 47.8258 36752.2   -166.8
```

Navigation File n

```
CPU Time Stamp          Latitude     Longitude       Used  Set  Drift
2000+074:00:03:00.000 N 13 6.2214  W  59 37.9399   gp1   0.0   0.0
```

Navigation Block nb0

Navigation is a compendium of Ewing logged data at shot time. The shot position here is the shot position from the Spectra system.

```
Shot Time              Shot # CPU Time              Shot Position
2001+088:00:00:00.606 016967 2001+088:00:00:03.031 N 30 11.8324 W 042 10.8162

Water  Sea    Wind   -------------Tailbuoy----------------- Line
Depth  Temp Spd  Dir Latitude     Longitude     Range Bearg Name   Speed Heading
2565.1 20.7 16.4 164 N 30 12.0427 W 042 14.7319 6296.3 93.5 MEG-10 4.2   101.1
```

Tailbuoy Navigation tb1.c

Raw tailbuoy fixes

```
CPU Time Stamp          Latitude     Longitude       GPS Precision
2001+088:00:00:02.000 N 30 12.0424 W 042 14.7309   SA
```

GPS Precision is either SA, DIFF or PCODE

Ewing Processed Shot Times ts.n

Shot times and positions based on the Ewing navigation data processing

```
CPU Time Stamp          Shot # Latitude     Longitude     Line Name
2000+079:00:08:01.507 000295 N 15 49.5703 W 060 19.7843 strike1
```

Shot Data Status ts.n.status

The ts.nxxx.status file describes the line information for that day, giving some basic statistics about the line: start, end times; missing shots; start and end shots.

```
LINE   strike1: 98+079:00:00:15.568 : 000283 .. 002286
        MISSING: 347, 410, 1727
LINE   dip2: 98+079:23:05:22.899 : 000002 .. 000151
```

This example says that on Julian Day 079 of 1998, two lines (strike1 and dip2) were run: the end of strike 1 (shots 000283 to 002286) and the start of dip2 (shots 000002 to 000151).

Line strike1 had some missing shots in the data file (probably missing on the SEG-d header as well).

Spectra Shot Times nb2.r

The shot times and positions based on the Spectra positioning; with raw tailbuoy range and bearing.

CPU Time Stamp	Shot #	Latitude	Longitude	Line Name
2001+084:00:00:05.924	009245	N 23 31.2410	W 045 25.0894	

Latitude	Longitude	Tailbuoy Range	Bearing	Line Name
N 23 30.4540	W 045 21.4338	6389.8	283.2	KANE-4

Raw Gravity Counts vc.r

sample BGM-3 gravity count record (without time tag):

```
pp:dddddd ss
|    |    |___________ status: 00 = No DNV error; 01 = Platform DNV
|    |                         02 = Sensor DNV;   03 = Both DNV's
|    |________________ count typically 025000 or 250000
|_____________________ counting interval, 01 or 10
                       The input of data can be at 1 or 10 seconds.
```

Gravity Data vt.n

* A minus sign in the time stamp is flagged as a spike point
* m_grv3 calculates the Eotvos correction as:

  eotvos_corr = 7.5038 * vel_east * cos(lat) + .004154 * vel*vel
* The theoretical gravity value is based upon different models for the earth's shape.
  - 1930 = 1930 International Gravity Formula
  - 1967 = 1967 Geodetic Reference System Formula
  - 1980 = 1980 Gravity Formula
* The FAA is computed as:

  faa = corrected_grv - theoretical_grv
* Velocity smoothing is performed w/ a 5 point window

CPU Time Stamp	Latitude	Longitude	Model	FAA	RAW
2000+148:00:10:00.000	N 09 34.7255	W 085 38.5826	1980	9.48	978264.16

Eotvos Smooth	Drift Total	DC Shift	Raw Velocity North	East	Smooth Velocity North	East
-74.78	0.06	4.16	1.875	-10.373	1.927	\10.166

Datum Time ts2.r

CPU Time	Datum Time	Time Reference
2001+069:00:15:29.727	069 00 15 29.378	datum

Raw GPS gp(12).d, tb1.d

Raw GPS is in NMEA Format.

Meteorological Data wx

CPU Time Stamp	Spd	True Dir
2001+045:00:00:00.967	7.8	22

Bird1: Speed Inst	60sA	60mA	60sM	Direction Inst	60sA	60mA	Bird 2 Speed Inst	60sA	60mA	60sM	Direction Inst	60sA	60mA
7.8	6.6	8.5	16.8	277	291	5	0.0	0.0	0.0	0.0	0	0	0

Temperature Inst	60mA	60mm	60mM	Humidity Inst	60mm	60mM	Barometer
15.0	14.2	14.3	15.1	92	90	93	1027.5

Inst: Current

60sA: 60 second average

60mA: 60 minute average

60sM: 60 second maximum

60mm: 60 minute minimum

60mM: 60 minute maximum

Shot Times from Spectra P1 Files — shots.p1

These files were created with the script: *extract_shots_from_p1* ***-a 1***

Epoch Time	Shot#	Source Lat/Lon		TB Lat	TB Lon
985788741.000	015570	30.283881	−41.854536	30.320144	−41.886642

Vessel Ref Lat/Lon		Antenna GPS Lat/Lon		Water Depth
30.283478	−41.854117	30.283531	−41.854078	2894.2

- Source is the Center of the Guns
- TB is the Tailbuoy, according to Spectra
- Vessel Ref is the location of the center of the Mast
- Antenna GPS is the location of Antenna 1 (−a 1 flag); in this case is the Tasmon GPS
- Water Depth is the HS Centerbeam depth

Shot Times from Spectra P2 Files — shots.p2

These files were created with the script: *extract_shots_from_p2 −o "V1 G1"*

Epoch Time	Shot#	Vessel Ref Lat/Lon		Source Lat/Lon	
985716772.4	00015572	30.282803	−41.866136	30.283207	\41.866540

- Vessel Ref is the location of the center of the Mast
- Source is the Center of the Guns

I have included some scripts for extracting information out of the P1 and P2 formatted files. In order to use these scripts you will also need to install the Ewing Perl libraries I have included in the scripts directory, or at least include that directory in your PERL5LIB environment. It is not my intention to describe how to use perl in this document though.

extract_shots_from_p1 [−a antenna] [−h] filename

Given an input P1 File, create a shotpoint file with the times, and the positions of the given antenna [1 = tasmon, 2 = Trimble] and optionally the header records at the beginning of the file.

The output will be:

```
epochtime shotnumber sourcePos tbPos vesselPos antennaPos depth
```

- **epochtime** is the # of seconds since Jan 1, 1970
- **shotnumber** is the shot number
- **sourcePos** is the center position of the sound source [lat lon]
- **tbPos** is the position of the tailbuoy [lat lon]
- **vesselPos** is the position of the vessel reference (center of mast) [lat lon]
- **antennaPos** is the position of the specified antenna [lat lon]
  1 = tasmon, 2 = trimble
- **depth** is the water depth in meters

extract_shots_from_p2 [−s shotnumber] [−o "output values"]

−s define if you only want the statistics for a single shot

−o "*outputs*" defines the outputs you want from the P2 file.

This routine will output by default the shotpoint, the line name and the shot time. Optionally, you can output position (Lat Lon) info for a number of items:

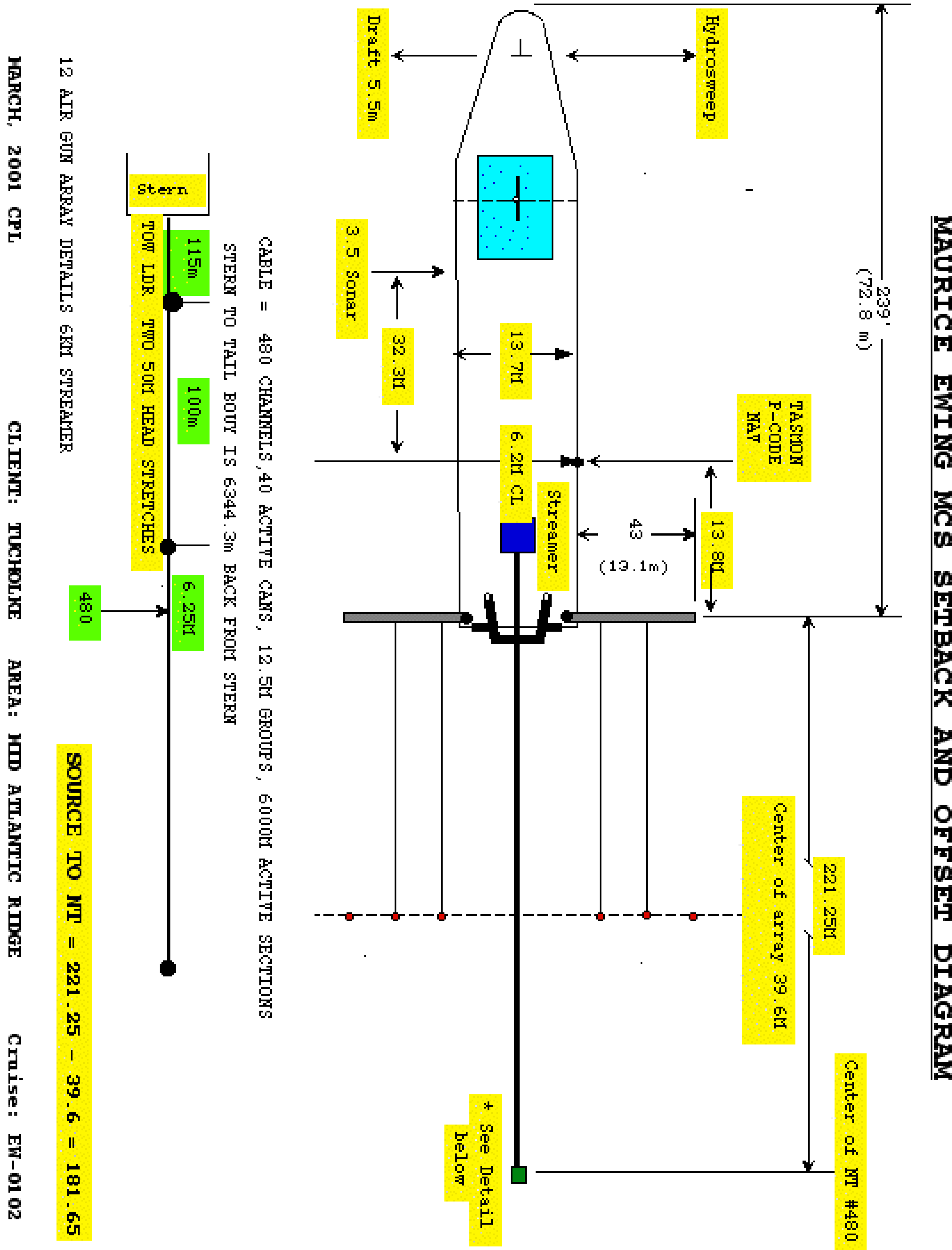
Outputs can be one or more of the following:

- V1 Vessel 1 Reference
- V1G1 Tasmon GPS Receiver
- V1G2 Trimble GPS Receiver
- V1E1 Hydrosweep Transducer
- TB1 Tailbuoy 1
- S1 Streamer 1
- V1SC Streamer Compasses
- G1 Gun Array 1

All the formats output a Lat Lon pair in decimal degrees. (*West and South being negative*)

Output will be: `epochtime shotnumber [output lat/lon pairs]`

Ship Diagram



Tape Contents

EW0104/	
EW0104.pdf	this document
ew0104.cdf	NetCDF database file of this cruise
ew0104.cdf_nav	NetCDF database file of this cruise' navigation
docs/	File Formats, Spectra manuals
processed/	Processed datafiles merged with navigation
shotlogs/	processed Shot Files
trackplots/	daily cruise track plots (*postscript*)
raw/	Raw data directly from logger
reduction/	Reduced data files
clean/	daily processing directory, includes daily postscript plots of the data.
scripts/	Perl scripts and their friends
spectra/	P1/90 and P2/94 files from MCS lines
streamer/	Excel spreadsheets of streamer configuration