R/V Maurice Ewing Cruise EW04-12

NICSTRAT High-Resolution Multichannel Seismic Survey, Sandino Forearc Basin

21 November – 22 December 2004

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INTRODUCTION

High-resolution, multichannel seismic (MCS) reflection data were collected from the inner shelf to the slope, in the Sandino forearc basin, offshore Costa Rica, Nicaragua, Honduras and El Salvador (Figure 1) by the University of Texas Institute for Geophysics (UTIG). The survey was designed to image Neogene depositional sequences indicative of sea-level change and stratal geometries that may reflect local tectonic history. Benefiting from good weather and the excellent performance of the seismic system, we exceeded our pre-cruise goal for line-km acquisition by covering ~4620 km of our planned profile grid. However, this includes distance covered when the seismic system was shut down or powered down owing to proximity of marine mammals or turtles, as well as minor equipment problems, resulting in data gaps scattered throughout the profiles. The actual amount of seismic data is, therefore, somewhat less than this total.

We greatly appreciate the invaluable assistance provided by the LDEO science staff, led by Science Officer Ted Koczynski, who provided outstanding guidance and support throughout the cruise. The Marine Mammal Observers, led by Meike Holst, were sensitive to our scientific needs and worked with us constructively to maximize data acquisition, while following their mandate to protect mammals and turtles. The professionalism of Captain Mark Landow, the officers, and crew of R/V *Maurice Ewing* contributed enormously to the success of the cruise, particularly because of their ability to navigate within the confines of the Gulf of Fonseca and their willingness to venture into relatively shallow (~18-20 m) water.

SCIENTIFIC RATIONALE

Forearc basin sediments are influenced by both tectonic events associated with plate convergence and global sea-level (eustatic) fluctuations. However, sequence stratigraphic investigators have tended to avoid convergent margins because of the perception that tectonic forcing would overwhelm the eustatic effect. Recent seismic investigation of the offshore Eel River Basin, northern California, suggests that this is not the case and supports the hypothesis that unconformities generated by tectonic uplift are localized near structures and distinguishable from the more regional sequences that are of eustatic origin.

This project has two overriding objectives: 1) Test the hypothesis that the stratigraphic records of eustatic and tectonic processes can be identified and distinguished on high-resolution, multichannel seismic (MCS) data from the Sandino forearc basin, on the Pacific margin of Nicaragua. These data will be used to interpret unconformities and sequences across and along the margin to document their geometries and extent. Subsequent IODP drilling will date interpreted sequences for correlation with coeval sequences on other margins and with the deep-sea oxygen isotope proxy for sea-level change. 2) Evaluate the record of tectonic events in the form of local unconformities and/or tectonically controlled variations in the geometries and stacking patterns of regional eustatic sequences. These will be correlated with known and proposed tectonic episodes in the region, including changes in plate motion, and uplift and subsidence associated with hypothesized tectonic erosion and accretion.

The survey also extends to the Gulf of Fonseca, which provides an opening through which to conduct a marine survey across the line of the volcanic arc. It allows us to image the boundary zone between the volcanic arc and the Nicaraguan Depression, a backarc basin that extends the length of Nicaragua and into El Salvador. We also speculate that the gulf may have provided an opening for sediment from the interior to reach the Sandino Basin offshore, where the bulk of our survey is located.

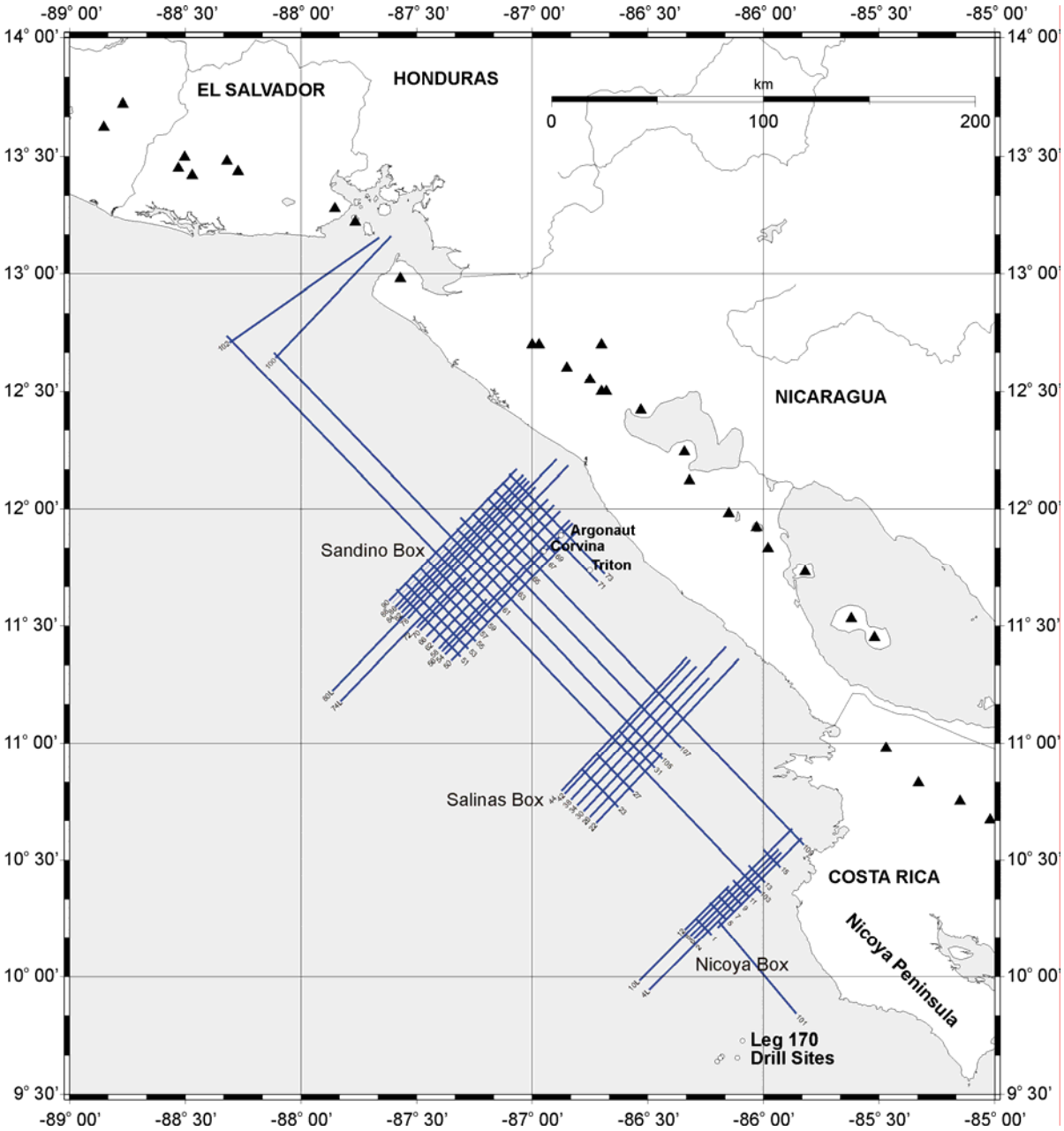

Figure 1. EW04-12 survey showing numbered profiles collected by the R/V *Maurice Ewing* during high-resolution multichannel seismic operations in the Sandino forearc basin. Data gaps resulting from marine mammal shut downs/power downs are not shown. Commercial exploration wells Argonaut, Corvina and Triton (in the Sandino Box) and ODP Leg 170 drill sites are indicated.

A vital part of defining the environmental impact of future sea-level change is understanding the stratigraphic record of past eustatic fluctuations. The relative importance of eustasy versus local tectonic and sedimentary processes in controlling continental-margin depositional cyclicity is integral to this effort. It is a fundamental question in sedimentary geology and a key to deciphering the long history of geological, climatic, and oceanographic processes imprinted on the preserved stratigraphic record. This project should constitute a large step toward proving whether regional unconformities worldwide, in a wide range of tectonic settings, can be ascribed to eustatic control, a result that could be applied to similar unconformities throughout the stratigraphic record, including the Mesozoic. It would provide a much-needed refocusing of the debate over the stratigraphic response to sea level change. Likewise, determining uplift and subsidence histories and defining the roles of tectonic erosion versus accretion are fundamental to understanding mechanisms of subduction and the evolution of convergent margins.

Recognition of the need for high-resolution MCS data arises from work on northern California, New Jersey, and New Zealand. In each location, commercial and/or academic, low-resolution MCS data were available, but proved inadequate for sequence stratigraphic interpretation and preparation for ODP/IODP drilling. In all cases, high-resolution MCS data led to identification of additional sequence-bounding unconformities not revealed by preexisting data and were essential for unraveling complex stratigraphic and structural interactions. Academic, deep-penetration, low-resolution MCS data (EW00-05 survey) are available in the Sandino Basin and provide an excellent structural framework, but the stratigraphy and structures of interest are at the limits of seismic resolution and the EW00-05 profiles are widely spaced (~20 km). To document the three-dimensional variability in sequence geometries that reflects local control and to map complex structures, the EW00-012 seismic program has high vertical resolution (~5 m in the upper 0.5 – 1 km), close line spacing (as low as 2 km), and numerous crossing lines.

Only by studying basins subject to a wide spectrum of tectonic and depositional controls can full understanding of the relative roles of eustasy, tectonics and local sedimentary processes in generating preserved continental margin stratigraphy be achieved. Precise, seismic delineation of sequence and structural geometries, including their along-strike variability, followed by drilling, is essential to develop criteria for assessing how local and global controls interact to form the stratigraphic record.

MCS ACQUISITION AND RECORDING

Source

- Three GI (generator-injector) guns @ 2000 psi. The guns were mainly used with both generator and injector chamber volumes of 45 cu. in. (usually written 45/45). However, we also used the 105/105 cu. in. configuration for some profiles.
- The guns were suspended from floats to maintain a 2.5 m towing depth and towed 39.62 m behind the ship (Figure 2).
- Shot spacing was 12.5 m for profiles shot with 45/45 cu. in. guns. Shot spacing was increased to 25 m for lines crossing the deep Central American Trench (water depth up to ~4900 m) because of the need to increase record length. Shot spacing was also 25 m for all profiles shot using 105/105 cu. in. GI guns. This was necessary, because the larger gun chambers cannot be filled quickly enough to shoot at 12.5 m (~5 sec) intervals. Line NS-006 was also inadvertently shot with a 25 m shot spacing.

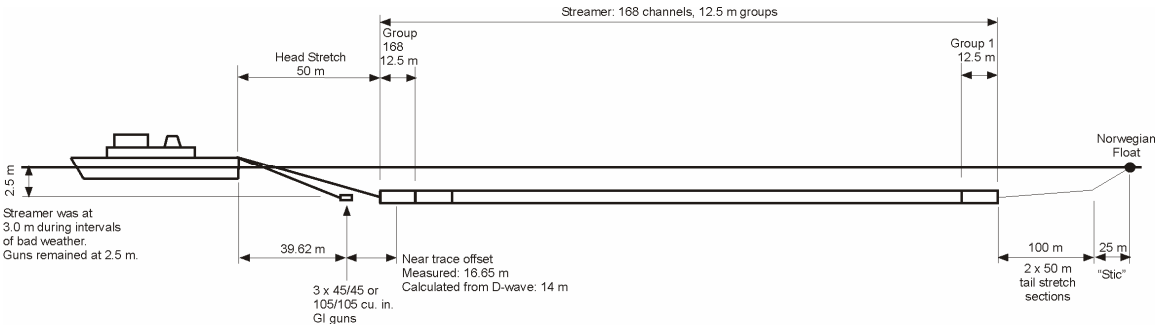

Figure 2. Source/streamer towing geometry.

GI guns reduce bubble oscillation through the use of two chambers. The generator chamber fires first and the injector chamber fires after a delay, slowing the collapse of the initial bubble and reducing subsequent oscillation. Both the generator and injector chambers of the GI guns have volumes of 105 cu. in. Spacers are necessary to reduce the chamber volumes to 45/45 cu. in. Three GI guns were fired simultaneously during acquisition; a fourth gun was carried as a spare. Two guns were deployed starboard of the streamer and the third gun to port. Firing signatures were monitored in the main lab as well as in the gun shop.

We tested a wide variety of delay times for firing of the second (injector) chamber for both the 45/45 and 105/105 configurations. The goal was to minimize the bubble pulse. During this testing, gun signatures were observed using an oscilloscope. The normal gun signature display was too insensitive. The oscilloscope allowed us to zoom in on the critical zone and to make semi-quantitative measurements of the pulse shape.

For the 45/45 configuration, delays times around 70 ms were tried initially, but this proved to be too long. We decreased the delay by 5 ms increments all the way to a delay of only 5 ms. This revealed dramatic improvement in the vicinity of 20 ms delay. We then tested delays between 17-23 ms, at 1 ms increments. Little difference was noted over this small interval, but we settled on 18 ms as a probable optimum delay.

For the 105/105 configuration, we likewise tested delays in the range from 20 to 60 ms. By a similar series of trials, we determined that the optimum delay was in the vicinity of 40 ms and finally settled on 37 ms.

Streamer

R/V *Maurice Ewing* carries a Syntron Reduced Diameter Array (RDA; diameter 64mm, [2.52 in.]), oil-filled, digital streamer containing Benthos RDA hydrophones. The streamer was deployed with one 50 m stretch section at the forward end. Active sections are 74.5 m long. We used 12.5 m groups, each of which contained 16 hydrophones. Two 50 m stretch sections and a 25 m STIC section attached to a Norwegian float terminated the streamer (Figure 2).

We recorded with 168 channels (2100 m active length). Towing depth was usually 2.5 m, although 3 m was used occasionally to reduce noise during periods of rough seas, particularly when a following current reduced ship speed through the water and made it more difficult for the birds to control streamer depth.

Streamer Configuration

- 168 x 12.5 m group length (2100 m total active length). Channel 1 is the farthest offset and channel 168 is closest to the ship.
- 17 birds: bird 1 was on the tail stretch section and bird 17 was closest to the ship. Birds 1-16 were 150 m apart and birds 16 and 17 were 75 m apart.
- The birds were programmed mainly to maintain a streamer depth of 2.5 m. However, streamer depth was frequently increased to 3.0 m, or even 3.5 m, to improve towing behavior with a following current and increased wave heights. Comparison of several frequency spectra of stacked data from lines shot with birds at 3.5 m and at 2.5 m on cruise EW00-01 (January 2000), shot using two 45/45 cu. in. GI guns, showed a slight increase in high-frequency content with birds at 2.5 m. Furthermore, notch frequencies are 214 Hz at 3.5 m towing depth, 250 Hz at 2.0 m, and 300 Hz at 2.5 m. Saustrup calculated during EW00-01 that while most of the source energy is below 250 Hz, there is some useful energy up to 250 Hz.
- 4 second records, except for lines extending to Middle America Trench, and profiles shot with 105/105 cu. in. GI guns, for which the record length was 8 seconds.
- 1 msec sampling writing to 3490 tape cartridges (~260 shots/tape with 4sec. record length, ~129 shots/tape with 8 sec.record length.).
- Measured near-trace offset was 16.65 m. However, that calculated from the D-wave arrival was 14 m.

During the course of the cruise, persistent noise developed first in channels 112-113 (JD 339-340), then in channels 10-12 (JD 340) and 19 (JD 341). Some of this noise was due to fishing gear entangled with the streamer. Removal of the gear corrected the problem. Channel 19, however, retained a low level of noise.

Recording

The Syntrak 480-24 Multiple Streamer Telemetry System (MSTS) acquires sampled seismic data in synchronization with the navigation and gun controller systems. For this survey the sampling interval was 1 ms. A series (14 total) of 24-bit digital acquisition modules (DAMs, also known as “cans”) within the streamer amplify and filter the seismic data, digitizes those signals, then multiplexes them. Each DAM receives and processes seismic data from 12 separate data channels. They are therefore spaced ~150 m apart (12 x 12.5 m group interval). Digital data is then fed through the Multiple Streamer Telemetry Processor (MSTP) to the Multiple Streamer Recording System (MSRS), both of which are located in the main lab, and recorded on 3490 tape cartridges in SEGD format.

The SeisNet system captures the data as it is transferred from the recording system to the 3490 tape drive and writes the data to disk. This provides easy access to the data for copying and processing, circumventing the need to read 3490 tapes. Unfortunately, SeisNet proved to be unreliable during this cruise. There were two problems. Firstly Spectra, which assembles navigation and other information into extended headers, was providing SeisNet with bad header information, so SeisNet was writing files with bad headers. Secondly, the UI (user interface) scripts that control copying of the data to SEGY format repeatedly crashed. Therefore, early in the cruise (3490 Tape 19, JD 327; 22 December), we switched to copying data directly from 3490 field tapes: the SEGD 3490 field tapes were converted to SEGY and copied to DAT DDS-3 tapes.

SeisNet was turned off entirely on JD 336 (1 December), because it was feared that it could have been responsible for repeated crashes of the Syntrak system with associated loss of shots. The origin of these crashes remained unclear, but it was ultimately felt by the LDEO technicians that SeisNet was not responsible. It may instead have been a further manifestation of the power problem suffered by the ship several hours later on the same day. SeisNet was therefore restarted on JD 340 (5 December).

Shipboard Processing

Shipboard processing used *Focus* software running on a workstation. Inside mutes and deconvolution were applied to reduce multiples. Brute stacks (using water velocity) were first made for each profile. Then stacking velocities were picked (usually every 400 CDPs) and preliminary stacks and FK migrations produced for most profiles. The stacked profiles were used to evaluate resolution (vertical and horizontal) and penetration and to discriminate between results of shooting with 45/45 versus 105/105 cu. in. GI guns.

OTHER DATA

Navigation

The ship followed lines defined by waypoints, most of which were selected prior to the cruise. A commercial C-Nav GPS receiver was used to provide differential GPS (DGPS) navigation. C-Nav combines into a single correction the errors produced by GPS satellite ephemeris, clock and Earth atmospheric delays to produce accuracy of <1 m (frequently <0.5 m). DGPS positions were fed to the ship's autopilot, which generally kept the ship within ~20 m of the true track, commonly <5 m (the ship itself has a beam of 45 ft [13.7 m]).

A CRT displaying an electronic chart system (dKart Navigator) on the bridge allowed the ship track to be monitored. The navigation fed to the dKart system was less precise GPS 16 Wide Area Augmentation System (WAAS; ~4-7 m accuracy), not DGPS. However, this was used for display only. A CRT in the main lab duplicated the bridge dKart display and enabled the scientific party to monitor progress.

An Applanix Position and Orientation System for Marine Vessels (POS MV) provided accurate navigation and attitude data for use by the Hydrosweep multibeam system. POS MV uses and Inertial Measuring Unit (IMU) and two GPS receivers to provide position, heading, attitude (roll and pitch), vertical displacement (heave), velocity, acceleration, angular rate of turn, etc.).

Bathy-2000 Chirp Profiles

The ship's hull-mounted, 3-11 kHz chirp profiling system (Ocean Data Equipment Corporation, Bathy-2000P) produced a continuous SEGY digital record, as well as a paper record on an EPC recorder, including all turns and MCS down time. Subbottom resolution is specified to be 0.08 m. The system requires operator intervention to adjust the water depth range of the image to match seafloor depth. This proved difficult to accomplish reliably and there are some gaps in coverage on the slope, where seafloor depth changes rapidly. There are other gaps in the data due to data storage problems. The chirp record also contains interference resulting from the 3.5 kHz signal, for the period during which the latter operated (see below). Furthermore, changing some settings (e.g., pulse length, sweep band) changed the vertical exaggeration on the paper plots.

3.5 kHz Profiles

Good quality analog 3.5 kHz profiles at 1-sec sweep were collected on an EPC recorder (including all turns and other MCS down time) for the first 6 days of the cruise. These data were not recorded on tape; only paper copies exist. The 3.5 kHz records contain interference resulting from the chirp signal (see next section). Beginning on JD 332, we decided to rely on the Bathy-2000 chirp record, which was superior to the 3.5 kHz record. Shutting off the 3.5 kHz system also stopped its interfering with the Bathy-2000 record.

Hydrosweep

We collected Atlas Hydrosweep multibeam bathymetry throughout most of the cruise. The Hydrosweep operates at 12.5 kHz and produces 140 "beams" spanning and angle of 120°. The centerbeam depth is derived from the Hydrosweep data.

Magnetometer

We collected magnetic field data almost continuosly using a Geometrics G-882 Cesium marine magnetometer towed on a 305 m cable, with ~270 m let out from the boom. We had to shut down the magnetometer in shallow water and reel it in to avoid contact with the seafloor. The G-882 operates over the Earth's magnetic field range of 20,000 to 100,000 nT. Absolute accuracy depends on sensor orientation, internal light shift and the accuracy of the external counter's time base. Orientation error does not exceed 1 nT (peak-to-peak) throughout the active zone.

SEISMIC SURVEY

Survey Design

Cruise EW04-12 began when R/V *Maurice Ewing* left its anchorage at Puntarenas, Costa Rica, at 14:55Z, Julian Day (JD) 326 (see Appendix I for JD/date conversion), corresponding to 08:55 AM, on Sunday 21 November 2004, local time (Greenwich Mean Time [GMT], or "Zulu" time, was used during the cruise). The cruise ended in Panama at 1500Z on JD 357 (10:00 AM, 22 December 2004, local time; local time in Panama is one hour ahead of local time at Puntarenas and during the survey). The survey area lies in the Sandino forearc basin.

The survey consists of 59 profiles (~4620 km) arranged in three dense grids. From southeast to northwest, these are the Nicoya (Figures 1, 3 and 4), Salinas (Figures 1, 5 and 6) and Sandino (Figures 1, 7 and 8) boxes, respectively. The boxes are linked by regional, more widely spaced strike (margin-parallel) profiles with a branch into the Gulf of Fonseca (Figures 1 and 9). The survey area extends ~200 n.mi. (~370 km) along strike and crosses from the inner shelf to the slope, with four profiles extending across the Middle America Trench (Figure 1). Experience interpreting similar data from New Jersey, Northern California and the Canterbury Bight, New Zealand, highlighted the need for close line spacings to assist with interpretation of such high-resolution data. The Nicoya, Salinas and Sandino boxes therefore provide relatively dense coverage (dip-profile spacings of 2-4 km, strike profile spacings of ~5 km) in regions of primary scientific interest. Seismic coverage in the central part of the survey area, between these focus areas, and over the northward extension to the Gulf of Fonseca was less dense (see below for details).

The principal characteristics of the survey layout were as follows (Figure 1):

- Shore-normal, "dip" profiles (even-numbered profiles) in the Nicoya, Salinas and Sandino boxes are spaced either 2 km or 4 km apart.
- Shore-parallel "strike" profiles (odd-numbered profiles) in the Nicoya, Salinas and Sandino boxes are spaced 5 km apart.

- Regional strike profiles connecting the three boxes and extending to the Gulf of Fonseca are more widely spaced (minimum spacing ~10 km).
- Profiles in the Sandino Box cross, or pass close to, the existing Corvina, Argonaut and Triton exploration wells.

Loss of Survey Time

We were fortunate in losing no time to bad weather and relatively little time resulting from problems with the acquisition system and other technical difficulties. The main cause of loss of time was shut downs and power downs caused by turtles (Figure 10), followed by those caused by marine mammals. The marine mammal shut downs could be devastatingly long (Figure 11), but were fortunately rare. The impact of turtle shut downs was magnified because, though they were generally shorter than those caused by marine mammals, they were far more numerous and resulted in fragmentation of the data, disrupting the continuity that is vital for seismic stratigraphic interpretation (Figure 10).

The amounts of time lost to various causes were as follows:

Marine mammal and turtle shut downs and power downs	31.8 hr.
Removal of fishing gear from streamer	8 hr.
Power failure	4 hr.
DAM ("can") failure	~3 hr.
Improperly attached bird	2 hr.
Syntrak crashes	~1.5 hr.
Tape-drive failures	~0.5 hr.
Total time lost, all causes	**50.8 hr.**

The time lost to marine mammal and turtle shut downs and power downs includes a lengthy turn on JD 328 (23 November) to reshoot the gap in seismic coverage resulting from a shut down caused by turtles. This was our first shut down and we still hoped to avoid data gaps. However, we were unsuccessful in this attempt because of the presence of a ship-following dolphin, which extended the shut down beyond the turn. Subsequent shut downs and power downs were too numerous to allow us to turn back to reshoot missing parts of profiles. We could only maintain course and accept the losses of data.

Operations

R/V *Maurice Ewing* transited to a location in ~1000 m water depth south of the Nicoya Box. We decided to begin streamer deployment at this location because we would be arriving at night. Therefore, it was necessary to minimize the safety radius for marine mammals and turtles so that the entire area within the safety radius could be observed visually, even in darkness (the safety radius decreases with increasing water depth). On arrival in our deployment area, we first deployed the Passive Acoustic Monitoring (PAM) streamer and then deployed the starboard outer GI gun. The marine mammal safety radius is only 27 m for one 105/105cu in. GI gun in >1000 m. In addition, there is a built-in safety factor because we are using the guns in 45/45 cu. in. configuration, instead of the 105/105 cu. in. configuration. Marine Mammal Observers (MMOs) monitored both visually and using PAM for 30 minutes before giving clearance to fire. Dolphin clicks and whistles were detected by the PAM, but none were judged to be close by. The first shot was at 0134Z, JD 327 (22 November). We deployed the streamer while gradually moving into shallower water toward the start of the first line (SE end line 15). Streamer

deployment (168 channels, 12.5 m group interval) began at 0150Z, JD 327. During streamer deployment, we deployed the remaining two GI guns (starboard inner and port) in order to begin ramping up the source array while in intermediate water depths (>100 m). The starboard inner gun began firing at 0424Z and the port gun at 0430Z after receiving approval from the MMOs. Streamer deployment was completed by 0550Z, near the start of line NS-015.

Our acquisition plan for the Nicoya Box was to begin by shooting strike profiles from landward to seaward to avoid the risk of driving marine mammals shoreward. We began shooting the first seismic profile (line NS-015, the most landward strike profile in the Nicoya Box) at 0632Z, JD 327. There was a considerable amount of fishing activity in the inshore region of the Nicoya Box and our Nicaraguan and El Salvadoran observers assisted with communication with fishing boats in the vicinity of the ship's track and continued to perform this duty, as needed, throughout the cruise.

During acquisition of line NS-011, significant noise was noted around the middle of the streamer. Some birds were not responding and streamer depth was variable. Communication with the birds was intermittent. Troubleshooting of the problem began during the turn from line NS011 to line NS-009. We also reset bird depths from 2.5 to 3 m during the turn to see if that would enable them to tow better. Bird 12 was not reset because it was not communicating. Changing the modem board fixed the communication problem problem and the birds also maintained depth well. Streamer depth was reset to 2.5 m. The 3.5 kHz profiler and Hydrosweep were started during Line NS-009. Streamer noise and bird-depth variation returned on the next line (NS-007). The main factor seemed to be whether the ship is moving with, or against, the NW-flowing current. The birds could not maintain depth as well when moving in the same direction as the current, introducing noise from swell and waves. Switched positions of port gun and PAM streamer during turn between NS-007 and NS-005 to reduce interference. Also started Bathy-2000 chirp during turn.

During turn from NS-005 to NS-001, the record length was reduced from 4 sec. to 3.584 sec. in order to allow a higher speed (~5.3 kt instead of 4.5 kt) without losing shots. The purpose was to increase the speed through the water on downcurrent line NS-001 to improve bird behavior and reduce streamer noise. This proved effective. The record length was changed back to 4 sec. for the next line, NS-010, the first dip profile.

The 3.5 kHz was started at ~1700Z, JD 327 and the Hydrosweep was started at ~1645Z, both during line NS-009. The Bathy-2000 chirp system proved temperamental. It was turned on at 2123Z, JD327, but was hung up from ~0305Z-0340Z, JD328 (23 November). Chirp and 3.5 kHz were interfering with one another.

During the turn from NS-010 to NS-004, a dolphin was observed near one of the guns and all guns were shut down. We were at the landward ends of NS-010 and NS-004, which extend farther landward than the other lines in the Nicoya box. Perhaps dolphins were more common in this nearshore area. When the MMOs gave permission, we ramped up to two GI guns (starboard inner and outer). The port boom was deployed during the turn so that the magnetometer could be towed from it. The port GI gun was also moved to the boom to ease congestion at the stern. This work extended past the start of line NS-004, which we therefore began acquiring with only two guns. The third was started shortly

MMOs observed two turtles at ~1616Z, JD 328, ~50 minutes into NS-004. Guns shut down. Simultaneously, bird 17 (closest to ship) was observed from the deck to be flying starboard of the streamer, instead of below, and causing a visible kink in the streamer. In addition, bird 17 had communication problems and may have been too far from the coil. We decided to end the

line and reshoot it as NS-004a, overlapping with NS-004. The streamer was pulled to retrieve bird 17 and add weight to the 50 m head stretch section (making a total of 10 kg on that section) while heading back on a reciprocal course to start of line. Communication with bird 17 was restored and its collars adjusted to correct its attitude. Bird 12 is not communicating, but the streamer is stable and it appears to be working, so we did not retrieve it.

More turtles were observed during this extended turn causing repeated stoppages and ramp-ups. We were unable to start shooting on line NS-004a: a lone dolphin persisted in following the ship. The magnetometer was started at ~2100Z, JD 328 on line NS-004a, but failed again after a few hours. We were finally able to start one GI gun at 2300Z, JD 238, and began to acquire data with one gun on NS-004a. The dolphin was just outside the safety radius and we could not ramp up to 3 guns until 2353Z, JD 328.

We were able to complete the remainder of NS-004a and shoot the following line (NS-008). A Seisnet crash resulted in no data being recorded to the RAID from 0900Z to 0939Z, JD 329 (24 November). These data were recovered from 3490 tape 87.

Operations were again suspended (12:30Z, JD 329) because of the presence of a dolphin after shooting for only ~20 minutes on the following line (NS012). For at least 24 hours, MMOs had been recording vocalizations, using PAM, that seem to be the signature of a single dolphin. This evidence strongly suggests that the same dolphin has been responsible for all shutdowns. The vocalizations were also recorded at night, when the animal was not observed visually and we were therefore shooting with all three GI guns. MMOs believed that this indicated that three GI guns are not harmful to the animal. The chief MMO, Meike Holst, contacted Michael Rawson at LDEO to request that he seek guidance from NMFS. We also requested that we be allowed to use reduced safety radii because we are using 45/45 cu in GI guns, instead of the 105/105 cu in guns for which the existing radii were calculated.

Meanwhile, at ~1400Z, JD329, we passed the >100 m bathymetric contour into deeper water, thereby contracting the safety radius. We were therefore authorized by MMOs to start a single GI gun and began acquiring data with one gun. The dolphin remained near the edge of the safety radius. We started a second GI gun at 1458Z, JD 329 and the third at 1504Z, because the dolphin appeared to have left. However, it returned at 1620Z and we had to cut back to one GI gun. We were able to ramp up to two GI guns at 1720Z and three by 1728Z, in spite of the presence of a large school of spinner dolphins nearby, but outside the safety radius.

We were able to continue shooting NS-012 and continue onto cross-trench lines NS-010L and NS-004L. These lines were shot with 25 m shot spacing and 8 sec record lengths, instead of the 12.5 m shot spacing and 4 sec record lengths, because of the great water depth over the trench (up to ~4900 m) The returns were weak in these water depths and we discussed using 105/105 cu in GI guns for trench crossing lines in the remaining, nore northerly boxes.

Meanwhile, we received permission to used revised, reduced marine mammal safety radii for 45/45 cu in GI guns that are 0.754 x those for 105/105 cu in GI guns ($0.754 = (45/105)^{1/3}$). Revised 180 dB safety radii for 3 x 45/45 cu in GI guns are: 433 m, 93 m and 62 m in water depths of <100 m, 100-1000 m and >1000 m, respectively. (Equivalent numbers for one GI gun, i.e., when powered down, are 143 m, 31 m and 20 m, respectively.) We were required to continue to use the 105/105 cu in 170 dB safety radii for turtles pending NMFS permission to reduce those as well.

The Bathy-2000 chirp system was turned off from 0329Z–0335Z, JD 330 (25 November), to change the recording disk.

The record length was reduced to 4 sec, but the shot interval was not returned to 12.5 m after completing NS-004L. Line NS006 was therefore shot with a 25 m shot spacing. The error was noticed in the middle of the line and it was decided to wait until the end of the line to change to 12.5 m shot spacing. We had to power down to one GI gun at 1154Z, JD 330 during NS-006 because of the presence of dolphins. We were able to resume shooting with three guns by 1211Z. We also powered down (to two GI guns instead of one because of a miscommunication) at 1445Z, JD 330, still on NS-006, because of a turtle sighting. We ramped back up to three guns at 1513Z. All guns were turned off at 1525Z, JD 330, line NS-006, because of a turtle sighting. Ramp-up began at 1600Z and was complete by 1611Z. There was a short power down to one gun at 1646Z because of the presence of two(?) humpback whales just within the safety radius. Three guns were restored by 1653Z in time to complete NS-006, the final line we would be acquiring in the Nicoya Box, at 1710Z, JD 330. The next line (NS-109) took us northward toward the Sandino Box.

It was noticed that the Bathy-2000 screen was not displaying a filename. The disk appeared to be full. It is possible that some or all Bathy-2000 data, gathered since change of recording disk at ~0330Z, JD 330, have been lost. The disk was changed again, but a disk full message was still displayed. The problem was investigated by Ted Koczynski and Anthony Johnson. The Bathy-2000 was restarted at ~1730Z, JD 330.

We started line NS-109 while ramping up from a shut down. The first shot point was SP5 with one gun. Ramp up was complete by 1845Z, JD330, at SP 140. We were shut down again at 1958Z because of a turtle sighting. Ramp up to three guns was delayed until 2106Z. Another shut down occurred from 2118Z to 2152Z, also because of a turtle sighting.

The 3.5 kHz was accidentally turned off ~1850Z, JD 330 (NS-109) and restarted at 0206Z, JD 331.

At ~0515Z, JD 331 (26 November), wind speeds were up to 20 kt and the ship was experiencing a current of ~1 kt in the direction of travel (NW along NS-109). Speed through the water was ~3.5 kt and speed over the ground was ~4.5 kt. Streamer depth was variable and there was considerable wave noise in sections that became elevated. Ship speed was increased to ~4.8 kt over the ground and this improved streamer behavior. The 3.5 kHz was down from ~1400Z-~1445Z, JD 331. A shut down from 1813Z-1925Z was caused by a turtle sighting (still on NS-109). The shutdown continued into the turn to NS-073, our first profile of the Sandino Box.

The 3.5 kHz plotter failed at the start of NS-073 and data were lost. The plotter was restarted at ~0312Z, JD332 (27 November) with NS-073 in progress. It was down again for maintenance from ~1445Z, JD 332 to 1615Z on Line NS-071 and shortly after restarting was turned off. We have decided to rely on the Bathy-2000 chirp and are feeding that record to the plotter previously used for the 3.5 kHz record.

Meanwhile we were shut down because of a turtle sighting from 1440Z to 1549Z, JD 332, on NS-071. We were almost immediately shut down again at 1603Z (turtle sighting) and this shut down extended to EOL NS-071. After 50 minutes of acquisition on the following line (NS-069), we were shut down from 1850Z to 1936Z, then again from 1946Z to 2113Z, 2159Z to 2237Z, and 2241Z-2319Z, again because of turtles. We were shut down for almost 3.5 hours out of a line that took ~5 hours to shoot. We sent an email to Michael Rawson of LDEO explaining our predicament and requesting that he attempt to obtain a relaxation of the mitigation procedures for turtles.

On NS-067, we powered down to one gun (0300Z to 0319Z, JD 333, 28 November), because of a dolphin sighting and shut down from 0323Z to 0403Z because of a turtle. These were the first time that animals had been observed in darkness. This was possible because of the calm seas.

We were able to talk to Michael Rawson (LDEO) by telephone ~0340Z, JD 333. He agreed that the 30-minute shutdown for turtles was extreme and that we should use a shorter period. We discussed this with the MMOs and agreed to use 10 minutes for <100 m water depth and 4 minutes for >100 m. The 10-minute figure is based on the time taken for the ship moving at 4.5 kt to leave a turtle outside the 170 dB safety radius for 3 x 105/105 cu. in. GI guns (1325 m in <100 m water depth; time to travel this distance = 9.5 minutes). The safety radii for 100-1000 m and >1000 m are 398 and 265 m, respectively, and the corresponding transit times are 3 and 2 minutes, respectively. We agreed to use a more conservative 4 minutes for both of these depth ranges. JDs 332 and 333 were Saturday and Sunday, respectively, so communications with NMFS seeking approval of these changes were delayed. In subsequent communications between NMFS and the MMOs, NMFS neither explicitly endorsed, nor objected to, the changes. NMFS concern was that the originally specified take not be exceeded. Since the new procedures remained based on the originally specified safety radii, we felt that this was unlikely. Furthermore, the procedures are equivalent to the IHA rule that we not proceed to shoot "…unless no marine mammals or sea turtles are detected within the appropriate safety zones…". The difference was that we were relying on the ship motion to clear the turtles from the safety zone, without direct observation of the turtle exiting the zone. Such observation was often impossible, depending on sea state. Finally, if the shut down is limited to 4 minutes, this should obviate the need for a ramp up (see IHA, item 5(g)). Although item 5(g) refers to a "power down", we (Co-Chiefs and MMOs) believed that it should be taken as meaning "shut down". This opinion was based on the Environmental Assessment, which states that (p. 12): "…a ramp up would be required after a power down or shut down period lasting ~ 4 min or longer…" and also on experience from previous cruises for which a time period was provided that represented the maximum shut-down period allowed before a ramp up became necessary on the restart. We, therefore, omitted the ramp up after shut downs of 4 minutes.

At 0458Z, JD 334 (29 November), we noticed that the latitude and longitude on the Bathy-2000 output (screen and paper record), and also the ship speed on the paper record, were not changing. It was not clear how long this has been going on (examination of the paper records should provide that information). Ted Koczynski shut down the Bathy-2000 at 0508Z and restarted it. That corrected the problem.

From ~0650Z to ~0723Z, JD 334, ~388 shots (numbers 2682-3069) were missed on NS-059 because of a problem with the Seisnet computer. We restarted recording to tape, but not to Seisnet. There are no 3490 reel numbers 327-329 and an uncertain amount of information on 326. Because of rough seas, we reset the birds from 2.5 m to 3.0 m at 1607Z in attempt to reduce streamer noise. As we came on line for NS-055, the center gun was too close to the streamer, which was still deflected as a result of the turn. Therefore, we shut down the center gun at 1703Z, 6 minutes into the line, to allow the streamer to straighten. We restarted the third gun at 1724Z. The streamer was reset to 2.5 m by 2320Z, JD 334, prior to the start of NS-053.

NS-051 was started at 0750Z, JD 335 (30 November) with only two guns firing. Streamer depth was variable because of the following current while shooting SE-NW. ~0926Z, it was discovered that the center gun had overridden the streamer. The third gun was not started until 1038Z. At 1102Z, the streamer depth was changed from 2.5 m to 3.0 m to reduce noise and the

record length was changed from 4 to 3.5 sec, to avoid missing shots because of the high speed over the ground necessary to keep up the speed through the water. About 40 shots (1535-1574) were missed while changing record length. At 1146Z, still on NS-051, recording spontaneously stopped after shot 2114. The next shot recorded was 2523 at 1205Z. The record length was reset to 4 sec and bird depth to 2.5 m after the end of line NS-051 during the turn to the first dip profile in the Sandino Box, NS-090.

We powered down to one gun at 2138Z, JD 335, because of a turtle sighting. Three guns were firing again by 2143Z, or first implementation of our revised power-down/shut-down procedures. Some fishing gear was observed to be caught on the streamer at bird 12 at ~2225Z. The fishing gear was removed using the rescue boat at 2300Z. It was not necessary to pull in the streamer.

During the turn from NS-090 to NS-086 (~0320Z, JD 336, 1 December), the magnetometer was turned off and reeled in until the tow fish was just beneath the surface to prevent the fish touching the seafloor (water depth ~50 m). The magnetometer was restarted at 0400Z, ~15 minutes after SOL NS-086 (0346Z). The ship was over 400 m left of the line at SOL NS-086 because of the need to avoid traffic. We were back on track at 0440Z.

The Syntron recording system stopped recording data some time between 0517Z, when the last tape was changed, and 0536Z, when the problem was noticed. Recording was restarted at 0556Z. Seisnet has been disconnected. It was thought to be the source of the crashes: there had also been earlier crashes. (This opinion changed later and SeisNet was restarted four days later.) We lost 312 shots (~26 minutes). The Syntron was again observed to be not recording data at 0625Z (it may have failed earlier) and ~423 shots were lost. Recording began again at ~0639Z. However, it stopped again at ~0716Z, with a loss of ~343 shots before restarting at 0745Z. It stopped for a third time at 0853Z. Dietmar Kathman swapped out one of the 3490 drives. The problem turned out to have been that GPS had failed, not the Syntron. We had powered down to one gun, but were firing with three guns and recording by 0927Z.

The ship suffered a total power failure, including propulsion, at 1105Z, JD 336 on line NS-086 (3490 tape 433). A broken linkage in the governor of one of the two engines that were running caused that engine to shut down. Instead of the compressors automatically being shut down to reduce the load on the remaining engine, that engine was overloaded and also shut down. Power was restored, but failed again briefly, perhaps twice. It had been fully restored by ~1130Z. The guns were retrieved, to avoid entanglement, by 1155Z. The PAM and magnetometer were left in the water, though the latter was reeled in to prevent it touching the seafloor as the ship slowed. It had been let out again by 1200Z. Bathy-2000 acquisition was also interrupted. It was restarted at 1206Z. We turned back to reshoot the line as NS-086A, overlapping with NS-086 to ensure coverage of the part of the line that had been lost as a result of the power failure. The guns were redeployed and we had ramped up to 2 guns by 1426Z, still in the turn back toward line NS-086A. NS-086A was started at 1500Z, JD 336. Copying of 3490 tapes to DAT DDS-3 tapes was shut down after the power failure. The original 3490 tape drive used for copying was damaged by the power failure and was replaced with a spare, but tape copying resulted in error messages. The problem arose as a result of corrupted headers on 3490 tapes 431 and 432, possibly caused by the problems with the Syntron system before the power failure. Tape copying resumed at ~0215Z, JD 337.

We shut down because of a turtle sighting at 2122Z, JD336 (NS-082), but restarted at 2126Z, the second implementation of the revised shut-down procedure. At 0000Z, JD 337 (2 December), the ship slowed to 4 kt and then, at 0019Z, deviated to port to avoid fishing gear on NS-082.

Maximum offline distance was 300 m at 0030Z. We shut down for a turtle at ~1310Z and restarted ~1314Z on NS-078.

After the end of line NS-078, the guns were retrieved and the spacers removed to convert their capacities to 105/105 cu. in. The purpose was to achieve better results on upcoming deep-water profiles NS-080L and -074L crossing the trench. However, we also planned to shoot profiles NS-080 and -074 across the shelf using the 105/105 cu.in. guns in order to compare results with those obtained using 45/45 cu. in. guns, in particular to determine whether penetration improved significantly using the larger gun volumes. The guns were redeployed and synchronized by 2038Z, JD 337, during an extended turn to the start of NS-080L.

Seas were rougher during NS-080L than at any time during the cruise so far, with wind speeds up to 29 kt ~0300Z-0400Z, JD 338 (3 December). The PAM streamer was reeled in at ~0550Z, during the turn from NS-080L to NS-074L, because the port gun was veering into it. It was not redeployed until ~1500Z. Tape drive 0 experienced problems at 1448Z, JD 338. We lost 19 shots on profile NS-074L while changing drives. We also lost ~10 shots intermittently at ~2131Z because of low air pressure, also on NS-074L. We turned a little before the end of NS-074L because we had reached 20 m water depth. The magnetometer was turned off and both it and the PAM were reeled in to reduce their towing depths as we approached the shallow-water end of NS-074L (times not noted).

We also missed the beginning of the next line, NS-080, in order to avoid traffic. We started NS-080 at 0321Z, JD 339 (4 December) at shot point ~90 and ~250 m to the left of the line, on a converging course with the streamer probably still not straight. We were on line by 0330Z. The magnetometer and PAM were redeployed at 0407Z. We stopped recording on Bathy-2000 during turn from NS-080 to NS-070 to swap recording disks (1524Z, JD 339). Also during the turn, the port gun was retrieved to repair chafing to the cable.

We decided to continue shooting with 105/105 guns on profile NS-070, because we had not yet produced a stack of either of the two shelf profiles (NS-074L and NS-080) shot with 105/105 guns for comparison with one of the dip profiles shot with 45/45 guns. Such a comparison was necessary before deciding whether to change back to 45/45 or continue with 105/105 for the remainder of the cruise.

NS-070 was started before the ship had passed the waypoint and the first shots were not supplied with navigation data. The line was therefore restarted after ~5 minutes at 1716Z, JD 339; the first shots (on 3490 tape 600) may not be useful. We were forced to shut down four times (2100Z-2028Z, 2032Z-2036Z, 2241Z-2245Z) and power down to one gun once (2142Z-2245Z) on NS-070 (JD 339). The streamer depth was increased from 2.5 m to 3.0 m at 2330Z, JD339, also on NS-070, to reduce noise during a period of rougher seas.

At ~0230Z, JD 340 (5 December) we compared preliminary stacks of NS-090, shot with 45/45 ci. in. GI guns, and NS-074L, shot with 105/105 cu. in. guns. We decided that the 45/45 guns provide better results: shooting with 105/105 guns did not significantly improve penetration, whereas there is an apparent loss of horizontal resolution as a result of the larger (25 m versus 12.5 m) shot spacing used with 105/105 guns. In consultation with the Captain, it was decided that we would not make the change back to 45/45 at the end of NS-070, because that lay at the landward edge of the grid where the volume of traffic is greater and we would be operating in darkness at ~0000 local time. Therefore, we decided to make the change at the end of the next profile (NS-066), at the seaward edge of the grid.

At 0538Z, at the end of line NS-070, we observed that channels 112 and 113 were very noisy, perhaps the result of debris caught there (at bird ~12?).

After the end of NS-066 (1613Z), we retrieved the guns during and extended turn to NS-062. The spacers were replaced to make their capacities 45/45 cu. in. once more. This work was completed by 1722Z. Record length was changed from 8 sec. to 4 sec. and shot spacing from 25 m to 12.5 m. Seisnet was also restarted during this turn.

The ship ran over some fishing gear at ~1947Z, JD340 (NS-062). Shortly afterwards a fishing boat approached the streamer. We could not contact it by radio and it was approaching the streamer. An emergency dive of the streamer to 25 m was performed at 1950Z. After the boat had passed the streamer, it was gradually returned to an operating depth of 2.5 m. This represented a change from the 3.0 m depth with which NS-062 was begun. Turtle shut downs occurred from 2004Z-2008Z, 2020Z-2024Z and 2226Z-2230Z, with a power down to one gun from 2218Z-2222Z, all on NS-062.

On the next profile, NS-058, we had multiple turtle-related shut downs at 1311Z-1315Z, 1409Z-1413Z-1417Z, 1546Z-1550, 1609Z-1614Z, and 1704Z-1709Z and power-downs to one gun at 1712Z-1714Z, 1755Z-1759 and 1816Z-1821Z, JD 341 (6 December). Unusually, these events occurred even near the most seaward edge of the grid on this dip profile. Turtles have more commonly affected acquisition nearer shore.

Channels 112 and 113 remained noisy and channels 10-12 had also been displaying noise for possibly ~24 hours (as of 1504Z, JD 341). These were the two most persistently noisy parts of the streamer. There was also intermittent noise in channels 61-63 and some around channels 19-20. We decided, therefore, to surface the streamer after the end of NS-058 and to inspect it from the ship's rescue boat to determine whether any debris had become entangled. NS-058 ended at 1834Z and we continued on a straight course. We surfaced the streamer and deployed the rescue boat at ~1840Z. The rescue boat was retrieved at 1930Z. Fishing floats were retrieved from birds 3 and 11, around problem channels 10-11 and 112, respectively. The boat crew also reported fishing line, which they were unable to remove because of the motion of the rescue boat, lying along much of the streamer. The hope was that would not cause such severe noise as the repeated impacts of the floats against the streamer. We then turned back towards the start of line NS-054 (started 2217Z). The removal of the floats improved the noisy channels, except for channel 19.

There were no shut downs on NS-054. However, on the next profile (NS-050) we experienced multiple turtle shut downs during a short period at 1436Z-1440Z, 1459Z-1503Z, 1504Z-1508Z, 1515-1520Z, 1521Z-1525Z and 1609Z-1613Z, JD 342 (7 December).

At 0122Z, JD343 (8 December), the bird depths were changed from 2.5 m to 3.0 m to improve depth control (profile NS-056). The next line, NS-103 (partial) was the regional profile that would take us northwest toward the Gulf of Fonseca. This northern part of NS-103 was started at 0506Z, JD 343. Streamer depths fluctuated widely at the beginning of the line because of the following current. The POS MV gave navigation errors at 1205Z. We experienced multiple turtle shut downs on NS-103 at: 1219Z-1224Z, 1527Z-1531, 1641Z-1647Z, 1709Z-1718Z, 1822Z-1826Z, 1848Z-1852Z, 1926Z-1930Z and 1937Z-1941Z, JD 343, and powered down to one gun from 1718Z-1726Z and 1814Z-1818Z, JD 343. Immediately following the power down from 1718Z-1726Z (JD 343), we remained shooting with only two guns from 1726Z-1748Z while the port gun was moved 1.7 m farther outboard along the gun boom to reduce interference with the main streamer and the PAM streamer (NS-103).

NS-103 ended at 0506Z, JD 344 (9 December) and we turned toward NS-102 that would take us to the mouth of the Gulf of Fonseca. We started NS-102 at O634Z, JD 344, and were just entering the Gulf ~1430Z, having passed six outbound fishing boats. There was a deviation (~90 m) from the line at ~1338Z and another (~80 m) at ~1420Z to avoid this traffic. The streamer was still set to 3 m and consistent noise was noted in channels 19 (also noted previously), 91 and 129 (1338Z). We deviated to starboard from the line again, beginning at ~1621Z, to avoid fishing gear. The ship continued diverging from the track until the end of line NS-102 (deviation was ~700 m at ~1701Z). We were powered down to one gun at 1629Z because of a pair of humpback whales (NS-102) and shut down at 1633Z. Ramp up began at 1637Z (1 gun) and three guns were firing by 1648Z. The bridge needed to go beyond the original end of line for NS-102 in order to make the turn, so we took advantage of this to continue shooting beyond the original end of line (added a “runout” of 150 shots). However, we were still diverging from the original track and increasing the offset. NS-102 ended at 1710Z, without completing the entire runout. We were shut down because of the return of a whale during the turn (1715Z). Ramp up began at 1720Z (1 gun) with two guns on at 1726Z, still during the turn. We took the opportunity to reset the birds from 3.0 m to 2.5 m during the turn. Seas are calm.

Line NS-100, taking us back out of the gulf, started at 1749Z. We were 665 m off track to port at the start of line, converging on the correct track, which we had joined by ~1810Z. The signals in the far offset channels were very weak in the shallow water, as they had been near the end of NS-102. It was reported that the ship had passed through a fishing line at ~1830Z, but the streamer continued to function well. NS-100 ended at 0314Z, JD 345 (10 December).

Profile NS-105 (partial) started at 0430, JD 345. The ship was 100 m to port of the track at the start of line. The streamer depth was set to 3 m from 2.5 m at 1152Z to improve its towing behavior and reduce noise. A small, open fishing boat came alongside at ~1430Z and reported that their fishing line ran through this area. When told that we were towing at 3.0 m, they appeared unconcerned and left, so their line must be deeper. We experienced turtle shut downs on NS-105 at 1451Z-1455Z, 1518Z-1522Z, 1603Z-1607Z, 1742Z-1747Z, 1908Z-1913Z and 1941Z-1945Z, JD 345. We also powered down to one gun because of turtles at 1715Z-1720Z and 1949Z-1953Z, JD 345. The streamer was noted to be noisy at 2330Z, JD 345 and the noise persisted. Wind speeds were ~22 kt at 0257Z, JD 346 (11 December), which may have contributed to the noise. However, the streamer was maintaining its depth of 3.0 m well. It is possible that we have picked up fishing gear, but the noise is distributed in broad zones along the streamer instead of localized, as might be expected if the streamer was entangled with debris (still on NS-105 (partial)). The streamer was still noisy at 1400Z, JD 346, when wind speeds were 19-27 kt and seas ~2 m. Line NS-105 (partial) ended at 1556Z.

The first profile in the Salinas Box, NS-022 (partial), began at 1707Z, JD 346. The streamer continued to be noisy and its depth variable because the seas were coming from astern. Streamer depth fluctuations created a wave along the length of the streamer. Reduced bird response times at ~1803Z to see if that would help stabilize the streamer. Profile NS-022 (partial) ended at 2300Z and NS-026 began at 2355Z with the ship ~750 m t port of the track. However, a problem with the Spectra system meant that the shot interval defaulted to 25 m at the beginning of the line. This was corrected to 12.5 m, but the first ~160 shots of NS-026 were lost. These data were, however, very noisy, with the streamer near the surface. There was still a great deal of streamer noise even on this new heading into the seas. Wind speeds were 23-27 kt on NS-026 at 0240Z, JD 347 (12 December). Wind speeds were up to 30 kt at 0544Z (NS-026). Data quality had greatly improved the next morning (~1400Z, JD 347), when wind speeds were down to 14-20 kt at the landward end of NS-026 and beginning of NS-034. Furthermore, winds were from the

NNE (offshore) and the fetch was very short at this turn, our closest approach to shore within the Salinas Box. Wind speeds increased as we moved farther from shore on NS-034, up to 27 kt at 1520Z. Depth control by bird 4 was erratic ("open fin loop") at 2207Z, JD 347. Bird 4 was reset at 2219Z and that corrected the problem.

Profile NS-034 ended at 0231Z, JD 348 (13 December). The next profile, NS-030, started at 0230Z. We started recording late and missed the first 88 shots. The streamer was very noisy at the start of line. This extreme streamer noise diminished shortly after the start of line, but noise continued at a reduced level, similar to the pattern of the last day or two, with winds from the south at up to 24 kt at 0520Z and 30 kt at 1207Z (NS-030). NS-030 ended at 1412Z, JD 348.

NS-038 started at 1527Z, JD 348. We initially started too early, before the ship had reached the start point, and had to restart, missing a few shots. At ~2247Z, it was noticed that some fishing gear had become caught on the magnetometer. The magnetometer was pulled in, but when it had almost been fully retrieved, the debris fell off and drifted astern, catching on bird 6 (fishing floats are holding it near the surface), and possibly bird 4. We therefore decided to pull in the streamer at the end of NS-038 to remove the gear. The magnetometer was working again at 2318Z, JD 348. It was shut off for retrieval at 0220Z, JD 349 (14 December). The PAM streamer and the magnetometer were retrieved first. Line NS-038 ended at 0226Z. We continued seaward and recovered the streamer. Parts of the streamer and several of the birds were tangled with fishing line and bird 6 was encumbered with floats and a high flier. Several other floats were attached along the streamer. A live mahi-mahi was recovered hanging from a fish hook. The streamer had been fully recovered by 0500Z and the ship turned toward the start of NS-042 so that we could redeploy the streamer on the approach to the waypoint. On redeploying the streamer, we replaced a section that was leaking oil. We had just completed redeployment when it was noticed that bird 7 was consistently near the surface. We suspect it may already have caught a fishing float. However, we had arrived at the start of NS-042 and all personnel were tiring. We decided to shoot NS-42 and revisit the question of bird 7 in the morning. NS-042 began at 0806Z, JD 349.

Bird 7 continued to remain near the sea surface and bird 6 was also frequently too high. Nearby channels were very noisy. Several attempts had been made to correct the problem. For example, bird 7 was set to zero fin angle and adjacent birds 6 and 8 were set to 4 m, in an effort to pull bird 7 deeper (remaining birds were still set to 3.0 m; ~1615 Z, JD-349). This did bring bird 7 down, though it remained high relative to the other birds. Furthermore, the streamer noise persisted, though at a somewhat reduced intensity. We decided to recover the streamer again at the end of NS-042. Meanwhile, we experienced our first turtle shut down since JD 345 from 1737Z-1741Z, JD 349, on NS-042.

NS-042 ended at 1914Z, JD 349, and we continued on course to recover the streamer. The center gun, magnetometer and PAM streamer were pulled to prevent interference. The streamer was pulled in to bird 7 without finding any fishing gear. However, bird 7 was hanging from only its forward collar. The bird batteries had drained and were replaced, but bird 7 was otherwise in good condition. Meanwhile, we pulled the streamer in to bird 6, which seemed fine (except for the wings being slightly out of alignment, a condition not previously noticed and not thought to be a problem). We therefore began redeploying the streamer at ~2025Z without recovering the rest of the streamer. However, we had noticed two new leaks in the streamer. Both were patched, since they did not appear to have caused significant loss of oil. The streamer had been redeployed by 2100Z and the ship was turning back toward the start of NS-044. All birds were

holding depth well: they were still set to 3.0 m because wind speeds were still ~25 kt. Magnetometer and PAM were redeployed by 2115Z.

Profile NS-044 was begun at 2225Z, JD 349. The streamer tended to form a sine wave with variable towing depth on this southwesterly heading due to the following current. The port gun appeared to have crossed over the PAM streamer, which was towing inboard of that gun (noticed at ~0451Z, JD 350; 15 December). The port gun was turned off from 0455Z to 0511Z and we continued NS-044 with two guns during this interval. The PAM streamer was partly reeled in (by ~0500Z) and the gun freed itself. However, there was concern that the PAM streamer might become entangled with the seismic streamer in these following seas, so the PAM was completely reeled in (by ~0520Z).

Shortly after the start of the next line, NS-023, the streamer depth was changed from 3.0 m to 3.5 m to reduce streamer noise (1217Z, JD 350). Wind speeds were up to 30 kt from the east and seas 2-3 m. The current speed was up to 2 kt: it reduced speed over the ground on this southeasterly course to 3 kt, while the ship made 5 kt through the water (1456Z). NS-023 ended at 1701Z, JD 350. NS-027 started at 1836Z with the ship still 250 m to port of the line. At 1847Z, the center gun was turned off because it was too close to the streamer. The quartering seas and following current were causing this interference. The ship was back on track at 1902Z; the ship heading was ~25° to the right of the course made good because of the current and seas. The third gun was restarted at 1915Z and the PAM streamer was redeployed at 2022Z. NS-027 ended at 2150Z, JD 350.

The next line, NS-031, started at 0010Z, JD 351 (16 December) and ended at 0412Z. We then turned towards NS-107 (partial) that would take us from the Salinas Box back to the Sandino Box to collect some additional dip profiles there in order to obtain partial coverage at 2-km line spacing. NS-107 (partial) began at 0633Z. Multiple turtle shut downs occurred from 1328Z-1333Z (2 guns back on at 1333Z and 3 guns at 1334Z), 1555Z-1559Z, 1640Z-1644Z, 1723Z-1727Z, 1820Z-1824Z, 1828Z-1833Z, 1852Z-1856Z, 1902Z-1907Z and 1927Z-1931Z, JD-351. We powered down to one gun for a turtle from 1802Z-1805Z and 2149Z-2151Z, JD 351. Meanwhile, weather conditions had improved substantially and at 1810Z the streamer depth was changed from 3.5 m to 3.0 m. When it behaved well at that depth, its towing depth was decreased further to 2.5 m at 1813Z, JD 351 (NS-107). NS-107 (partial) ended at 2314Z, JD 351.

We turned onto NS-088 (partial), in the Sandino Box, starting the line at 0036Z, JD 352 (17 December). At 0217Z, the center and starboard guns became tangled and were shut off. We continued acquisition with only the port gun while the other two were recovered and untangled. The center gun was restarted at 0232Z. The starboard gun was redeployed, but continued to veer into the center gun. The chains connecting the starboard gun to its float were rearranged to improve its towing attitude. The starboard gun was finally restarted at 0251Z. At 0340Z, we powered down to one gun because bow-riding dolphins were observed visually. Water depth was 400 m and the 3 x 45/45 cu. in. GI gun safety radius was therefore 93 m. The ship was 70 m long and the guns were towed 40 m behind, so the distance from the bow to the guns was 110 m. The bow was therefore technically outside the safety radius, but the PAM was picking up the vocalizations of many animals, so we powered down in any case. We ramped up to two guns at 0436Z and to three at 0440Z, JD 352. NS-088 ended at 0624Z.

The next line, NS-084, began at 0715Z, JD 352. Speed was reduced to 4.0 kt to allow a fishing boat ahead to bring in gear. This lasted until ~1000Z. We experienced multiple turtle shut downs from 1244Z-1248Z, 1407Z-1411Z, 1417Z-1421Z, 1422Z-1426Z, 1522Z-1526Z, 1559Z-1603Z,

JD 352. We also powered down for turtles from 1643Z-1649Z, JD 352. NS-084 ended at 1726Z and we turned toward NS-076.

NS-076 began at 1834Z, JD 352 and significant turtle shut downs began shortly afterwards. These involved sightings of multiple successive turtles during each shut down, lengthening the shut downs and necessitating ramp ups. In addition, the earliest shut downs occurred in <100 m water depth, requiring, at minimum, 10-minute shut downs. Shut downs (if ramp up was involved, periods between shut-down and start of ramp up are given) occurred from 1851Z-1907Z, 1914Z-1942Z and 2007Z-2019Z JD 352. We also experienced a turtle power down to one gun from 2119Z-2126Z. We made an XBT cast at ~0220Z, JD 353 (18 December). Then, at 0253Z, we had to power down to one gun for dolphins, once again bow-riding as they had the previous night. Ramp up began at 0326Z and we were back to three guns at 0332Z, JD 353. We performed an XBT cast at 0455Z, but the wire broke. NS-076 ended at 0459Z, JD 353. We subsequently made a successful cast in ~1680 m water depth at 0510Z, during the turn to NS-072 (partial).

NS-072 (partial) started at 0545Z, JD 353. There was a power down from 0851Z-0908Z and NS-072 (partial) ended at 0937Z, JD 353. The ship then turned onto NS-103A, the strike profile that would take us from the Sandino Box, back through the Salinas Box to the Nicoya Box.

NS-103A was begun at 1041Z, JD 353. Ted Koczynski (Science officer) reported that the GPS positions were being degraded and had been for ~2-3 hours (as of 1646Z). Accuracy was 3.9 m instead of ~0.5 m. The C-Nav system was cycled at ~1700Z, JD-353, correcting the problem and producing accuracy of ~0.33 m. At 1947Z, recording stopped because of a bad “can” (DAM), (No. 10: there are 14 “cans” and 10 is the fifth from the ship). All communication with the streamer was lost and no data were recorded. We partially recovered the streamer to replace the bad “can”. In addition, we decided to turn back and reshoot the part of the profile that was lost, because we had not yet reached the Salinas box to complete our along-strike tie between it and the Sandino Box. NS-103A, therefore, ended at 1947Z. The remaining portion was shot as NS-103B, overlapping with NS-103A. The “can” had been replaced and the streamer redeployed by 2115Z, while first moving farther along the track and then during the turn to a reciprocal course to achieve overlap. NS-103B was begun at 2236Z, JD 353, ~2 km NW along track from the position occupied on NS-103A at 1945Z. We made an XBT cast at 0330Z, JD 354 (19 December), on NS-103B within the Salinas Box (190 m water depth). Streamer depth was increased from 2.5 m to 3.0 m at 1030Z. NS103B ended at 1300Z, JD 354 and we turned toward NS-002 (partial) in the Nicoya Box.

NS-002 (partial) began at 1408Z, JD 354. We made an XBT cast at ~1440Z in 105 m water depth. NS-002 (partial) ended at 1743Z and we started the turn to the last line of the survey, NS-101 (partial). We launched an XBT during the turn at ~1800Z in ~1300 m water depth. At the same time, the ship passed between at least three fishing floats, but it was not apparent that any gear had been snagged.

NS-101 (partial) started at 1914Z, JD 354. The ship veered off line to avoid fishing gear at 1917Z and 1938Z, straying up to ~130 m from the track (to starboard). Streamer depth was changed from 3.0 m to 3.5 m at 2224Z, JD-354. Bird 13, 14 and 15 were noticed to be abnormally deep (5-6.5 m) and attempting to rise ~0155Z, JD 355 (20 December). Bird 13 was generally deepest of the three. They subsequently rose, but always had large wing angles as they worked hard to stay up. Wind speeds were E to ENE, 25-33 kt at 0212Z. Last shot on NS-101 (partial) was at 0354Z, JD 355. The ship turned to port, into the wind, to recover the streamer for the last time on cruise EW04-12.

The guns, PAM streamer and magnetometer were recovered first, during the turn. The starboard inner (center) gun was encumbered with fishing line and a float. In addition, the port boom, from which the port gun and magnetometer had been towed, was brought inboard. The head stretch section was removed from the streamer and fed onto a separate reel. The streamer was then recovered. There was a considerable amount of XBT wire on the streamer forward of bird 13. Bird 13, the bird that dived at ~0155Z, was entangled with fishing line and a float. Birds 12-9 were also encumbered with fishing line (plus one more float). The forward collar of bird 9 was loose and the bird was hanging only from its rear collar and lanyard. There was more fishing line on birds 4 and 3 and the tail float was trailing line, floats and a high-flier. Streamer recovery was completed by 0600Z. The log read 3240 n. mi. as the ship got underway for Panama at 0614Z, JD 355, or 0114Z, 20 November, ship's time (note the ship's clocks were advanced one hour on the night of 18 December (JD353) to conform to Panama's time zone).

The ship dropped anchor at ~1100Z JD 357, ~6:00 AM local time, 22 December off the mouth of the Panama Canal, then weighed anchor at ~1400Z (~9:00 AM local time), moving to a mooring at Rodman, on the North American side of the channel leading to the canal. The Ewing tied up at the dock at 1500Z (10:00 AM local time) ending cruise EW04-12. The log read 3787.42 n. mi.

RESULTS

Interpretation will be deferred until final processing is complete. However, some observations are possible at this early stage.

Shelf

Cenozoic strata above Cretaceous(?) basement thicken northward (compare Figures 3, 5 and 7). In the Sandino Box, the northernmost survey box, these strata are over 6 s. (two-way traveltime) thick in the deepest part of the basin, far in excess of the penetration (2-3 s.) of our seismic system (Figures 7 and 8). In the Sandino Box, strata with steep basinward dips, truncated at an angular unconformity near the seafloor, occur at the landward ends of dip profiles NS-74L and NS-80, which extend farther landward than most other dip profiles. These strata pass basinward into anticlines with more gentle dips, imaged on all dip profiles within the Sandino Box (Figure 7). The numbers (typically 2-3) and positions of these anticlines, as well as the tightness of the folding, change from profile to profile. We should be able to map this along-strike structural variation. The crests of the anticlines reach the seafloor in places and are visible on chirp profiles. Faults occur at the crests of some anticlines. Basinward of the anticlinal zone, but still beneath the shelf, strata are sub-horizontal, with clinoforms near the shelf edge, where the section is also commonly cut by faults. The top of the Outer-Shelf High of the Margin Wedge is just imaged at ~3 seconds near the shelf edge (Figure 7).

Over much of the shelf, chirp profiles reveal a thin (up to 20 m) layer of recent sediment overlying an irregular erosional uncomformity, possibly an erosional surface developed during the last glacial maximum. This unconformity, as well as other surfaces imaged by chirp profiles adjacent to anticlines, can also be resolved on the MCS profiles. The chirp profiles will therefore be an excellent complement to the deeper penetration MCS profiles

Only a thin (~0.2 s) layer of Cenozoic strata underlies the shelf to the south in the Nicoya Box. This layer overlies an irregular, erosional unconformity on top of basement (Figures 3 and 4).

Slope

Beneath the slope, the faulted top of the basement (Margin Wedge) is resolved, overlain by ~1 s. of slope sediment) Figures 3, 5 and 7). Faulting occurs within slope sediments and there is

evidence of both buried and surficial slope failure. In addition, the slope is incised by both modern and buried canyons. During the turn from the southeast end of NS-023 towards the start of NS-027 (Salinas Box), features resembling the current-related bedforms of the Eel River Basin were observed at ~900 m water depth on the chirp data. The presence of such bedforms is likely in view of the 1-2 kt southeasterly surface currents experienced during the cruise. A prominent bottom-simulating reflector (BSR), indicative of the presence of a hydrate layer, occurs below ~2.4 s. and lies ~0.6 s. below the seafloor.

Gulf of Fonseca

A major terrane boundary in onshore Honduras, the Guayape fault zone, extends from northeast to southwest toward the gulf and may be one reason for the existence of the gulf. The profiles appear to cross the tectonic boundary between the volcanic arc and the Nicaraguan Depression. This boundary developed recently as the volcanic arc migrated to the southwest. It is proposed to be a normal fault, down to the northeast, but it has not been seismically imaged and onshore exposures are non-diagnostic. The Nicaraguan depression may have had a significant effect on sedimentation patterns in the Sandino Basin because is probably traps most or all the sediment transported from the interior, except where it is breached in the Gulf of Fonseca. However the deveopment of the Nicaraguan Depression also coincides with a seaward shift of the volcanic arc, so its principal sedimentary effect may be a change in source from interior erosion products to a proximal volcanic source.

We crossed an uplifted block or anticline near the mouth of the Gulf of Fonseca (Figure 9). On the other side, within the gulf, lies a basin equivalent to the Nicaraguan Depression. The block/anticline is highly faulted. In addition, the strata both landward and basinward of the block/anticline are more pervasively faulted than equivalent strata beneath the shelf in the Nicoya, Salinas and Sandino boxes. Shallowly buried, subsurface channels, visible on both MCS and chirp records, may have been formed during the last glacial maximum and indicate that rivers flowed from the gulf and across the exposed shelf during that lowstand. Further interpretation of the structurally deformed section may show that earlier channel systems also exist.

SCHEDULE FOR MEETING OBLIGATIONS

International Participation

Local scientists Manuel Trana (INE, Nicaragua), Manuel Alvarez (INETER, Nicaragua), and Luis Castillo (University of El Salvador) participated in the cruise.

Data

Digital copies of the seismic data will be provided to the U.S. State Department for distribution to the Costa Rican, Nicaraguan, Honduran and El Salvadoran governments when data processing is complete. We expect to be able to provide the data by December 2005. We may also provide data directly to collaborating institutions in the region.

Scientific results will be made available through presentation at scientific meetings, beginning with the December 2005 meeting of the American Geophysical Union, and publication in the scientific literature, possibly beginning in 2006. We will also be interacting directly with local scientists, including our shipboard observers from Nicaragua and El Salvador.

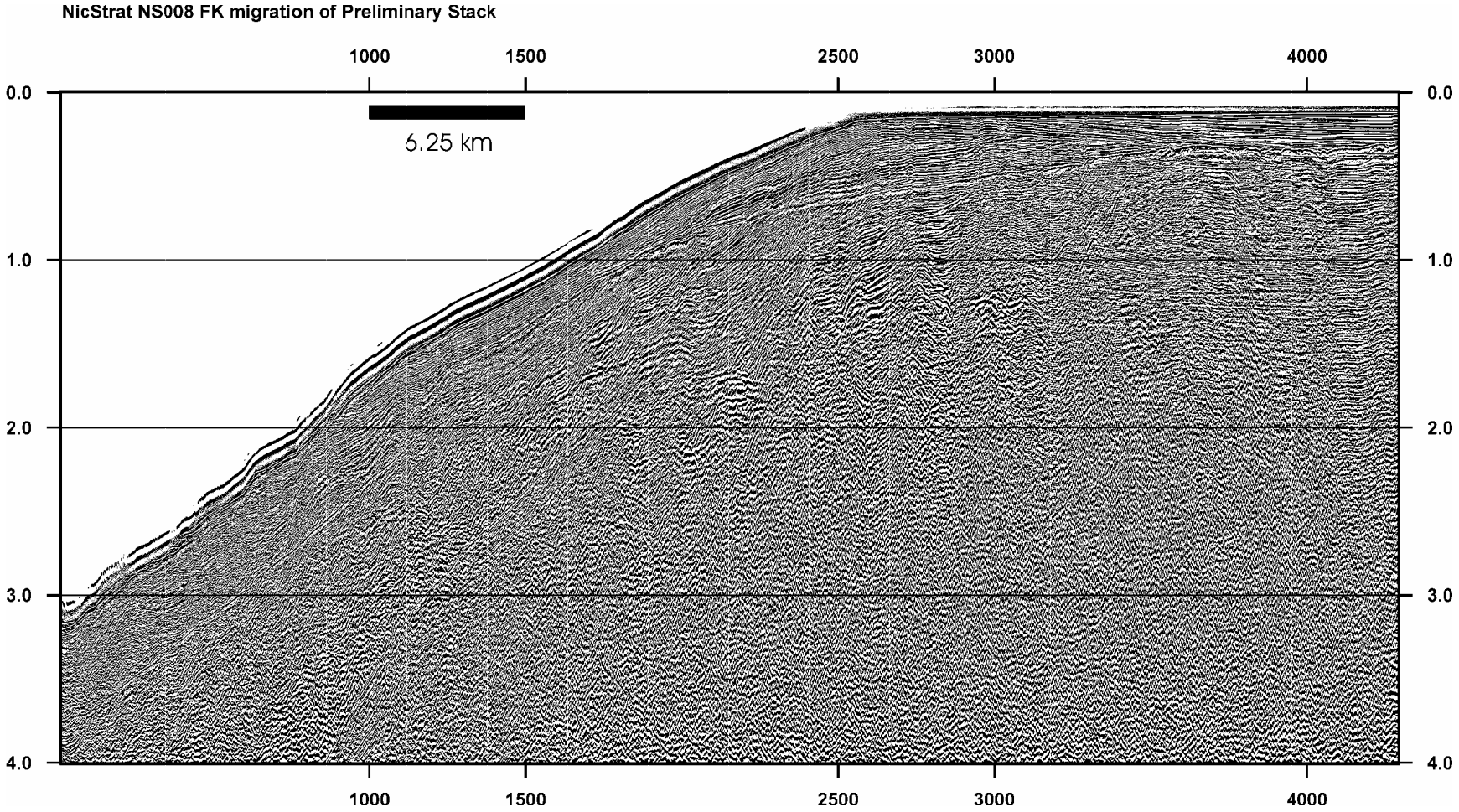

Figure 3. Dip profile NS008, Nicoya Box (FK migration of preliminary stack).

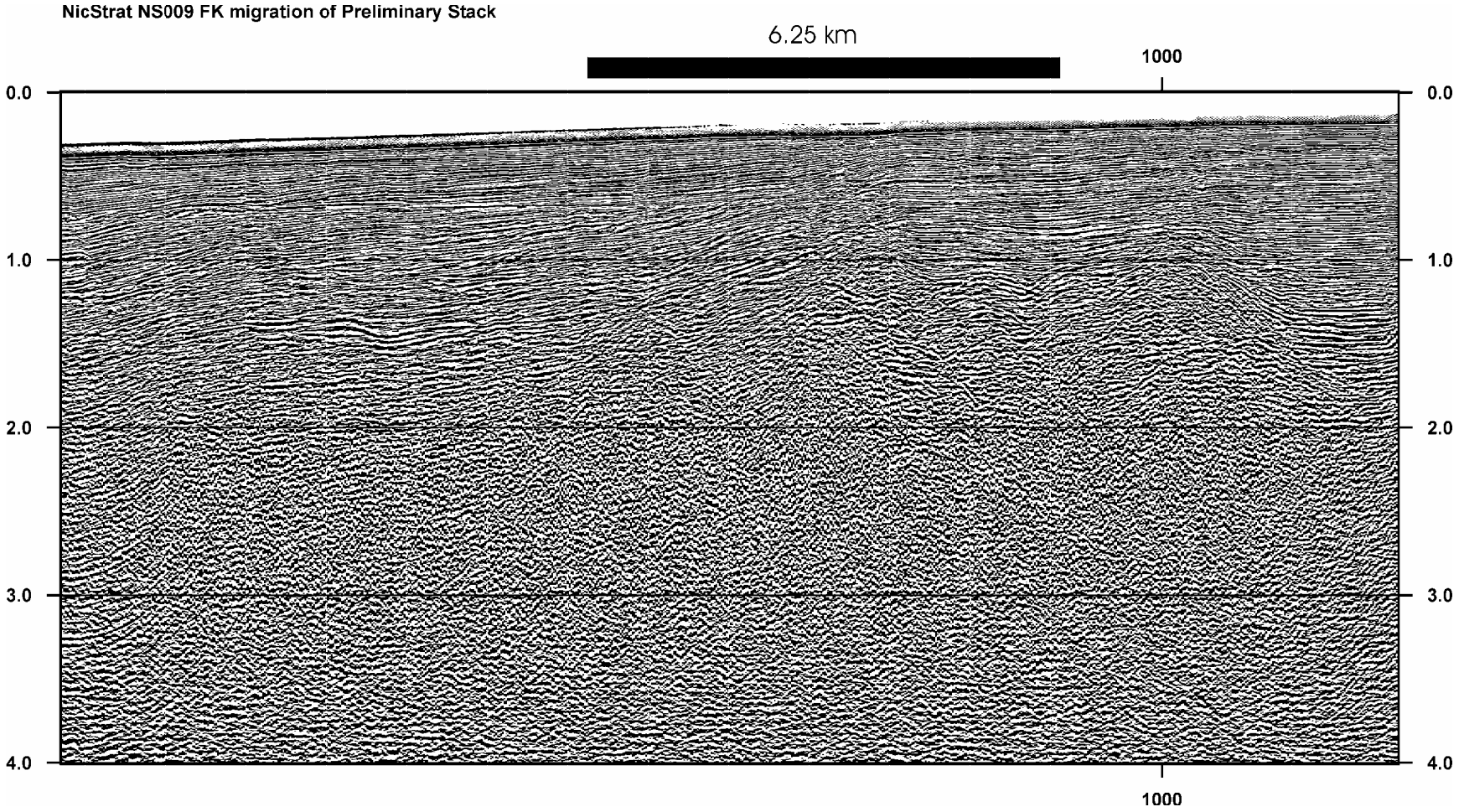

Figure 4. Strike profile NS009, Nicoya Box (FK migration of preliminary stack).

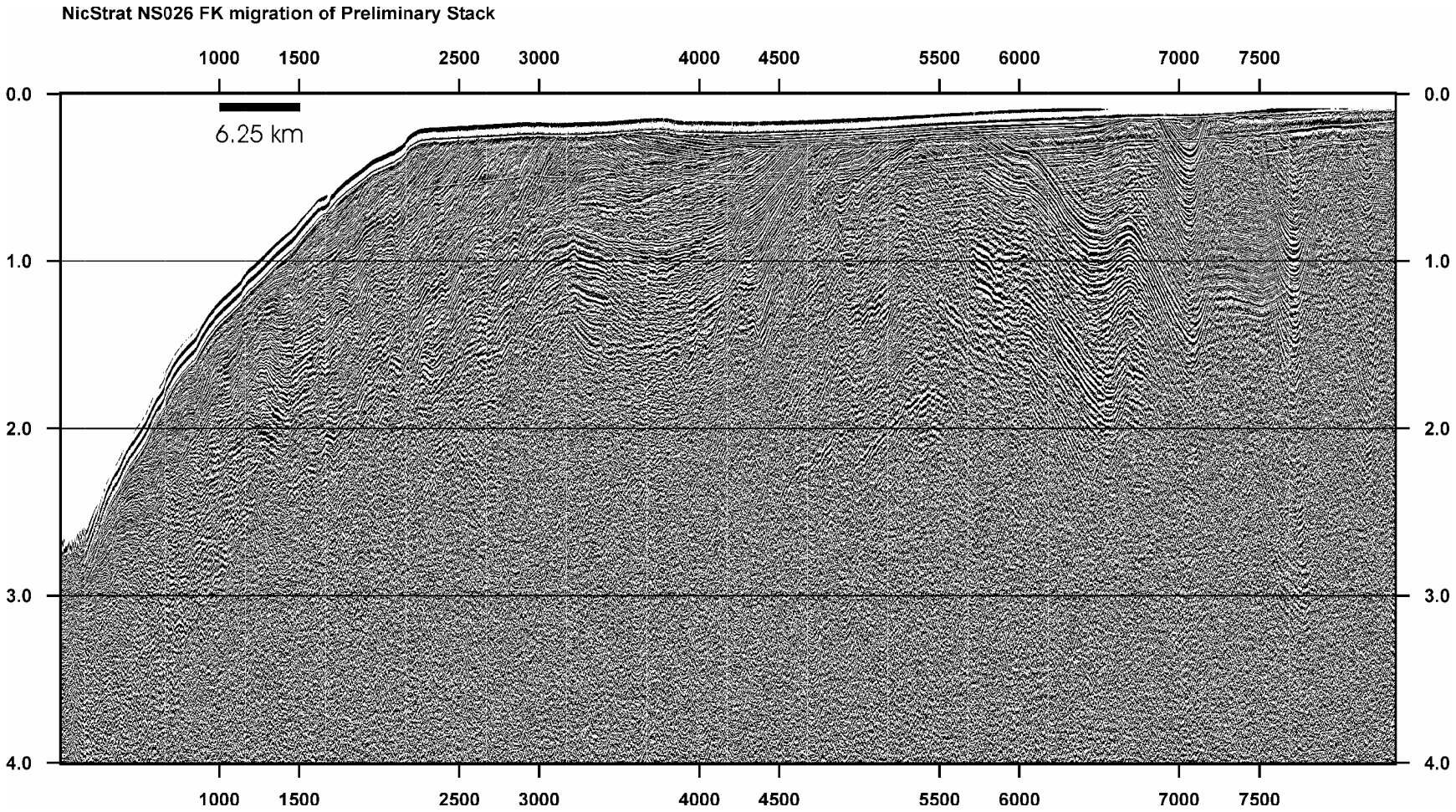

Figure 5. Dip profile NS026, Salinas Box (FK migration of preliminary stack).

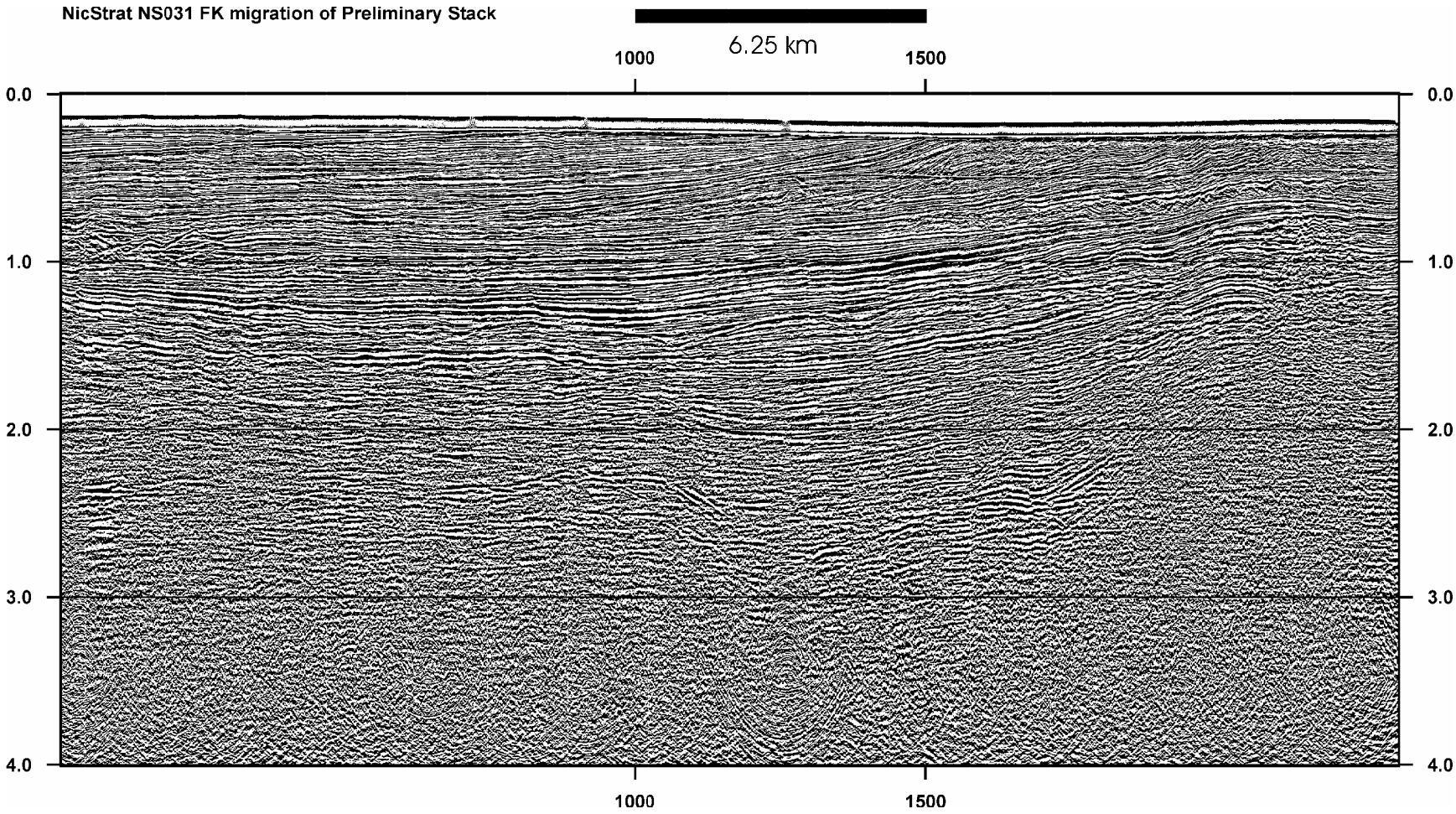

Figure 6. Strike profile NS031, Salinas Box (FK migration of preliminary stack).

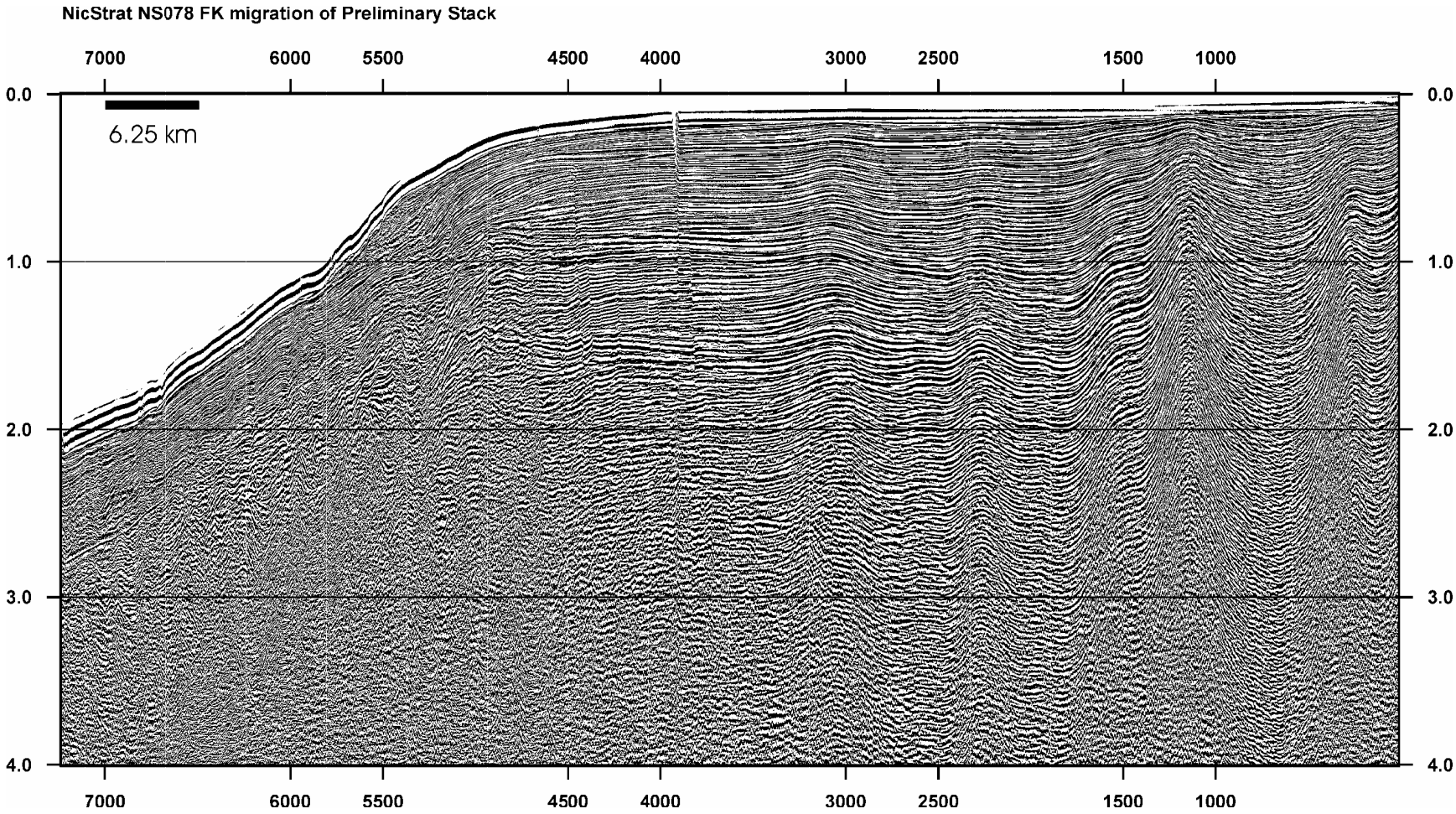

Figure 7. Dip profile NS078, Sandino Box (FK migration of preliminary stack).

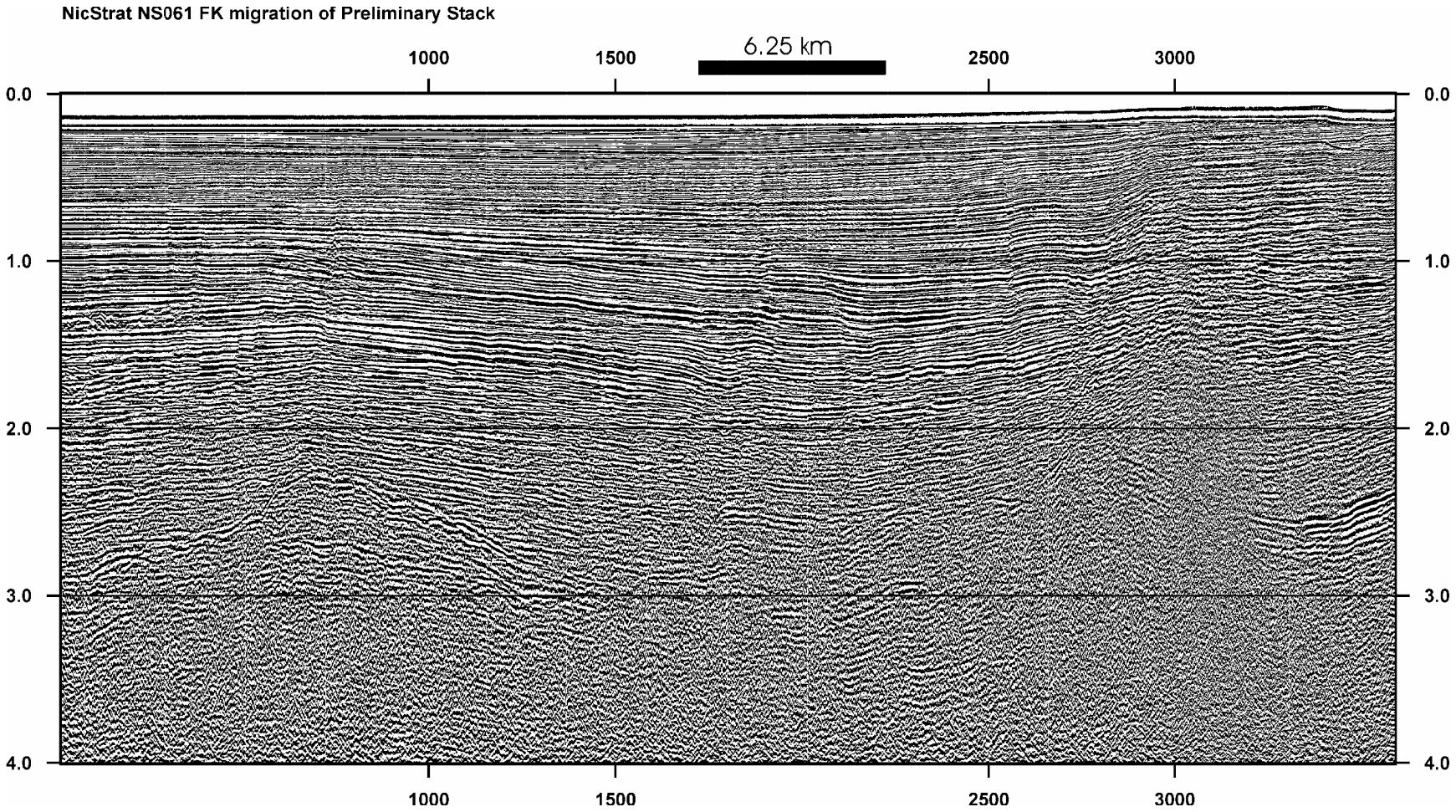

Figure 8. Strike profile NS061, Sandino Box (FK migration of preliminary stack).

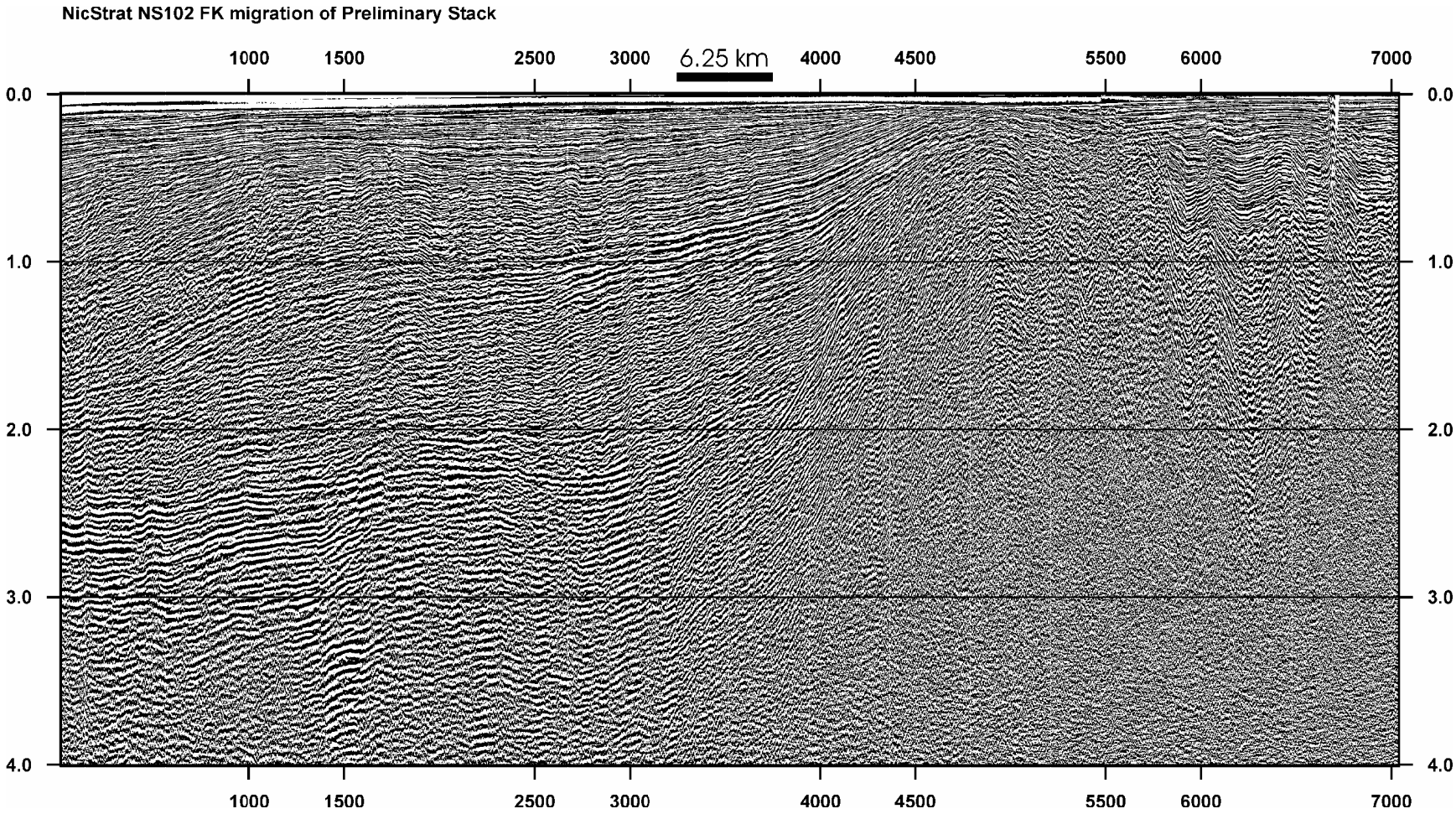

Figure 9. Dip profile NS102, crossing into Gulf of Fonseca (FK migration of preliminary stack). Note the uplifted block or anticline near the mouth of the Gulf. On the other side, within the gulf (to the right; NE), lies a basin equivalent to the Nicaraguan Depression. The block/anticline is highly faulted.

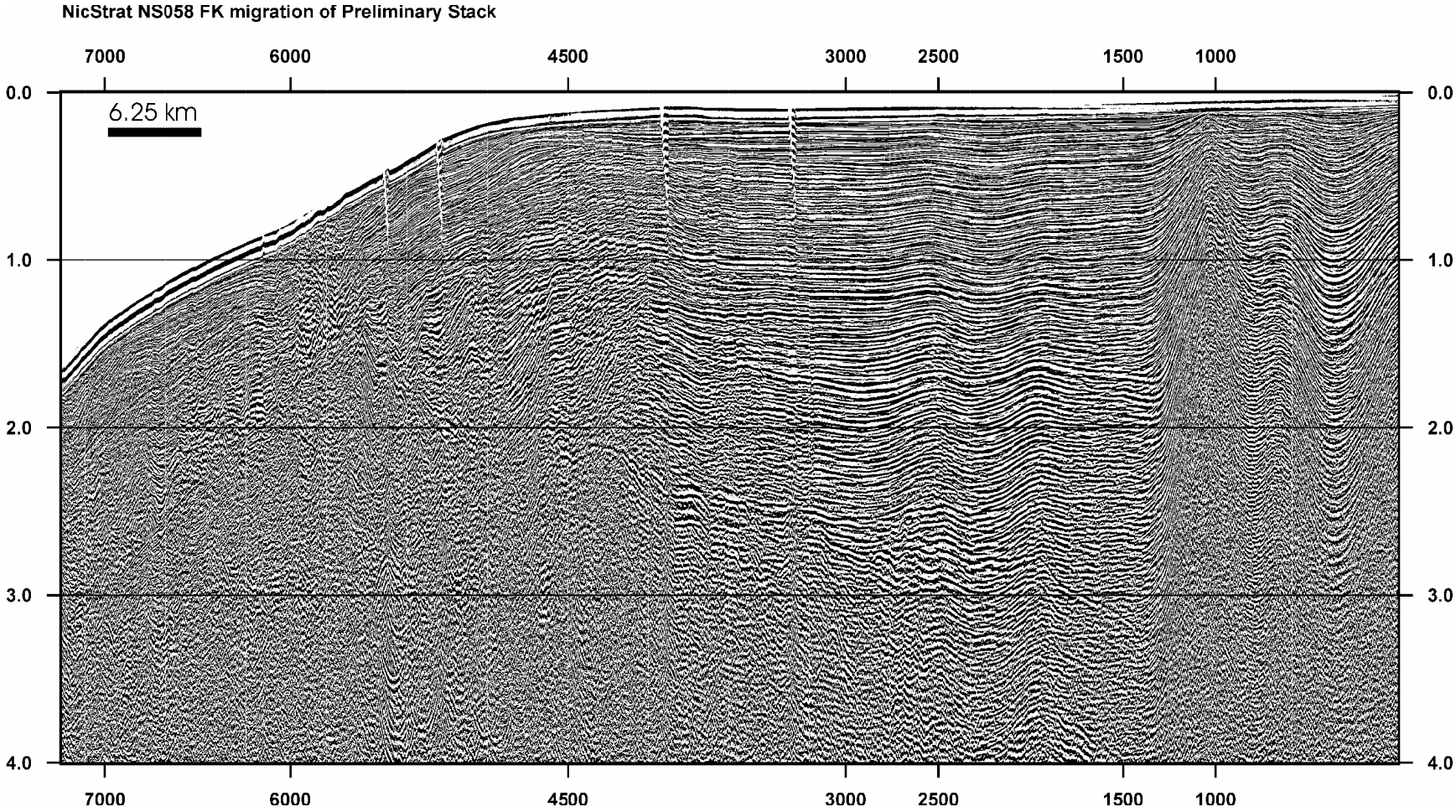

Figure 10. Dip profile NS058, Sandino Box showing short gaps caused by turtle shut downs (FK migration of preliminary stack).

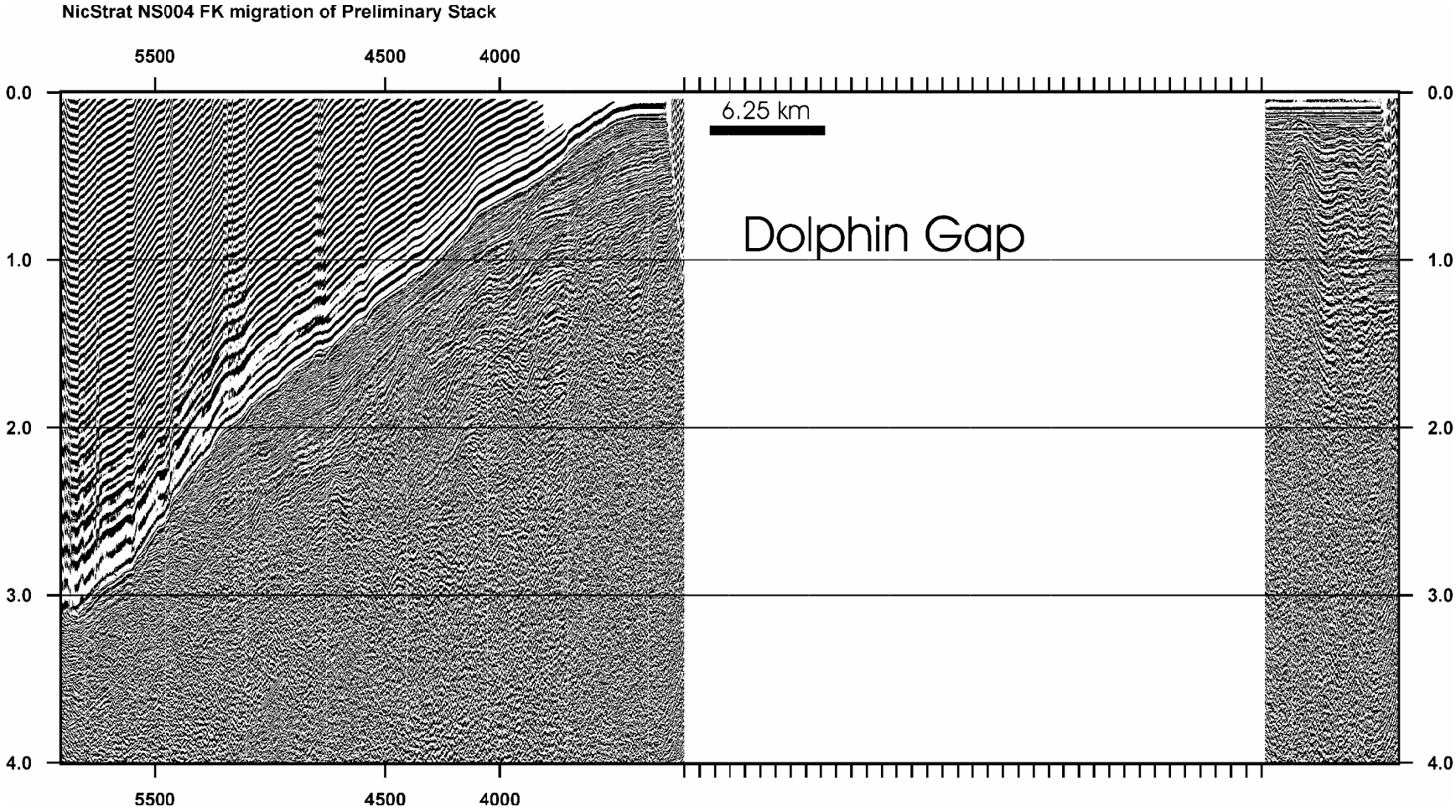

Figure 11. Dip profile NS004, Nicoya Box (FK migration of preliminary stack) highlighting gap resulting from marine-mammal shut down.

APPENDIX I

Julian Day/Date Conversion, EW04-12

	Sun.	**Mon.**	**Tues.**	**Wed.**	**Thurs.**	**Fri.**	**Sat.**
JD	*326*	*327*	*328*	*329*	*330*	*331*	*332*
Date	*21*	*22*	*23*	*24*	*25*	*26*	*27*
JD	333	334	335	336	337	338	339
Date	28	29	30 Nov.	1 Dec.	2	3	4
JD	340	341	342	343	344	345	346
Date	5	6	7	8	9	10	11
JD	347	348	349	350	351	352	353
Date	12	13	14	15	16	17	18
JD	354	355	356	357	358		
Date	19	20	21	22	23		