CHIX05

CHIX05 - 3D Tomographic Imaging
of the Chicxulub Crater

The 2005 Chicxulub Impact Crater Seismic Experiment

Cruise: R/V Maurice Ewing, EW0501 funded by NSF and NERC

Port of Origin: Colon, Panama - January 5 th, 2005

Port of Terminus: Progreso, Mexico - February 19 th, 2005

Co-chief scientists: Dr Sean Gulick, University of Texas, USA
& Dr Penny Barton, University of Cambridge, UK

Assembled Data Set 05-008

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Report on Chicxulub seismic experiment 2005

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CONTENTS

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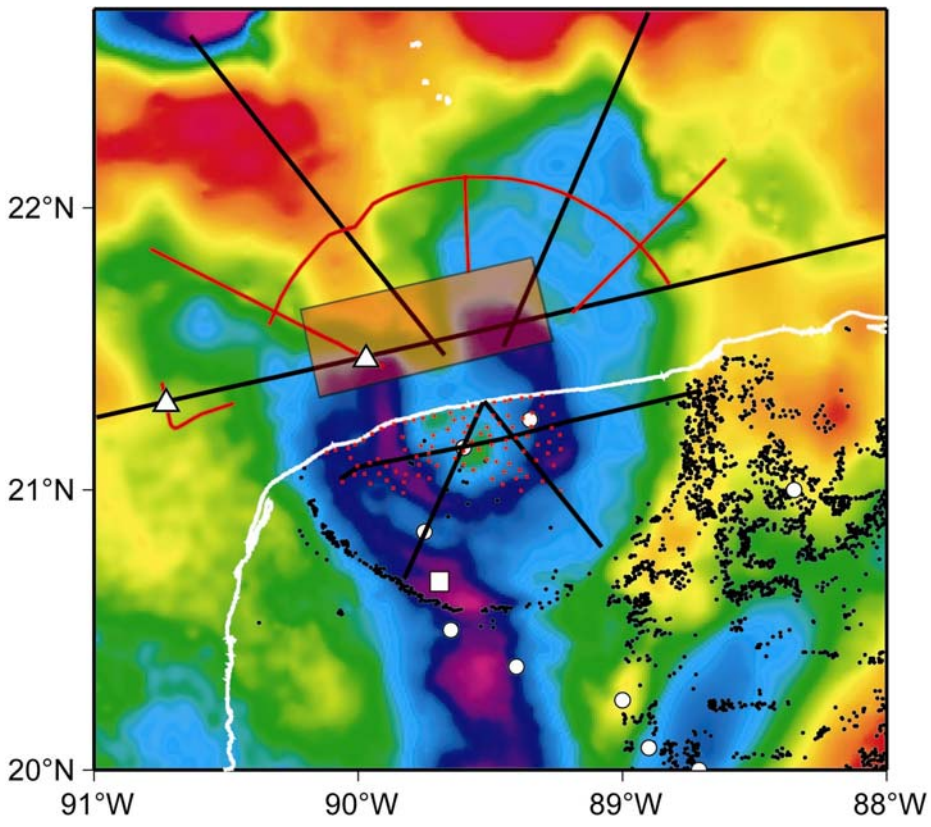

Figure 1. Location figure. Color image is Bouguer gravity anomaly (reds and yellows are high gravity values; blues and purples are low gravity values). White line is coastline of the Yucatan peninsula. Black points indicate cenote locations. Black lines indicate location of 1996 seismic survey. Red lines and shaded region indicates offshore 2005 seismic survey and red points shows seismometers. White points are existing or planned drill sites.

Introduction

Sixty-five million years ago a ~10 km diameter meteor crashed into the Yucatan Peninsula of Mexico leaving behind the 195 km wide Chicxulub crater (Figure 1) which is one of only three known impact craters on Earth with diameters larger than 150 km. Seventy percent of the species on the Earth including the dinosaurs became extinct at the Cretaceous-Tertiary (K-T) boundary, which appears to have been caused, at least in part, by this impact. In addition to being the cause of the K-T extinction event, Chicxulub is the only one of the three

large craters on Earth that is well preserved due to a cover of ~1 km of Tertiary (post-impact) limestones. The Chicxulub crater is uniquely suited for a seismic investigation into the way large diameter impacts deform the Earth and what the specific environmental effects of the Chicxulub impact were at the KT boundary.

The goals of our combined reflection-refraction seismic experiment are: 1) We seek to determine the direction of approach and angle of the Chicxulub impact as modeling has shown that a 15-20 time greater amount of airborne particles are produced by low-angle impacts; 2) We will map the deformation (faults and broken rock) recorded in the upper crust near the crater center that may explain the way the surface of the Earth is damaged by large meteor or comet impacts; 3) By imaging the key features in the northwest portion of the crater we can further understand the Chicxulub impact structure and prepare for possible future sampling to examine the melted and shattered rocks deep within the crater; 4) We intend to model the 3-D collapse of the crater to examine both the deformation and the environmental effects of the impact to better understand how such an impact can cause worldwide mass extinctions.

Activities Realized

The operations that occurred on the cruise included deployments and recoveries of towed and seafloor scientific equipment and the firing of an array of 20 airguns totaling 6970 cubic inches during allowed windows. Equipment deployment and recovery took place on 15th-19th January, 3rd-4th February, 14th February, 16th February and 18th-19th February. Airgun operations occurred on the following dates: January 20th – February 2nd, February 5th-February 14th, and February 17th. Within those days the time windows when airgun operations were allowed were highly constrained dependent on daylight (operations only allowed between 0630 and 1800 local time), weather (operations only allowed in sea conditions less than Beaufort 5), lack of marine mammal or turtle sightings within the safety radius of 3.5 km from the ship, and being a safe radius from fishing or diving activities. Additionally, the research vessel collected underway 2.25-6.25 kHz bathymetric sonar data, along-track gravity measurements, and wind/weather data throughout the period from January 15th to February 19th, 2005.

SUMMARY	MCS profiling with streamer - number of shots		Shooting into seabed instruments only - number of shots		TOTAL number of shots
	partial gun array	full gun array	partial gun array	full gun array	
TOTALS	3393	26807	4131	2229	36560

MCS profiling with streamer - line length in km		Shooting into seabed instruments only - line length in km		TOTAL line length in km
partial gun array	full gun array	Partial gun array	full gun array	
168.35	1338.75	204.85	110.90	1822.85

Table 1: Summary of the total shots recorded by the hydrophone streamer and the ocean bottom seismometers and the total line-kilometers of data acquired.

The airgun data were recorded using the towed hydrophone streamer, seafloor seismometers (ocean bottom seismometers) and land seismometers. Airgun shots can be divided into partial array shots recorded on the hydrophone streamer and seismometers, partial array shots recorded only on the seismometers, full array shots recorded on the streamer and seismometers, and full array shots recorded just on the seismometers. Times when the seismic vessel was shooting during turns are included in those shots recorded only on the seismometers. Partial array shots occurred due to the need to ramp up the seismic array from one airgun to full power at the start of each window of operation. In total there were 3393 partial array shots and 26807 full array shots recorded by both hydrophone streamer and seismometers for a total of 168.35 line-kilometers and 1338.75 line-km, respectively. Additionally, there were 4131 partial array shots and 2229 full array shots recorded only by the seismometers, which is equivalent to 204.85 and 110.90 line-kilometers. The total survey therefore included 36560 shots and 1822.85 line-km of seismic data (Table 1).

EW05-01								
Air gun position	Vol. Cu.In.	output db	0 min.	5 min.	10 min.	15 min.	20 min.	25 min.
1	145	226			145	145	145	145
2	350	233					350	350
3	235	230.5					235	235
4	305	232					305	305
5	80	223	80	80	80	80	80	80
6	640	235						640
7	466	235					466	466
8	875	239.5						875
9	145	226		145	145	145	145	145
10	200	229				200	200	200
11	250	231					250	250
12	200	229			200	200	200	200
13	850	239.5						850
14	235	230.5				235	235	235
15	500	236						500
16	466	235					466	466
17	350	233					350	350
18	260	231					260	260
19	250	231				250	250	250
20	145	226				145	145	145
Number on			1	2	4	8	16	20
added Vol cu.in.			80	145	345	830	2682	2865
total Vol cu.in.			80	225	570	1400	4082	6947
total db peak			223	230	236	242.5	249	253.5
							16 gun	20 gun
							chicx6HR	chicx6
Guns added:			5	9	1 and 12	10,14,19	2,3,4,7,11	6,8.13,15
						and 20	16,17,18	
Guns on:			5	5,9	1,5,9,12	1,5,9,10,	1,2,3,4,5	All 20
						12,14,19.	7,9,10,12	
						20	14,16,17,	
							18,19,20	

Table2: Ramp-up pattern for EW0501 array.

The data were acquired in two phases centered on the deployments of the ocean bottom seismometers (OBS). The first deployment of the hydrophone streamer and the 28 OBS occurred from January 15-19th after which the airgun profiling served as the source while the OBS and the hydrophone served as the receivers from January 20th-February 2nd. The multichannel seismic (MCS) lines (those recorded on the hydrophone streamer) recorded during this time interval are shown as red lines on Figure 2 and the positions of the 23 OBS that functioned properly are shown as red dots on Figure 2. The lighter red portions of the MCS lines record when the airgun array was only partially firing as in ramp-ups. The second phase of airgun profiling followed on a recovery of 25 of the 28 OBS including two which did not record any data; the three other OBS self-released early and two of them were later recovered by fishermen and transported to the Ewing via the pilot boat from the port, the other one was lost. The recovery and redeployment of the OBSs occurred on February 3rd-4th. From February 5th-February 14th and again on February 17th profiling continued and the blue lines on Figure 2 show the MCS lines collected during this time (light blue are partial array sourced lines) and the blue dots show the 25 OBS which recorded these shots. Final recovery of the OBS and hydrophone streamer occurred on February 18th and 19th.

The operational limitations placed on this cruise were the most restrictive ever imposed on a seismic cruise. Figure 3 shows a pie chart of how the allotted time was consumed during the cruise and unfortunately more than 50% of the time at sea was not spent on science due to waiting on clearances (21% of the time), shutdown for the night (31%), shutdown due to weather conditions (8%), and shutdowns caused by turtles, marine mammals, or fishing vessels encroaching on their respective safety radii (< 1% each). The night-time restriction was placed on the cruise by SEMARNAT such that the airgun array was only able to operate between the hours of 0630 and 1800 local time, instead of 24 hours a day as normally

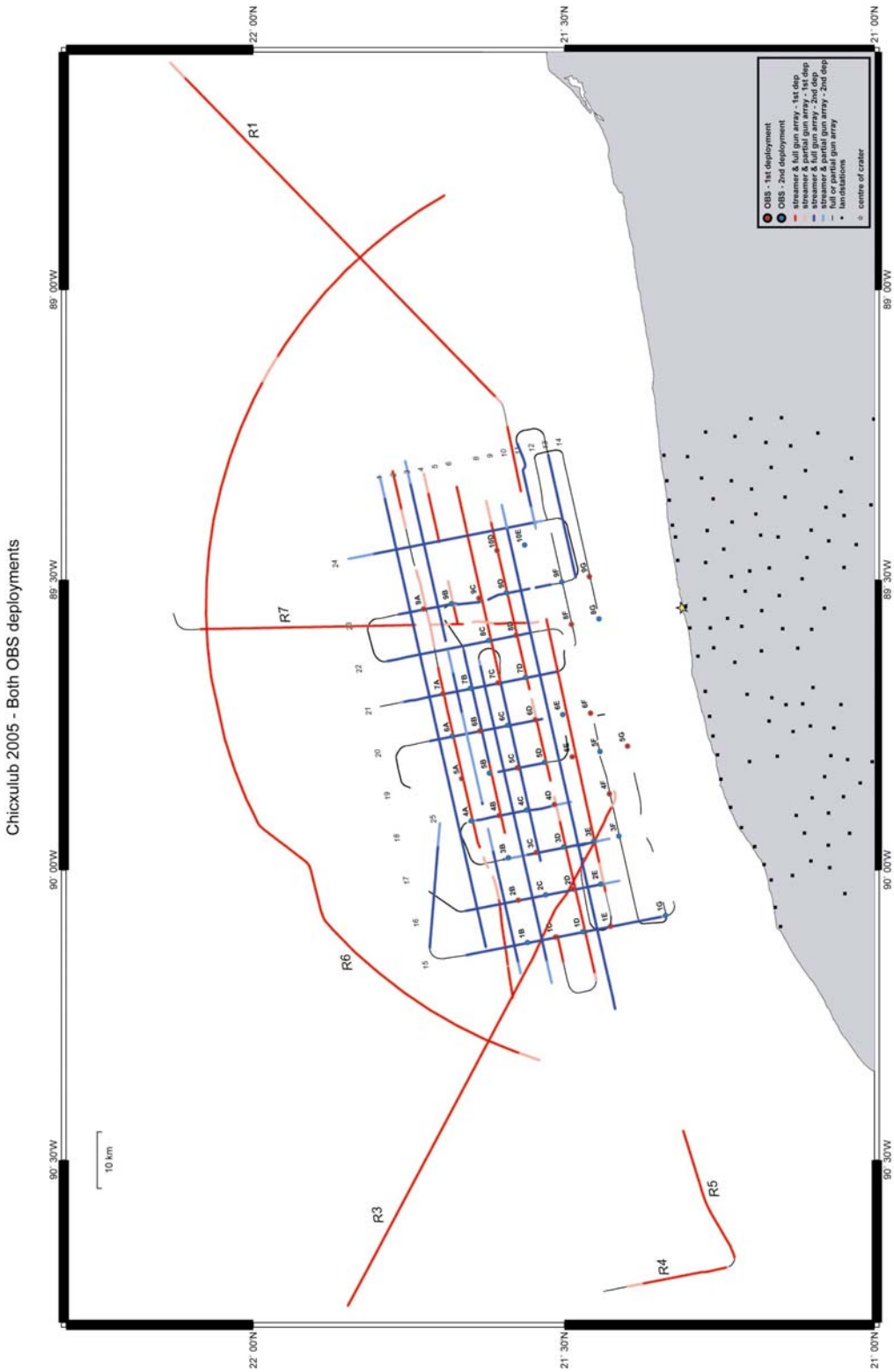

FIGURE 2: The 2005 Chicxulub seismic experiment including 30200 airgun shots recorded on the 6 km, 480 channel hydrophone streamer and 48 ocean bottom seismometers (OBS) in two deployments (shown in red and blue, see legend) and 6360 airgun shots not recorded on the streamer (shown in black, see legend). The 82 land seismometers (black squares) recorded all 36560 shots. Yellow star is the center of the crater.

expected. Due to the need to ramp up the airgun array at no more than 5 dB per 5 minutes the full airgun array was not operational until close to 0700 local time most mornings. The exact ramp-up sequence is shown in Table 2. The best use of night-time was made by processing the already collected data, maneuvering the vessel into position for start of the next day's operations, and conducting maintenance on the hydrophone streamer. During any

deployment and recovery operations (OBS or MCS) the ship operated 24 hours a day. The gravimeter, 2.25-6.25 kHz Chirp, and 15 kHz echosounder were also used 24 hours a day either because there were no limitations imposed on these systems or for safety reasons, as the echosounder is the primary indicator on the vessel of water depth.

The weather conditions set on seismic operations at the beginning of the cruise were no airgun use in wind states over Beaufort 2 (7 knots of sustained wind). After much discussion this condition was eased to allow operations in wind states not exceeding Beaufort 4 (17 knots of sustained wind). To determine the level of sustained wind, in order to remain in compliance, a program was written by Kevin Johnson and Anthony Johnson (system administrators for UTIG and LDEO, respectively), which captured the wind measurement every second and then generated a 90 minute running average. Whenever the 90 minute running average went above 17 knots we shutdown operations until the 90 minute running average fell below 17 knots again. Figure 4 shows the graphic user interface for this program. A 90 minute running average was used as winds must consistently blow in the same direction for at least 90 minutes to generate a rougher sea state (see 'The American Practical Navigator, by N. Bowditch, 1995, p527-529). It should be noted that the normal operation of seismic profiling allows successful data collection in sea states up to about Beaufort 5-6 which seldom occurred during the course of this cruise; the weather restrictions imposed here were to allow observation of the safety radius by the marine mammal observers.

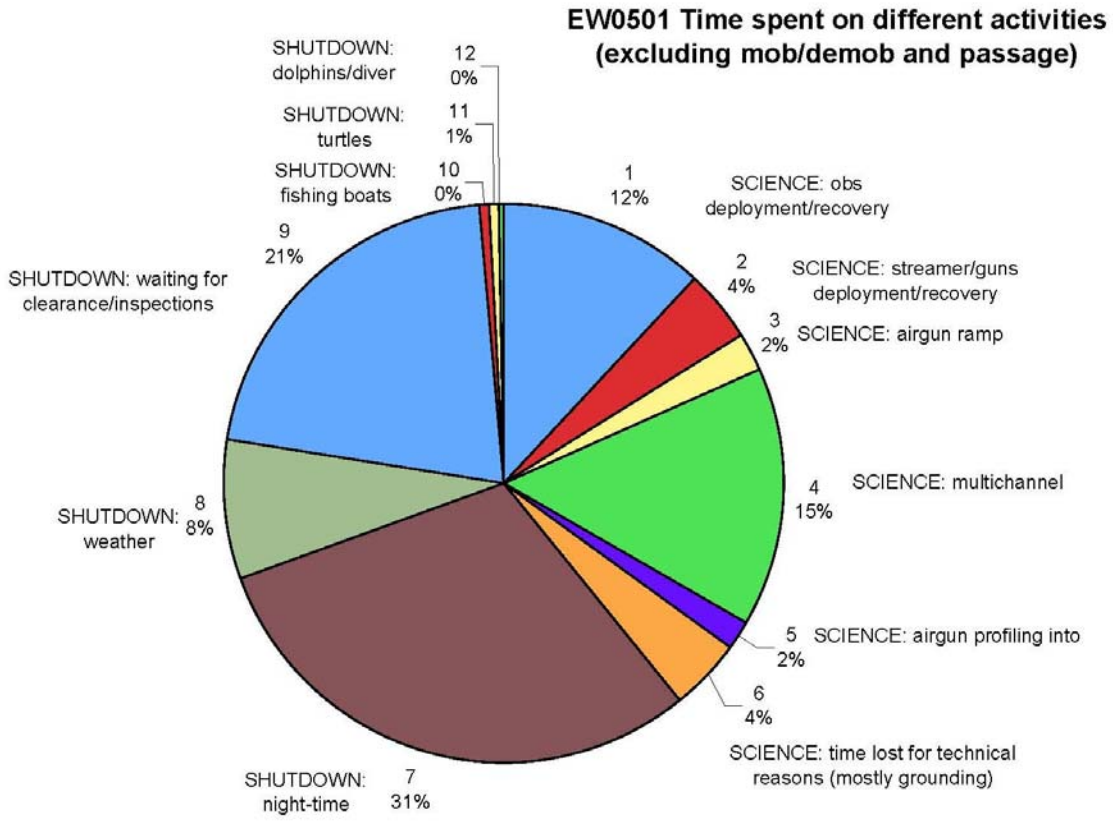

Figure 3. Pie-chart showing time spent on different activities during EW0501. Note that shutdowns due to airgun limitations or clearances/inspections amounted to more than 50% of the time spent at sea.

Despite all the public attention on the issues of marine mammals and turtles in the study area, there were very few sightings of either. Attached to this report, as Appendix 1, is a summary by the U.S. lead marine mammal observer, Meike Holst, of LGL, Inc. This report details all methods used and observations obtained by the joint Mexican-US marine mammal observation team. Additionally, the notes (Bitácora) from the Mexican marine mammal observers were delivered to SEMARNAT shortly after the end of the cruise.

Figure 4. Screen on the *Ewing* that displays the wind data. The bars along the left show the 90 minute running average of the wind and become bright if the 90 minute average exceeds 17 knots. The numbers on the right are the 15 minute and 90 minute running averages. The vertical dashed lines are at 5 knot intervals.

A series of aerial surveys were conducted by Michael Rawson of LDEO in support of this project in accordance with the terms and conditions detailed in document S.G.P.A.-DGIRA.-DDT.-0577/04 that stipulates in Conditions, Section 2, that the project sponsor "will implement air and sea searches for organisms that may be injured as a result of airgun operations and, when detecting animals that are beached or close to the coast, proceed to determine the cause. If that is the case, immediately notify the Federal office of PROFEPA in the state of Yucatan." A total of 19 aerial surveys (e.g. Figure 5) were conducted departing from the commercial airport of Merida, Yucatan during a period of time from Jan 12 through February 19, 2005 when the seismic project was completed. A total of 6,604 nautical miles were covered in survey operations (this does not include the transit from Merida airport to the coast) during 58.45 hours of survey flight time. No turtles were sighted during the aerial survey flights. Two instances of marine mammal sightings were recorded: January 21: 3 dolphins (probably Tursiops truncatus), and February 12: 2 groups dolphins, 3 individuals and 5 individuals (probably Tursiops truncatus). No injured animals or turtles were sighted by aircraft.

The fact that shutdowns from turtles and marine mammals each occurred < 1 % of the time is testament to the rarity of sightings in the shallow Yucatan waters. Whenever a marine mammal or turtle was spotted within the safety radius for this cruise (3.5 km) the guns were either powered down or shut-down depending on the exact distance. Once the biota were no longer observed we waited 15 minutes for turtles and 30 minutes for marine mammals before starting ramp-up procedures again in order to move a safe distance away from the turtles or to allow marine mammals time to exit the safety radius completely.

A larger problem was fishing vessels. The mitigation measure we operated under for fishing vessels was that the airguns had to be shutdown whenever a vessel was engaged in fishing within 0.8 nautical miles (nm) of the *Ewing*. In practice it was often difficult to determine when vessels were actively engaged in fishing and the efforts of our chase boats to warn vessels away from the path of the Ewing were frequently unsuccessful. Therefore, shutdowns for fishing vessels were frequent although sometimes much shorter in duration than shutdowns for turtle or marine mammals. If a fishing vessel exited the 0.8 nm safety radius then airgun operations could resume. If this resumption occurred within 8 minutes then a ramp-up was not required; if longer then 8 minutes, we were required start ramp up procedures again. Nonetheless much of the patchy nature of our final data acquisition in the main grid of the study area (Figure 2) is due to fishing vessels and in order to avoid shutdowns the *Ewing* swerved off its charted course on several occasions to avoid vessels engaged in fishing. Only once during the cruise was a human diver spotted and this diver was treated the same as a marine mammal with a 3.5 km safety radius.

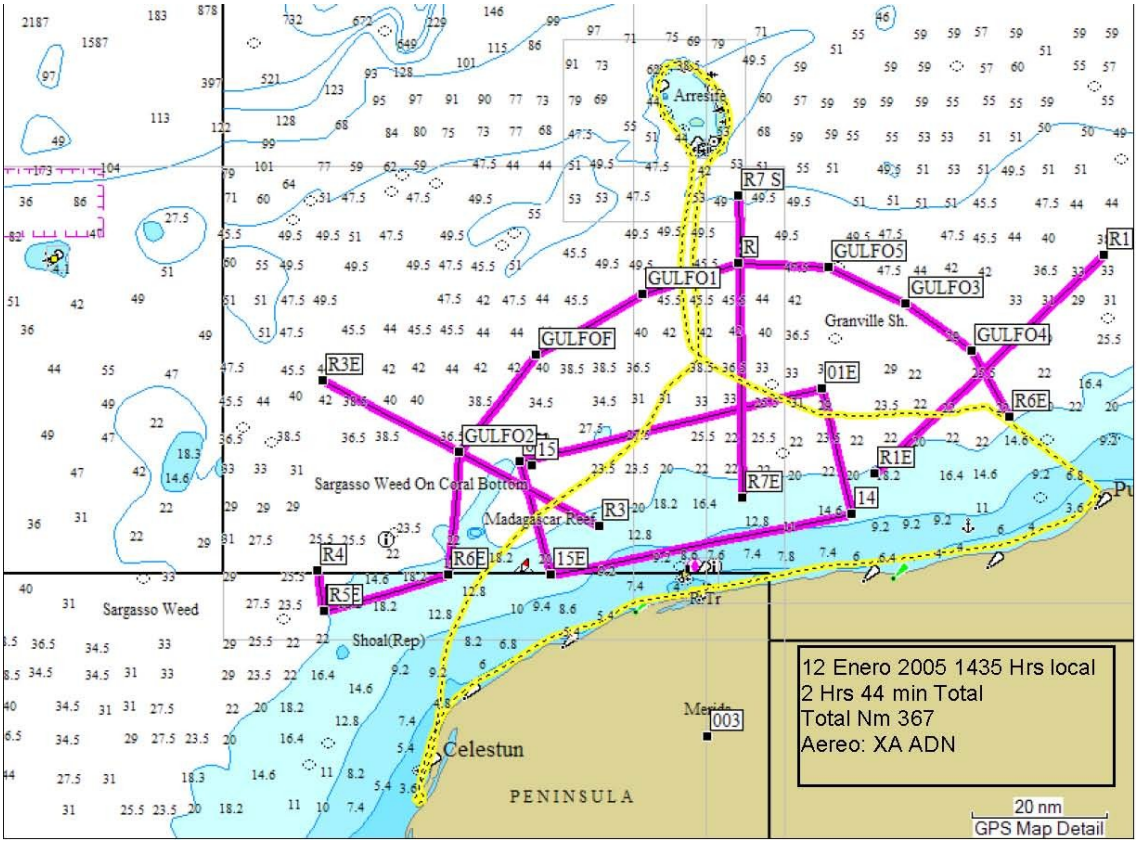

Figure 5: An example aerial survey flight path (dashed yellow line) during EW0501.

A team from PROFEPA visited the R/V *Maurice Ewing* on three separate occasions to inspect our operations and again to deliver legal papers on 18th February due to the grounding. These inspections amounted to the first at-sea inspections of the *Ewing*'s seismic operations ever conducted and were considered by all onboard the vessel, especially the Captain and Mates, to be very dangerous for the visiting personnel and not advisable for the future. Personnel transfer via a boat at sea is done extremely rarely on research vessels due to the inherent dangers and these inspections resulted in more at-sea personnel transfers during cruise EW0501 than were completed the entire preceding year of operations on the *Ewing*. Copies of these inspection reports are filed with PROFEPA, LDEO, and the co-chief scientists.

One notable incident occurred during the cruise on the night of February 14th, while maneuvering to present a lee so that visiting PROFEPA inspectors and a group of visitors that included Senator Erika Larregui and Martha Torrez from the State Department could disembark. The *Ewing* swung wide around the charted position of a rocky reef to the west of our profile Chicx05-9 and then steered farther north to put more distance between the shoal and the vessel, only to scrape the sonar trunk of the ship on the seafloor ~ 1 nm north of the charted position of the rocky reef. Later investigations showed that where the nautical charts reported the rocky reef to exist, the waters are ~17 m deep, while where the reef was really located the charts show the waters to be navigable. The 2.25-6.25 kHz bathymetric sonar (which looks down not forward) showed the seafloor rose from 16 m water depth to < 5 m depth in less that 150 m (the *Ewing* itself is ~75 m long) which given the vessel was traveling at ~5 knots (normal towing speed) and towing ~6 km of gear behind it meant there was no possible way for the ship's crew to detect the presence of the mischarted shoal (the *Ewing* has no forward looking sonars) or to react in time to avoid it. The Seaman's Club found the Captain and Mates not at fault for the incident since the charts were incorrect. No significant damage occurred to the vessel's sonar trunk as was demonstrated by thorough diving inspections of the ship on February 15th and 16th allowing for the resumption of seismic operations on February 17th. Legal papers were served on February 18th requiring the *Ewing* to come to port in Progresso due to the grounding; negotiations with PROFEPA allowed for the complete recovery of the towed and seafloor equipment before coming into port which was completed on February 20th.

Methods Used

EW0501 used a 20 gun airgun array of 6947 cu. in., a 6 km 480 channel hydrophone streamer, 28 OBS of which 25 recorded successfully in two different locations, and 82 land seismometers (Figure 2). The airguns were shot on distance every 50 m along each line (approximately every 20 seconds with our average survey speed of 5 knots). During turns or airgun-only lines the airguns were shot on time every 20 seconds for the majority of the airgun-only surveying but occasionally every 60 seconds. The airgun array was towed at 6 m and the streamer at 7 m depth.

The airgun array used during EW0501 was modified from the standard *Ewing* 20 gun array that totals 8570 cu. in. In order to generate an airgun pulse with a higher peak-to-bubble ratio and a smaller total dB, our modified 20 gun array was better tuned with guns that total 6947 cu.in. Figure 6 shows the array diagram with positions of the different sized airguns and Figure 7 shows what the array looks like when firing. Amplitudes up to 125 Hz should be recordable as shown by Figure 8. The peak-to-bubble ratio for this array is 11.0 as shown by the far field signature in Figure 9.

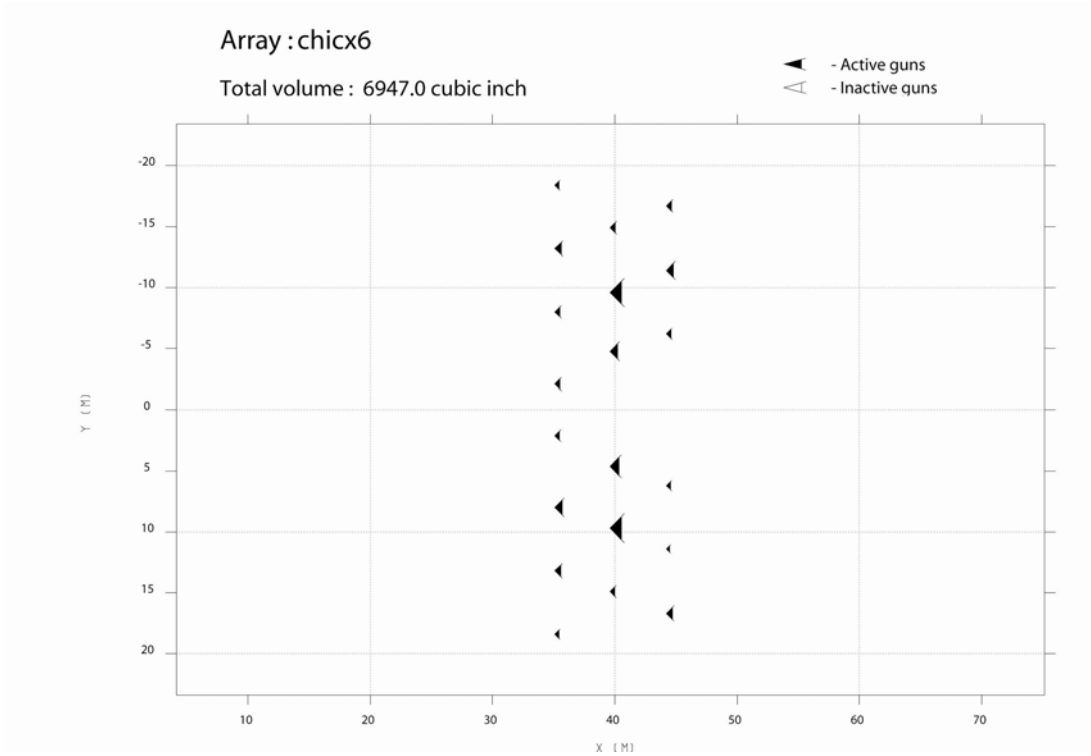

Figure 6. Diagram of the positions of the airguns in the EW0501 array plotted according to their relative size. The total array size was 6947 cu. in. See Figure 13 for details of gun sizes.

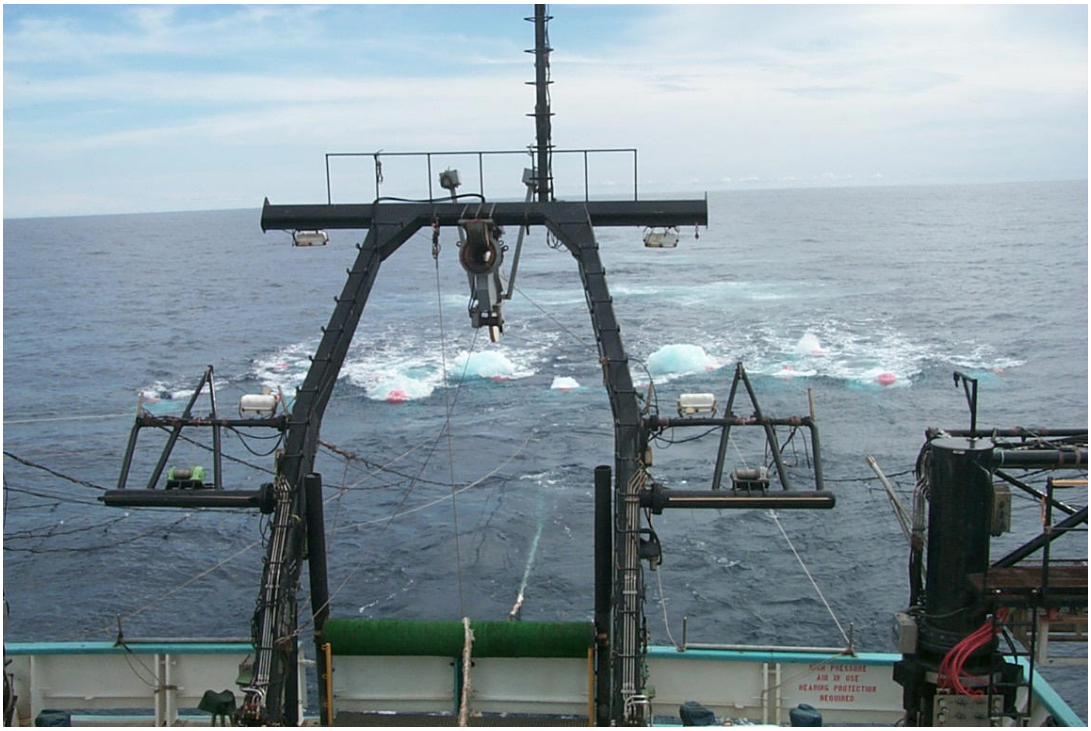

Figure 7. The EW0501 airgun array being fired during the experiment.

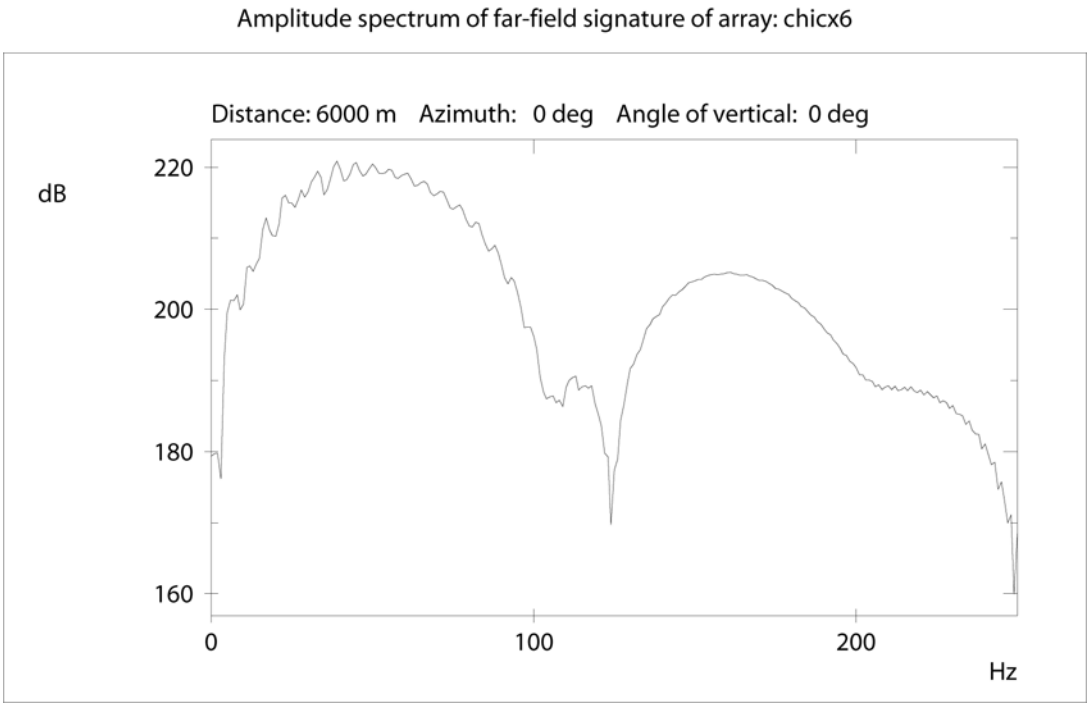

Figure 8. The amplitude spectrum in frequency space of the EW0501 array with energy up to 125 Hz (Nyquist Frequency) being available to record.

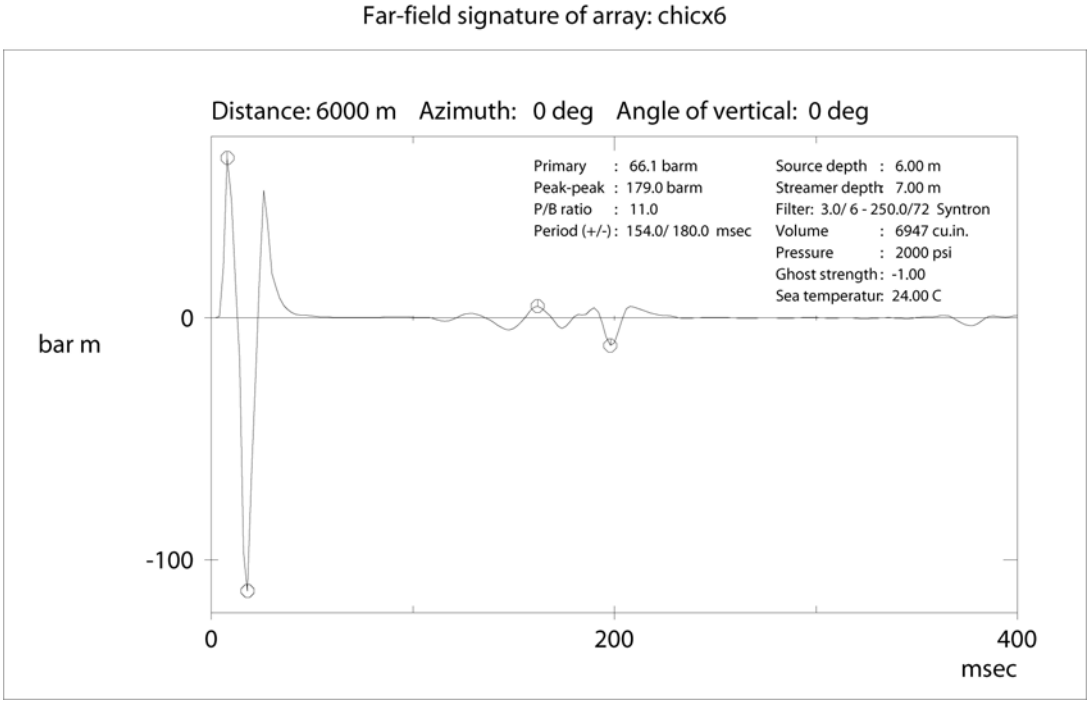

Figure 9. The far-field signature of the EW0501 array showing a peak-to-bubble ratio of 11.0 and a primary output of 66.1 bar m. The standard *Ewing* array has a ratio of 5.8 and an output of 71.4 bar m.

The hydrophone streamer used on EW0501 is the standard, full length *Ewing* streamer with 480 channels formed by groups of hydrophones centered every 12.5 m along its length.

Figure 10 shows the streamer on the reel. The streamer's depth was controlled using 28 compass navigation birds (e.g. Figure 11).

The geometry during the survey changed due to the electronic failure of our initial tow leader (section connecting the streamer to the vessel). From January 20th-26th, the near offset (distance between the array and the first receiver) was 180m, during the tow leader maintenance one short line was shot with a 13 m near offset, and the rest of the survey from January 26th-February 17th was shot with a 112.5 m near offset. A diagram of the geometry is shown in Figure 12.

The R/V *Maurice Ewing* is equipped with four GPS antennas. The ship was navigated based on the Trimble for the majority of the survey while the exact position of the vessel for use in determination of the source and receiver locations was calculated by SPECTRA, the seismic navigation software. SPECTRA took in all four GPS positions and calculated a best fit to the data to write out the shot position and then using the information on bearing from the compass birds, also calculated the receiver positions to be reported in UKOOA format. At UTIG these UKOOA format files were merged with the seismic data for interpretation purposes. Figure 13 shows the positions of the GPS receivers with respect to the gun array and streamer for EW0501 (only the 112.5 m near offset case is shown).

Figure 10. The *Ewing*'s 480 channel hydrophone streamer on the reel on the fantail. Replacement sections can be seen in the background and digitizing cans can be seen spaced along the streamer (these sum the acoustic signals and send them up the streamer to the recording systems on the vessel).

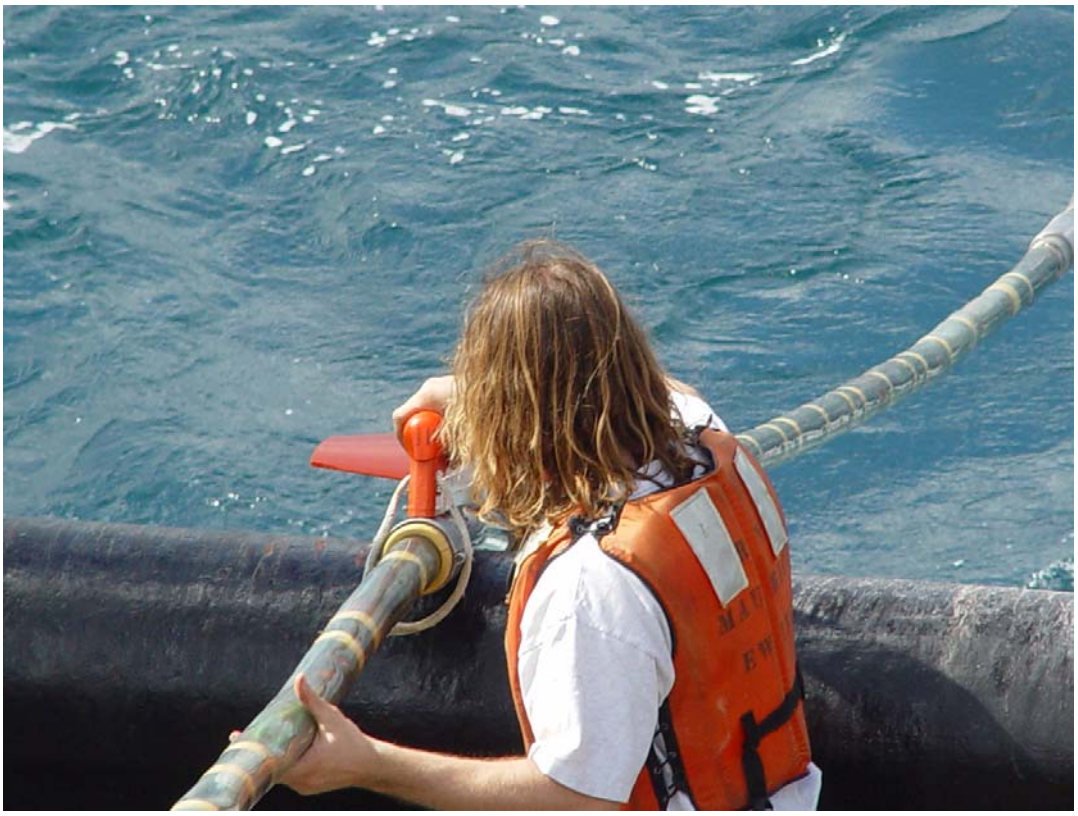

Figure 11. Compass bird being clipped on the streamer during deployment.

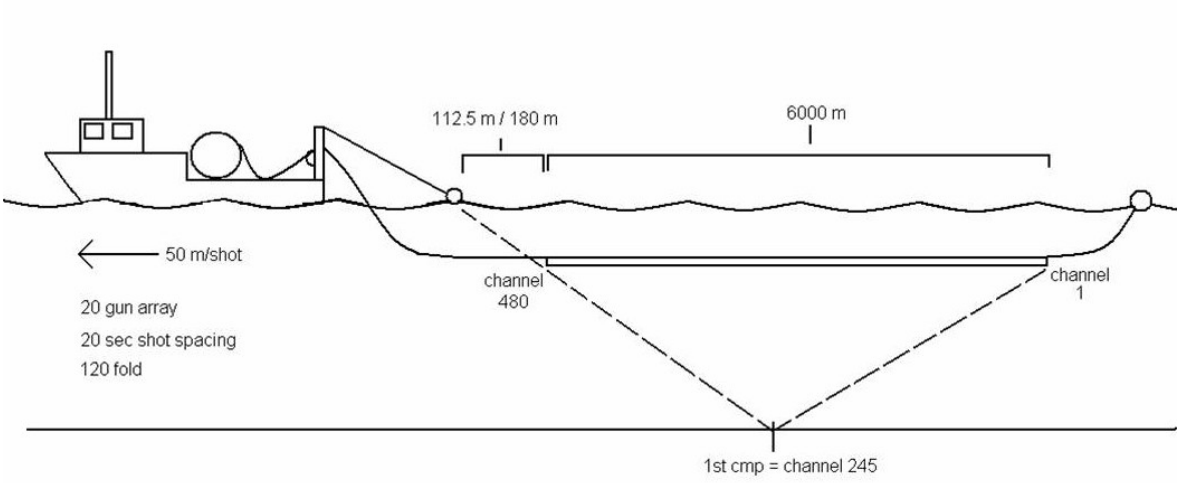

Figure 12. Survey geometry for EW0501 showing near offset that changed during the cruise.

The ocean bottom seismometers (OBS) used were from the UK and were of two different design specifications. There were 18 units of the LC design (Figure 14) which each carried a hydrophone and a vertical component geophone, and ten units of the DOBS design (Figure 15), which recorded hydrophone and 3-component geophone. Each instrument is dropped to the sea bed before the start of seismic profiling (Figures 14 and 15) and there records digital seismic data continuously until called back to the surface using an acoustic command signal, and picked up by the ship. The OBS were recovered from the sea bed in the middle of the cruise and replaced in different positions (shown by red and blue dots in Figure 2) in order to maximize the number of sites sampled. Both types of OBS are sealed autonomous devices which are passive in the environment. During the first deployment three OBS (one LC and

two DOBS) broke free from their moorings and during the second deployment one LC broke free. Three of these four instruments were recovered by local fishermen and handed to the Port Captain, and the fourth was lost. We are grateful to the fishermen for their help in recovering these instruments.

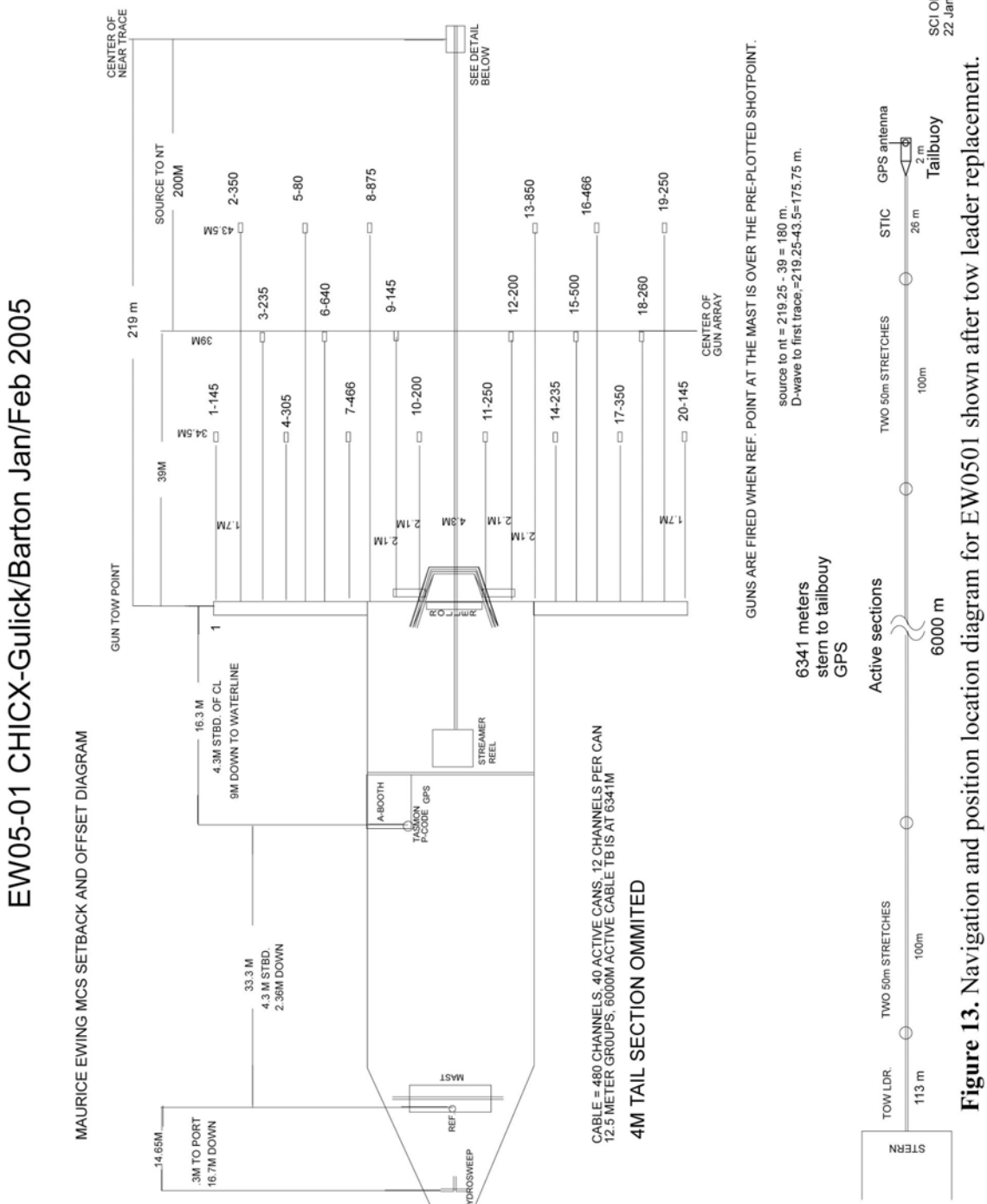

Figure 13. Navigation and position location diagram for EW0501 shown after tow leader replacement.

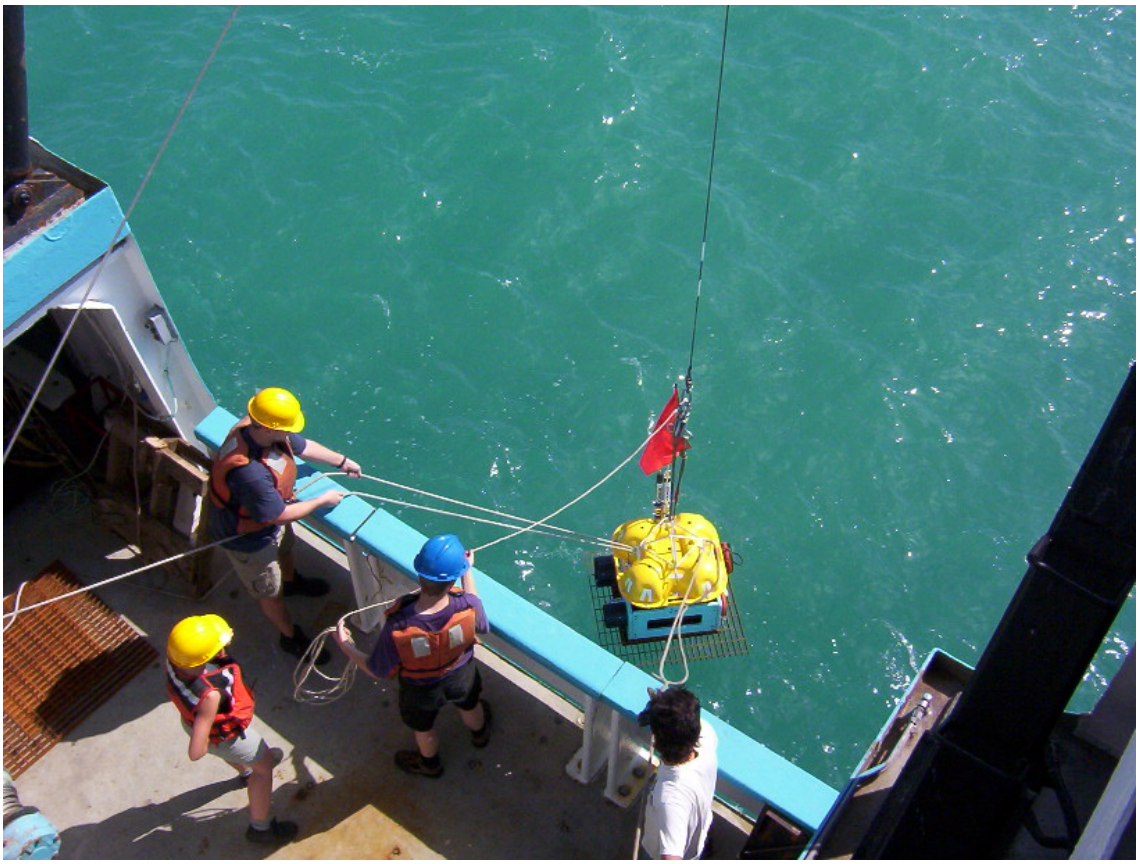

Figure 14: OBS of LC design being launched from the side of the *R/V Ewing* during EW0501.

Figure 15: OBS of the DOBS design being launched during cruise EW0501.

Objectives obtained

All the major scientific objectives of the project were met to a greater or lesser extent, and the work programme was modified continuously to achieve the maximum results within the imposed restrictions. The stages of the project may be seen in the map of Figure 2 and are laid out in Table 3, with expected line-km of airgun profiling with and without the streamer and around turns, and the actual line-km collected shown below. Stage 1 was the first pass of the regional tomography grid (red profiles in the grid box, Figure 2), for which the seabed seismometers were in their first (red) positions. This took place approximately as expected, but with more of the profiles collected whilst towing the streamer than originally anticipated, due to the surprising ease of towing the streamer at a constant depth. Stage 2 consisted of a series of long profiles radial to the crater (R1, R3, R4, R5, R7, Figure 2). These profiles were reduced significantly from the original work plan, partly in response to the restricted time available due to no night-time shooting, and partly to avoid approaching the Alacran Reef too closely. Stage 3, a high resolution survey over the proposed IODP drillsite, was dropped due to lack of time, and replaced by a more basic survey which is incorporated into stages 1 and 4. Stage 4 consists of the second pass of the regional tomography grid (blue profiles on Figure 2): the relatively higher number of line-km collected during this stage relative to the expected figure is due to the incorporation of some of the Stage 3 objectives into this stage, though not at the high resolution originally expected. Stage 5 is the arc-shaped regional profile R6 (constant radius profile). Stage 6 consists of operations to relocate ocean bottom seismometers between stages 1 and 4. Stage 7 was a second detailed survey over a second possible IODP drillsite: the objectives of this survey were achieved at a more basic level as part of Stage 2 (profile R4).

Stage	Experiment		Total km with streamer	Total km without streamer	Turns km	Total km
1. Regional tomography grid pass 1	A1	EXPECTED	225	255	144	624
		ACTUAL	318	145	35	498
2. Regional MCS profiles	C1 (R1,R3,R4,R5,R7)	EXPECTED	675	0	-	675
		ACTUAL	286	12	-	298
3. High res survey 1	B1	EXPECTED	-	900	-	900
		ACTUAL	-	-	-	0
4. Regional tomography grid pass 2	A2	EXPECTED	495	-	144	639
		ACTUAL	703	49	76	827
5. Regional MCS profile	C2 R6 (CRP)	EXPECTED	325	-	-	325
		ACTUAL	200	-	-	200
6. OBS operations without airguns		EXPECTED	-	-	-	0

		ACTUAL	-	-	-	0
7. Detailed survey	B2	EXPECTED	150	-	-	150
		ACTUAL	0	-	-	0
TOTAL		EXPECTED	1870	1155	288	3313
		ACTUAL	1506	206	111	1822

Table 3: An attempted categorization of the collected data versus the original stages of work proposed. Note the total allowed line-km with and without the streamer were not exceeded during this experiment.

Our primary imaging targets included the peak ring, the inner and out rings, the tertiary basin, and the underlying slump blocks. All of these targets were successfully imaged. Our primary tomographic goals were to gather 3-D velocity data by recording the airgun sources on the streamer, the OBSs and the land seismometers. These receivers recorded the over 30,000 shots successfully and will allow a good 3-D tomographic model of the velocity structure of the crust. Additionally, the reflection and refraction data serve as a site survey for future sampling of the lithology within the crater at depth.

Results and Conclusions

At this stage our results are a suite of preliminarily processed MCS lines, and the 3-D collection of refracted arrivals on the streamer, OBS, and land stations. We include two versions of each of the reflection section as a jpegs in Appendix 2. The first version shows the entire 14 seconds of data while the second shows just the upper 1 second of data for easier viewing of the Cretaceous-Tertiary boundary, peak-ring, and rings. We also include example shots gathers recorded on the LC and DOBS instruments. Appendix 3 shows all four channels on DOBS 1B shot to on Chicx05-15 and DOBS 5D shot to on Chicx05-9 and both channels on LC 9B shot to on Chicx05-23 and LC 10D shot to on Chicx05-8. The preliminarily processed seismic data, the chirp (Bathy2000) data, weather and wind data, and the gravity data have been sent to the U.S. State Department to be distributed to Mexican officials.

Scientific conclusions would be very premature at this stage however we list some preliminary conclusions that were reported at the American Geophysical Union Joint Meeting in New Orleans, May, 2005. The Chicxulub impact crater is confirmed as a multi-ring basin (Gulick et al., 2005). The topographic peak-ring is observed to be irregular in 3-D but with clear transitions to crater floor inside and outside of the peak-ring (Gulick et al., 2005). Initial analysis of the refraction data showed that the peak ring is characterized by lower seismic velocities than adjacent features (Surendra et al., 2005). There is no evidence for an inner ring in the northeast quadrant of the impact crater raising questions of a possible blow-out feature associated with an oblique impact (Gulick et al., 2005). The concentration of deformation in the terrace zone (slump blocks) to the northeast also suggests the downrange direction of the impact is in that quadrant (McDonald et al., 2005). The slump blocks everywhere in the crater reach to depths beneath the peak-ring suggesting an interaction between the collapsing peak-ring and the lateral gravitational collapse into the transient crater (McDonald et al., 2005). An enigmatic set of inward-dipping set of reflectors are observed beneath the inner ring at lower crustal depths in several azimuths around the crater (Gulick et al., 2005).

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APPENDIX 1: MARINE MAMMAL AND SEA TURTLE MONITORING

Introduction

Six trained marine mammal observers (MMOs) were aboard the *Ewing* throughout the period of operations for visual and acoustic monitoring. The primary purposes of the monitoring and mitigation effort were to ***(1)*** document the occurrence and numbers of marine mammals and sea turtles near the seismic source, and ***(2)*** to implement a power down or shut down of the airguns when marine mammals or turtles were sighted near or within the designated safety radii.

Methods

Mitigation Procedures

Mitigation procedures included the following: ***(1)*** Ramp ups whenever the airguns were started after periods without airgun operations or after prolonged operations with one airgun, and ***(2)*** Immediate power downs or shut downs of the airguns whenever marine mammals or sea turtles were detected within or about to enter the safety radius. A power down was a reduction to one operating airgun, whereas a shut down involved complete cessation of airgun operations.

The safety radii for cetaceans and sea turtles during the survey were based on the distances within which the received level of airgun sounds diminish to 180 dB re 1 µPa (rms) in shallow water (<100 m). This safety criterion was based on an assumption that seismic pulses received at lower received levels are unlikely to injure these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. For the 20-airgun array used during the study, the safety radius for cetaceans and turtles was 3500 m. For the single airgun used during a power down, the safety radius was 108 m.

Visual monitoring

At least one MMO watched for marine mammals and sea turtles at all times while airguns operated during daylight periods, and when the vessel was underway but the airguns were not firing (e.g., during periods of poor weather). MMOs watched from 06:15 EST (30 min before ramp up) to 18:00 EST (the end of seismic operations). Seismic operations were not conducted at night.

The visual MMOs scanned the surface of the water around the vessel for marine mammals and sea turtles. The MMOs used 7×50 reticle binoculars, 25×150 Big-eye binoculars, and the naked eye. When marine mammals or turtles were sighted, the distance from the observation point (flying bridge) to the nearest member of the marine mammal or turtle group was estimated using reticles on one ocular lens of the binoculars. When a marine mammal or turtle was detected in or approaching the safety radius, the visual MMO contacted the airgun operators to power down or shut down the airguns.

Passive acoustic monitoring

MMOs also conducted passive acoustic monitoring (PAM) during seismic operations. The acoustical array was monitored from 05:45 EST (1 h before ramp up) until total darkness (18:30 EST) while at the seismic survey area during airgun operations and during most periods when airguns were off. The primary purpose of the acoustic monitoring was to aid visual observers in the detection of vocalizing marine mammals, particularly during periods with poor observation conditions, including high sea states. The acoustic MMO listened with headphones or speakers to sounds received from the hydrophone array and simultaneously monitored a real-time spectrogram display. When the acoustic MMO detected a cetacean call, the visual MMO was notified to determine if mitigation measures were required.

Data Analysis

For the data analysis, visual and acoustic effort, as well as marine mammal sightings and acoustic detections, were divided into several analysis categories related to vessel and seismic activity. In general, data were categorized as "seismic" or "non-seismic". "Seismic" included all data collected while the airguns were operating, including ramp ups, and periods up to 90 s after the airguns were shut off. Non-seismic included all data obtained before airguns were turned on (pre-seismic) or >6 h after the airguns were turned off. Data collected during post-seismic periods from 1.5 min to 2 h after cessation of seismic were considered "recently exposed" (90 s–2 h) or "potentially exposed" (2–6 h) to seismic, and were excluded from analyses.

This categorization system was designed primarily to distinguish situations with ongoing seismic surveys from those where any seismic surveys were sufficiently far in the past that it can be assumed that they had no effect on current behavior and distribution of animals. The rate of recovery toward "normal" during the post-seismic period is uncertain. Therefore, the post-seismic period was defined so as to be sufficiently long (6 h) to ensure that any carry-over effects of exposure to the large 20-airgun array sounds surely would have waned to zero or near-zero.

Survey effort as well as cetacean and sea turtle sightings were generally presented for "useable" survey conditions representing 83% of the total visual effort (Table 1). "Useable" effort excluded periods 90 s to 6 h after airguns were turned off (post-seismic), poor visibility (<3.5 km) conditions, and periods with Beaufort Wind Force >5. Also excluded were periods when the *Ewing*'s speed was <3.7 km/h (2 kt) or with >60° of severe glare between 90º left and right of the bow.

Results

Survey effort

The *Ewing* traveled a total of 9476 km within the study area (Table 1). The airguns operated only during daylight along 20% of the total ship track. About 79% of seismic operations were conducted with the 20-airgun array. Ramp ups of the airguns occurred on 56 occasions, including 16 ramp ups from 1 airgun to the full 20 airgun array, and 40 start up ramp ups from no airguns.

In total, 4281 km of visual observations and 2935 km of PAM were conducted (Table 1). MMOs were on visual watch during all airgun operations, and PAM occurred during >99% of all seismic periods. During <1 h of seismic operations, PAM could not be conducted because of technical difficulties with the acoustic array. Nearly all visual (>99%) and PAM (94%) effort occurred during daylight; the remaining PAM effort occurred near dawn and dusk. During 9476 km of *Ewing* operations during the cruise, 3562 km of useable visual observations were made (Table 1). About 78% of all PAM effort was concurrent with useable daylight visual effort.

Beaufort Wind Force (Bf) during observations ranged from 1 to 6, with 95% of the observations in conditions of Bf ≤5 (i.e., useable). About one-third (35%) of the useable observation effort (Bf 1 to 5) occurred during Bf ≤3 (wind speed 0.0–5.1 m/s); the remaining 65% occurred during Bf 4 or 5.

Cetaceans

Only the bottlenose and Atlantic spotted dolphin are known to occur regularly in the shallow (<100 m) waters of the study area; in fact, these were the only species identified in the seismic survey area proper. One group of pantropical spotted dolphins was seen during transit in deep water. Within the study area, including transits, ~119 individual cetaceans (all delphinids) were sighted in 24 groups: eight bottlenose, seven Atlantic spotted, one pantropical spotted and eight unidentified dolphin groups (Table 2). In terms of individuals, Atlantic spotted dolphins were the most abundant (n = 36), followed by bottlenose dolphins (n = 32; Table 2). Two calves and one juvenile Atlantic spotted dolphin were seen

TABLE 1. Total *Ewing* operations, observer and PAM effort, and marine mammal and sea turtle sightings during the Chicxulub seismic survey, southern Gulf of Mexico.

	Non-Seismic			Seismic			
	Useable	**Other**	**Post Seismic**	**Useable**	**Other**	**Total Useable**	**Total**
Operations in h							
Ewing Nighttime	-	428	111	-	-	-	539
Ewing Daylight	147	47	54	201	4	348	453
***Ewing* Total**	**147**	**475**	**165**	**201**	**4**	**348**	**992**
Observer Nighttime	-	-	-	-	-	-	-
Observer Daylight	139	43	48	201	4	340	434
Observer Total	**139**	**43**	**48**	**201**	**4**	**340**	**434**
PAM Nighttime	-	14	4	-	-	-	19
PAM Daylight	51	1	48	200	4	251	303
PAM Total	**51**	**15**	**52**	**200**	**4**	**251**	**322**
Operations in km							
Ewing Nighttime	-	3987	1011	-	-	-	4998
Ewing Daylight	1824	283	479	1855	37	3679	4478
***Ewing* Total**	**1824**	**4270**	**1490**	**1855**	**37**	**3679**	**9476**
Observer Nighttime	-	-	-	-	-	-	-
Observer Daylight	1707	275	406	1855	37	3562	4281
Observer Total	**1707**	**275**	**406**	**1855**	**37**	**3562**	**4281**
PAM Nighttime	-	127	42	-		-	168
PAM Daylight	435	7	441	1847	37	2282	2767
PAM Total	**435**	**134**	**482**	**1847**	**37**	**2282**	**2935**
No. Cetacean Sightings (Indiv.)	13 (80)	1 (10)	3 (16)	6 (12)	1 (1)	19 (92)	24 (119)
No. Cetacean Acoustic Detections	4	3	1	5	-	9	13
No. Sea Turtle Sightings (Indiv.)	14 (14)	2 (2)	6 (6)	7 (7)	-	21 (21)	29 (29)
No. Power/ Shut Downs (PD/SZ) for Cetaceans	-	-	-	5	-	5	5
No. PD or SZ for Sea Turtles	-	-	-	7	-	7	7
PD or SZ Total	**-**	**-**	**-**	**12**	**-**	**12**	**12**

among the 119 individual delphinids observed. No injured cetaceans potentially associated with the operations were sighted at any time during the cruise.

Of the total 24 sightings, 7 were made while the airguns were on, 14 sightings were made during non-seismic periods, and the remaining 3 groups were seen during "post-seismic" periods (i.e., "non-useable"; Table 1, 2). Four of the seven groups sighted during seismic were seen while 20 airguns were operating, two groups were seen while one airgun was firing, and the remaining group was seen during ramp up.

The airguns were fully shut down on one occasion because a single bottlenose dolphin was seen in the safety zone, and on four occasions a power down was implemented for four different delphinid groups (six total individuals; Table 3). The four power downs were conducted for two groups of Atlantic spotted dolphins and two groups of unidentified dolphins. The one shut down and three power downs occurred while the full 20-airgun array was in use. The remaining one power down occurred during a ramp up when eight airguns were operating.

Sighting rates (# groups sighted per unit effort) during various types of MMO effort are presented in Table 4. The mean visual encounter rates during useable non-seismic periods were more than twice those during seismic periods (7.6 vs. 3.2 sightings/1000 km, respectively). These rates are based on similar amounts of visual effort (Table 1).

Delphinids were seen closer to the array when the airguns were off vs. on based on only useable sightings (178 vs. 472 m; n = 6 vs. 13 groups). This difference was greater (~775 m) when additional unusable sightings were included. However, the mean closest point of approach (CPA) during seismic periods may be underestimated if animals avoided the airgun array farther than they could be detected by MMOs. The sighting rates during seismic and non-seismic periods suggest that some animals may have remained >2 km from the active array, beyond detection range of MMOs during seismic periods. Thus, the differences in CPAs is likely greater than noted. Furthermore, the relatively close (~180 m) mean CPA during non-seismic periods suggests that some delphinids may have been attracted to the *Ewing*. In fact, four bowriding episodes were observed during non-seismic periods.

Passive Acoustic Monitoring

PAM was conducted for a total of 2935 km (322 h) during the study period, and a total of 13 acoustic detections were made. Eleven detections were of unidentified dolphins and two were of bottlenose dolphins. In 3 of 13 cases, the acoustic detection could be matched with a visual sighting. Three detections were made during nighttime.

Five of the 13 acoustic detections were initially made while the airguns were operating. Three of those detections occurred during operations of the full 20-airgun array, and two others occurred while only one airgun was operating during a power down. All other detections were made when the airguns were not operating. However, on three occasions, the airguns were ramped up when dolphins could still be detected acoustically, when the distance of the dolphins to the airgun array was unknown. On one occasion, 28 Jan., the cessation of dolphin vocalizations coincided with the start of the ramp up.

PAM effort during "non-seismic" periods (66 h) was about one-third that during "seismic" conditions (204 h; Table 1). The mean acoustic encounter rates during useable non-seismic periods were more than three times higher than during seismic periods (9.2 vs. 2.7 acoustic encounters/1000 km, respectively; Table 4).

TABLE 2. Total number and number of useable sightings and individual cetaceans observed from the *Ewing* in the study area during the Chicxulub seismic cruise.

	Seismic		Post-Seismic		Non-seismic		Total	
	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
All Sightings								
Odontocetes								
Delphinids								
Bottlenose dolphin	2	6	2	15	4	26	6	32
Atlantic spotted dolphin	2	4	0	0	5	32	7	36
Pantropical spotted dolphin	0	0	0	0	1	10	1	10
Unidentified dolphin	3	3	1	0	4	22	7	25
Total Cetaceans	**7**	**13**	**3**	**15**	**14**	**90**	**24**	**119**
Useable Sightings								
Odontocetes								
Delphinids								
Bottlenose dolphin	2	6	N/A	N/A	4	26	6	32
Atlantic spotted dolphin	2	4	N/A	N/A	5	32	7	36
Pantropical spotted dolphin	0	0	N/A	N/A	0	0	0	0
Unidentified dolphin	2	2	N/A	N/A	4	22	6	24
Total "Useable" Cetaceans	**6**	**12**	**N/A**	**N/A**	**13**	**80**	**19**	**92**

Note: N/A means not applicable; useable sightings excluded sightings during post-seismic periods.

TABLE 3. List of power downs (PD) and shut downs (SZ) of the airguns implemented for cetaceans sighted within the safety radii during the Chicxulub cruise.

Species	Group size	Date (2005)	Water depth (m)	Dove? (Yes/ No)	No. of airguns on prior to SZ or PD	Total airgun volume prior to SZ or PD (in^3)	Estimated 180-dB radius (m)	CPA (m) to operating airguns before mitigation	Mitigation measure taken (PD or SZ)
Atlantic spotted dolphin	2[a]	24 Jan	18	No	8[b]	1400	2000	303	PD
Unidentified dolphin	1	1 Feb	15	No	20	6970	3500	1039	PD
Atlantic spotted dolphin	2	9 Feb	16	No	20	6970	3500	676	PD
Bottlenose dolphin	1	17 Feb	28	No	20	6970	3500	107	SZ
Unidentified dolphin	1	17 Feb	25	No	20	6970	3500	2033	PD

[a] One adult and one juvenile.

[b] Seen during ramp up.

TABLE 4. Encounter rates for acoustic detections and visual sightings from the *Ewing* during the Chicxulub seismic survey

	Non-seismic			Seismic			Total [a]		
Effort Type	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)
All Visual	14	1983	7.1	7	1892	3.7	21	3875	5.4
Useable Visual	13	1707	7.6	6	1855	3.2	19	3562	5.3
Useable PAM	4	435	9.2	5	1847	2.7	9	2282	3.9
All PAM	7	569	12.3	5	1884	2.7	12	2453	4.6
PAM Daylight Only	4	442	9.1	5	1884	2.7	9	2326	3.9
PAM Nighttime Only	3	127	23.6	0	-	-	3	127	23.6

[a] The total detections and effort for **seismic+non-seismic** do not equal **total**, because of detections and effort in the **recently** and **potentially exposed** *(i.e., "Post-seismic")* categories that are not included in this table. Some other totals may not add up exactly, due to rounding.

Sea Turtles

During the study, 29 single sea turtles were seen, including 17 hawksbill, 2 loggerhead, and 10 unidentified turtles (Table 1). Hawksbills were the most frequently observed turtle during the Chicxulub seismic survey; they made up 89% of the turtles that were identified to species (Table 5). Given the year-round presence of feeding hawksbills in the shallow waters of the study area, it is not surprising that they were the most commonly seen turtle species. One additional sea turtle was found dead, entangled in fishing gear, and SEMARNAT was notified of the occurrence on that same day. Sea turtles were distributed throughout the seismic survey area.

Of the 29 turtles seen, 21 were sighted during "useable" survey conditions (Table 1). This excludes six turtle sightings during the "post seismic" period (90 s to 6 h after seismic operations had ceased), and two turtles sighted when the *Ewing* was traveling <3.7 km/h. Seven of the 21 useable turtle sightings were made while seismic operations were underway, and 14 of the sightings occurred during non-seismic periods (Table 5). The mean closest observed points of approach of turtles were similar during non-seismic vs. seismic conditions (290 vs. 284 m, respectively, n = 14 vs. 7 groups).

Ramp ups were postponed three times during the survey because of the presence of sea turtles. The airguns were powered down three times and shut down four times due to the presence of sea turtles within the 180 dB sound radius.

The single dead loggerhead sea turtle was seen 9 February during seismic activities. The dead loggerhead was observed floating at the surface, its hind, right flipper entangled in fishing gear (a rope several meters long). The turtle appeared to have been dead for ~5 days, and it smelled of decomposition. The observers concluded that the turtle's death was due to fishing activities and did not implement a shut down. SEMARNAT was notified of this dead turtle on the day it was observed, and it was retrieved by the spotter vessel, as requested by SEMARNAT.

Report on OBS operations EW-0501

Penny Barton

Instruments

The OBS used were 28 units on loan from the UK OBS Consortium (Southampton University, Durham University and Imperial College, London). 18 of the units were two-component (hydrophone and vertical geophone) 'El-Cheapo' (LC) design supplied by Scripps, and ten were a version of the LC electronics packaged into large aluminium pressure vessels (DOBS) and recording hydrophone and 3-component geophone. Photographs can be seen in the main cruise report. There were two dedicated engineers (James McIntosh and Alan Burchell) and during deployments and recoveries each engineer led a team of two students, at least one of whom had prior training or experience. In addition there was a watchstander in the lab and a Chief Scientist around to help as needed.

Unpacking and setting up

The two containers arrived at the ship late on 3 January. One was loaded onto the ship and the other unloaded on the dockside. Everything moved into the lab on 4 January. We were due to sail on 5th Jan but were delayed awaiting and eventually sailed on 7 Jan. Went straight out into exceptionally unpleasant weather, which affected a number of people badly for several days. On arrival in the work area the start of work was further delayed by permit issues, so that time lost to seasickness was recovered and the OBS were declared ready to deploy by midday on 13th Jan.

First deployment

DOBS #28 was deployed on 15th Jan and a few airgun shots from a single small gun fired into it to test gain levels. The records were examined and the gains thought to be about right. The instruments were deployed over the evening of 15th Jan, 16th Jan and early morning on 17th Jan. The process went fairly smoothly, gradually getting faster as the teams became more familiar with the tasks. Extreme care was taken with setting up and checking of each instrument, and a comprehensive checklist was completed for each deployment. Overall the deployment of LCs was noticeably easier and safer than that of DOBS. Safety issues for the DOBS include the lifting of the top half of the sphere into place, with the need for someone to reach inside to attach the wire, and the difficulties and dangers of attaching the release mechanism and bottom weight by lying underneath it on a deck which may be moving significantly and running with water. Extra time had to be taken on each deployment to conduct a wire test of the DOBS release, and because of their tendency to float for a few seconds while the base floods it was necessary to attach an extra weight to them, to prevent the A-frame winch wire from jumping off the spool, which all took extra time. Various problems encountered with the DOBS included a pinger wire being pulled off when a lid had to be reopened (DOBS #28?). Two instruments failed release tests (DOBS #19 which had actually been deployed and then lost contact, so that it was immediately released and recovered, and DOBS #26), and were set aside for investigation. The notable symptom was a strong pinger response in air and a very weak response in water. It was suspected that these had release electronics wired up backwards, and indeed the problem disappeared as soon as the wiring was reversed. It transpired that this problem had been known about on these instruments before they left the UK. On opening one of these instruments it was noted that the hydrophone pre-amps,

equipped with two 9-volt batteries, were already significantly dropped in voltage, despite only having been fitted a few days. DOBS #22, 23 and 25 had already been deployed. Therefore all the remaining instruments (#19, 20, 21, 24, 26, 27, 28) were hurriedly rewired with six batteries. Note that instruments #15 and #17 were mixed up during assembly, so that two hybrid instruments were deployed.

Recovery and second deployment

After a very intense working period for the first two weeks of the cruise until the first deployment was completed, the OBS operation was then relatively quiet until the recovery/redeployment programme, which began on the evening of 2nd Feb and was completed in the early hours of 5 Feb. A schedule was compiled in consultation with the engineers that allowed an average time of station of 20 minutes per deployment or recovery, plus steaming time between stations at 8 knots. The 28 deployed instruments were divided into three self-contained spatial groups and within each group first a number of instruments were recovered (including all the DOBS in that group), then there was a period of alternating recoveries and deployments, and finally the remainder of the group were deployed. It would be worthwhile for the OBS engineers to initiate a meeting with key deck crew and officers before the start of this type of operation, although in the event it quickly ran smoothly. Also it would be useful to do a walk-through rehearsal of operations before starting, to anticipate the need for small items such as eye bolts, freshwater hose, ramp etc, all of which had to be searched out as recoveries began.

Recovering and redeploying the first two groups of instruments went smoothly and the timetable seemed realistic in this shallow water, where released instruments popped up in about 30 seconds. It was disappointing to discover that the Matlab program that is supposed to be used to check data files after downloading would not work with this quantity of data (despite it being much less than the capacity of the instruments). Therefore it was not possible to check the data for problems before redeploying the instruments – this may have led to unnecessary data loss on the second deployment (e.g. LC #11 which recorded no useful data on either deployment). The third group was marred by the almost simultaneous discovery of an instrument that would not respond to pinging and a report from shore that two instruments, one of each design, had been handed in to the Port Captain at Progreso (DOBS #28 and LC #15). Unfortunately neither of these instruments was from the site that did not respond to pinging (DOBS #26). The two errant instruments were returned to the ship in the pilot boat in the early hours of 5 Feb but were not redeployed: thus 25 instruments were used in the second deployment. In addition, two instruments did not record any data (DOBS#23 and LC #10: one possibly not switched on, one possibly set with wrong start time), and one was discovered later to have recorded only noise (LC #11).

Final recovery

The final recovery went very smoothly, even though started at 4 hours notice when we found that we were about to be ordered into port for legal proceedings. We had scheduled it at 20 minutes per site plus steaming time at 8 knots. Due to the very fast pop-up times (30 seconds for DOBS and five minutes for LCs) the time on station was usually slightly under 20 minutes – it generally took around 7-8 minutes to get an instrument on board after it had been spotted. A couple of instruments came up at night without lights working – one had neither light or radio – but were still found:

fortunately the sea was quite calm. One instrument (LC#8 at 8G) did not respond to pinging. We received news shortly afterwards that an instrument had been found floating offshore Celestun. Before it was confirmed that that this was the missing LC (we still had a DOBS unaccounted for from the first deployment) we spent a significant time doing concentric and crossing lines with the ship whilst pinging, to ensure that the pinger was not in a shadow zone. We also had the site searched by a diver (Paco) who did a detailed survey but found nothing. We also revisited site 10F for further pinging.

Instrument co-ordinates

The OBS co-ordinates for the two deployments are shown in Table 1 and also in Figure 1, with the shooting lines recorded on each deployment indicated by colour.

Instrument loss

Four instruments broke free of their moorings, three on the first deployment and one on the second. All were from the same area in the southeast of the grid box.

First deployment

DOBS #28, site 10F: Found floating about 10nm NNE of Chiburna in 10-12m of water on January 21st. Handed to Progreso Port Captain by a fisherman on February 3rd and returned to ship by Mike Rawson and Tim Owen on Feb 4th. Reward paid $200.

LC #15, site 7A: Found floating off Chiburna approximately same time as DOBS #28. Handed to Progreso Port Captain by a fisherman on February 3rd and returned to ship by Mike Rawson and Tim Owen on Feb 4th. Reward paid $200.

DOBS #26, site 7E: Diver checked site on 8th February. Recovered concrete weight, base plate and nut from underneath it, apparently having undone in the current. Instrument not found as of June 2005.

Second deployment

LC #8, site 8G: Found floating off Celestun on 17th or 18th Feb. Collected and returned to ship 21st Feb by Jo Mrogan. Releases not fired, bar in place, screw link missing. Deployment site spot-checked by diver and nothing found – sandy and flat with no weeds. Screw holding black plastic tube to blue-green frame had worked loose so it projected into black tube and scratched and snagged recording cylinder as we attempted to remove it. Reward paid $200.

Replaying data at sea

Due to the very fragmented nature of the shooting lines (many shut-downs due to weather, fishing boats, turtles, dolphins etc) it was relatively complicated to compile lists of shotpoints into 'lines' to be used to extract data from disk. An initial playback of data from the first deployment revealed that, for about half the instruments, the data extraction program was succeeding in extracting only about one in four of the requested traces. There was also a bug in the program that wrote raw data files onto DVD so that it was not possible to store that data in a single large file.

No replay of data from the second deployment was possible before the equipment was packed for shipping.

Data delivery

The full dataset was delivered on DVDs to Cambridge in early June 2005, in both raw and SEGY format. An external hard disk containing the full dataset was also written and this will be copied at Cambridge for distribution to collaborators.

Data quality

Some examples of OBS data are shown in Figures 2, 3, 4.

Data for the 0-20 km offset range was examined for every instrument after the first deployment. High amplitude long period (5-7 second) wave noise dominated the El-Cheapo hydrophones, but was removed easily using a filter. The DOBS hydrophone records did not show the same response, although a 1 second time mark crosstalk was visible on several instruments. When replaying at sea the geophones of both instruments showed frequent short bursts of noise – usually very high frequency followed by low frequency; it was not clear if this is a physical or electrical disturbance. Replay of all the data in Cambridge shows a general trend to a much better bandwidth in the hydrophone data, with a rather low frequency signal characterising the geophones of both designs.

Data quality and recovery were adversely affected by the noisy seabed conditions, and by the strong currents. Data quality appears to deteriorate in windier conditions and in shallower water. In addition, this was the first time that this set of instruments had been used 'in anger' and the team were relatively inexperienced. Data quality is summarised in Table 1, with 0=did not record, 1=recorded noise and/or unpickable signal, 2=recorded pickable but noisy data and 3=good data.

In the first deployment 28 units were deployed (18 LCs and 10 DOBS). Of these 28, 22 have yielded data from the hydrophone or vertical geophone that will be pickable. The hydrophone generally performed better than the vertical geophone, but the verticals on the DOBS were particularly good and in three cases the verticals recorded good data when the hydrophones failed. From the 28 instruments deployed we have 79% data recovery for a pickable hydrophone or vertical trace.

In the second deployment 25 units were deployed (17 LCs and 8 DOBS). Of these 25, 20 have yielded data from the hydrophone or vertical geophone that will be pickable. The hydrophone is again the most reliable channel, scoring the maximum '3' for all of the DOBS that recorded and 9 of the LCs. No geophone channels were assessed as '3', but the DOBS geophones seemed to perform more consistently as a '2' relative to the LCs, which performed significantly less well on the second deployment. Thus from the 25 instruments deployed we have 80% data recovery for a pickable hydrophone or vertical trace.

We had hoped for 56 deployments but in the end achieved 53, and got useful data (a score of 2 or 3 on the hydrophone or vertical component) from 42 deployments, giving 75% success overall relative to original expectations.

Recommendations

1. It is recommended that a more comprehensive toolkit is brought to allow for *ad hoc* adaptions and repairs. For example, we had to borrow a soldering iron from the ship and were reduced to cutting wires with a pair of scissors, and the only pieces of prototyping board available involved stripping down a different power supply.

2. Software should be tested with test data files similar in size and structure to that being collected, to allow problems to be ironed out in advance.

3. Further consideration should be given to the media used for the delivery of data as volumes are very large and considerable time is needed to write the data to DVDs.

4. As the OBS group develops *esprit de corps* it will become clearer what roles it would be appropriate for them to take leadership on, such as possibly programming deployments and recoveries, briefing deck crew etc. I also recommend that they look for ways to integrate themselves into the scientific party more closely, such as by volunteering help with watchstanding or other tasks when they are not overwhelmed by OBS work, as this will help to prevent boredom and earn credit for when they in turn need help.

TABLE 1

Cruise EW0501

Record of OBS deployments and summary of data quality

0=did not record, 1=recorded noise/unpickable, 2=pickable but second quality, 3=good data

FIRST DEPLOYMENT (data quality scores based on line 8)

Inst	Site	Latitude	Longitude	Water depth	Ch 1: Hyd	Ch 2: Vert			
LC-1	9C	21.637499	-89.531325	21.0	3	3			
LC-2	6D	21.546817	-89.740734	20.0	3	2			
LC-3	5C	21.575676	-89.823437	22.1	3	2			
LC-4	1C	21.514371	-90.115376	23.8	3	2			
LC-5	4F	21.427436	-89.868786	15.4	3	2			
LC-6	2D	21.485566	-90.033066	20.7	3	2			
LC-7	5G	21.398220	-89.786261	23.2	3	2			
LC-8	8F	21.488698	-89.576408	16.1	3	2			
LC-9	10D	21.608342	-89.448973	20.6	3	3			
LC-10	8B	21.666621	-89.613646	22.4	0	0			No data
LC-11	4B	21.605027	-89.905784	23.9	1	1			No data
LC-12	5E	21.487237	-89.804543	17.1	3	1			
LC-13	4D	21.516341	-89.887094	20.8	3	2			
LC-14	9G	21.459658	-89.494062	22.1	2	1			
LC-15/17	7A	21.695512	-89.696092	27.9	3	2			
LC-16	1E	21.425575	-90.096992	19.7	1	2			
LC-17/15	9E	21.548580	-89.512537	18.1	1	1			No data. Broke from mooring: recovered
LC-18	6F	21.457994	-89.729322	15.1	3	1			
					Ch 1: Hyd	**Ch 2: Hor1**	**Ch 3: Hor2**	**Ch 4: Vert**	
D-19	5A	21.664959	-89.842181	27.2	3	2	2	3	
D-20	9A	21.726385	-89.550016	25.6	3	1	1	3	
D-21	7C	21.606823	-89.677435	24.0	3	2	2	3	
D-22	3C	21.545388	-89.969513	23.9	1	3 (Vert)	2	2 (Hor1)	
D-23	3E	21.456508	-89.950800	18.0	0	0	0	0	No data
D-24	6B	21.635848	-89.759803	26.4	3	1	1	2	
D-25	2B	21.574321	-90.051778	19.0	1	2	2	3	
D-26	7E	21.517809	-89.658830	17.5	0	0	0	0	No data. Broke from mooring: lost
D-27	8D	21.577622	-89.595036	20.6	3	2	2	3	
D-28	10F	21.519451	-89.430368	16.3	0	1	1	1	No data. Broke from mooring: recovered

SECOND DEPLOYMENT (data quality scores based on line 9)

Inst	Site	Latitude	Longitude	Water depth	Ch 1: Hyd	Ch 2: Vert			
LC-1	9B	21.681870	-89.540736	26.2	2	2			
LC-2	6A	21.680279	-89.769080	27.3	3	1			
LC-3	5B	21.620725	-89.832839	25.1	3	2			
LC-4	3D	21.501040	-89.960167	19.2	3	2			
LC-5	3B	21.589874	-89.978859	24.7	3	1			
LC-6	2C	21.530108	-90.042576	25.0	2	2			
LC-7	6E	21.502507	-89.731662	18.1	3	1			
LC-8	8G	21.444300	-89.567007	15.5	0	0			No data. Broke from mooring: recovered
LC-9	9F	21.504107	-89.503275	17.7	2	0			
LC-10	7B	21.651179	-89.686701	23.6	3	1			
LC-11	3F	21.412102	-89.941401	16.6	0	0			No data
LC-12	6C	21.591374	-89.750470	23.8	3	1			
LC-13	1G	21.337012	-90.078127	16.7	2	1			
LC-14	10E	21.563940	-89.439615	20.5	3	2			
LC-15	7D	21.562312	-89.667935	20.7	3	1			
LC-16	2E	21.441266	-90.023958	17.8	1	2			
LC-17	-	-	-	-	-	-			Not deployed
LC-18	5F	21.442754	-89.795470	15.7	1	1			
					Ch 1: Hyd	**Ch 2: Hor1**	**Ch 3: Hor2**	**Ch 4: Vert**	
D-19	4A	21.649615	-89.915123	29.0	0	0	0	0	No data
D-20	8C	21.622098	-89.604312	22.9	0	0	0	0	No data
D-21	4C	21.560809	-89.896411	24.6	3	2	2	2	
D-22	1B	21.559223	-90.124949	26.1	3	2	2	2	
D-23	3E	21.452405	-89.949976	19.4	3	2	2	2	
D-24	5D	21.531667	-89.814025	21.6	3	2	2	2	
D-25	1D	21.470329	-90.106306	21.3	0	2	2	2	

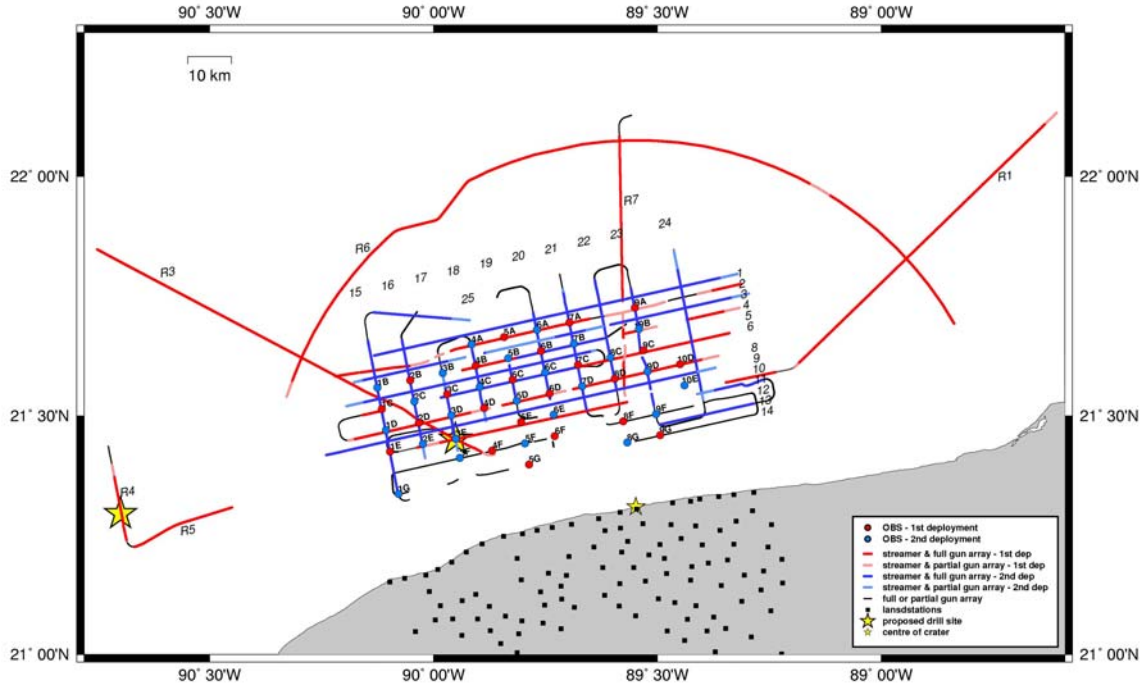


Figure 1. Map of OBS deployment sites. Red dots show OBS positions for first deployment (see Table 1 for co-ordinates), which recorded the red shotpoints. Blue dots show second deployment.

Figure 2. Sample data from DOBS #22, site 1B, line 15. Reduced at 6 km/s.

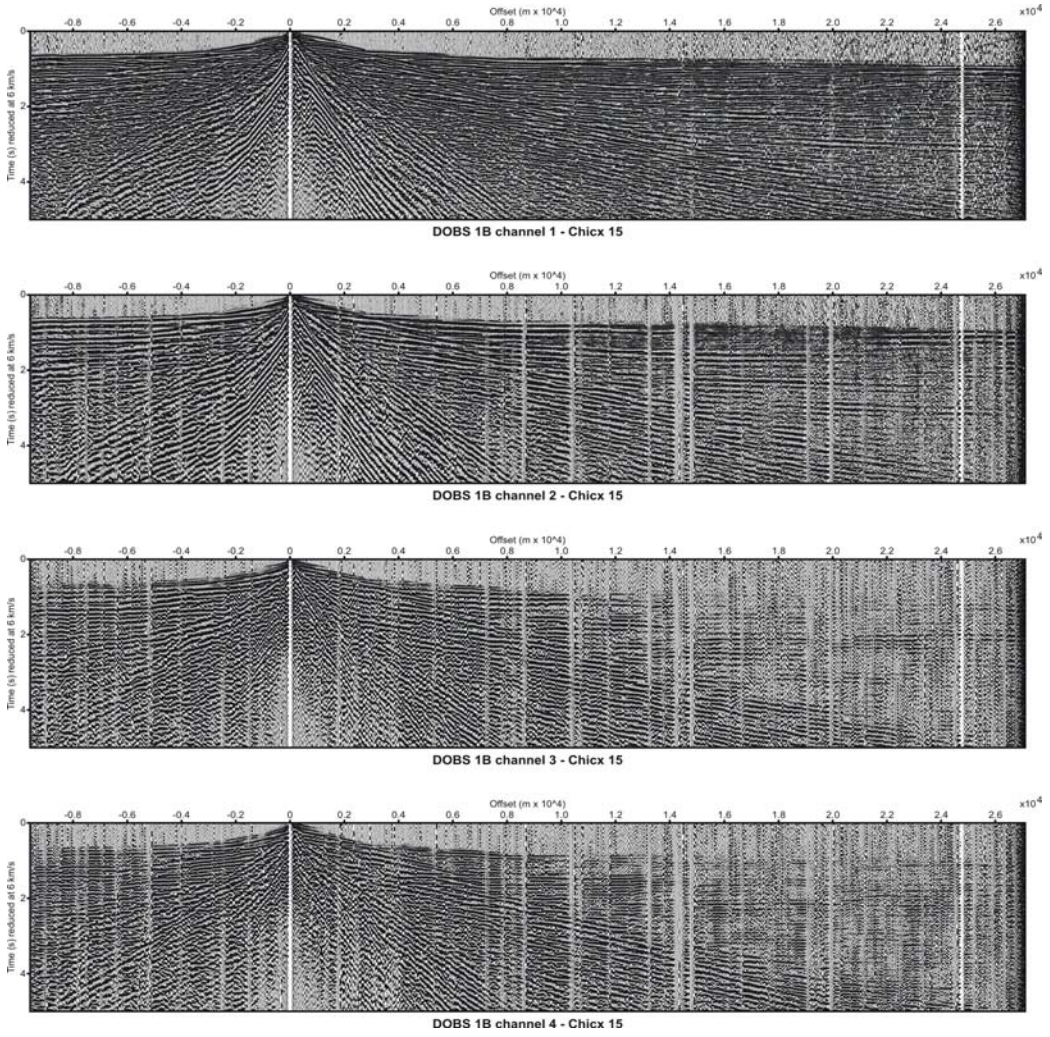


Figure 3. Sample data from DOBS #24, site 5D, line 9. Reduced at 6 km/s.

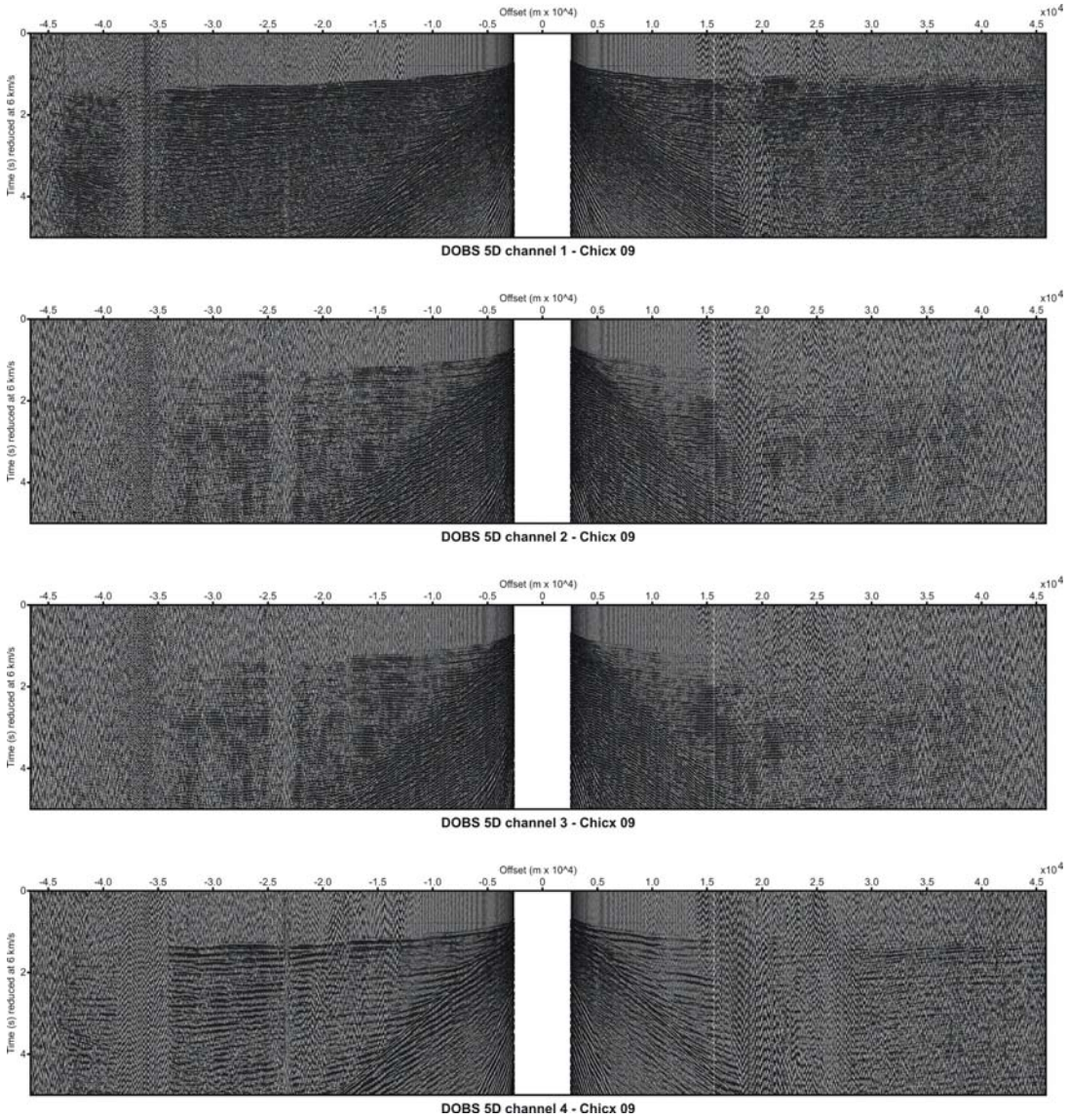
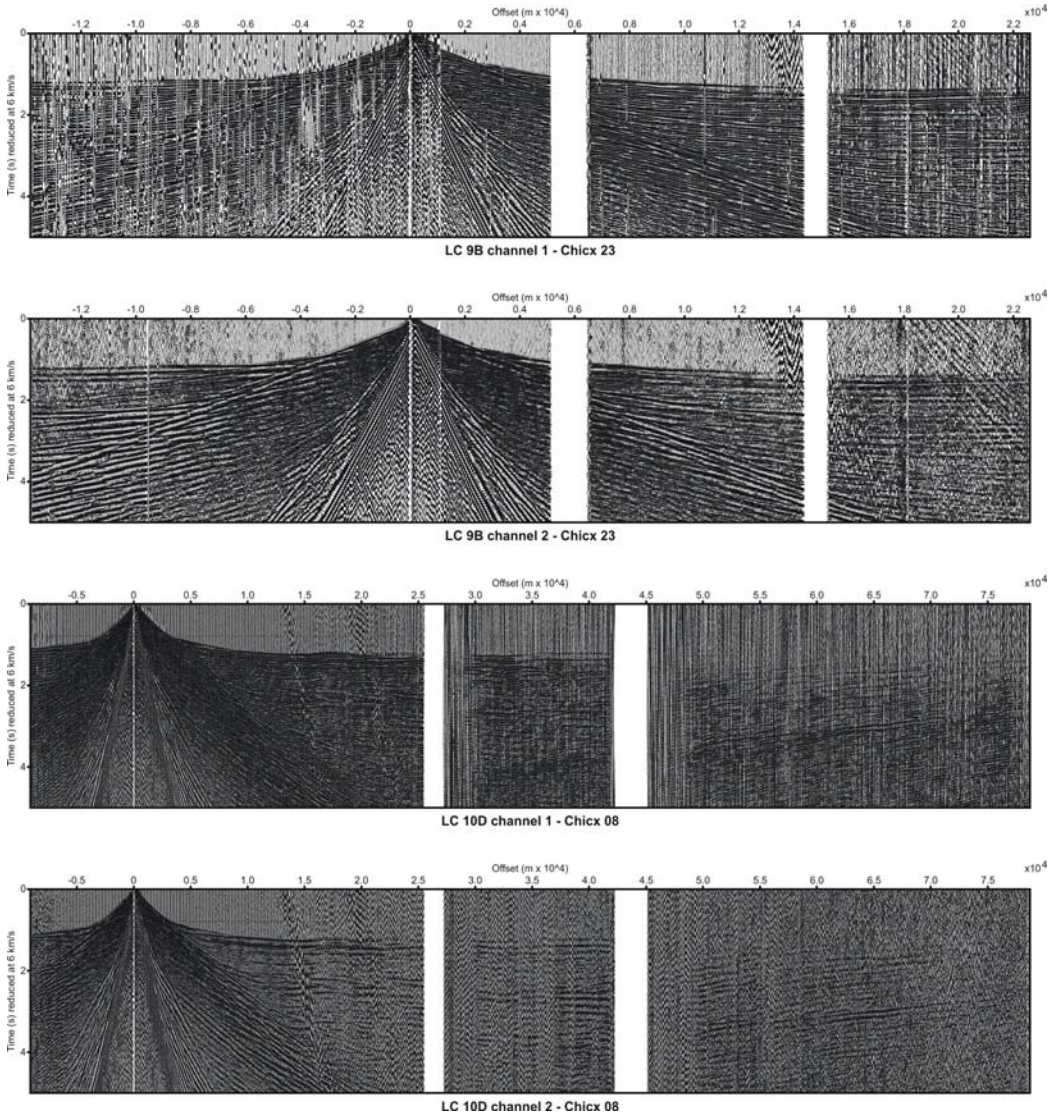


Figure 4. Top two panels: Sample data from LC# 1, site 9B, line 23. Bottom two panels: Sample data from LC # 9, site 10D, line 8. Reduced at 6 km/s.



EW0501: Cruise Diary

Monday 3 January
In port Panama. US and UK science party departed from Panama City for the ship at Colon at 0700 after arriving from various directions the night before. The two OBS containers arrived late afternoon, and one was loaded on board.

Tuesday 4 January
In port Panama. OBS containers unpacked. Meetings of Co-chiefs Sean Gulick and Penny Barton with Captain James O'Laughlin, Science Officer Ted Kocyznski and marine mammal observers (MMOs), and later a conference call with Lamont at the agent's office to discuss the interpretation of their mitigation document of 30 December. Also discussed fax from Mike Warner (Imperial University, co-chief Land Party) expressing concerns about Ben White. Main current concern is the Mexican MMOs, as we have had no information about them. Two UNAM students, Keren Mendoza and Oscar Martinez, expected Wednesday, so will wait for them. Total number of days for cruise is not clear. On return from agent's we pursued Mexican MMO question – Jo Morgan (Imperial University, co-chief Land Party) thinks that three have been found (Eduardo Cuevas, Maria Teresa Zapata and Diana Antochiw) but that they cannot be confirmed until SEMARNAT re-opens on 6 January, and they are all based in Merida. Considering possibility of attempting to get our existing MMOs approved as Mexican MMOs.

Wednesday 5 January
In port Panama. Getting labs sorted out ready to sail at 1600. Lamont instruct us not to sail until we have a definite arrangement for getting the Mexican MMOs to the ship. Keren Mendoza and Oscar Martinez arrive, expecting to be on board for 2-3 weeks only. Delayed sailing until 2000. Mike Purdy telephoned to say that Meike Holst, who is already on board, has been approved as a Mexican MMO and that SEMARNAT were meeting to decide whether Claudio Fossati (also on board) could also be approved. Delayed sailing until midnight. Paul Ljunggren called with news that we need to wait for Maria Teresa Zapata to arrive on Friday before sailing (to bring us to full complement of 'Mexican' MMOs). He also asked us for an estimate of the cost of the project so far for Jaime Urrutia (UNAM, project collaborator) to use in a court case with Mexico Greenpeace – we estimated $1.5M science costs plus $1.6M for ship time.

Thursday 6 January
In port Panama. It was a despondent day waiting for news. Mike Rawson in Merida confirmed that Maria Teresa Zapata would be arriving Friday morning.

Friday 7 January
In port Panama – on passage. Maria Teresa Zapata arrived at midday and the ship sailed at 1430. To start with there was a party mood up on the flying bridge as we left port, but it soon got unpleasantly rough and everyone gradually disappeared.

Saturday 8 January
On passage. Most people pretty under the weather. Got almost everyone to the boat drill then most collapsed again. At 1800 we had some short talks in the lounge – today talks by Sean Gulick and Penny Barton.

Sunday 9 January
On passage. We received news that the official Mexican MMOs must be Mexican nationals, so that it will be necessary to pick up two more people from Progreso by launch. Candidates should be approved on Monday. Most people beginning to feel better. Anusha Surendra and Peggy Vermeesch gave talks at 1800.

Monday 10 January
On passage. We received news from Mike Warner of a lot of bad publicity in Yucatan. There is a proposal to film seafloor whilst guns go over at request of fishermen. In afternoon got alarming message that the additional Mexican MMOs had declined to come on the cruise. Talks at 1800 from Meike Holst and Claudio Fossati on MMO (visual and acoustic).

Tuesday 11 January
On passage – offshore work area. Arrived near the work area at midday and stood well offshore to the northeast. Maria Teresa Zapata received a message that the new MMOs would arrive on Wednesday. Ship's drill to repel boarders practised. OBS deployment plans discussed. Message from agent to say we do not have authorization to approach the port.

Wednesday 12 January
Offshore work area. We waited all day. Rumour that Ben White was on his way to harass us. Plane flew over. In evening word from Jaime Urrutia that Diana Antochiw and Eduardo Cuevas had been approved by SEMARNAT. Still do not have navigation permit to approach port, so moved to east of Alacran reef to be closer to Progreso.

Thursday 13 January
Offshore work area. Word from Paul Ljunggren in the morning that we must not approach port until Navy permit issued. 1340 OBSs declared ready to go. Plane flew over. In the evening received messages indicating that more of the permits were in place. At 2200 Paul Ljunggren phoned to say we should go into Pilot station at 1100 tomorrow to pick up MMOs and Navy observer. Orders are to approach at high speed, and to use a Spanish speaker on the bridge radio referring only to Captain Jaime (Jim). We were embargoed from emailing out any details to anyone overnight. Hope to get Navy permit tomorrow. Fantastic lightning storm watched by all on deck. Critical article appeared in the London Guardian today.

Friday 14th January
Offshore work area. We are steaming steadily towards 1100 rendezvous at pilot station 1.5 miles from end of Progreso pier. At 0930 informed that port is closed because of bad weather – too rough for pilot boat. We are told to return at 0800 tomorrow. We telephoned Mike Warner at Chicxulub house. He says: 1) Ben White is not allowed to use any local fishing boats; 2) local media interest in the project is not very great; 3) we should get Navy permit on Saturday; 4) he thinks the Mexicans would be happy to offer a few days extension of the permits; and surprisingly 5) that he has had instructions not to talk to us – this may explain the lack of information on board.

Saturday 15th January

Pilot station Progreso and OBS deployments. We arrived at pilot station at 0800 as requested, and two Mexican MMOs (Diana Antochiw and Eduardo Cuevas) arrived in the pilot boat at 0845 with Customs team. Pilot boat returned at 1030 with Mexican Navy observer Lt. Rubin Romero. Apparently now all permits including Naval and navigation permits are in hand, and we are free to start work. Moved to NE corner of grid to begin period of OBS tests, including test deployment of DOBS with a few single-gun airgun shots. We began main OBS deployment at around 2130. Various pieces of information surfaced today. Firstly, there is a large exclusion zone around and in line with the pier, and we may not enter this zone at all. This affects all the airgun-only lines and MCS line 11, as it cuts around a fifth of each profile out of its centre, and will also mean relocating several of the OBS. Secondly, PROFEPA wish to inspect our operations on board next Monday. We are concerned that this will disrupt our schedule, and that we had not been aware of this as a requirement previously. Thirdly, we were given a Notice to Mariners showing the site of a scuttled ship near the port entrance, intended as an artificial reef. At 0200 (16/1/05) the port radioed the ship to say that the actual location of the wreck was different, and that we should keep 2nm away from it: Captain thinks this is over-cautious, and in any case we had deployed an OBS closer than this before receiving the position change. Fourthly, received a fax from Paul Ljunggren that is a copy of a permit document addressed to Sean Gulick and dated 8 December – the first any of us have seen of it. This document specifies observations to a 145dB safety radius (almost over the horizon) which we and the MMOs feel must simply be a mistake.

Sunday 16th January

OBS deployment. Deployment continues. One DOBS pinging weakly then disappeared, so popped it back up and substituted an LC. Symptom of pinging loudly in air and quietly in water is apparently typical of wiring being reversed. At the same time it was noticed that the batteries in the DOBS preamp had dropped to 8V since the instrument was closed up. Therefore it was decided to modify DOBS not yet deployed so that they had six batteries in their preamps, not just one – a chance for some truly appalling soldering by Penny Barton. DOBS deployments significantly slower that LCs, due to having to wire test the pingers, crawl around underneath them on deck etc. Another DOBS had a pinger problem – this and the other needed rewiring. News from Lamont that we cannot commence shooting until the 145dB issue is resolved. Short diversion to assure ourselves that the second wreck location was in fact the correct one, which it was as confirmed by the buoy on top of the wreck being sighted.

Monday 17th January

Streamer deployment. We finished OBS deployments at 0730. Were expecting visit from PROFEPA at 1100 but weather too poor. Jaime Urrutia says 145dB is wrong, but we await word from Lamont. MMOs concerned about sea-state – they have been told maximum is Beaufort 3. We began streamer deployment at 0900. We spent considerable effort balancing streamer and checking that birds were working properly. Two sections changed. We got news that we could commence work after the PROFEPA inspection.

Tuesday 18th January

Streamer/gun deployment. We finished streamer deployment at around 5am. Expecting PROFEPA at 0800 but still too windy. Deployed gun booms in morning – extremely slick operation – and then PAM streamer – less so. Weather continued too

poor to start work. In the evening got word from Lamont that we could not start work until the US Embassy receives an 'official enough' document about the 145dB issue. We receive news that NSF is looking at trying to fund 8-day extension if Mexico permits it.

Wednesday 19th January

PROFEPA inspection. We are still waiting for confirmation that we can shoot. PROFEPA was due to arrive 0800, but got on board by 0930. Arrived in a Navy interceptor that could not come alongside whilst we are moving, so ship's zodiac boat had to be launched in three trips to bring them aboard. There were seven people – 6 from PROFEPA and a Lieutenant from the Navy. Their main interest was in paperwork. They required us to produce the originals or certified copies of all the permit papers. This was awkward and embarrassing, as we have faxes or emails of most of them – no originals or certified copies: Jaime Urrutia at UNAM and/or the Lamont office have these and they inform us of the contents in emails. They gave us a few days to get these papers to the PROFEPA office in the Yucatan, before initiating legal proceedings against us. We received confirmation by fax from LDEO that the 145dB had been modified to 180dB radius. Concern about the issue of wind speed – in the letter we received on 15 January there was a clause of 'Not Force 3 or greater', which Diana Antochiw pointed out to us today. The head of LGL recommends we comply with that, whilst head of the PROFEPA team recommends we get it changed. PROFEPA team is expecting to come once or twice more, so we tried to negotiate a more convenient arrangement so they arrive before we start shooting and depart afterwards. The inspection resulted in a handwritten report produced by the three scribes, amounting to around 30 pages: each page of two copies had to be signed by about 5 people. PROFEPA departed at 1630 leaving us stunned. We sent emails to Jaime Urrutia to get the key original documents copied, certified and sent to the PROFEPA offices. Diana Antochiw concerned that the papers approving the MMOs should also be on board before the next inspection. We also asked Jaime Urrutia to contact SEMARNAT urgently about sea state restrictions. It was an extremely discouraging day.

Thursday 20th January

Waiting – profiling grid. It is a beautiful calm morning. Apparently wind speed is 10 knots and it has to be below 6.5 knots to shoot with current conditions. We took photos and videos to demonstrate perfect sea conditions. We are awaiting news from Ramirez of SEMARNAT, who signed the conditions letter. It has been clarified that the ship cannot go through the exclusion zone around the port approach at all. Day carried on with beautiful weather, with wind dropping tantalisingly close to force 2. Looking at ways to integrate wind speed in some meaningful way. At 1640 dropped below 6.5 knots and we could begin shooting, and carried on until 1800. Collected the far east end of line 2 – around 50 minutes of data. It was good to get the system going and iron out the bugs. Everyone was grinning – including the MMOs. News that our limit may be increased to Beaufort 3, but this will not be enough.

Friday 21st January

Profiling grid. Beautiful calm conditions so began profiling at 0715 (30 minutes of observing for animals begin at first light at 0615, followed by a 25 minute ramp up from 0645). At 0800 wind rose above 7 knots and we had to stop. Restarted a little later then had to shut down for a fishing boat which refused to move, after which time

the wind had increased again. Managed to shoot between 1200 and 1400, and then shut down for the rest of the day. We spent a lot of time trying to design a protocol for deciding wind speed threshold, as current display is a one minute spot value. Standard US navigation manual (The American Practical Navigator, by N. Bowditch, 1995, p527-529) from bridge states that it takes 90 minutes for a wind increase to force 3 to affect the wave height, so we are using this as a running average. Mid evening got the excellent news that the limit is being increased 'through' Beaufort 4, i.e. to a maximum of 17 knots.

Saturday 22nd January
Profiling grid. Hopes dashed again, as Lamont need a proper document about the Beaufort 4, and it is Saturday. Wind is hovering in the mid teen values, nowhere near 7 knots, so we cannot work. At 1130 we were called by Mike Purdy who has had legal consultation about the problem of Beaufort 4 and visibility for marine mammal observation. The lawyers require a statement from all 6 MMOs that they are satisfied that they can monitor effectively to 3.5 km radius in a Beaufort 4. We gathered all MMOs on the flying bridge and they agreed readily to this, so that we began shooting the east half of line 6 soon after noon. Wind increased slowly and steadily and hit 17 knots at 1705, when we closed down, just at the end of the line. Celebrated 200 years of the Beaufort scale.

Sunday 23rd January
Profiling grid. It was a fine calm morning. Wind veering, perhaps because of promised stormy front. Began line 8 E-W at 0715. We profiled through the day with two short interruptions for fishing boats and a turtle. Reached end of line at 1610 and turned north onto west end of line 6. Wind increasing but we made it to 1800. There was both a barbeque and an XBT.

Monday 24th January
Profiling grid. The weather was quite poor through night, but we were able to start work by 0830, and we began line 10. Halfway through the ramp up procedure, we had to shutdown for a dolphin and then a turtle. We were very anxious to get the part of the profile running through the proposed ODP site so decided to loop back and start line again. This looping around took longer than anticipated, but we collected the pass through the site and collected about 60% of the line. Later heading to north of R1 to shoot it N-S. We have been trying to go a little faster over the ground – about 5 knots - in order to be able cover the survey in the restricted shooting hours. However this puts a strain onto the propulsion with only two engines on – both because of the extra speed and to keep up the repetition rate on the compressors. Problem is eased if we go with the wind/current, which is generally from the northeast. Apparently if we use a third engine we may not have enough fuel in the event of an extension.

Tuesday 25th January
Profiling regional. It is a beautiful calm morning. Started line R1, a little late because the ship was not fully lined up and the PAM monitoring was delayed. Good day of profiling, working with the current, so no strain on engines. Finished R1 at 1615 and branched west onto line R2, which we had otherwise dropped from the programme due to time constraints. We followed R2 almost to the east end of line 10. We observed manta rays and large fish leaping behind the boat. In the evening brought in first half of streamer to change batteries in some birds and to attempt to improve noisy

section by cleaning contacts. Replaced two sections – one was found to be full of water on recovery.

Wednesday 26th January
Profiling grid. We are aiming to re-shoot line 2, east-west. However, there was a major problem with the tow leader to the streamer, which lost its electrical connectivity. The tow leader was changed for a shorter one (alarmingly corroded in appearance), bringing the near offset trace closer to the shots which was our preference anyway. This entailed profiling in several different configurations during the day, with and without the streamer held in a clamp, and three distinct geometries. We continued along line 2 with several interruptions for fishing boats, missing a few shots near the end as a run-out had not been entered into Spectra. Eduardo Cuevas has raised an issue about the work box specified in the permit. We have been given four points all offshore, to delineate the box, and we have been interpreting this to mean that we should close the box by projecting normally or NS/EW into the coast. Eduardo suggests the box should be formed by joining the four points directly, which cuts out part of our work area (line R1 and the end of the CRP survey), but includes a chunk of land, which does not seem logical. Eduardo Cuevas has asked PROFEPA for clarification, so we have spent a lot of effort on rationalising our position, and have asked Jaime Urrutia to contact SEMARNAT.

Thursday 27th January
Profiling regional. Shot regional line R3, S-N. Weather moderated just in time for start of line to get a good profile through the secondary drill site. It was an excellent day with no interruption from fishing or animals. There are reports in the local press of 10s to 100s of fish being killed. Mario has agreed to appear in a television debate tomorrow with a representative of PROFEPA and an environmentalist. Ted Kocyznski organised a meeting with all MMOs in the evening in order to air any concerns. Discussion of necessary weather conditions for the pre-ramp up observation period, not specified in the Mexican document, plus checks that the shutdown procedure is working. So far they have seen 3 dead fish (one sunfish, one catfish and one 'bait' fish) and there has been one mammal shutdown and two turtle shutdowns. Weather got quite choppy later.

Friday 28th January
Profiling regional. Weather continued to be rough through the night but moderated at the last minute and it was possible to start R4 after a large circle to ensure full fold over the second drill site. A dolphin was heard on the PAM so we did a slow one-gun start up and it disappeared. Collected R4 through the drill site then turned onto link profile R5. Weather deteriorated and we had to close down at 1530. A group of 5 dolphins is observed around the boat. We heard that Ben White is planning to visit the ship tomorrow. Mario Rebolledo (CICY, project collaborator) recorded his TV debate, but the environmentalist opposition did not show up, on the grounds that she would not argue with a specialist. Mario Rebolledo contacted us late in the evening to say that replacement Mexican MMOs could not be found for Eduardo Cuevas and Maria Teresa Zapata who are scheduled to leave the ship in the next few days and that he was trying to persuade Eduardo and Maria Teresa to stay. Discovered discrepancies between the some planned line locations and their actual positions, perhaps due to the manual reading of coordinates from an inaccurate map: all waypoints being reviewed for errors.

Saturday 29th January

Profiling regional. We began Constant Radius Profile (CRP) 3nm to the southwest of where it crosses R3. The weather is moderate in the morning, but gradually increasing in wind speed. We collected halfway around CRP without interruption, although we had to divert significantly off the circle to avoid a set of fishing nets and a boat. No sign of Ben White. Got line coordinates sorted out, plus a way-pointed plan for the OBS recovery and redeployment. In late afternoon it was noted that there were an unacceptable number of parity errors in the streamer, so that in the evening it was brought in for the problems to be addressed. Searching for replacement Mexican MMOs has become a major preoccupation – Eduardo Cuevas and Maria Teresa Zapata have agreed to stay a day or two more but no longer.

Sunday 30th January

Profiling regional. Streamer much improved after last night's maintenance, which went on until 0230. We completed the east half of the CRP profile, with only one power-down for a turtle. We extended the line in towards shore during run out. We are trying to organise paperwork for next PROFEPA inspection, and still pursing Mexican MMOs.

Monday 31st January

Profling regional. Regional line R7 from north to south. Started at closest allowed point to Alacran Reef then steamed south towards grid. Just north of grid got shut down for turtle then fishing boat then weather, and managed to do little more after that, although there are a few shots here and there in the grid. Finally shut down at around 1530 and the wind gradually increased to 30 knots by mid evening, so we called off PROFEPA inspection due 0500 tomorrow morning. They had asked to bring a journalist with them, but Lamont have turned this down. PROFEPA is apparently planning to come in their interceptor again. Rumours about Mexican MMOs continue. In the evening brought the streamer in over a 4 hour period. One section needed patching.

Tuesday 1st February

Airgun profiles. Weather was fine by the morning. Shot airgun-only lines 12b EW then 14b WE, stopping due to weather just before the end of 14b. There is still no news about replacement MMOs. We are expecting PROFEPA inspection tomorrow, via chase boat.

Wednesday 2nd February

Airgun profiles - Profepa inspection – OBS redepoyment. We asked PROFEPA to arrive at 0500 and they were on board by 0715. We started shooting immediately. Line 12a went fairly well, but then we turned onto 14a and had numerous shutdowns – turtles, dolphins, divers, fishing boats and finally at 1630, weather – resulting in an extremely fragmented profile. Inspection went well (and we certainly demonstrated the mitigation procedures!), and the team left at 1815. One surprising outcome was that the inspectors told us that the 28 December diplomatic note that specifies an end date of 15 February is not the definitive date, just an indicative date for that document. The actual permit end date from SEMARNAT is 31 March. We sent information to shore for clarification. Brought in guns and immediately started long process of OBS recovery and redeployment. We unfortunately discovered that the data display

program for the OBS data did not work with this quantity of data, so having to redeploy 'blind'.

Thursday 3rd February
OBS redeployment. OBS recovery and redeployment continued around the clock. In evening dropped Maria Teresa Zapata and Eduardo Cuevas on pilot boat and brought on board two students from CINVESTAV, Gabriella de Portilla and Manuel Reyes. Mike Rawson had also arranged some fresh supplies and goodie-bags from the shore. Mike Rawson had alarming news that a 'green' instrument had turned up at the Port Captain's office. Diana Antochiw has news that Lt. Ruben Romero may be approved as an MMO, and that PROFEPA may be taking action against the biological director of SEMARNAT (Ramirez), on the grounds that he should not have got involved in modifying the regulations under which we work.

Friday 4th February
OBS redeployment. By morning there was news of two instruments handed in to Port Captain, and the DOBS at another site (7E) failed to respond to pinging. Phoned Tim Owen at the shore house who went straight to Port Captain to investigate – found a DOBS and an LC. DOBS had released its weight and had a smashed connector. LC still had screw link attached but no weight and the release had not fired. We arranged to have these brought out on the pilot boat when we have a personnel transfer later. OBS recovery and redeployment continued in sober mood, completed at around 2200. One LC caught an octopus, most were covered in smelly mud and a coating of algae. Returned to site 7E and conducted detailed pinging survey in case of acoustic shadows, but nothing found.

Saturday 5th February
Profling grid. At 0120 pilot boat arrived with the two lost OBS and three new people: student Elizabeth Reyes from UNAM, and new Mexican MMOs Ernesto Vazquez and Gabriel Gonzalez. Gabriel Gonzalez has not yet been approved, but our rationalisation is that we have six MMOs (i.e. more than the 4 minimum), that three of them are Mexican (as required) and that four of them are approved (Meike Holst, Claudio Fossati, Diana Antochiw and Ernesto Vazquez). Deployed streamer and guns through the night, and were ready to begin profiling by 0800, some way off line. Profiled back (along spontaneously-designated line 25) to top of line 15 then shot southwards. Concern that streamer had sunk around turn and that this might happen again in shallow water at southern end, and that there was little extra power left in the engines to keep up speed. Tried floating to 4m for the turn but became unstable. Reduced power on both compressors to increase engine revs and briefly went to 60 second OBS shooting, but in fact had to shut down for weather. In the evening, we practised some racetrack manoeuvres with the streamer at 7m – by this time it had stabilised and behaved perfectly. Key seems to be keeping up speed, and have decided to take out a compressor or add an extra engine for the turns if necessary to maintain sufficient revs.

Sunday 6th February
Profiling grid. We began line 16 from the south at 0745, streamer behaving perfectly. Turned down onto line 17, but this line beset with shutdowns, for weather, turtle and weather again, stopping just north of the proposed ODP hole.

Monday 7th February
Profiling grid. We try another attempt at line 17 (NS), as it is crucial for the ODP survey. Unfortunately shut down for weather before reaching the site, then turned and collected some of line 18. Turned back onto 17 and just managed to get centre of streamer across the drill site before getting shut down for weather again.

Tuesday 8th February
Profiling grid. We began line 21 from the north in lovely weather. Towards south end of line shot close to and past a seabed camera set up by Tim Owen from a small fishing boat. Fishing boat steamed up and down near Ewing filming our operations. After recovering the camera they put a diver onto site 7E (where the DOBS had disappeared from) and recovered the concrete weight, base plate and nut. We continued onto line 22 and almost halfway down line 23 before being shut down for weather at 1715. People are getting very bored after this long at sea.

Wednesday 9th February
Profiling grid. We started NS down line 24. Unfortunately had to stop early due to fishing boats so turned back onto 23 in an attempt to join up with region shot yesterday, but had to stop again just short of overlap due to fishing boats. Turned west onto line 4, and shot until 1800 for the first time for several days.

Thursday 10th February
Profiling grid. Started out along line 5. In early afternoon a large fleet of tiny fishing boats was spotted ahead, and so instead of trying to negotiate them we did a 180 degree turn and went back along a new part of line 6. Ongoing uncertainty with proposed visit of Green Party Senator – was going to be on Friday, then Saturday and now Monday, with the next PROFEPA inspection. Also awaiting news of cruise extension – indications are encouraging and we hope to know more tomorrow. We have a looming crisis with MMOs in that Gabriel is not approved, and Ernesto has to leave on 15th, so will not be available for an extension. Therefore we have a problem for the PROFEPA inspection on Monday, and a further problem if we get the extension. We contacted Jaime Urrutia to try to address this problem. Received news that whether or not we get the extension we can continue shooting up until 1800 on 15th February – OBS recovery can take place after this.

Friday 11th February
Profiling grid. Strong winds overnight persisted into morning. Steamed down line 20 unable to shoot, but came into spec as we turned towards line 19. Collected part of line 19, before being shut down again, and then attempted line 20 for the second time. We received a faxed letter from SEMARNAT approving both Ernesto and Gabriel as observers. Whole ship is very tense awaiting news about the extension.

Saturday 12th February
Profiling grid. Shot line 1 E-W. Profiling went well all day until shut down for weather just after 1600: our most complete EW line so far. We prepared a folder of information for the visit of the Green Party Senator on Monday.

Sunday 13th February
Profiling grid. Shooting lines 11b and 13b east of the forbidden zone. These lines were originally planned to be airgun-only but it has been agreed to do them with the

streamer out, and indeed there was no problem. However, weather was poor so only managed to shoot in the middle of the day – east one third of line 11b, then turned onto east two thirds of line 13b. Finished preparations for visit tomorrow, including sanitising lab. Long discussions with Manuel Reyes and Gabriella de Portillo who are desperate to go ashore tomorrow although originally signed up to 15th evening: Captain is adamant that he will only transfer to the Hamlet and there will not be enough space for them.

Monday 14th February – Valentine's Day/Black Monday
Profiling grid – Profepa inspection – Green Party Senator visit - grounding.
Expecting PROFEPA inspectors with Green Party Senator Erika Larregui, Martha Torrez from the State Department and Mario Rebolledo at 0500 – in fact had only just left Telchac at that time. Captain had given direct orders that he would only allow boat transfers from the Hamlet, but in fact most of the party arrived on the Fever, which has a high superstructure and fixed canopy over the back. PROFEPA arrived with five inspectors instead of three. Extremely dangerous boat transfer, and they were all on board shortly before 0700. We immediately deployed PAM to begin line 9 E-W at 0800. Perfect conditions and continued shooting all day without interruption. PROFEPA inspection seemed relaxed. Visiting party spent a lot of time on the flying bridge, inspecting the labs and airguns, and in the afternoon, snoozing in the lounge. The Senator appeared to be quite interested in the project and appreciated the information we gave her. At lunch someone asked Sean Gulick of news of the extension, and Martha Torrez piped up that she had all the necessary papers on her desk, and that she would action them when she got to Mexico City, probably on Wednesday. She then agreed to telephone her office and get copies faxed to Lamont. Continued shooting to 1800 as it was going so well, although aware this would mean we turned past Madagascar Reef, not in front of it, and that the departure of the visitors might be delayed. Signed all the PROFEPA papers and took endless photos with the visitors. There was a problem getting the guns in for the transfer as two guns had got tangled in the centre and this took some while to sort out, but eventually we were able to turn to bring Hamlet alongside for transfer. However, it quickly became clear we were not able to offer enough shelter for a safe transfer, and we were also heading towards the charted position of the reef, so we brought the visitors back to the lounge while the ship turned away to steam further from the reef before turning up again.

At about 2005 everyone heard a splash, followed by another and a shuddering groan as the ship came to a stop on rocks. In the few minutes preceding this incident, the gunners had seen the guns snatching and the booms jerking, and had rung the bridge just as the hull struck. Rapid attempt to float cable, but it and the guns sank quickly. Water under ship only a few metres deep but the gear was mostly on the bottom in around 20m depth. Emergency bells rung and muster called in the lab – lab seemed very crowded with all the visitors, despite the large number of people on the fantail getting the gear in. Bridge, deck and engine room swung into a well organised emergency procedure, checking safety of people and integrity of ship, hand sounding water depths around the ship, re-ballasting in order to shift weight off the grounded part, and keeping everyone informed. We gingerly brought in the guns and streamer. After about an hour it was decided that as we were stationary anyway, it would be possible to take off the visitors using the Fever, and we transferred the eight visitors plus Manuel Reyes and Gabriella de Portillo (who had been pushing so hard to depart

today), with emotional goodbyes. It turned out that it took 4-5 hours for the Fever party to reach the shore, as choppy seas stopped them landing at Sisal. Freeing the final gun, which had stuck firmly in the seafloor, was achieved by firing it two or three times at low pressure. Once the guns were in it was possible to begin bringing in the cable, and the relative motion caused it to come up, apart from the area around bird 13 which remained stuck on the bottom, giving bursts of noise on the cable. The ship began to reverse slowly, which took the strain off the cable, and eventually after a number of shudders like aeroplane turbulence, the ship floated free. Ship turned westward and moved back along its track with cable coming in steadily. Ship heading straight for tailbuoy and there was momentary confusion about which side the streamer was leading. We sunk the cable in case we went over it and re-floated it, and this finally freed bird 13. Miraculously no oil leaks or significant damage observed on the streamer. Got tailbuoy onboard by 0100 and went to find somewhere to anchor. There are indications of possible water ingress into one of the tanks. The point we went aground was around 1 km north of the charted position of the Madagascar Reef – no indication of an obstruction on the chart. Echo sounder record came up vertically in two ship lengths. It was dark and rather calm at the time, so there was no visual indication of shallow water.

Tuesday 15th February

At anchor – hull inspection. We started day quietly at anchor, feeling tired and stunned. It is a beautiful day, perfect for shooting. Upped anchor and moved eastwards to meet diving team then anchored again. Diving team arrived mid-afternoon – Gabriella de Portillo and three cave-diving friends. Divers came aboard for a briefing then suited up and dived off the Fever with video and still cameras. Films showed some damage to transducers and housings, plus a lot of scraping, but no obvious hole (there was a brief panic – we called out 'did you see the hole?' and they heard 'did you see the hull?' and answered an emphatic yes). Breach of the hull is now thought to be a false alarm, and we are all much reassured. Gabriella de Portillo is expecting questions from media and from PROFEPA upon return to shore. Apparently some anxiety exists ashore that we may have hit the wreck, but we are well clear of that. Gabriella de Portillo suggests key points are that we ran into something not marked on the chart, that there were no spillages, and that there are no coral reefs in the area. PROFEPA is planning to inspect the reef with divers. Gabriella de Portillo has 'before' pictures as the rocky reef is her Master's thesis study area. We receive friendly email from the Senator.

Wednesday 16th February

At anchor – hull inspection Another quiet morning; moved to the anchorage just outside Progreso. More perfect weather. Certified divers and ABS surveyor arrived in afternoon for the official survey of the hull. Discussed options with Mike Rawson and we believe that everything is in place to resume work once the hull has been given clearance, which happened at around 1700. Resumed watches at 1800 and deployed the streamer between 1930 and 2200, ready to resume profiling tomorrow.

Thursday 17th February

Profiling grid. We are shooting line 3, E-W. We were allowed by MMOs to begin 7 minutes earlier, due to lengthening days. Going well until about 1100, when there was a succession of shutdowns for dolphins (twice), a turtle and a diver. We continued until shut down for weather at 1630, at the end of the line. We again received a

friendly email form the Senator and almost simultaneously a copy of a statement from her website calling for our project to be stopped on the grounds of damaging a coral reef. At 1915 received an email from Jaime Urrutia to say that we may be getting a legal notice to stop work because we damaged the reef. Captain spoke to Paul Ljunggren and we found out that papers may have been served on Mike Rawson. After a brief council of war decided to bring in all the equipment – first streamer and guns, and then the OBS, before the ship is ordered into port. We began OBS recovery at 0200.

Friday 18th February

OBS recovery – boarding by PROFEPA lawyer. The OBS recovery is continuing well, although one instrument has vanished from its moorings in the same general vicinity as the errant instruments from the first deployment. Adverse articles in satellite news and New York Times. We received news that PROFEPA are on their way to serve some papers. Navy interceptor arrived at around 1500 with PROFEPA lawyer, 3 scribes and the Lieutenant from the Navy base. The lawyer said process would take 20 minutes. We had to nominate two interpreters/translators (Matt McDonald, UT student, and Diana Antochiw) but they were not allowed to see the documents. The lawyer explained in English that there were two documents and that one was a complaint that we had damaged the reef and ecosystem. (I think the other was a complaint from Rosario Sosa (local environmentalist) that we had killed two fish). We have 5 working days to prepare a defence, and must return immediately to port. Something about another 10 day process after this, until UNAM pay a fine. He said once we were in port we could put in a request to Sergio Chan, PROFEPA Director in Yucatan, to go back out to sea to collect the remaining OBS. We argued that we would prefer to request to pick up the remaining instruments now, as we were concerned that once in port it might be difficult to leave. Also we needed the time in port to prepare the case. Chan was telephoned and agreed verbally that we may stay out to collect OBS, and that we would send a written request to shore with the visitors. They wanted us to sign papers to say the complaint had been received, but Lamont advise against signing anything without legal advice. PROFEPA lawyer would not allow us to see the documents or to fax them to a lawyer. Captain agreed to sign if a note was added to state that he did not understand what he was signing and did so under protest, but they refused to add this, and 'posted' the documents on the wall. We all got very angry and upset. They stormed off at 1800 taking with them our formal request to Chan plus a letter from the Captain stating his protest. We spent time earlier talking to the navy Lieutenant about the reef - they have already inspected it and found damage approximately 1.5 x 3m, with some soft corals knocked over. He was extremely interested to see the charts and our track chart, and will return to the area in the next couple of days to check whether there is anything at the charted reef position. We carried on with OBS recovery through the evening.

Saturday 19th February

OBS recovery. All OBS recovered by around 0730, apart from one lost LC from this deployment and the DOBS still missing from the first deployment. We proceeded back to the site of the LC instrument and did a prolonged detailed survey in a square spiral. We later heard that Jo Morgan had managed to arrange a diver on the site, who had done a detailed search and found nothing. Jo Morgan went to see an OBS which has turned up in Celestun and has found that it is the missing LC, rather than the

DOBS from the first deployment. We continued to site 10F, where the DOBS went missing for a further detailed survey of the only remaining place that could conceivably contain an instrument. Apparently our lawyer is quietly confident and that we should go into port tomorrow and expect to be able to leave on Monday.

Sunday 20th February
To Progreso. It was a quiet morning steaming towards Progreso. Pilot taken on at 1300, then tied up at quay, to be met by Rafael Murillo, our lawyer, for a series of long briefings with Captain, Rafael Murillo, Sean Gulick, Penny Barton, Mike Rawson, Ted Koczynski, the Chief Mate, and Mario Rebodello, who had turned up as if by magic. Rafael Murillo is fairly optimistic, but expects the process to take until Tuesday or Wednesday even if nothing goes wrong. Papers will have to be filed with Port Captain and the District Attorney, and the demands of PROFEPA have to be met. We finally got into town for a large dinner jointly with the land party, Mexican observers and Mario at Flamingoes – and extremely friendly and high-spirited occasion.

Monday 21st February
In port Progreso. Tidying up lab. The errant LC (#8) was returned to the ship – its release was intact and the screw link had disappeared. Press prowling around. Diana returned to the ship – she had a dead chicken tied to her door last night. In the evening another wild 'last night in port' occurred.

Tuesday 22nd February
In port Progreso There is a lot of legal business to be done. Captain went to District Attorney's office, then there was a panic because the third mate and Stanislav the AB on duty during the night of the collision were also needed as witnesses on the Bridge at the time, and they had to be found in Progreso. Sean Gulick, the Captain and Mike Rawson then continued on to the US Consulate in Merida to hand power of attorney to Rafael Murillo, in case needed after the ship's departure. They then went to the PROFEPA offices and things seemed to be going well until Rafael Murillo was called out by the PROFEPA lawyer to be told that they were going to demand the maximum fine of $200k plus an admission of guilt for damaging the reef, or the ship will have to stay in Progreso while the case is fought. Although sailing board had been set for 1600, we were still waiting for news at 1900. Board reset for 2000 tomorrow. Another enthusiastic 'last night in port' occurred.

Wednesday 23rd February
In port Progreso. Held a lab meeting of scientists at 1000, and decided to go ahead with backing up data, packing everything away and getting ready to decamp. Rafael Murillo is at PROFEPA, negotiating. In afternoon had a visit from Luis Capurro from CINVESTAV, with a couple of students. He was wonderfully enthusiastic and positive – had worked with Maurice Ewing, Maurice Hill etc etc, now in his nineties. He has been appearing on TV pushing the project, and being a great ambassador. At 1815 Mike Rawson brought a list on board of what PROFEPA wanted to spend the $200k on – most of the items seemed extremely inflated by a factor of 5-15.

Thursday 24th February
In port Progreso. Have booked flights for Tim Sears (Cambridge Univ. student) and Tamara Goldin (Univ. of Arizona student) tomorrow and the rest of us on Saturday.

Murillo is still negotiating with PROFEPA – an admission of guilt being the sticking point. We spent day packing the lab and organising everything. The OBS equipment is now more or less packed and the on-board container filled. Another wild 'last night in port' occurred.

Friday 25th February
In port Progreso . Tim Sears and Tamara Goldin left the ship at 0500. We are officially finished packing. We heard from Mario Rebolledo that he may have to give evidence to District Attorney with Chan and the Senator. Tried to meet up for a meal in the evening but the arrangements did not work well and the food was indifferent – everyone looked downbeat and tired; a sedate true last night in port for the science party.

Saturday 26th February
In port Progreso. Rest of the science party left the ship at 0500 to catch the Merida-Houston flight.

Sunday 27th February - Tuesday 1st March
In port Progreso. Ship sailed from Progreso for Jacksonville at 0730 on 1/3/05.

Miscellaneous points

Complaints about the engines being shaken apart
In addition to the problem of operating at the limit of engine power capacity for two engines, and having insufficient fuel to use three, there were also frequent concerns expressed by the Chief Engineer about the wear and tear to parts of the ship's propulsion, steering etc by the airguns. We were operating in extremely shallow water (15-30m) with a generally hard seabed and a strong groundroll, which may have contributed to the perception that the ship was experiencing more reverberation than on a 'normal' seismic cruise.

Our policy to be starting a line at 0710 each morning, then steam along it hoping to shoot.
Our permit allowed us to collect seismic data between 0630 and 1800 each day. To maximise the use of this time, the programme was redesigned with long sections of profile that could be collected continuously within these hours, and periods of ship repositioning without shooting, which took place at night. Shooting with the full seismic array entailed a period of 30 minutes of visual observation by the MMOs, which could not begin until first light at 0615, followed by a 25 minute ramp-up of the gun array, so that the first real full strength shot could not occur until 0710. In addition, the array did not reach full fold until the centre of it passed over the start of line, so that for lines where full fold was needed from the ends of the line, the start point at 0710 was moved 3 km before the official start-of-line point. It was frequently not possible to actually start shooting at 0710, due to weather, animal sightings or fishing activity, and our general policy in this case was to continue steaming along the line and to begin shooting as soon as possible – having learnt at an early stage that circling took up too many precious shooting hours and was only worthwhile in exceptional cases, such as when we were crossing the proposed ODP sites.

17 knot protocol
Explained in the general text.

Currents and their variability
The currents were very much stronger than marked on the chart, both at the surface and in particular on the seabed, predominantly from the northeast.

need list of dramatis personae
Cruise members appear in Anthony's report. Should we list others involved?

Line Name	MCS profiling with streamer - number of shots		Shooting into seabed instruments only - number of shots		TOTAL number of shots	MCS profiling with streamer - line length in km		Shooting into seabed instruments only - line length in km		TOTAL line length in km
	partial gun array	full gun array	partial gun array	full gun array		partial gun array	full gun array	partial gun array	full gun array	
Chicx 2	412	1148	373	-	1933	20.55	57.35	18.60	-	96.50
Chicx 2 - overlap	*70*	-	*124*	-	*194*	3.45	-	6.15	-	*9.60*
Chicx 4	234	564	-	-	798	11.65	28.15	-	-	39.80
Chicx 6	66	903	-	83	1052	3.25	45.10	-	4.10	52.45
Chicx 8	263	1400	-	-	1663	13.10	69.95	-	-	83.05
Chicx 10	-	1232	17	165	1414	-	61.55	0.80	8.20	70.55
Chicx 10 - overlap	*75*	-	-	-	*75*	3.70	-	-	-	*3.70*
Chicx 12	-	-	291	1037	1328	-	-	14.50	51.80	66.30
Chicx 14	-	-	261	559	820	-	-	13.00	27.90	40.90
R1	107	1581	-	-	1688	5.30	79.00	-	-	84.30
R3	60	2009	-	-	2069	2.95	100.40	-	-	103.35
R4	56	300	116	-	472	2.75	14.95	5.75	-	23.45
R5		489	-	-	489		24.40	-	-	24.40
R6	221	3688	-	-	3909	11.00	184.35	-	-	195.35
R6 - overlap	*82*	*10*	-	-	*92*	4.05	0.45	-	-	*4.50*
R7	202	917	126	-	1245	10.05	45.80	6.25	-	62.10
OBS 101	-	-	124	-	124	-	-	6.15	-	6.15
OBS 102	-	-	230	-	230	-	-	11.45	-	11.45
OBS 103	-	-	119	-	119	-	-	5.90	-	5.90
OBS 104	-	-	36	69	105	-	-	1.75	3.40	5.15
OBS 105	-	-	26	-	26	-	-	1.25	-	1.25
OBS 106	-	-	105	-	105	-	-	5.20	-	5.20
Chicx 1	78	1645			1723	3.85	82.20			86.05
Chicx 3	594	1154			1748	29.65	57.65			87.30
Chicx 4b	-	409			409	-	20.40			20.40
Chicx 5	96	1086			1182	4.75	54.25			59.00
Chicx 6b		650	44	43	737		32.45	2.15	2.10	36.70
Chicx 9	84	1761			1845	4.15	88.00			92.15
Chicx 11	78	235			313	3.85	11.70			15.55
Chicx 13		447	49	25	521		22.30	2.40	1.20	25.90
Chicx 15	5	713	177		895	0.20	35.60	8.80		44.60
Chicx 16	62	498			560	3.05	24.85			27.90
Chicx 17	127	562	76		765	6.30	28.05	3.75		38.10
Chicx 17 - overlap	*98*				*98*	4.85				*4.85*
Chicx 18	96	277			373	4.75	13.80			18.55
Chicx 19		166	27	33	226		8.25	1.30	1.60	11.15
Chicx 20		407	44	48	499		20.30	2.15	2.35	24.80
Chicx 21	10	558	71		639	0.45	27.85	3.50		31.80

Chicx 22		520	81	36	637		25.95	4.00	1.75	31.70
Chicx 23		508	41	131	680		25.35	2.00	6.50	33.85
Chicx 24	111	597	49		757	5.50	29.80	2.40		37.70
Chicx 25	85	367	25		477	4.20	18.30	1.20		23.70
OBS 201			146		146			7.25		7.25
OBS 202			177		177			8.80		8.80
OBS 203			100		100			4.95		4.95
OBS 204			190		190			9.45		9.45
OBS 205			85		85			4.20		4.20
OBS 206			190		190			9.45		9.45
OBS 207			230		230			11.45		11.45
OBS 208			130		130			6.45		6.45
OBS 209	21	6	141		168	1.00	0.25	7.00		8.25
OBS 210			110		110			5.45		5.45

SUMMARY	**MCS profiling with streamer - number of shots**		**Shooting into seabed instruments only - number of shots**		**TOTAL number of shots**	**MCS profiling with streamer - line length in km**		**Shooting into seabed instruments only - line length in km**		**TOTAL line length in km**
	partial gun array	**full gun array**	**partial gun array**	**full gun array**		**partial gun array**	**full gun array**	**partial gun array**	**full gun array**	
TOTALS	**3393**	**26807**	**4131**	**2229**	**36560**	**168.35**	**1338.75**	**204.85**	**110.90**	**1822.85**

Julian day	Line Name	start time	LAT	LONG	shot number	FFID	Shot interval	Number of guns		Comments
20	Chicx 2	22:37:31	21.753	-89.420	1603	1	20 sec	1		ramp up started
		23:10:57	21.814	-889.377	1673	70		20	69	ramp up complete
		23:59:54	21.780	-89.295	1810	208		20	138	end of line chicx 2
21		12:46:19	21.726	-89.315	1	1	10 sec			1st 12 shots are cycle tests
	Chicx 4a	12:54:15	21.72434	-89.3255	147	13	20 sec	1	12	ramp up started
		13:11:12	21.719	-89.348	198	63		20	50	ramp up complete
		14:09:25 pm	21.702	-89.433	376	242		0	179	shutdown - weather
	Chicx 4b	14:58:11	21.687	-89.503	530	243		1	1	ramp up started
		15:24:26	21.679	-89.540	603	316		20	73	ramp up complete
		15:49:34	21.671	-89.577	680	394		0	78	shutdown - fishing vessel
	Chicx 4c	18:01:46	21.634	-89.756	1067	397		1	3	ramp up started
		18:27:28	21.626	-89.793	1138	472		20	75	ramp up complete
		20:04:46	21.596	-89.936	1444	778		0	306	shutdown - weather
22	Chicx 6	18:11:01	21.588	-89.750	1036	1		0		ramp up started
		18:34:58	21.594	-89.719	1103	68		20	67	ramp up complete
		23:01:59	21.673	-89.341	1908	873		0	805	shutdown - weather
23	Chicx 8	12:45:59	21.626	-89.364	124		20 sec	1		ramp up started
		13:10:40	21.618	-89.399	198	75		20	75	ramp up complete
		16:30:02	21.556	-89.688	814	691			616	shut down - fishermen
		16:41:44	21.553	-89.705	850	692		1	1	ramp up started
		17:06:57	21.545	-89.742	927	769		20	77	ramp up complete
		18:16:18	21.523	-89.843	1149	991			222	shut down - turtle
		18:40:13	21.516	-89.877	1215	999		1	8	ramp up started
		19:05:59	21.508	-89.914	1295	1079		20	80	ramp up complete
		22:07:57	21.451	-90.180	1857 - 1870	1641	1641-1655	17	562	3 guns pulled in in preparation for turn onto line chix6
		22:15:18	21.449	-90.190	1880	1664		17	23	end of line chicx8 (starting an OBS line for the turn to line chix 6)

	OBS	22:15:18	21.449	-90.190	-	-	50 m	17		starting OBS line with 3 guns off
		23:07:05	21.496	-90.186	-	-		20		all guns back on
		23:25:07	21.501	-90.161	-	-		20		end of OBS line - about to start chicx6
	Chicx 6A	23:27:14	21.502	-90.158	169	1	20 sec	20	1	start of line with all 20 guns firing
		0:00:02	21.511	-90.112	266	98		20	97	end of line 6A
24	**Chicx 10**	14:26:15	21.436	-90.024	416	1	20 sec	1		ramp up started (late due to bad weather)
		14:41:45	21.440	-90.006	453	38		4 to 1	37	power down to 1 gun (from 4 guns) - dolphin
		14:58:25	21.444	-89.987	490	75		1	37	shut down of 1 gun - turtle sighting
	OBS	15:26:31	21.469	-89.979	-	-	50 m	1		ramp up started
		17:34:04	21.428	-90.063	-	-		20		ramp up complete
	Chicx 10	17:56:08	21.434	-90.036	189	76	20 sec	20	76	start of line 10 with all 20 guns on
		23:59:51	21.529	-89.567	1185	1072		20	996	end of line 10
25	**Chicx R1**	13:07:18	22.133	-88.608	-20	1	20 sec	1		ramp up started
		13:32:27	22.109	-88.635	56	77		20	76	ramp up complete
		22:04:02	21.612	-89.183	1636	1654		20 to 18	1577	2 guns turned off in preparation for end of line turn
		22:13:43	21.602	-89.194	1666	1684		18	30	end of line R1
	OBS	22:13:43	21.602	-89.194			50 m	18	0	turning towards line R2
		22:19:49	21.598	-89.202				20	0	all guns back in the water
		22:43:18	21.592	-89.236				20	0	end of OBS line (turn completed)
									0	
	Chicx R2	22:43:18	21.592	-89.236	141	1	20 sec	20	1	start of line with all 20 guns
		0:00:04	21.570	-89.347	376	236		20	235	end of line R2
26	**OBS**	12:48:05	21.773	-89.327			50 m	1	0	ramp up started
		13:33:09	21.762	-89.381				16 to 1	0	shut down (from 16 guns) due to fishermen
		13:47:11	21.758	-89.397				1	0	ramp up started
		14:12:10	21.750	-89.425				16	0	reached 16 guns - then remained at 16whilestreamer was being fixed
		14:57:48							0	~4 manual shots as Spectra stopped firing when switching to line Chicx2
									0	
	Chicx 2a	15:03:52	21.738	-89.483	263	1	20 sec	16		start of chicx 2 at 16 guns

										streamer power off for repairs, still shooting as chix2 (not an
		16:02:23	21.722	-89.551	391	129		16	128	OBS line)
		16:08:00	21.721	-89.557	421	130		16	1	streamer started recording again (towed off the clamp)
		16:56:48	21.709	-89.615	543	252		16	122	streamer powered down and line Chicx 2a ended
	OBS	16:56:48	21.709	-89.615			50 m	16	0	very short OBS line started (other 4 guns added during it)
		17:26:24	21.703	-89.651				20	0	end of OBS line once other 4 guns added
	Chicx 2b	17:26:24	21.703	-89.651	618	1	20 sec	20		start of Chicx 2b once all 20 guns were firing
		21:01:09	21.636	-89.960	1278	661		0	660	shutdown due to fishing boats
		21:13:52	21.629	-89.981	1317 (-2?)	662		1	1	ramp up started (2 shots were not recorded on the streamer)
		21:26:37	21.623	-89.996	1354	699	8 blank shots?	0	37	shutdown (from 4 guns) due to fishing boats
		21:38:41	21.615	-90.012	1390?	708		1	9	ramp up started
		22:04:58	21.605	-90.049	1471	789		20	81	ramp up complete
		~23:20??	21.590	-90.171	1708	1026		0	237	shooting stopped for a few minutes as there was no run out on the line
					1718	1027		20	1	shooting restarted
		0:00:05	21.583	-90.220	1827	1136		20	109	end of line chicx2b
27	**Chicx R3**	12:45:29	21.420	-89.864	-194	1				ramp up started
		13:08:01	21.425	-89.893	-135	60			59	ramp up complete
		0:00:02	21.848	-90.751	1874	2096			2036	end of line chicx R3
28	**OBS**	15:20:24	21.435	-90.727				1	0	ramp up started - 50 min long due to dolphin sighting
		15:49:18	21.396	-90.718				4	0	starting line R4
									0	
	Chicx R4	15:49:18	21.396	-90.718	76	4		4	4	starting line R4
		16:10:55	21.366	-90.711	143	68		20	64	ramp up complete by shot no 130
		17:43:32	21.239	-90.685	?	?		0		end of line chicxR4
		OBS line??							0	
									0	
	Chicx R5	18:00:04	21.226	-90.668	225	1		20	1	starting line R5
		20:48:01	21.309	-90.449	713	489		0	488	shut down - weather
29	**Chicx R6a (CRP LINE)**	12:45:53	21.540	-90.328	467	1		0	1	ramp up started
		13:11:32	21.574	-90.315	546	80		20	79	ramp up complete
		0:00:03	22.073	-89.611	2477	2000		0	1920	end of line chicxR6
30	**Chicx R6b (CRP LINE)**	12:46:24	22.069	-89.653	2389	4		0		ramp up started
		13:12:00	22.073	-89.616	2466	81		20	77	ramp up complete
		18:49:05	21.985	-89.160	3442	1057		1	976	power down - turtle sighting
		19:50:59	21.968	-89.126	3522	1137		2	80	starting ramp up again from 1 gun

		19:26:24	21.953	-89.101	3553	1197	20	60	ramp up complete
		23:59:56	21.693	-88.837	4385	2000	0	803	end of line chicx R6b
									ramp up started - doing an OBS line till we have turned onto the
31	**OBS**	12:45:37	22.128	-89.559			0	0	line
		13:26:48	22.086	-89.585			20	0	ramp up complete
		13:27:47	22.084	-89.585			20	0	end of OBS line / start of Chicx R7
								0	
	Chicx R7	13:27:47	22.084	-89.585	235	2	20	2	start of Chicx R7 - possible one blank shot on the tape
		17:35:18	21.740	-89.578	999	766	0	764	shutdown - fishing vessels. Last shot prob empty
		17:52:21	21.717	-89.577	1050	767	0	1	ramp up started
		18:17:33	21.681	-89.576	1129	846	20	79	ramp up complete
		18:30:54	21.663	-89.576	1169	886	0	40	shutdown - fishing vessels.
		one gun firing??						-886	
		18:48:11	21.640	-98.572	1220	903	1?	903	ramp up started - perhaps from 1 gun
		19:07:25	21.613	-89.575	1281	964	20	61	ramp up complete
		19:45:28	21.561	-89.574	1392	1075	1	111	power down to 1 gun - turtle sighting.
									After shot 1392 a few guns were on for a few shots then down to 1 gun
		19:58:50	21.542	-89.572	1436	1119	0	44	shutdown - weather
								###	
32	**OBS**	12:50:27	21.500	-89.599			0	0	ramp up started but 1st 20 min not recorded as manual firing
	(Chicx								
	12&14b)	13:42:25	21.489	-89.569			20	0	ramp up complete
		15:21:23	21.519	-89.426			1	0	powerdown - dolphin
		15:25:36	21.521	-89.420			0	0	shutdown - fishing vessels
		15:43:09	21.528	-89.396			0	0	ramp up started
		16:30:09	21.540	-89.328			20	0	ramp up complete
		20:34:48	21.440	-89.548			0	0	shutdown - weather
33	**OBS**	13:36:30	21.436	-89.732			0	0	ramp up started
	Chicx								
	12&14a)	13:44:25	21.446	-89.733			2	0	shut down (from 2 guns) - small boat
		13:58:34	21.451	-89.749			o	0	ramp up started
		14:17:47	21.447	-89.774			8	0	shutdown (from 8 guns) - fishing vessel
		14:22:05	21.446	-89.780			8	0	ramp up continued from 8 guns
		14:31:52	21.444	-89.793			20	0	ramp up complete
		14:35:49	21.443	-89.798			0	0	shutdown - fishing vessels
		14:39:23	21.443	-89.803			20	0	recommence shooting - no ramp up needed
		16:49:23	21.402	-89.987			19	0	gun 10 turned off for repairs
		16:54:16	21.400	-89.994			20	0	gun 10 back on
		18:22:33	21.349	-90.091			18	0	pulled out 2 guns to start the turn onto line 14a
		18:53:18	21.341	-90.056			0	0	shutdown - turtle sighting
		19:53:54	21.367	-89.968			0	0	ramp up started
		20:10:53	21.367	-89.945			8	0	shutdown from 8 guns
		20:41:01	21.377	-89.904			0	0	ramp up started

		21:07:59	21.381	-89.865				20	0	ramp up complete
		21:30:14	21.388	-89.833				0	0	shutdown - turtle sighting
									0	
36	**Chicx 25**	14:00:05	21.700	-89.919	43	6		0	6	ramp up started
		14:27:02	21.703	-89.958	117	80		20	74	ramp up complete
		16:29:08	21.717	-90.134	484	447		20	367	end of line - starting OBS line
									-447	
36	**OBS**	16:29:08	21.717	-90.134				20	0	
		16:56:21	21.688	-90.152				19	0	gun 11 turned off
		16:59:54	21.683	-90.151				20	0	gun 11 turned on
		17:17:18	21.659	-90.147				20	0	end of OBS line
									0	
36	**Chicx 15**	17:17:18	21.659	-90.147	177	4		20	4	
		21:10:19	21.342	-90.080	888	715		17	711	3 guns pulled in for turn at end of line
		21:12:21	21.340	-90.080	893	720		17	5	end of line
									-720	
36	**OBS**	21:12:21	21.340	-90.080				17	0	
	OBS60	21:32:31	21.323	-90.059			**60 sec**	17	0	switched to shot rate of 60 sec - shotfile OBS60
		21:36:10	21.325	-90.054				17	0	shut down - weather
									0	
37	**Chicx 16**	13:28:25	21.412	-90.019	237			0	0	ramp up started - missed 1st 18 shot timings - 1st recorded=237
		13:48:49	21.439	-90.024	299			20	0	ramp up complete
		16:36:59	21.659	-90.070	796			20	0	end of line. Brought in 3 guns for a turn at end of line
									0	
37	**OBS**	16:36:59	21.659	-90.070	202			17	0	OBS line on the turn
		17:27:38	21.718	-90.036	347			17-20?	0	shutdown - weather
									0	
38	**Chicx 17**	19:16:25	21.596	-89.139	390	4		0	4	ramp up started
		19:41:57	21.561	-89.974	463	77		20	73	ramp up complete
		20:52:07	21.466	-89.954	680	294			217	shutdown - weather
									-294	
38	**Chicx 17a**	13:51:05	21.496	-89.961	611	2			2	ramp up started
		14:25:47	21.455	-89.952	708			17 to 0	-2	shutdown - weather
									0	
38	**Chicx 18**	16:16:14	21.491	-89.883	347	4		0	4	ramp up started
		16:41:58	21.520	-89.890	412	65		20	61	ramp up complete
		18:15:26	21.642	-89.914	689	342		17	277	guns 11,12&13 turned off for turn
		18:24:45	21.655	-89.917	715	368		17	26	end of line
									-368	
38	**OBS**	18:24:45	21.655	-89.917	202			17	0	
		13:30:04	21.629	-89.989				20	0	finished turning - assume all guns back in.
		19:53:21	21.598	-89.982				20	0	end of OBS line / start of Chicx 17b
									0	
38	**Chicx 17b**	19:53:21	21.598	-89.982	381	4		20	4	

		21:44:27	21.446	-89.950	722	345	20 to 17	341	3 guns in preperation for a turn
		21:58:48	21.427	-89.946	767	390		45	shut down - weather
								-390	
39	**OBS**	12:47:38	21.794	-89.718	201		0	0	ramp up started
		13:10:10	21.764	-89.711			16	0	end of OBS line
								0	
39	**Chicx 21**	13:10:10	21.764	-89.711	145	1	16	1	Start of Chicx 21
		13:12:57	21.760	-89.710	154	10	20	9	end of ramp up
		16:14:13	21.512	-89.658	712	568	20	558	end of Chicx 21
								-568	
39	**OBS**	16.16.47	21.509	-89.657	201		17	0	3 guns brought in for turn
		16:44:54	21.500	-89.621			0	0	shut down - fishing boats
		17:03:40	21.503	-89.594			0	0	ramp up started
		17:30:21	21.536	-89.587			20	0	ramp up complete
		17:43:52	21.555	-89.591			20	0	end of line - start of Chicx 22
								0	
39	**Chicx 22**	17:43:52	21.555	-89.591	269	1	20	1	
		20:35:05	21.785	-89.640	788	520	20	519	end of Chicx 22 and start OBS line
								-520	
39	**OBS**	20:35:05	21.785	-89.640			20	0	start of OBS line
		20:40:41	21.793	-89.640			17	0	3 guns turned off for turn
		21:53:02	21.786	-89.564			20	0	all guns back on
		22:08:02	21.766	-89.559				0	
								0	
	Chicx 23	22:08:02	21.766	-89.559	209	1	20	1	start of Chicx 23
		23:15:00	21.675	-89.540	413	205	0	204	shut down - weather
								-205	
40	**Chicx 24**	12:47:42	21.844	-89.463	84	9	0	9	ramp up started
		13:15:01	21.807	-89.455	165	90	20	81	ramp up complete
		16:30:58	21.544	-89.400	762		1	-90	power down - dolphin
		16:37:53	21.534	-89.398	783	708	1	708	end of line Chicx 24 / start of OBS line
								-708	
40	**OBS**	16:37:53	21.534	-89.398	201		1	0	start of OBS line - start ramping up soon
		18:40:52	21.521	-89.508			20	0	ramp up complete and ending line
								0	
	Chicx 23a	18:40:52	21.521	-89.508	160	1	20	1	
		18:59:04	21.545	-89.513	216	51	0	50	shut down - fishing vessel
		19:06:30	21.555	-89.515	239	58	20	7	all guns restarted
		19:57:23	21.623	-89.534	390	213	0	155	shut down - fishing vessel
		20:07:57	21.637	-89.538	420	214	20	1	all guns restarted
		20:36:57	21.676	-89.543	506	300	17	86	3 guns turned off for turn
		20:43:04	21.684	-89.543	527	321	17	21	end of Chicx 23
								-321	
40	**OBS**	20:44:44	21.684	-89.543			17	0	start of OBS line
		20:49:59	21.692	-89.548			0	0	shut down - fishing boats

		21:05:12	21.692	-89.570			1	0	ramp up started
		21:30:14	21.673	-89.600			20	0	ramp up complete
		21:47:57	21.662	-89.622			20	0	end of OBS line / start of Chicx 4d
								0	
40	**Chicx 4d**	21:47:57	21.662	-89.622	776		20	0	start of Chicx 4d
	(2nd pass)	0:00:00	21.622	-89.814	1184	408	0	408	end of Chicx 4d
								-408	
41	**Chicx 5**	12:45:43	21.520	-90.195	107	1	0	1	ramp up started
		13:11:07	21.528	-90.158	184	512	20	511	ramp up complete
		19:17:43	21.635	-89.648	1270	1164	17	652	3 guns off to turn onto line Chicx 6
		19:25:08	21.637	-89.637	1288	1182	17	18	end of Chix 4
								###	
41	**OBS**	19:25:08	21.637	-89.637			17	0	
		20:16:32	21.603	-89.656	354		20	0	all guns back on - turn finished
		20:30:37	21.603	-89.676				0	end of OBS line
								0	
41	**Chicx 6b**	20:30:37	21.603	-89.676	920	535	20	535	start of Chicx 6b
		0:00:00	21.538	-89.983	1567	649	20	114	end of line Chicx 6b
								-649	
42	**OBS**	16:20:28	21.497	-89.770	205		0	0	ramp up started
		17:01:38	21.513	-89.813			20	0	ramp up complete
		17:12:44	21.533	-89.815	360		20	0	end of OBS line
								0	
42	**Chicx 19**	17:12:44	21.533	-89.815	319	1	20	1	
		18:13:57	21.606	-89.831	483	165	0	164	shutdown - weather
								-165	
42	**OBS**	20:13:27	21.751	-89.857	208		0	0	ramp up started
		21:29:04	21.737	-89.782	434		20	0	ramp up complete
								0	
42	**Chicx 20**	21:71567	21.716	-89.777	219	1	20	1	
		0:00:04	21.536	-89.740	625	407	20	406	end of line Chicx 19
								-407	
43	**Chicx 1**	12:46:24	21.797	-89.321	115	1	0	1	ramp up started
		13:11:44	21.789	-89.357	192	78	20	77	ramp up complete
		22:01:02	21.627	-90.130	1837	1723	20	1645	shutdown - weather
								###	
44	**Chicx 11b**	15:42:18	21.546	-89.409	620		0	0	ramp up started but streamer did not record the first few shots
		15:55:30	21.550	-89.391	656	2	4	2	streamer started recording
		16:07:58	21.553	-89.375	690	35	20	33	ramp up complete
		17:28:42	21.576	-89.264	925	270	20	235	end of line 11b
								-270	
44	**OBS**	17:28:42	21.576	-89.264	201		17	0	
		18:28:00					20	0	all guns back on after turn
		18:38:00					20	0	end of OBS line

								0	
44	**Chicx 13b**	18:38:00			297	1	20	1	start of Chicx 13b after turn is over
		21:02:12	21.485	-89.495	742	446	0	445	shutdown - weather
45	**Chicx 9**	14:02:41	21.600	-89.373	355	1	0	-445	ramp up started
		14:28:11	21.593	-89.410	432	84	20	83	ramp up complete
		23:59:43	21.418	-90.239	2194	1846	20	1762	end of line
								###	
48	**Chicx 3**	12:43:03	21.756	-89.296	181	1	0	1	ramp up started
		13:08:13	21.748	-89.332	259	79	20	78	ramp up complete
		16:12:00			837		0	-79	shutdown - dolphin
	Chicx 3a	16:27:15	21.697	-89.622	873	1	0	1	ramp up started
		16:52:21	21.680	-89.659	951	79	20	78	ramp up complete
		17:40:31	21.665	-89.729	1103		1	-79	powerdown - dolphin
		19:24:49	21.633	-89.881	1423	551	20	551	ramp up complete
		19:28:05	21.632	-89.886	1434	562	0	11	shutdown - human divers
	Chicx 3b	19:56:14	21.623	89.929	1525	563	0	1	ramp up started
		20:22:03	21.615	-89.965	1602	639	20	76	ramp up complete
		22:36:40	21.574	-90.160	2015	1052	17	413	guns in for turn
		22:47:21	21.571	-90.175	2053	1090	0	38	shutdown - weather

Lamont– Doherty Earth Observatory
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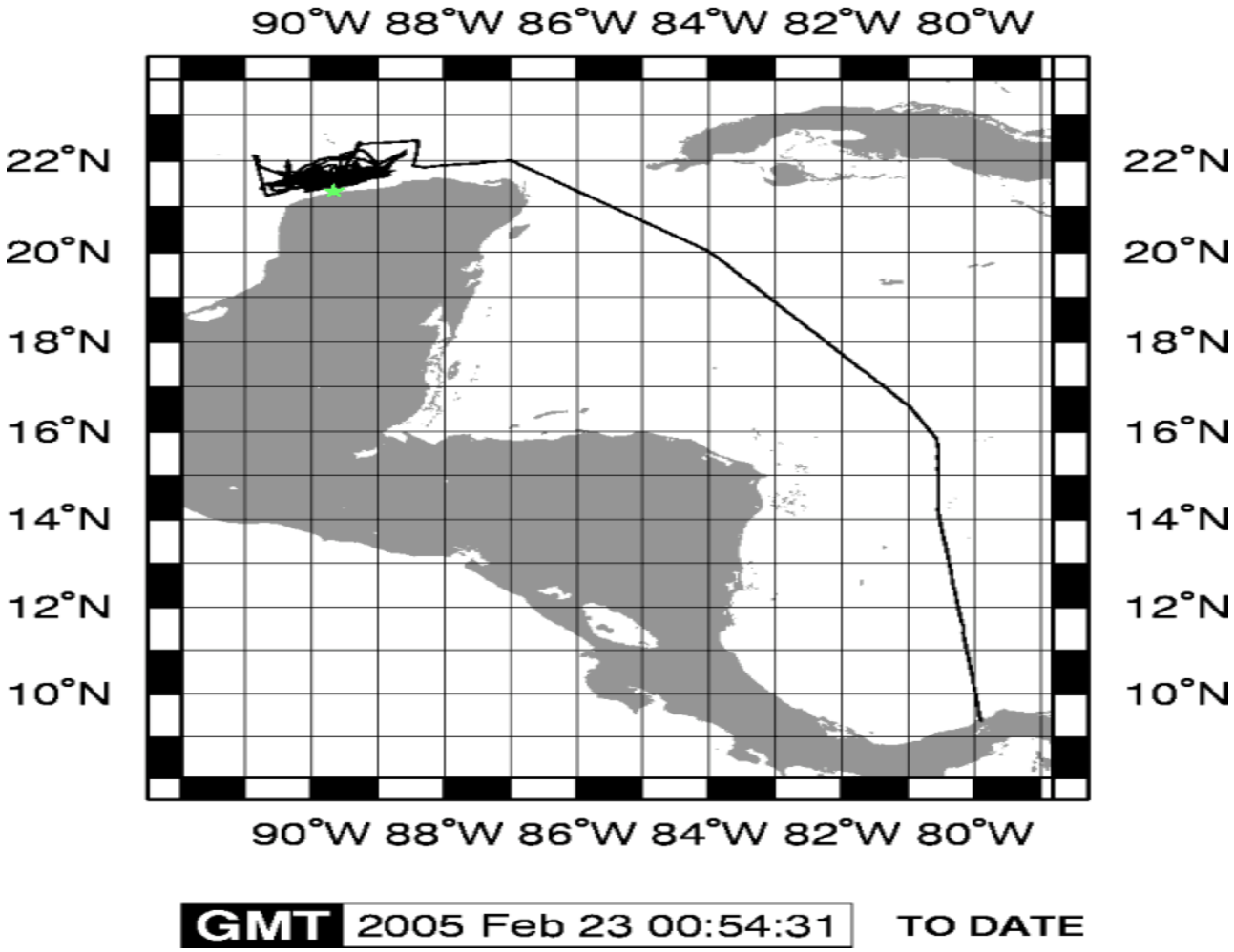
R/V Maurice Ewing Data Reduction Summary

EW0501 Colon, Panama –– Progresso, Mexico

Date	Julian Date	Time	Port
January 7, 2005	7	14:05:00	Colon, Panama
February	357	22:13:30	Progresso, Mexico



Project Summary

DESCRIPTION

Background and Scientific Objectives

The cruise objective was to deploy OBSes and the MCS streamer to image the Chicxulub impact crater.

On JD 046, at 0206 UTC, the ship's main sonar pod impacted the ground at 21 24.670 N 90 20.477 W. Operations were halted for hull inspections. Operations were resumed on JD 048 at 0630 UTC, only to be halted again on 050 at 0730.

The only instruments affected by the impact were the hydrosweep and the Bathy2000. See the relevant section for details on data interruptions.

Note:
The cruise was summarily halted during an unexpected port stay in Progresso, Mexico. Consequently, this report is incomplete. Please contact OMO at Lamont−Doherty for an up−to date report.

Cruise Members

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Howie Goldstein	MMO	
Claudio Fossati	MMO	
Maria Theresa Zapata	MMO	
Eduardo Coevas	Mexican Observer	
Diana Antochiw	Mexican Observer	
Ruben Romero Rojas	Mexican Observer	
Manuel Reyes	Mexican Observer	
Gabriella Portilla	Mexican Observer	
Ernesto Vasquez	Mexican Observer	
Gabriel Gonzalez	Mexican Observer	
Elizabeth Reyes	Mexican Observer	
Juan Carlos Salinas	Mexican Observer	

Ship's Science

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

Hydrosweep

The hydrosweep is designed for deeper water, and consistently dropped 75% of the beams while operating near Chicxulub.

Gravity

The gravimeter performed normally.

Magnetics

No magnetometer data was collected during the cruise.

Navigation

The POS/MV (gp4, gp04) exhibited a problem in which correct positions were reported. The reported track would veer off from actual, getting progressively worse, until the POS was restarted. The time and duration of these problems is noted below. POS/MV data is incorrect and should not be used for the times listed.This behavior did not affect the seismic data collection.

Seismic

Seisnet was used throughout the cruise without problems.

Syntrak and the GCS90 operated normally.

The ts files do not reflect shottimes during OBS−only lines, and should not be used. Refer to the shotlog files for shottimes.

Timing

The ts files do not reflect shottimes during OBS−only lines, and should not be used. Refer to the shotlog files for shottimes.

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 to a 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

Joetime

logging interval: 30 min
file id: tr2

Used as the CPU synchronization clock. This clock is polled once every thirty minutes 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.

This clock was running and synchronizing the system the entire cruise.

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

Log Date	LogDate	Comment
2005+007:19:35:00		Logging officially started
2005+053:23:59:59		Logging officially ends

GPS Receivers

GPS data is usually logged at 1−2 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 POS/MV with the CNAV GcGPS as an auxiliary input was the primary gps for this cruise.

Trimble Tasmon P/Y Code Receiver

logging interval: 2 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
2005+007:19:35:00		Logging officially started
2005+053:23:59:59		Logging officially ends

Trimble NT200D

logging interval: 2 seconds
file id: gp2

The Trimble is the secondary receiver for GPS data. Data is logged at 2 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
2005+007:19:35:00		Logging officially started
2005+053:23:59:59		Logging Ends

C−Nav

logging interval: 2 seconds
file id: gp3

The C−Nav is a global satellite−based differential receiver. This is the best individual receiver currently on the ship.

Interruptions greater than 10 minutes are displayed in the following table

Log Date	LogDate	Comment
2005+007:19:35:00		Logging officially started
2005+053:23:59:59		Logging Ends

POS/MV

logging interval: 1 second
file id: gp4

The POS/MV is a receiver which uses C−Nav input, its own antennae, an inertial sensor, and optional RTG, WTC, or WAAS corrections (when available) and a kalman filter to produce a smooth nav output and very accurate heading. As of June 2003 it is used as the primary GPS for Hydrosweep, as an input to Spectra, and can be used as the gps for reduction processing. With the C−Nav auxiliary input, this is the most accurate receiver on the ship.

Interruptions greater than 10 minutes are displayed in the following table

Log Date	LogDate	Comment
2005+007:19:35:00		Logging officially started

Log Date	LogDate	Comment
2005+013:22:36:00	2005+014:00:10:00	Bad position
2005+020:22:36:32	2005+021:00:10:41	Bad position
2005+028:00:11:43	2005+028:01:03:50	Bad position
2005+035:01:04:48	2005+035:03:28:39.341	Bad position
2005+042:03:29:06	2005+042:04:20:21	Bad position
2005+049:04:20:48	2005+049:05:06:52	Bad position
2005+053:23:59:59		Logging Ends

Speed and Heading

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

logging interval: 3 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
2005+007:19:35:00		Official start date
2005+053:23:59:59		Official end date

Gravity

Bell Aerospace BGM−3 Marine Gravity Meter System

logging interval: 1 second
file id: vc. (raw), vt. (processed)
drift per day: 0.018

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
2005+007:19:35:00		Official start date
2005+048:01:48:50	2005+048:01:59:15	Data Interruption
2005+053:23:59:59		Official end time

Bathymetry

Krupp Atlas Hydrosweep−DS2

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 5.0beta3 is necessary to process data after June 1, 2001.

Interruptions greater than 10 minutes are displayed in the following table

Log Date	LogDate	Comment
2005+007:19:35:00		Official start logging
2005+046:04:16:18	2005+046:07:12:55	Shutdown after grounding
2005+046:14:03:59	2005+048:06:07:04	Shutdown for divers
2005+053:23:59:59		Official end logging

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
2005+007:19:35:00		Official start logging
2005+053:23:59:59		Official end logging

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

Gravity Ties

Location1

EW0412 Balboa, Panama

Pier/Ship	Latitude	Longitude
	18 27.84N	66 06.36W
Pier 2		

Reference	Latitude	Longitude
	18 27.8N	66 05.5W
Cruise Ship terminal		

	Id	Julian	Date	Mistie	Drift/Day	Prev Mistie
Pre Cruise	EW0410	326	04. Nov 04	−5.53	0.15	8.99
Post Cruise	EW0412	357	22. Dec 04	−2.59	0.061	−5.53
Total Days			48.00	2.94		

Time	Entry	Value	
1446	CDeck Level BELOW Pier	2.00	
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	1	1 if corrected

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

Difference in meters between Gravity Meter and Pier: 7.50 meters

Height Cor = Pier Height*	FAA Constant				
7.50	0.31			2.33	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	13.60		978692.06	mgals

Gravity in mGals at Meter

Pier Gravity+	Height Correction			Gravity@meter	
978692.06	2.33			978694.39	mGals

Current Mistie

BGM Reading−	Calculated Gravity			Current Mistie	
978691.80	978694.39			−2.59	mGals

Location 2

No tie taken in Progresso.

Contact LDEO to receive updated cruise report when available.

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                      Tailbuoy Position
Latitude     Longitude                Latitude     Longitude

N 15 49.6189 W 060 19.8101    N 15 47.1234 W 060 20.1901

Furuno  Streamer
Gyro    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.

```
                        Gun Depths
Shot Time               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

```
                              Centerbeam
CPU Time Stamp       Latitude Longitude          Depth

2000+074:09:55:00.000  N 13 6.6206    W 59 39.3908   134.9
```

Merged Data m

```
                                                        GPS
CPU Time Stamp         Latitude     Longitude          Used  Set  Drift Depth

2000+200:12:25:00.000  N 45 54.1583 W 42 47.1770       gp1   0.0  0.0

Magnetic                        Gravity
Total Intensity   Anomaly     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 Centerbeam Depth
2000+079:00:08:01.507 000295 N 15 49.5703 W 060 19.7843 strike1     2345.6
```

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

                                Tailbuoy
Latitude      Longitude      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  Drift DC      Raw  Velocity     Smooth Velocity
Smooth  Total Shift   North     East     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

```
                          True
CPU Time Stamp          Spd Dir

2001+045:00:00:00.967   7.8  22

Bird1:                                                Bird 2
Speed                     Direction                   Speed                     Direction
Inst  60sA   60mA  60sM  Inst 60sA 60mA              Inst  60sA  60mA  60sM    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                    Humidity
Inst  60mA  60mm  60mM         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
```

Merged Meteorological Data mmet

```
TSG, WX, CT merged with Nav at 1 minute fixes
date        time        lat       lon       gpu head spd
2001+244:00:00:00.000 12.14071 44.98469 gp1 10.2 83.0

tws  twd   temp hum  press  cti  cte  con sal  ct
26.5 228.0 30.6 87.0 1000.8 28.8 28.8 5.9 36.3 28.8

gpu  = gps unit in use
head = ship's heading
spd  = ship's speed in knots
tws  = true wind speed
twd  = true wind direction
temp = air temp (celcius)
hum  = relative humidity (%)
press= pressure in mb
cti  = sea temp from the internal TSG sensor
cte  = sea temp from the external TSG sensor
con  = conductivity, Siemens/meter
sal  = salinity, practical salinity units
ct   = sea temp from the C-keel sensor (to tenths of a degree)
```

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

Tape Contents

Tar #1 – EW0501

Bathy2000 data

Tar #2 – EW0501

Cruise_Report_EW0412.pdf	this document
ew0501.cdf	NetCDF database file of this cruise
ew0501.cdf.nav	NetCDF database file of this cruises navigation
configs/	Ewing Data System configuration files
docs/	File Formats, Spectra manuals
processed/	Processed datafiles merged with navigation
trackplots/	daily cruise track plots (*postscript*)
mbsystem/	Latest MBSystem source code
raw/	Raw data directly from logger
reduction/	Reduced data files
clean/	daily processing directory, includes daily postscript plots of the data.

LNAME	FFID	LFID	FSHOT	LSHOT	DDS	SDLT	3490	MISSED SHOTS
CHIX2	1	208	1603	1810	1:1-5	1:1-5	1-5	
CHIX4a	13	242	147	376	1:6-10	1:6-10	6-11	261
CHIX4b	243	393	530	680	1:11-14	1:11-14	12-14	
CHIX4c	401	778	1067	1444	1:15-22	1:15-22	15-22	
CHIX6	1	873	1036	1908	1:23-40	1:23-40	23-40	484521
CHIX8a	1	691	124	814	1:41-54	1:41-54	41-54	
CHIX8b	692	991	850	1149	2:1-6	1:55-60	55-60	
CHIX8c	992	1664	1208	1880	2:7-20	1:61-74	61-74	1876
CHIX6a	1	97	169	265	2:21-22	1:75-76	75-76	
CHIX10	76	1071	189	1184	2:23-42	1:77-96	79-98	
CHIXR1	1	1684	-20	1666	2:43-54,3:1-22	1:97-130	99-132	
CHIXR2	1	236	141	376	3:23-27	1:131-135	133-137	195326
CHIX2a	1	252	263	543	3:28-33	1:136-141	138-143	391-421
CHIX2b	1	1136	618	1827	3:34-56	1:142-164	144-166	1278-1317,1362-1390,1708-1718
CHIXR3	1	2069	-194	1874	4:1-42	1:165-206	167-208	
CHIXR4	4	358	76	430	4:43-50	1:207-214	209-216	
CHIXR5	1	489	225	713	4:51-56,5:1-4	1:215-224	217-226	
CHIXR6a	1	2000	467	2477	5:5-44	1:225-264	227-266	1463-1464,1573,1575-1578,1685-1688
CHIXR6b	4	2000	2389	4385	5:45-53,6:1-31	1:265-304	267-306	
CHIXR7	2	1120	235	1437	6:32-52,7:1-2	1:305-327	307-330	1000-1049,1170-1204
CHIX25	6	447	43	484	7:3-11	1:328-336	392-400	
CHIX15	4	720	177	893	7:12-26	1:337-351	401-415	
CHIX16	18	577	237	796	7:27-38	1:352-363	416-427	
CHIX17	4	294	390	680	7:39-44	1:364-369	428-433	
CHIX17a	1	98	610	708	7:45-46	1:370-371	434-435	704
CHIX18	1	368	344	715	7:47-54	1:372-379	436-444	395-399
CHIX17b	4	390	381	767	8:1-8	1:380-387	445-452	
CHIX21	1	568	145	712	8:9-20	1:388-399	453-464	
CHIX22	1	520	269	788	8:21-31	1:400-410	465-475	
CHIX23	1	212	209	420	8:32-36	1:411-415	476-480	
CHIX24	1	708	76	783	8:37-51	1:416-430	481-494	
CHIX23a	1	321	160	527	8:52-54,9:1-4	1:431-437	495-502	217-234,391-419
CHIX4	1	408	777	1184	9:5-13	1:438-446	503-510	
CHIX5	1	1182	107	1288	9:14-37	1:447-470	511-534	
CHIX6b	46	649	964	1567	9:38-50	1:471-483	535-547	
CHIX19	1	165	319	483	9:51-54	1:484-487	548-551	

CHIX20	1	407	219	625	10:1-9	1:488-496	552-559	
CHIX1	1	1723	115	1837	10:10-44	1:497-531	560-594	760
CHIX11b	2	270	657	925	10:45-50	1:532-537	595-600	
CHIX13b	1	446	297	742	10:51-52,11:1-7	1:538-546	601-609	
CHIX9	1	1846	349	2194	11:8-44	1:547-583	610-646	
CHIX3	1	657	181	837	11:45-50,12:1-8	1:584-597	647-659	
CHIX3a	1	562	873	1434	12:9-20	1:598-609	660-671	
CHIX3b	564	1090	1527	2053	12:21-31	1:610-620	672-682	

nav file	line name	nav points	data shots	needed?
chix2.0	chix2	0-1810	1603-1810	Yes
chix2.1	n/a	1-2	none	No
chix2.2	chix2a	147-546	263-391,421-543	Yes
chix2b.0	chix2b	618-1708	618-1708	Yes
chix2b.1	chix2b	1718-1827	1718-1827	Yes
chix3.0	n/a	none	none	No
chix3.1	chix3	181-837	181-837	Yes
chix3.2	chix3a	873-1434	873-1434	Yes
chix3.3	chix3b	1525-2053	1527-2052	Yes
chix4.0	n/a	1,1-23	none	No
chix4.1	chix4a	23-681	147-376	Yes
	chix4b		530-680	Yes
chix4.2	chix4c	1061-1444	1067-1444	Yes
chix4.3	n/a	none	none	No
chix6.0	chix6	1036-1908	1036-1908	Yes
chix6a.0	chix6a	169-266	169-265	Yes
chix8.0	chix8a	124-814	124-814	Yes
chix8.1	n/a	none	none	No
chix8.2	chix8b	850-1149	850-1149	Yes
chix8.3	chix8c	1208-1880	1208-1880	Yes
chix10.0	n/a	266-490	416-490	No
chix10.1	chix10	189-1185	189-1184	Yes
chix15.0	n/a	none	none	No
chix15.1	n/a	none	none	No
chix15.2	chix15	(-25)-893	177-893	Yes
chix16.0	chix16	219-796	237-796	Yes
chix17.0	chix17	201-680	390-680	Yes
chix17.1	chix17a	610-703	610-703	Yes
chix17.2	chix17a	705-708	705-708	Yes
chix17.3	n/a	none	none	No
chix17.4	n/a	201-203	none	No
chix17.5	chix17b	381-767	381-767	Yes
chix18.0	chix18	343-715	344-715	Yes
chix21.0	chix21	145-712	145-712	Yes
chix22.0	chix22	269-788	269-788	Yes
chix23.0	chix23	209-420	209-420	Yes
chix24.0	chix24	76-571	76-571	Yes
chix24.1	n/a	none	none	No
chix24.2	n/a	none	none	No
chix24.3	chix24	573	573 need to 783?	Yes
chix25.0	n/a	none	none	No
chix25.1	chix25	1-484	43-484	Yes
chixR1.0	chixR1	(-21)-1666	(-21)-1666	Yes
chixR1.1	n/a	none	none	No
chixR3.0	chixR3	(-194)-1874	(-194)-1874	Yes
chixR4.0	chixR4	271,74-431	76-430	Yes
chixR5.0	n/a	none	none	No
chixR5.1	n/a	none	none	No
chixR5.2	chixR5	225-714	225-713	Yes
chixR6.0	chixR6a	467-2477	467-2477	Yes
chixR6.1	chixR6b	2385-4385	2389-4385	Yes

chixR6.2	n/a	1438	none	No
chixR7.0	chixR7	235-999	235-999	Yes
chixR7.1	chixR7	1050-1169	1050-1169	Yes
chixR7.2	chixR7	1204-1438	1204-1437	Yes
chixR7.3	n/a	none	none	No

Description of Land experiment

Chicxulub: December 2004 to February 2005

Written by Jo Morgan in August 2005
Department of Earth Science and Engineering
Imperial College London
South Kensington Campus
London SW7 2AZ
j.morgan@imperial.ac.uk

Seismometers
SEIS-UK supplied the land seismometers
SEIS-UK are located at:
Department of Geology
University of Leicester
University Road
Leicester LE1 7RH, UK

The instruments used in the land experiment were Guralp CMG-6TD, 3 component, 30s-100Hz, 24bit digitiser, instrument clocks synchronized to GPS. A full specification can be found at: http://www.le.ac.uk/seis-uk/

The instruments were powered by 24 D-cell batteries that were placed in battery packs. Inland, instruments were placed in bins with a hole cut out of their base, and concreted to the limestone surface. After installation of the seismometer, these bins were half filled with sand. Close to the shore, the bins were buried in the sand, and concrete was unnecessary. The bins were sealed with cable ties. The GPS and battery pack were placed above the sand (see picture below) the GPS was placed in a hole drilled in a wooden frame.

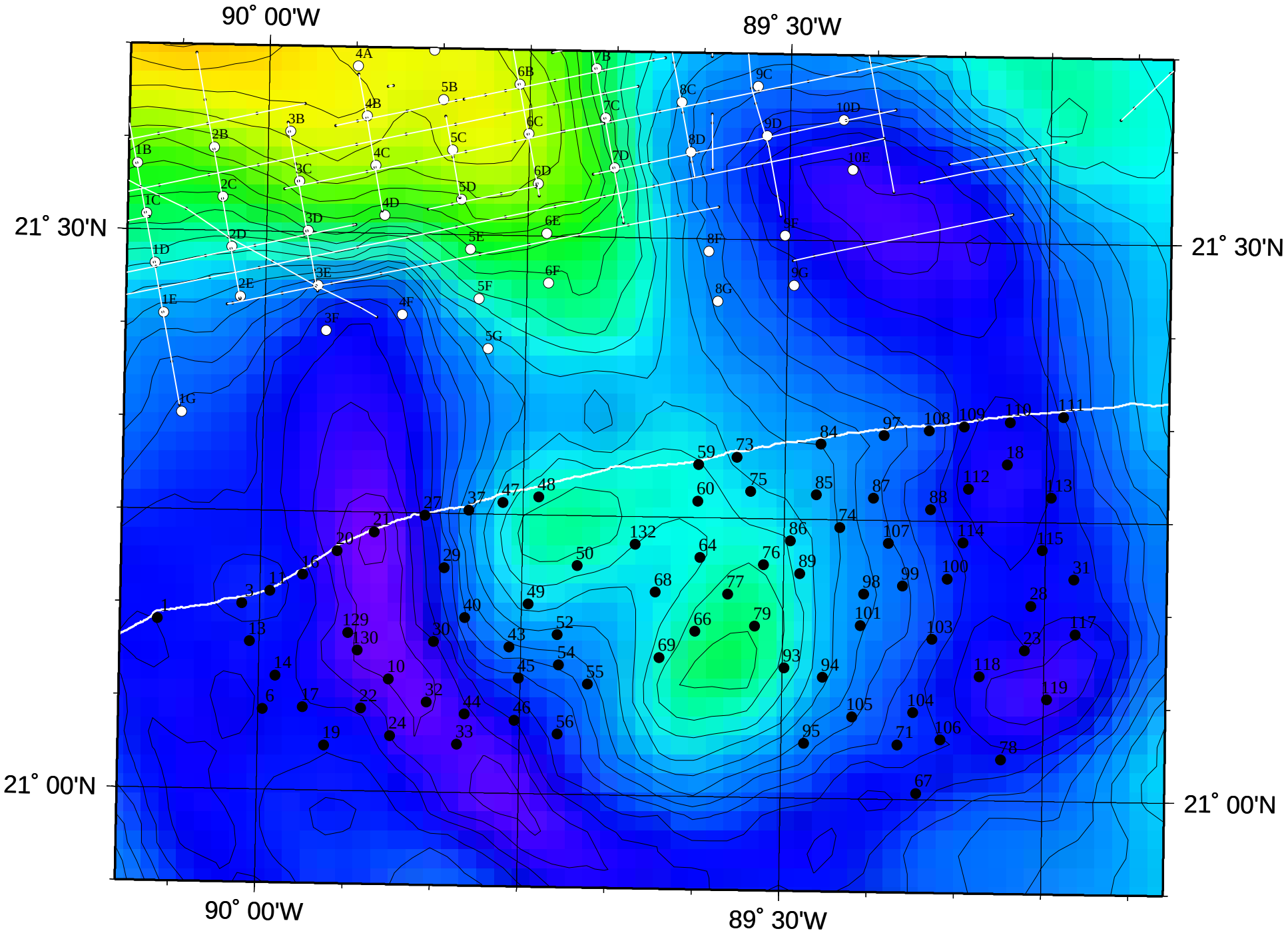
Sites were located and partially built from 15th Dec 2004 ((Land party lead by Jo Morgan, Imperial)
Instruments first switched on between 5th and 14th Jan (Land party lead by Mike Warner, Imperial)
Batteries were changed between 26th Jan and 4th Feb (Land party lead by John Dennis, Imperial)
Instruments were recovered between 16th and 21st Feb (Land party lead by Jo Morgan, Imperial)

Airgun shooting began on the 20th January and ended on 17th February 2005.

During the battery change, several instruments were moved because of tampering with sites or sites being noisy; these are indicated in the data quality check below.

88 sites were occupied during the survey, 80 sites recorded all or a partial dataset. No data were recorded at 8 sites, and at 4 of these the seismometers were stolen. Sites recorded partial data either because batteries went flat earlier than expected, or because the sites were moved during the battery change. Several difficult sites had a double battery – so had no mid-experiment battery change.

A map with the location of all the land stations, in relation to the southernmost OBS and shot lines, is shown below. The background colour is gravity data.


90° 00'W
89° 30'W
21° 30'N
21° 00'N
1A
1B
1C
1D
1E
1F
1G
2B
2C
2D
2E
3B
3C
3D
3E
3F
4A
4B
4C
4D
4F
5B
5C
5D
5E
5F
5G
6B
6C
6D
6E
6F
7B
7C
7D
8C
8D
8F
8G
9C
9D
9F
9G
10D
10E

Description of SEGY data

For each land site the data have divided into 48 gathers, and there is a vertical and two horizontal components ate each site.

The 48 gathers are related to individual shot profiles:
Chix1, Chix2, Chix3, Chix4, Chix4b, Chix5, Chix6, Chix6b, Chix8, Chix9, Chix10, Chix11b, Chix12, Chix13b, Chix14, Chix15, Chix16, Chix17, Chix18, Chix19, Chix20, Chix21, Chix22, Chix23, Chix24, Chix25, ChixR1, ChixR3, ChixR4, ChixR5, ChixR6, ChixR7, OBS-101, OBS-102, OBS-103, OBS-104, OBS-105, OBS-106, OBS-201, OBS-202, OBS-203, OBS-204, OBS-205, OBS-206, OBS-207, OBS-208, OBS-209, OBS-210

Example Gather names are:
chix2005.chix9.CX013.6123.z.segy
chix2005.OBS-210.CX020.6162.z.segy

chix9 and OBS210 indicate the shot profile, CX013 and CX020 indicate that these data are from land station 013 and 020. 6123 and 6162 identify the seismometer, and z indicates these are vertical data. Horizontal data are indicated by e and n in place of the z.

Chix1-Chix25 are reflection profile shot within a central grid, ChixR1 – ChixR7 are regional reflection profiles, and OBS lines are shots only (no reflection profile).

Gathers were made for most shot profiles into each land station, however many gathers have no data in them. In these cases, either the seismometers were not working correctly or, more usually, the batteries had gone flat earlier than expected.

Within the SEGY headers, GPS Positions are an averaged position taken from the SEIS-UK GPS recorder or, when this was not available, recorded by a hand-held portable GPS. The projection is WGS84. Lat/Lons are recorded in the normal Shot and Receiver positions in 10^{th}s of a second. UTM co-ords in zone16 and are in the following header positions:

sourceSurfaceElevation	Bytes 45-48	source UTM easting
sourceDepth	Bytes 49-52	source UTM northing
datumElevRec	Bytes 53-56	receiver UTM easting
datumElevSource	Bytes 57-58	receiver UTM northing

and are in metres. Offsets has been calculated with Pythagoras from the utm co-ords, and are in the normal header position.

Both receiver and source elevations are set to zero. Topography within the crater basin, where the receivers are located, varies by 1 or 2 meters.

There is a complementary continuous dataset: XI-2005 at IRIS for earthquake data.

Quick data quality check

Below is a quality check of profile Chix10 recorded on each station, but where the station has not recorded line 10, the data has been checked for lines 9, 16 or R3.

Good = clear arrivals for large number of shots
OK = clear arrivals for reasonable number shots
Weak = some arrivals observed.
None = No obvious data observed.

Site Number Seismometer Lat/Lon Comments

~~CX001 6124 21.1519 -90.0974~~ **No Data** site destroyed, site moved at battery change
CX002 **No data**, Seismometer stolen
CX003 6169 21.1666 -90.0173 Weak (line 10) site moved at battery change
CX006 6089 21.0722 -89.9959 Weak, some good (line 10)
CX010 6057 21.1007 -89.8755 Weak, some good (line 10)
CX011 6140 21.178 -89.9905 Weak (line 10)
CX013 6123 21.1326 -90.0093 Good (line 9)
CX014 6103 21.1024 -89.9844 Ok (Line 10)
CX016 6108 21.1933 -89.9596 Good (line 9)
CX017 6132 21.0743 -89.9573 Weak - OK (line 10) Site moved during battery change
CX018 6185 21.3016 -89.2876 Good (line 10)
CX019 6117 21.0403 -89.9365 Good (line 9)
CX020 6162 21.2146 -89.9268 OK (line 10)
CX021 6086 21.232 -89.8919 OK (Line 10)
CX022 6062 21.074 -89.9017 Weak, some good (line 10)
CX023 6155 21.1352 -89.2685 Weak (line 10)
CX024 6149 21.0499 -89.8735 Good (line 10)
CX027 6166 21.2481 -89.8435 Weak (line 10)
CX028 6076 21.1751 -89.2629 Weak, some good (line 10)
CX029 6204 21.2014 -89.8242 Weak, some good (line 10)
CX030 6081 21.1351 -89.8334 Weak, some good (line 10) No battery change
CX031 6056 21.1993 -89.2222 Weak(line 10) Site moved at battery change
CX032 6168 21.0806 -89.8393 Weak (line 10)
CX033 6047 21.0434 -89.8097 Good, but partial data (line 10)
CX037 6100 21.2532 -89.8016 Weak (line 10)
CX040 6197 21.1568 -89.8041 Weak, some good (line 10)
~~CX043 6160 21.1314 -89.7611~~ **No data**, battery flat, site moved at battery change
CX044 6118 21.0705 -89.8027 Good (line 10)
CX045 6184 21.1035 -89.7518 Weak, some good (line 10)
CX046 6016 21.0656 -89.7552 Weak, some good (line 10)
CX047 6109 21.2606 -89.7691 Weak, some good (line 10)
CX048 6049 21.2662 -89.735 Weak, some good (line 10)
CX049 6119 21.1702 -89.7433 Good (line 9)
~~CX050 6102 21.2053 -89.6973~~ **No data**, battery flat, site moved at battery change
CX051 **No data**, seismometer stolen
CX052 6192 21.1428 -89.7153 Weak (line 10)
CX054 6072 21.1158 -89.7135 Weak (line 10)
CX055 6132 21.0992 -89.6854 None (line 9) Site installed at battery change
CX056 6179 21.0541 -89.7138 **No data,** not switched on
CX059 **No data**, instrument failure.
CX060 6211 21.2647 -89.5828 OK (line 10)
CX064 6167 21.2144 -89.58 Good (line 10)
CX066 6083 21.1483 -89.584 Weak, some good (line 10)
CX067 6014 21.0055 -89.3707 Some OK (line 10)
CX068 6013 21.1826 -89.6222 Some OK (line 10)
CX069 6121 21.1239 -89.6175 Weak (line 10)
CX071 6036 21.0491 -89.3891 Weak (line 10)
CX073 6137 21.3048 -89.5462 Good (line 10)
CX074 6223 21.2432 -89.4468 Good, partial data (line 10)
CX075 6351 21.2744 -89.5328 Weak, some good (line 10) No battery change
CX076 6220 21.2086 -89.5194 Good (line 10)
CX077 6090 21.182 -89.553 OK (line 10)
CX078 6019 21.037 -89.2901 Weak (line 9)

CX079 6224 21.1535 -89.5267 OK (line 10)
CX084 6031 21.3176 -89.4661 OK (line 10)
CX085 6091 21.2720 -89.4701 Good (line 10) No battery change
CX086 6165 21.2307 -89.4938 Good (line 10)
CX087 6052 21.2697 -89.4149 Good (line 10)
CX088 6097 21.2603 -89.3601 Good (line 10)
CX089 6195 21.2013 -89.4846 Good (line 9)
CX093 6080 21.1168 -89.4982 Weak (line 10)
CX094 6201 21.1087 -89.4613 OK (line 10)
CX095 6192 21.0492 -89.4782 OK (line 16) Site installed at battery change
CX097 6104 21.3261 -89.4056 Good (line 10)
CX098 6051 21.1839 -89.4231 Good (line 10)
CX099 6074 21.1915 -89.3861 Good (line 10)
CX100 6217 21.1983 -89.3432 Good (line 10)
CX101 6058 21.1555 -89.4258 Good (line 10)
CX103 6199 21.1442 -89.3572 OK (line 10)
CX104 6110 21.0784 -89.3747 Good (line 10)
CX105 6163 21.0736 -89.4326 OK (line 10)
CX106 6158 21.0542 -89.3478 Good (line 10)
CX107 6012 21.2297 -89.4 Good (line 10)
CX108 6208 21.3311 -89.3627 OK (line 10)
CX109 6205 21.3349 -89.3291 Good (line 10)
CX110 6207 21.3396 -89.2851 OK (line 10)
CX111 6164 21.3447 -89.2341 Good (line 10)
CX112 6142 21.2792 -89.3243 Good (line 10)
CX113 6041 21.2723 -89.2451 Good (line 9)
CX114 6172 21.2311 -89.3289 OK (line 10)
CX115 6116 21.2252 -89.2527 OK (line 9)
CX117 6107 21.1499 -89.2204 Good (line 10)
CX118 6043 21.1114 -89.3114 Weak (line 10)
CX119 6183 21.0913 -89.247 Weak (line 10)
CX129 6124 21.1416 -89.914 Good (line 9) Site installed at battery change
CX130 6025 21.1261 -89.9059 Weak, some good (line 10)
CX131 **No data**, seismometer stolen
CX132 6087 21.2252 -89.6421 Good, partial data (line 10)

List of land personnel

Jo Morgan (Imperial, London)
Mike Warner (Imperial, London)
John Dennis (Imperial, London)
Peggy Vermeesh (Imperial, London)
Veronica Bray (Imperial, London)
Graham Nash (Imperial, London)
Richard Ghail (Imperial, London)
Millan Marcos (Imperial, London)
Matt Brown (Imperial, London)
Cristiano Lana (Imperial, London)
Rebecca Blackhurst (Imperial, London)
Mario Rebolledo-Vieyra (CICY, Cancun)
Mélina Soto (CICY, Cancun)
Adrien Le Cossec (CICY, Cancun)
Alex Brisbourne (SEIS-UK, Leicester, UK)
Paul Denton (SEIS-UK, Leicester, UK)
Anthony Hardwick (SEIS-UK, Leicester, UK)
Tim Owen (Cambridge, UK)
Tom Barton Owen (Cambridge, UK)
Gail Christeson (UTIG, USA)
Steffen Saustrup (UTIG, USA)
Margaret Kroehler (UTIG, USA)
Eric Lyons (UTIG, USA)
David Gorney (UTIG, USA)
Javier Sánchez (PeMex, UNAM)
James Hammond (Leeds, UK)