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2. UNDERWAY GEOPHYSICS[1]

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INTRODUCTION

The term "underway geophysics" encompasses all shipboard geophysical data used for pre-cruise selection of drill sites as well as data collected during the drilling leg. These data form an important and integral part of the Ocean Drilling Program process by providing the primary data set for (1) defining the problems to be addressed, (2) site selection, and (3) regional interpretation and extrapolation of drilling results. This chapter describes only shipboard underway geophysics, that is, the equipment, methods, and actual data collected aboard the *JOIDES Resolution* during Leg 123. Details of geophysical data used in the selection, description, and interpretation of specific sites are discussed in more detail in individual site chapters (see "Seismic Stratigraphy" sections, Sites 765 and 766 chapters, this volume). Discussions and interpretations of regional geophysical data in relationship to drilling results will be addressed in *Proceedings of the Ocean Drilling Program, Scientific Results, Leg 123*.

SHIPBOARD UNDERWAY GEOPHYSICS

The *JOIDES Resolution* provides scientists the capability of collecting, displaying, and processing a variety of geophysical information, including navigation, bathymetric, magnetic, seismic reflection, and sonobuoy data. The equipment used for this is located in the Underway Geophysics Laboratory (UGL) and adjacent deck space located aft on the poop deck under the helicopter platform. Each capability is discussed in the following sections. First, equipment and methods for each capability are described, then data collected during Leg 123 are discussed briefly.

After the cruise, navigation, bathymetry, and magnetic data were processed further, and then edited and corrected by the Geological Data Center (GDC) at the Scripps Institution of Oceanography under contract to ODP. Data in the following formats were produced by the GDC and submitted to ODP:

1. List of navigation times and positions of course and speed changes, fixes, and drift velocity.
2. On magnetic tape: separate time series files of fixes, course and speed changes, depth and magnetics in SIO "uwts" format, navigation list file; merged file of navigation, depth, and magnetics in MGD77 Exchange format.
3. On 35-mm microfilm: index track charts, navigation listing; fast and slow seismic profiler records; 12- and 3.5-kHz echo-sounder records; and magnetometer records (on one or more 100-ft rolls).

An informal report summarizing these data also was produced. Copies of the data were provided to both the ODP Data Bank at Lamont-Doherty Geological Observatory and to the National Geophysical Data Center in Boulder, Colorado.

Navigation

Equipment and Methods

Navigation data were collected during Leg 123 using a Magnavox Transit/Global Positioning System (GPS) Satellite Navigator (Model MX 1107 GPS) located in the UGL. Additional backup navigational equipment is located on the bridge, including a Magnavox MX 4400 GPS receiver, a Magnavox MX 702A Transit receiver, plus Decca and Loran C positioning systems. The navigation system in the UGL receives fixes from both GPS satellites as well as standard transit satellites. GPS fixes were available continuously during an approximately 11-hr window each day, while transit satellite fixes were available at various times throughout the day. The system calculated dead reckoning (DR) positions between satellite fixes. All fixes, along with ship's course and speed, were recorded in a special Navlog file at selected time intervals using a Masscomp 561 super microcomputer system (usually every 15 to 30 min during transit and every 2 min while shooting seismic data). These data were extracted later to produce a plot of the ship's track. A paper record of all transit fixes, plus GPS and DR fixes at 30-min intervals, also was produced. Fixes collected while at each site were averaged, and a single accurate fix was determined as the official location for that site. A generalized track for Leg 123 is shown in Figure 1. Detailed navigation was recorded only for that part of the track in the Indian Ocean (solid line). A complete list of all navigation data and course and speed changes used to generate the track line is presented in Table 1 (backpocket microfiche) and Plate 1 (backpocket foldout).

Transit Between Sites

After leaving Singapore at 1500 hr (all times are Universal Time Coordinated unless designated otherwise) on 1 September 1988, our route took us southeast across the Java Sea to just north of Bali, where we headed south through the Lombok Straits into the Indian Ocean (Fig. 1). At this point, we began recording navigation data on tape at 1901 hr on 4 September 1988 (Fig. 2). From there, we crossed the Bali forearc trough and the deep Java Trench and again headed southeast to DSDP Site 261 in the northeast Argo Abyssal Plain. Here, we began collecting seismic data during the run south to our first site (Site 765; Fig. 2, Line 1). Site 765 was approached from the northeast, following the Australian Bureau of Mineral Resources (BMR) site-survey multifold seismic Line 56/022, and a beacon was dropped at 1830 hr on 6 September 1988 at 15°58.5′S, 117°34.5′E (Fig. 3). A sonobuoy also was deployed during this run.

While leaving Site 765 on 17 October 1988, a second sonobuoy was deployed and another short seismic line was shot across the site (Line 2A, Fig. 3) before we headed southwest directly across the northwest Exmouth Plateau (Fig. 2). Site 766 was approached from the east, again following a BMR site-survey line (55/003E; Fig. 4). Seismic data were collected during

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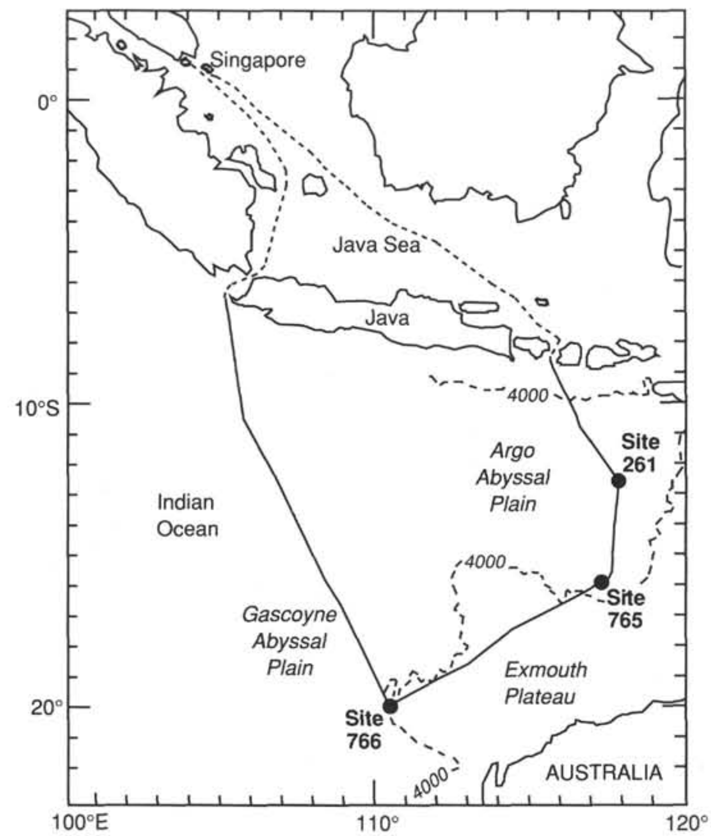


Figure 1. Generalized track of *JOIDES Resolution* for entire Leg 123 from Singapore to Singapore. Detailed underway geophysics data recorded on magnetic tape only in Indian Ocean (solid line).

this final run (Line 2B), and a beacon was dropped at 1241 hr on 19 October 1988 at 19°55.98′S, 110°27.13′E.

Just before leaving Site 766 on 26 October 1988, a small seismic survey was conducted just southwest of the site (Line 3) and included a third sonobuoy line across the site, before we headed north toward Singapore (Fig. 4). We then transited the Gascoyne Abyssal Plain (Fig. 2) past Christmas Island, and then back across the Java Trench and into the Sunda Straits between Java and Sumatra. All geophysical operations were terminated late in the afternoon of 29 October, just before experiencing an excellent view of the famous volcano, Rakata, on Palau Krakatau. After transiting back through the Java Sea, we returned to Singapore by 0500 hr (local time) on 1 November 1988.

Bathymetry

Equipment and Methods

Bathymetry data were collected using both 3.5- and 12-kHz precision depth recorder (PDR) systems and were displayed on two Raytheon LSR 1807M recorders at a sweep speed of 1 s. The 3.5-kHz system uses a Raytheon PTR105B transceiver and 12 Raytheon transducers, while the 12-kHz system operates with a PTR105B transceiver and an EDO 323B transducer. These systems normally operate with CESP-III correlators to improve the signal-to-noise ratio (20 dB). Both systems are mounted in a new sonar dome located outside the ship's hull, forward of the moon pool at 18 m below the rig floor. The new dome was installed during the Singapore port-call in an attempt to decrease hull noise and improve records, especially during high-speed transits and rough seas.

Because of its higher frequency and sharper image of the seafloor, the 12-kHz system was used to determine depths. Bathymetry readings were recorded every 5 min in a log for later processing. The 3.5-kHz system provides some sub-bottom penetration, often up to 50 to 100 m when sediments are relatively soft. These records are useful for interpreting shallow seismic stratigraphy, shallow structure, and depositional processes.

Data Collected

PDR systems began operating and data collection started at approximately 1901 hr on 4 September 1988 (JD-Julian Day-248) as we entered the Indian Ocean on a course of 152° and speed of 11 kt. Seas were relatively calm for the entire transit, and we obtained excellent records, even across the deep Java Trench having depths of more than 7000 m. The 3.5-kHz records showed excellent sub-bottom penetration across the central Argo Abyssal Plain, with penetration of more than 0.1 s in places (greater then 75 m). An example of the records taken as we crossed Site 261 is shown in Figure 5A. Penetration at Site 765 deteriorated somewhat, probably because of changing sub-bottom conditions (Fig. 5C). Even the 12-kHz records exhibited good penetration, as shown by the examples from Sites 261 and 765 (Figs. 5B and 5D).

Bathymetry data were collected continuously during our transit across the Exmouth Plateau to Site 766 and then during much of our transit back to Singapore (Fig. 2). PDR systems were terminated on 29 October at 0546 hr, just before entering the Sunda Straits. Profiles of bathymetry along the track are depicted in Figure 6. A log of the records collected is presented in Table 2.

During the Argo transit, a brief test to compare records from the PDR systems mounted in the new sonar dome with those from the old hull-mounted systems was conducted at high speeds (11 kt; Fig. 7A). Only slight improvement was seen in the 3.5-kHz records (Fig. 7A), as seas were smooth. However, dramatic improvement was observed in the 12-kHz records (no record from the hull-mounted system vs. the strong bottom reflection from new system; Fig. 7B). This test of the 3.5-kHz system was inconclusive, and further tests under higher sea states were needed. We had this opportunity during the 11-kt transit across the Exmouth Plateau (Fig. 4), where seas were choppy and sea state was between 4 and 5. As before, the 12-kHz record disappeared when switched to the hull-mounted system. In addition, the 3.5-kHz signal also disappeared (Fig. 8), thus documenting the ability of the new sonar dome-mounted, 3.5-kHz system to provide better records at high speeds under high sea states.

Magnetics

Equipment and Methods

Total intensity measurements of the Earth's magnetic field were obtained using a Geometrics 801 proton precession magnetometer. A sensor was towed approximately 400 m astern. Measurements were performed at 3-s intervals with 1 nT sensitivity. Values were recorded digitally in the header of the seismic tape on the Masscomp computer every 99 s during transit and once per shot during seismic surveys. Data also were displayed graphically in real time on a strip chart recorder, and log readings were recorded every 5 min. These magnetic data later were processed by GDC to remove the regional field (IGRF) and to correct for any large time variations.

Data Collected

During the transit to Site 765, a magnetometer was deployed and data collection began at approximately 1901 hr on 4 September 1988 (JD-248) as we transited the Lombok Straits into

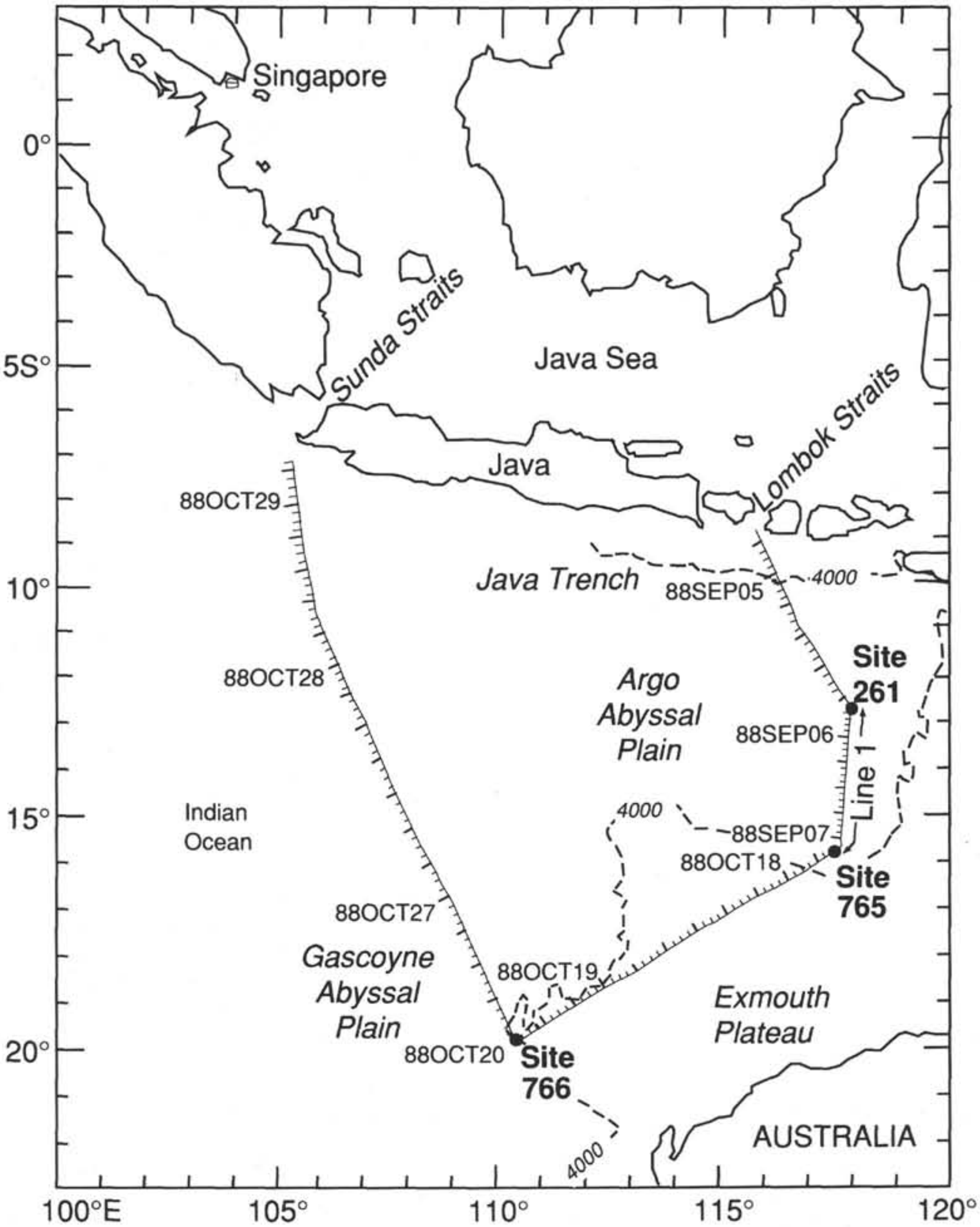


Figure 2. Detailed track chart of transit in Indian Ocean. Magnetics were collected during all of the transit; seismic Line 1 was collected between Sites 261 and 765. Bathymetry in meters.

the Indian Ocean (Fig. 2). Data collection continued across the northern Argo Abyssal Plain to Site 261 and then south to Site 765. Profiles of the processed data along track are shown in Figure 6. Magnetic data across the Argo Abyssal Plain were especially important for confirming our location with respect to seafloor magnetic anomalies postulated for the area. Of particular importance was the identification of Mesozoic anomalies M23 through M25, around which Site 765 was planned. Details of the processed magnetic data collected along seismic Line 1 are plotted below the analog seismic records (Fig. 9, backpocket foldout). These profiles show our best correlation with the magnetic anomaly patterns that had previously been interpreted as M23 through M25 (Late Jurassic) by Heirtzler et al. (1978), Veevers et al. (1985), and Fullerton et al. (1989). On the basis of a possible younger age (Earliest Cretaceous) for the crust inferred by drilling at Site 765, these anomalies will be re-evaluated.

A magnetometer again was deployed during the transit between Sites 765 and 766 across the Exmouth Plateau (Fig. 6). The large anomaly at the northern Plateau margin corresponds to the continent/ocean boundary (COB) of Veevers et al. (1985). The field across the Plateau itself has little relief, except at the southwest margin, where again oceanic magnetic anomalies were picked up during the approach to Site 766 (Fig. 6). Additional magnetic data were collected during the transit north across the Gascoyne Abyssal Plain, again showing the magnetic anomalies in the area of oceanic crust (Fig. 6). As our transit was almost at right angles to the inferred opening direction, our data probably will be of minimum use for identifying anoma-

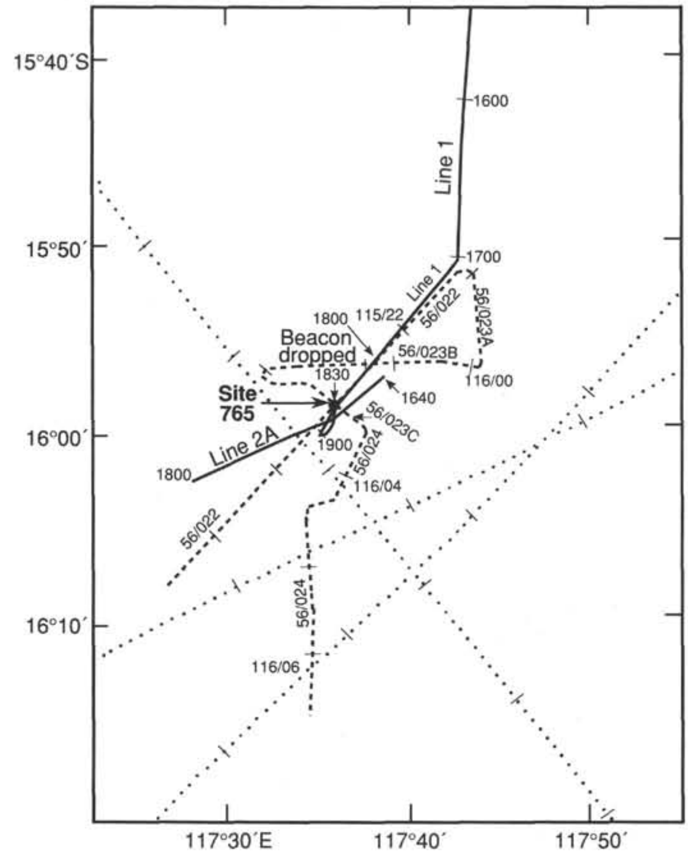


Figure 3. Map of Site 765 area showing track of *JOIDES Resolution* during approach (Line 1) and departure (Line 2A) when seismic and sonobuoy data were collected (solid line). Also shown is track of BMR site survey data (dashed line) and other singlefold seismic data in the area (dotted lines).

lies. Collection of magnetic data also was terminated at 0546 hr on 29 October 1988. A log of the records collected is presented in Table 2.

Seismic-Reflection Profiling

Equipment and Methods

Singlefold seismic reflection data were collected aboard the *JOIDES Resolution* during the approach to both Sites 765 and 766. The energy source used was two 80-in.^{3} water guns (manufactured by Seismic Systems, Inc.) that were operated at approximately 2000 psi air pressure. These guns were towed 14 m apart about 25 m behind the ship at depths ranging from 6 to 13 m, depending on ship's speed. A seismic signal was received by a 100-m-long Teledyne streamer containing 60 hydrophones, which are summed to improve signal-to-noise ratio and to produce one channel of data. The streamer was towed about 300 m behind the ship at an estimated depth of about 15 to 20 m, depending on ship's speed.

Seismic data were digitally recorded on 9-track magnetic tape using a Masscomp 561 super microcomputer system and then displayed in real time on a 15-in.-wide Printronix high-resolution graphic printer (160 dots/in.). Shots were fired every 13 s and recorded at a digital sample rate of 1 ms. The signal entry into the Masscomp was filtered at 25 to 250 Hz, and a digital amplifier gain was set at 115 dB. Record length for each shot was 5 s. The magnetic tape uses a SEGY format and has a density of 1600 bpi. In addition to the magnetic data discussed above, the tape header file for each shot includes information such as first file ID number, shot point number, field time break delay, date, time, wind speed and direction, ship's speed (pit log), ship's gyro heading, cumulative distance traveled, streamer and gun depths, and information about timing of gun firing. The Masscomp computer system also was used for preliminary pre-processing of digital data on board the ship.

The raw seismic signal from the streamer also was displayed in real time in analog format on two Raytheon LSR 1807M recorders at different scales (4 s sweep and 1 or 2 s sweep). Recorder speed was either 50 or 75 lines/in. The signal was passed through an Ithaco amplifier and a Krohn-Hite filter set at 50–120 Hz.

Transit Between Site 261 and Site 765

A long regional seismic line (Line 1) was collected across the Argo Abyssal Plain between Site 261 and Site 765 (Figs. 2 and 9). The purpose of the line was to correlate seismic stratigraphy between the two sites and to better establish regional structural and stratigraphic relationships in the area. A copy of the analog record is presented in Figure 9, and a copy of the processed seismic line is shown in Plate 1 (back pocket).

The seismic gear was deployed at approximately 1830 hr on 6 September 1988 at a position just north of Site 261. After heading south on a course of 184°, the first shot was recorded at 1838 hr. Ship's speed was approximately 6 kt to keep noise to a minimum during this part of the line. We passed Site 261 at 1924 hr (Fig. 2) with the analog records showing excellent definition of seismic stratigraphy at the site (Fig. 9). At 2100 hr, we increased our speed to 8 kt, which increased streamer noise and caused some deterioration in data quality. The records were still interpretable at these higher speeds (Fig. 9), and thus, we decided to continue recording the line as we headed south toward Site 765 (Fig. 2).

Surveys at Site 765

Our planned approach to Site 765 was to intersect the northeast end of BMR site-survey Line 56/022 and then proceed along this line to the site (Fig. 3). At 1701 hr, we changed to a course of 224° to parallel the line; at 1730 hr, we decreased our speed to 5.5 kt to improve record quality as we approached the site (Fig. 9). At 1737 hr, we launched a sonobuoy to supplement seismic data at the site (see below). At 1830 hr, a comparison of analog records with the BMR site survey line indicated that we had reached Site 765, and a beacon was deployed. The ship made a slow turn, with one additional pass over the site area, before securing the seismic system at 1935 hr (Figs. 3 and 9). The final location of the site was at the intersection of BMR multifold site-survey Lines 56/022 and 56/023c at 15°58.5′S, 117° 34.5′E (Fig. 3).

When leaving Site 765, a short seismic line was shot while recording a sonobuoy heading southwest across the site area (Line 2A, Fig. 3). The survey began approximately 3 nmi northwest of the site at 1640 hr on 17 October 1988 and was terminated 10 nmi to the southwest at 1800 hr (Fig. 3), when we lost the sonobuoy signal. The monitor record for this short line (showing the closest point of approach to Site 765) is presented as Figure 10, and a copy of the processed line is presented in Plate 1 (back pocket).

Surveys at Site 766

We deployed seismic gear again on 19 October 1988 at 1108 hr, approximately 10 nmi east of proposed Site 766 at the intersection with BMR multifold site-survey Line 55/003E (Fig. 4). We then began a seismic line at 1115 hr, while steaming 6 kt parallel to the BMR line (Line 2B; Figs. 4 and 11). The purpose of this survey was to guide us when selecting a site. A beacon was

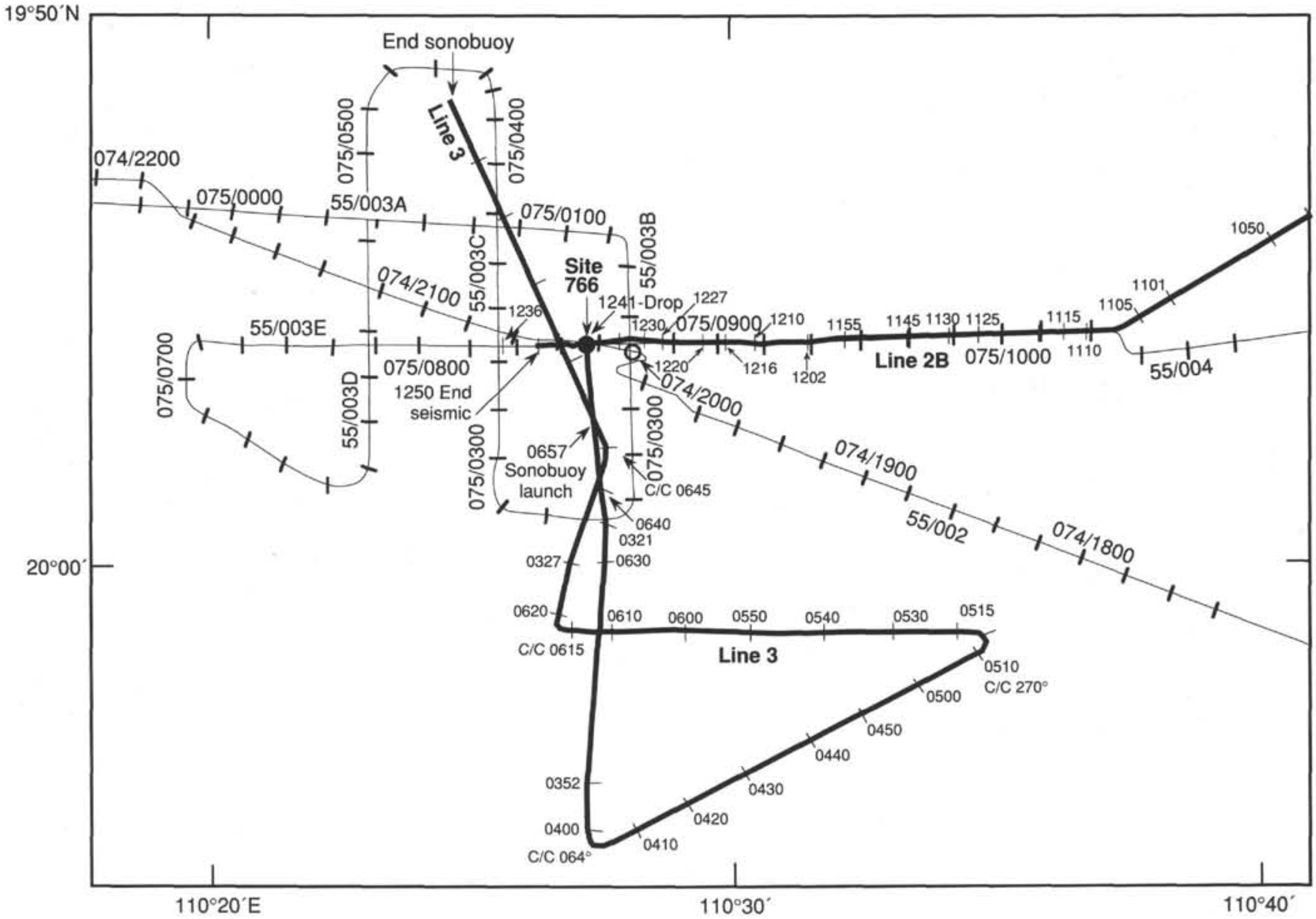


Figure 4. Track of *JOIDES Resolution* during approach to Site 766 (Line 2B) plus seismic and sonobuoy surveys following drilling (Line 3; solid line). Also shown is track of BMR site-survey data in area (dashed line).

dropped on target at 1241 hr in the middle of the second erosional terrace (Fig. 11) along BMR Line 55/003E, near the intersection with Lines 55/002 and 55/003B (Fig. 4). The line was terminated just past the site at 1250 hr.

Following drilling and logging at Site 766, a short seismic survey was conducted just southwest of the site area on 26 October 1988 (Line 3; Fig. 4), primarily to investigate the distribution of seismic sequences just drilled (Fig. 12). Of particular interest was the distribution and thickness of the lowermost sandstone/siltstone unit, Lithologic Subunit IIIB. This survey consisted of four short segments along a complex faulted margin (Figs. 4 and 12). We then continued the survey northwest across the site, while shooting a third sonobuoy. The survey ended when we lost the sonobuoy signal at 0739 hr (Fig. 4), at which time we secured our seismic gear and began our transit to Singapore.

Copies of the processed lines collected at Site 766 are presented in Plate 1 (back pocket). A log of all seismic data collected during Leg 123 is listed in Table 2.

Sonobuoys

Equipment and Methods

Sonobuoy data were collected at drill sites to provide additional velocity vs. depth information. Sound sources were two 80-in.[3] water guns used for seismic surveys. Signals from sonobuoys were converted to normal FM broadcast band frequencies and then received by a high-frequency Realistic AM/FM stereo. These data were recorded along with the seismic data on digital tape using the Masscomp computer system. Routines for processing data are not available on board the *Resolution*. The data will be analyzed post-cruise at shore-based laboratories using Tau-P methods for extracting velocity vs. depth information. An analog monitor record of the sonobuoy data was displayed on one of the Raytheon recorders. All sonobuoys were Navy Model SSQ 53B.

Site 765

A sonobuoy was deployed at 1737 hr on 6 September during our final approach to Site 765, after turning to a course of 224° and slowing to 5.5 kt (Fig. 3). We used sonobuoy channel 3, set phone depth at 90 ft, and set life for 3 hr. The buoy was located at approximately 15°55.15′S, 117°37.97′E. Shot repetition rate was changed to 16 s, with a 10-s record length to accommodate the sonobuoy data. Data were recorded until 1825 hr, at which time the signal was lost.

Because of a short recording time for the sonobuoy during our approach, a second sonobuoy was deployed while we were leaving Site 765 (Line 2A; Fig. 3). Settings on the sonobuoy were the same as before. We increased the shot repetition rate to 25 s, and record length for the sonobuoy was 20 s. Data were digitized at a sample rate of 2 ms. After we drifted about 3 nmi northwest while pulling pipe, we deployed the sonobuoy at 1640 hr (17 October 1988) at a location of 15°57.18′S, 117°36.97′E. We then proceeded southwest on a course of 241° at a speed of 8 kt across the site area for about 10 nmi (Fig. 3). This signal appeared stronger and lasted longer than that of the first buoy and

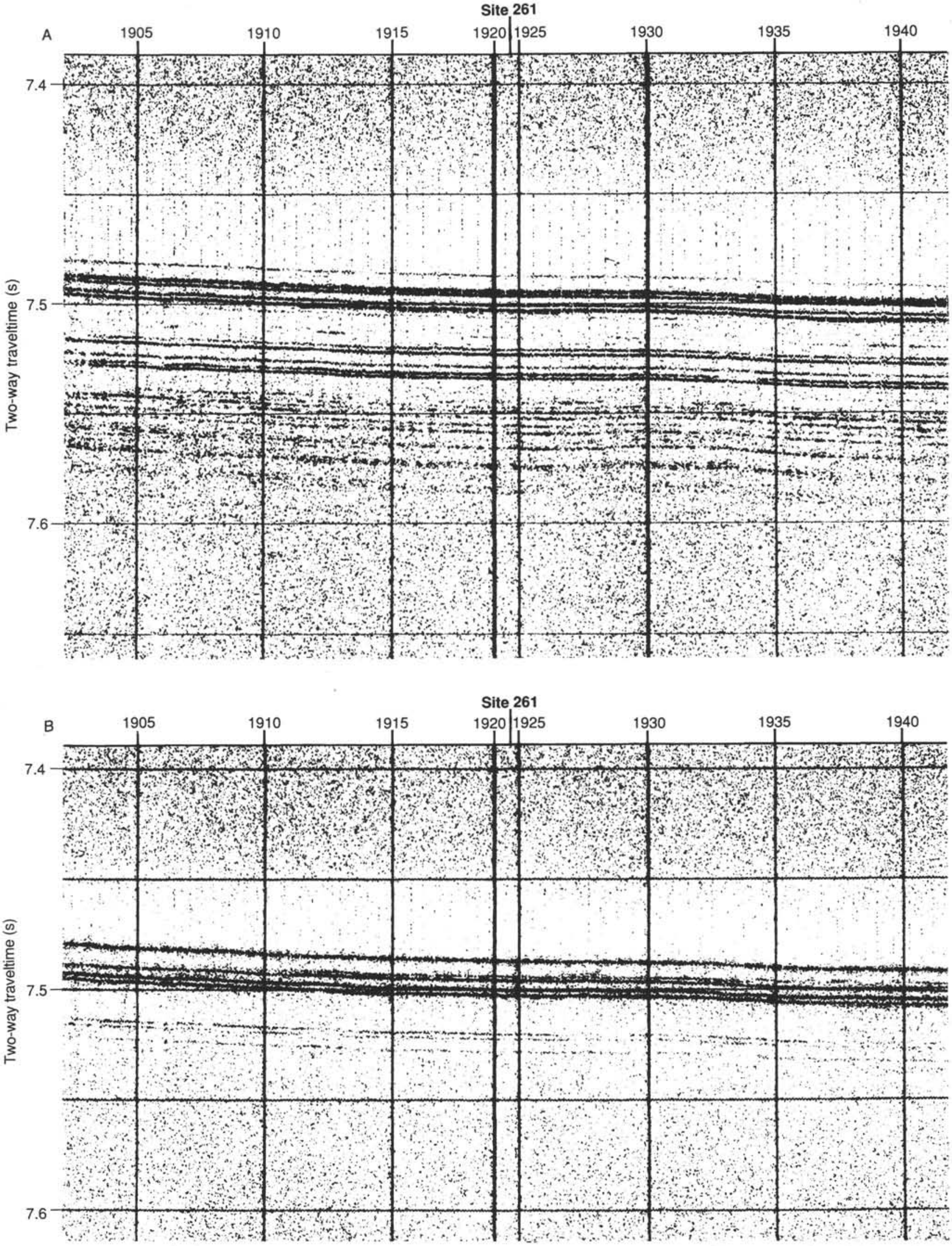
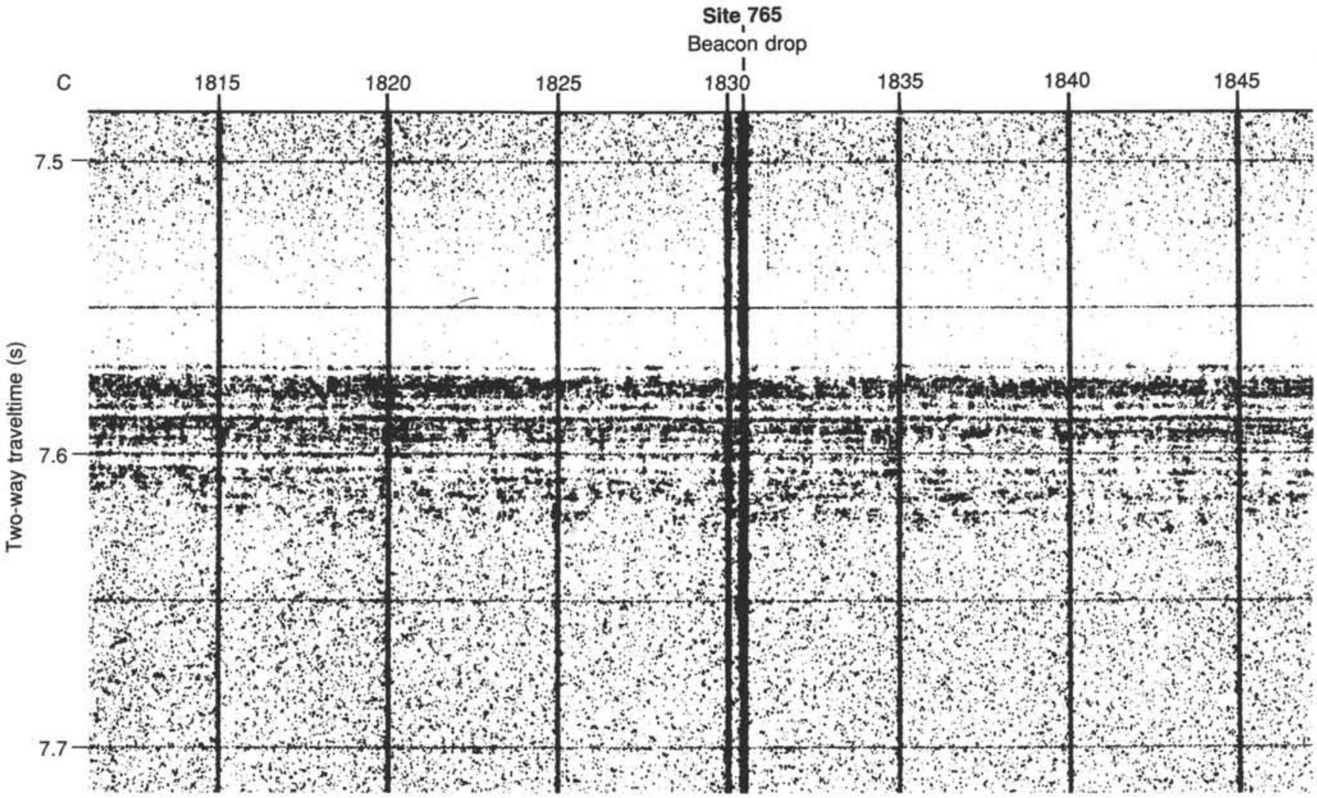


Figure 5. Examples of 3.5- (A, C) and 12-kHz (B, D) records at Sites 261 and 765, respectively. Each vertical subdivision equals approximately 37.5 m in the water column.



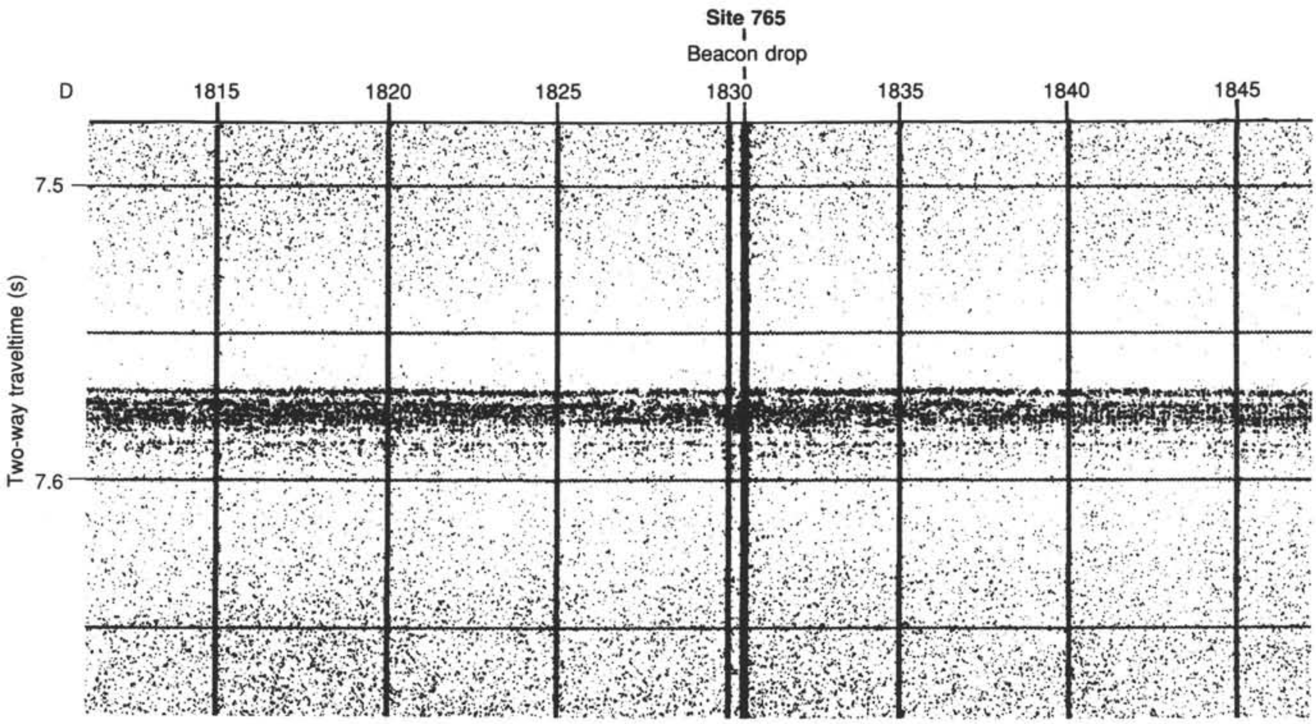


Figure 5 (Continued).

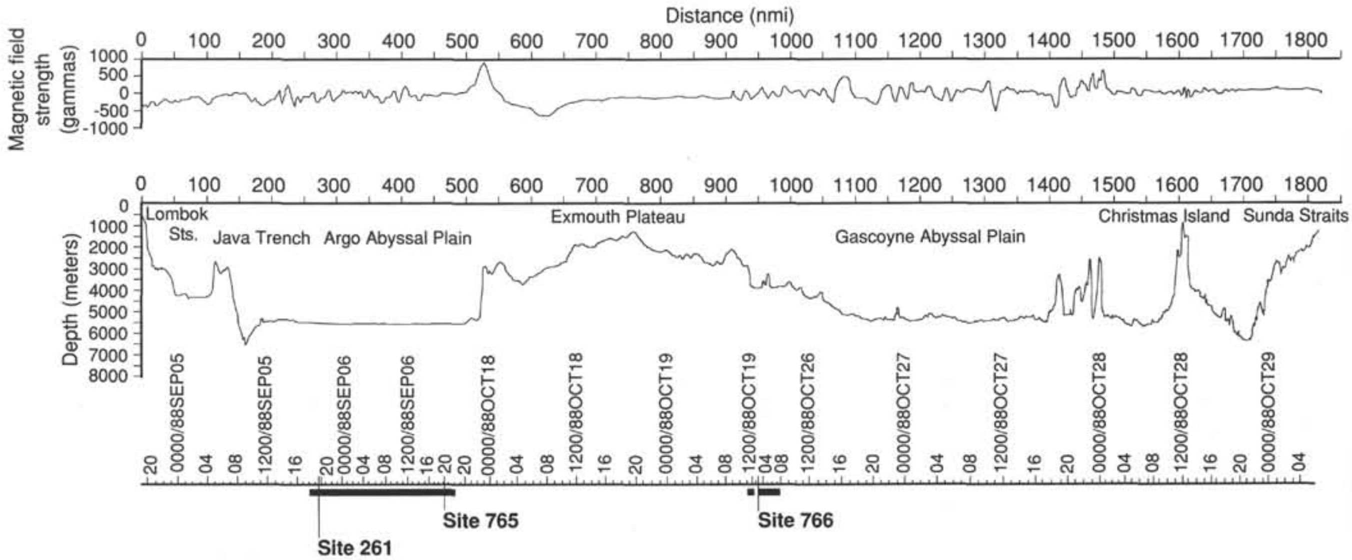


Figure 6. Profiles of magnetics (upper) and bathymetry (lower) data processed by GDC. See Figure 2 for location of tracks. Black bars at bottom represent location of seismic lines shot.

Table 2. Log of records collected during Leg 123.

Time (UTC)	Date	Sample (code)	Sample (identifier)	Latitude (south)	Longitude (east)
Precision depth records					
1857	040988	DPRT B	PDR 12 kHz L-01	8°540	115°460
2022	060988	DPRT E	PDR 12 kHz L-01	15°585	117°345
1541	171088	DPRT B	PDR 12 kHz L-02	15°585	117°345
1512	191088	DPRT E	PDR 12 kHz L-02	19°559	110°272
0221	261088	DPRT B	PDR 12 kHz L-03	19°559	110°272
0542	291088	DPRT E	PDR 12 kHz L-03	7°021	105°123
1857	040988	DPRT B	PDR 3.5 kHz L-01	8°540	115°460
2012	060988	DPRT E	PDR 3.5 kHz L-01	15°585	117°345
1541	171088	DPRT B	PDR 3.5 kHz L-02	15°585	117°345
1321	191088	DPRT E	PDR 3.5 kHz L-02	19°559	110°272
0219	261088	DPRT B	PDR 3.5 kHz L-03	19°559	110°272
0542	291088	DPRT E	PDR 3.5 kHz L-03	7°021	105°123
Magnetic records (total earth field)					
1901	040988	MGRA B	Magnetometer L-01	8°540	115°460
1830	060988	MGRA E	Magnetometer L-01	15°585	117°345
1630	171088	MGRA B	Magnetometer L-02	15°573	117°369
1245	191088	MGRA E	Magnetometer L-02	19°560	110°268
0305	261088	MGRA B	Magnetometer L-03	19°569	110°273
0541	291088	MGRA E	Magnetometer L-03	7°023	105°123
Seismic-reflection records					
1841	050988	SPRS B	Water gun L-01	12°533	117°554
1936	060988	SPRS E	Water gun L-01	15°593	117°338
1628	171088	SPRS B	Water gun L-02T	15°574	117°367
1803	171088	SPRS E	Water gun L-02T	16°029	117°290
1117	191088	SPRS B	Water gun L-02	19°558	110°361
1250	191088	SPRS E	Water gun L-02	19°560	110°263
0300	261088	SPRS B	Water gun L-03	19°563	110°272
0739	261088	SPRS E	Water gun L-03	19°515	110°247

should give excellent results. A copy of the monitor record for this sonobuoy is displayed in Figure 13 and indicates direct and critical reflected waves. When this signal was lost, we terminated recording at 1800 hr (Figs. 3 and 13).

Site 766

A final sonobuoy was deployed at 0651 hr on 26 October during our departure from Site 766 (location of 19°57.31′S, 110°27.44′E), following seismic Line 3 (discussed above) on a heading of 340° at 7.5 kt (Fig. 4). All settings were similar to those of the second buoy at Site 765. This record also appeared to be of good quality.

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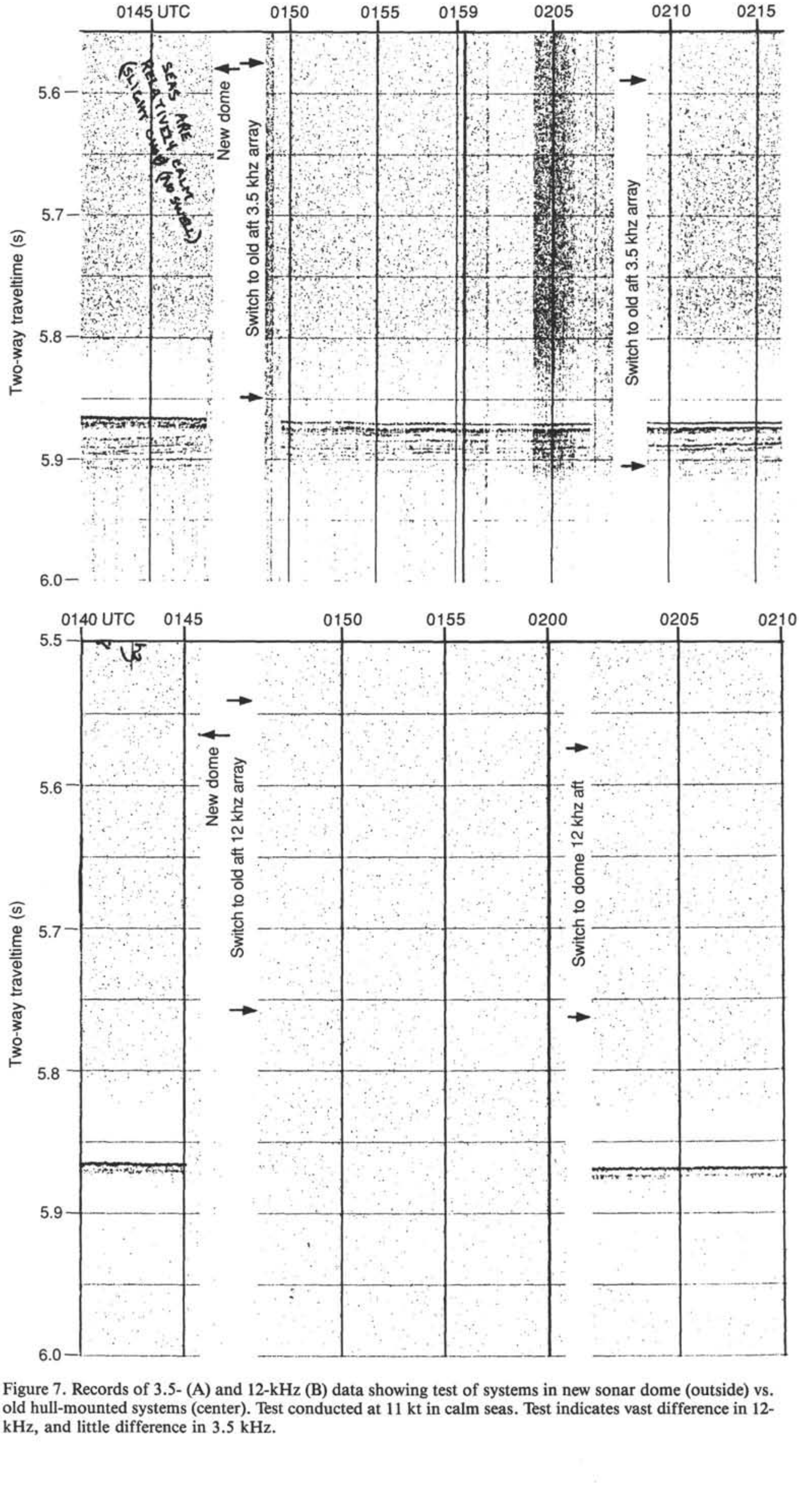

Figure 7. Records of 3.5- (A) and 12-kHz (B) data showing test of systems in new sonar dome (outside) vs. old hull-mounted systems (center). Test conducted at 11 kt in calm seas. Test indicates vast difference in 12-kHz, and little difference in 3.5 kHz.

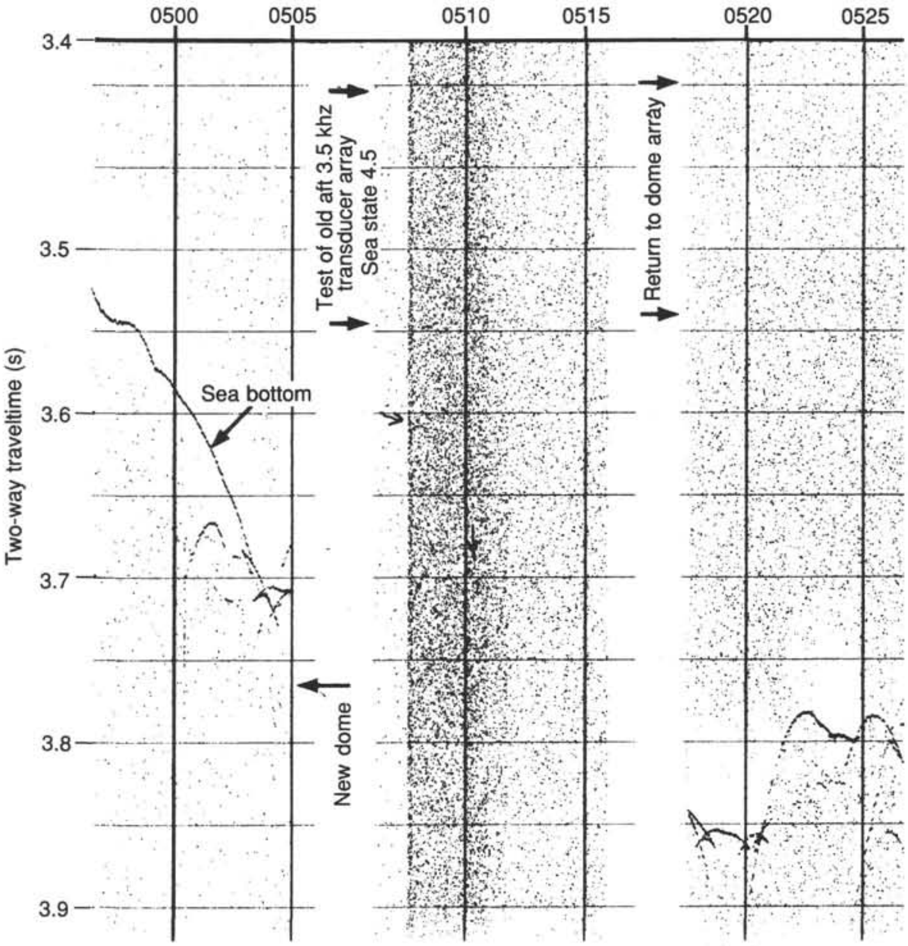

Figure 8. Test of 3.5-kHz systems in sonar dome (outside) vs. hull-mounted systems (center). Seas were choppy, sea states were 4 to 5. Note lack of record from hull-mounted system.

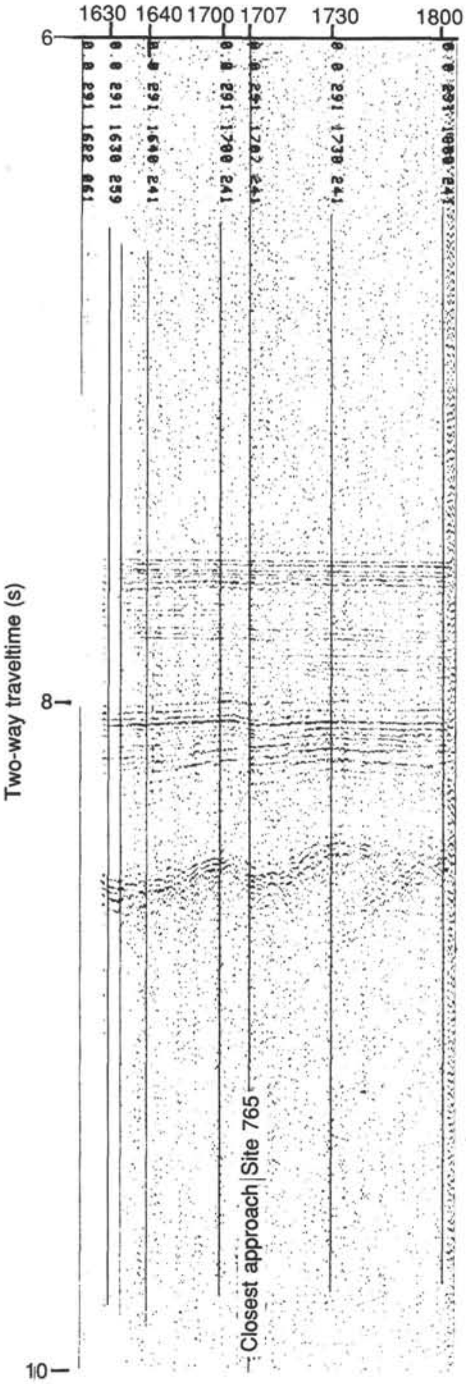

Figure 10. Shipboard monitor record of seismic Line 2A, shot while collecting sonobuoy data (Fig. 13) during departure from Site 765. The line passed approximately 1/4 mi south of Site 765 (see Fig. 3 for location).

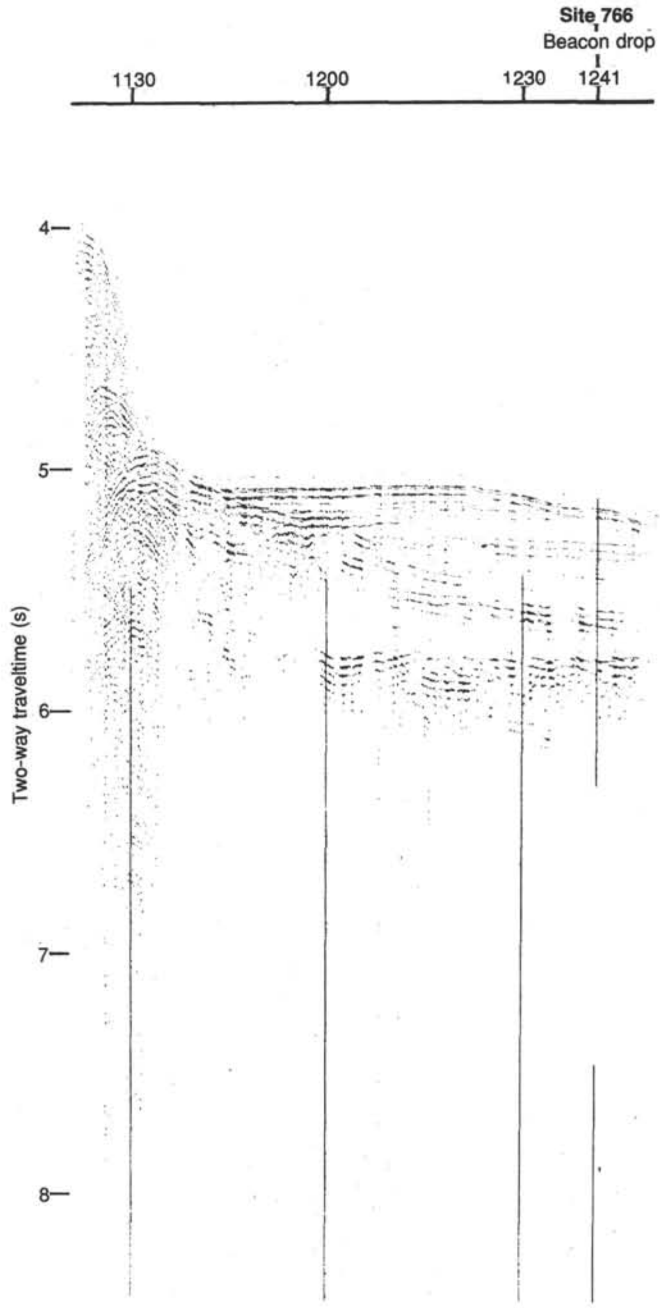

Figure 11. Shipboard monitor record of seismic Line 2B, collected during approach to Site 766. Beacon was dropped on second erosional bench (see Fig. 4 for location).

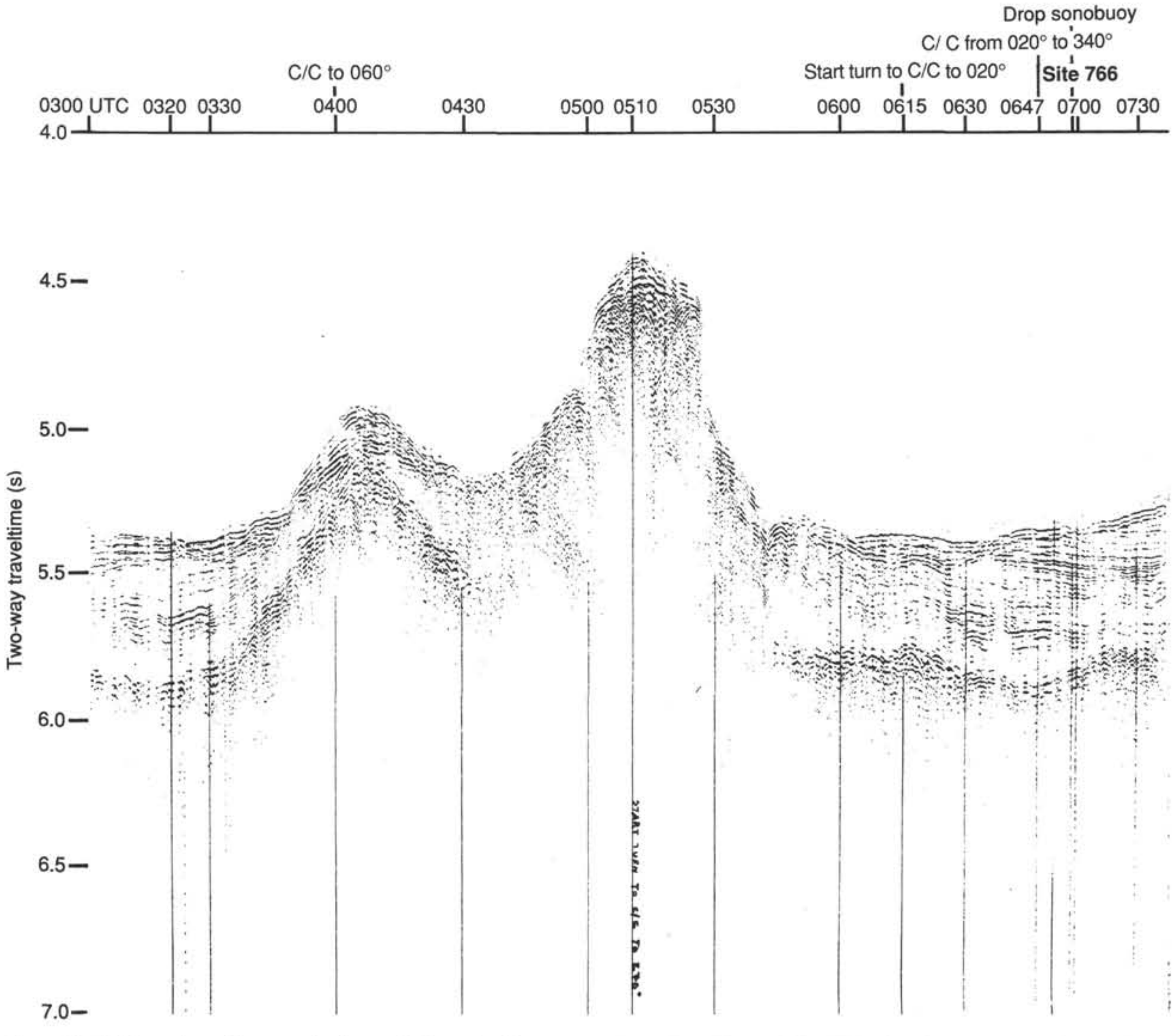

Figure 12. Shipboard monitor record of post-drilling seismic survey conducted southwest of Site 766, plus site crossing during sonobuoy survey (see Fig. 4 for location).

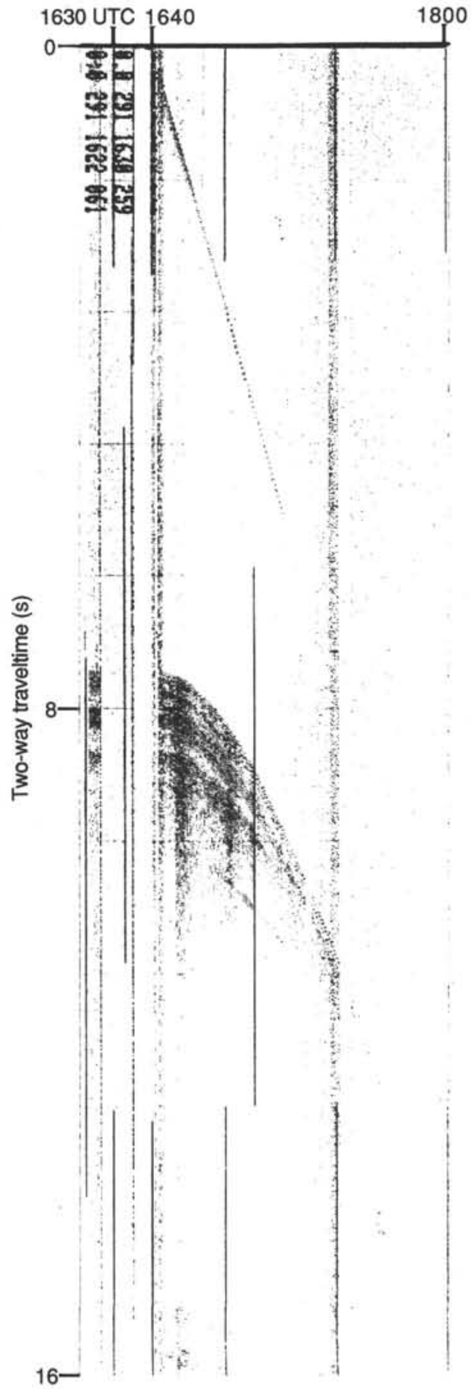

Figure 13. Shipboard monitor record of sonobuoy data collected during departure from Site 765 (see Fig. 3 for location).