Dziewonski, A., Wilkens, R., Firth, J., et al., 1992
Proceedings of the Ocean Drilling Program, Initial Reports, Vol. 136

3. SITE SURVEY AND UNDERWAY GEOPHYSICS[1]

John A. Collins,[2] Fred Duennebier,[3] and Shipboard Scientific Party[4]

SITE SELECTION

The strategic requirements for the first Ocean Seismic Network (OSN-1) site were proximity (<300 km) to an island-based, broad-band seismographic station, the availability of logistical support from an oceanographic institution, and location in water depths representative of the deep ocean (≈4000 m). An additional requirement was for a sediment cover (typical of much of the deep ocean floor) so that signal and noise comparisons could be made between sensors clamped within the igneous crust and sensors surficially buried in the sediment column (Fig. 3 in Chapter 1, this volume). The actual OSN-1 site meets all of these requirements. There is a well-established, broad-band seismographic station on Oahu (at Kipapa tunnel), and Hawaii Institute of Geophysics is within half a day's transit by ship. Water depth at the site is 4407 m, and the sediment thickness is about 240 m. At the tactical level, the particular selection of site OSN-1 (Hole 843B) was constrained by a number of additional factors and requirements. A relatively thin sediment column would reduce drilling time. It was also highly desirable to avoid the avalanche deposits and submarine lava flows that fill much of the Hawaiian Moat. High-quality seismic data as a control on the sedimentary and igneous crustal structure at the prospective site were considered essential. Other investigators, who expressed interest in using the drill hole for geological studies unrelated to the interest of OSN, favored a site south of the Hawaiian Islands as this would allow sampling of volcanic ash blown downwind from the islands of Maui and Hawaii. These considerations led to the selection of the actual site on the Hawaiian Arch about 225 km south of Oahu (Figs. 1 and 2).

Sediment thicknesses within 140 km of the Hawaiian Ridge are in excess of 1 km (Brocher and ten Brink, 1987). Consequently, total drilling time for a site within the Hawaiian Deep would have been substantially greater than for a site on the Hawaiian Arch, where sediment thicknesses are 240–400 m.

Moore et al. (1989), using the GLORIA sidescan sonar system, have shown that debris avalanche deposits cover a large area of the Hawaiian Ridge and adjacent seafloor. These deposits extend seaward of the axis of the Hawaiian Deep, and blocks up to 1 km in size are common in the distal part of these flows. It is likely that these distal deposits are made up of blocks of all sizes. Drilling through these deposits might have been difficult, perhaps analogous to the difficulties encountered in drilling through zero-age oceanic crust. Drilling at a site where the GLORIA images do not show significant back-scattered energy would not have guaranteed avoiding landslide deposits because (1) these deposits may be buried by a few tens of meters of mud or sand, and/or (2) the deposits may crop out on the seafloor but have blocks that are too small (<50–100 m) to be resolved by the GLORIA system. Site OSN-1 is sufficiently distant from the Hawaiian Ridge that substantial quantities of avalanche deposits were considered unlikely. GLORIA imagery (Torresan et al., 1991) collected at the site show no evidence for these types of deposits (Fig. 3).

Further difficulties might have been encountered at a site within the Hawaiian Deep, south or southeast of the island of Hawaii. A hole in this location would risk burial by submarine lava flows or landslide deposits. Lipman et al. (1989) suggest that the lava flows mapped by the GLORIA system in this area—which extend to the crest of the Arch—may be as young as 1 ka. Moore et al. (1989) suggest that the landslide deposits within 100 km to the south and east of Hawaii are of recent origin. From a seismological point of view, a site close to Hawaii would not have been desirable because of the certainty of recording seismicity associated with Kilauea volcano. Such seismicity is "noise" for the purposes of studying teleseismic events, which is the objective of OSN.

While a substantial quantity of seismic reflection data exists for the Hawaiian region, high-quality refraction data is not as common. It is difficult to accurately identify the sediment/igneous basement contact on many of these reflection profiles. Consequently, seismic refraction control on total sediment thickness was considered an essential requirement in the selection of site OSN-1. The combined multichannel reflection and refraction data collected by Watts et al. (1985) on *Robert Conrad* Cruise 2308 were used to make the final site selection. The drill site is located within 12 km of the mid-point of an Expanding Spread Profile (ESP) along which Common Depth Point (CDP) data (RC2308-303) were simultaneously acquired. Two CDP lines (RC2308-301, RC2308-304) intersect ESP-1 in the vicinity of the drill site.

Because the CDP data were collected with particular interest in imaging the Moho, the sound source used was designed to have highest power at low frequencies (≈10 Hz). Consequently the sediment/basement contact is not well imaged, although reflections from Moho are unambiguous. However, ESP-1 (Fig. 4) tightly constrains the two-way traveltime of the sedimentary section because a refracted phase ($V_p \approx 4.5$ km/s) can be traced through the seafloor reflection phase to a relatively high-amplitude reflection event ≈0.26 s below the seafloor (Brocher and ten Brink, 1987). The high velocity of this refracted phase strongly suggests it has turned in the top of the igneous crust. Although no refractions are observed from the sedimentary section, the observed two-way traveltime of this reflection event implies a sediment thickness of about 250 m, assuming a mean sediment velocity of 2 km/s. DSDP results from Site 67 to the north of the Hawaiian Islands (Winterer et al., 1971) suggest that this velocity value is probably an overestimate. Lindwall (1991) has attempted to refine the sediment thickness estimate by a more detailed analysis of ESP-1. Based on (1) the relative amplitudes of the seafloor and basement reflections, (2) the traveltime of the basement reflection phase, and (3) the efficiency of *P*-wave to *S*-wave conversion at the top of the igneous crust, he proposed that the sediment thickness is 220 m and that *P*-wave velocities at the top and bottom of the sediments are 1.65 ± 0.05 and 2.2 ± 0.1 km/s.

The correlation of the basement reflection phase on ESP-1 to the CDP data (Fig. 4) shows that in the vicinity of Site OSN-1 the two-way traveltime to basement does not vary laterally by more than about 0.05 s. Shallow reflection events on the CDP profiles with two-way traveltimes greater than 0.26 s are probably due to energy reverberating within the sedimentary section.

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[1]Dziewonski, A., Wilkens, R., Firth, J., et al., 1992. *Proc. ODP, Init. Repts.,* 136: College Station, TX (Ocean Drilling Program).

[2]Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, U.S.A.

[3]Department of Geology and Geophysics, School of Ocean and Earth Science and Technology, University of Hawaii, Honolulu, HI 96822, U.S.A.

[4]Shipboard Scientific Party is as given in the list of participants preceding the contents.

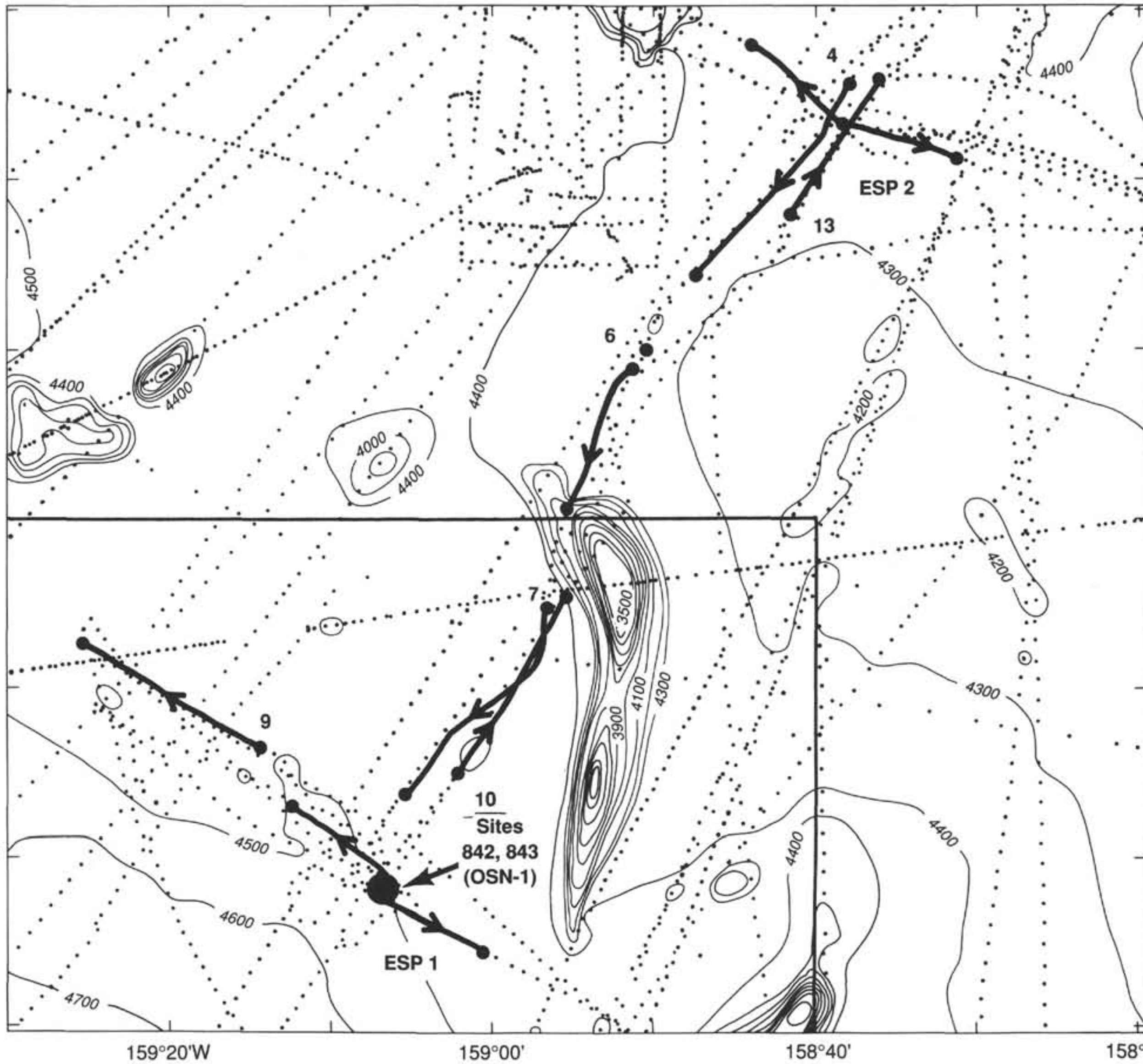

Figure 1. Detailed bathymetry around Sites 842 and 843. Bathymetry, contoured at 100-m intervals, is based on soundings along the ship tracks shown as dotted lines. Bold solid lines show the location of sonobouy and ESP refraction profiles. The box outlines the boundaries of Figure 2.

SITES 842 AND 843

Sites 842 and 843 are located within 1.5 km of each other. Water depths at these sites are 4430 and 4407 m, respectively. Hole 843B is also known as OSN-1. Site 842 is on the slope of a hill trending north-northwest, rising about 60–70 m above the regional abyssal plain. GLORIA sonar images (Torresan et al., 1991) show relatively undisturbed sediments in the region, with abyssal hill fabric evident striking NW–SE. Both sites lie to the south of the Molokai Fracture Zone. The drill sites lie within the Cretaceous magnetic quiet zone, and prior to Leg 136 the age of the crust was loosely constrained to be 80–110 m.y.

Prior to drilling, 3 hr at the start of Leg 136 were scheduled for an echo sounding, seismic reflection, and magnetometer survey (Fig. 5). Both the 3.5-kHz and 12-kHz echo sounders were used, and the latter was used to generate a detailed bathymetry map (Fig. 6). To refine the basement depth, two 80-in3 water guns were used to collect high-resolution, single-channel seismic reflection data.

Analysis of the spectra from the 3.5-kHz system showed that the outgoing signal was severely distorted in the high-power output mode, resulting in strong spectral peaks at about 2.2 kHz and 6 kHz and a lengthening of the source pulse. As there was no time to consider repair, the system was used as it was, with an unknown amount of degradation in signal-to-noise ratio. The resulting 3.5-kHz data (Fig. 7) show thinning of the shallow-most sedimentary layers on the abyssal hills, relative to the sediments in the surrounding basins.

The water guns and port seismic streamer were deployed 1 hr prior to the start of the survey for check-out. A spectrum analyzer showed that the port streamer had a strong (40 dB) resonance at about 220 Hz, causing the records to be nearly useless. The starboard streamer was deployed, although it was known to be noisy. Flow noise at 25 Hz and below is considerably worse on the starboard streamer than the port streamer, but the 220-Hz noise was absent, and the starboard streamer was used for the remaining half of the survey (after shot 1065). Digital data (2055 shots) were recorded on magnetic tape, and re-processing might allow correlation of reflection events with the drilling results

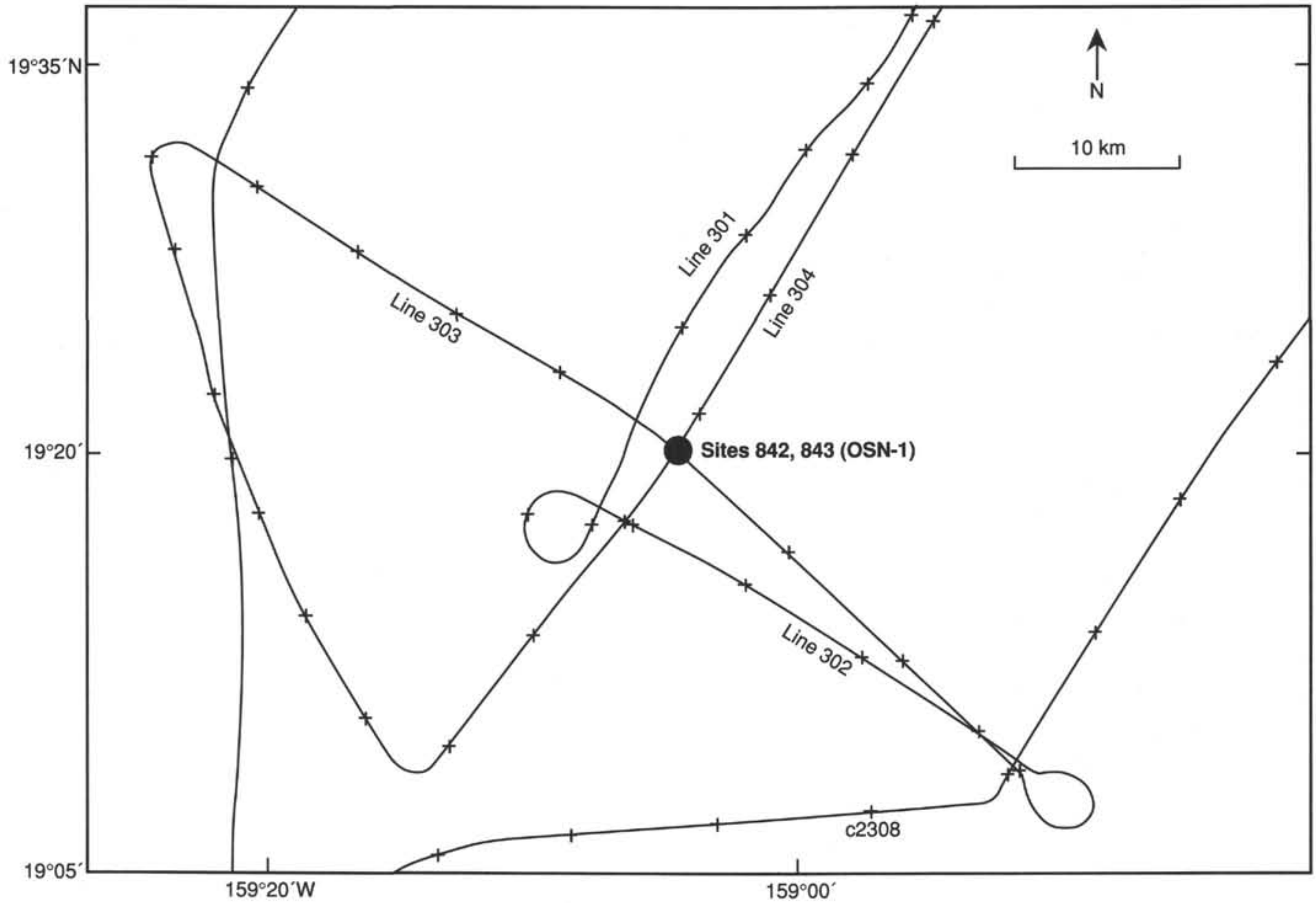

Figure 2. Multichannel reflection profiling tracks in the vicinity of Sites 842 and 843. Note that the sites are close to the intersection of two MCS profiles, one of which is located along ESP-1. The drill sites are located at the mid-point of ESP-1, the results of which are shown in Figure 4.

(Fig. 8). Knowledge of the impedance structure within the sedimentary section will allow a more refined interpretation of the CDP and ESP data.

Despite the use of a much higher frequency source, no obvious basement reflection (characterized by strong reflections, reflection hyperbolas, and a lack of reflections below) was observed. The sediment column is reverberant, and reflections are observed as deep as 0.5 s below the bottom, beyond which reflected energy is relatively much weaker. Sediment thickness appears to thin by as much as 100 m under the topographic highs when compared to the sediments in the basins off the flanks. This thinning was the basis for choosing the drill site on a high, in an attempt to save drilling time.

REFERENCES

Brocher, T. M., and ten Brink, U. S., 1987. Variations in oceanic layer 2 elastic velocities near Hawaii and their correlation to lithospheric flexure. *J. Geophys. Res.,* 92:2647–2661.

Lindwall, D. A., 1991. Old Pacific crust near Hawaii: a seismic view. *J. Geophys. Res.,* 96:8191–8203.

Lipman, P. W., Clague, D. A., Moore, J. G., and Holcomb, R. T., 1989. South Arch volcanic field—newly identified young lava flows on the seafloor south of the Hawaiiian Ridge. *Geology,* 17:611–614.

Moore, J. G., Clague, D. A., Holcomb, R. T., Lipman, P. W., Normark, W. R., and Torresan, M. E., 1989. Prodigious submarine landslides on the Hawaiian Ridge. *J. Geophys. Res.,* 94:17465–17484.

Torresan, M. E., Shor, A. N., Wilson, J. B., and Cambell, J., 1991. Cruise report, Hawaiian GLORIA Leg 5 F5-88-HW. *Open File Rep.—U.S. Geol. Surv.,* 89-198.

Watts, A. B., ten Brink, U. S., Buhl, P., and Brocher, T. M., 1985. A multi-channel seismic study of lithospheric flexure across the Hawaiian-Emperor seamount chain. *Nature,* 315:105–111.

Winterer, E. L., Riedel, W. R., et al., 1971. *Init. Repts. DSDP,* 7 (Pt. 1): Washington (U.S. Govt. Printing Office).

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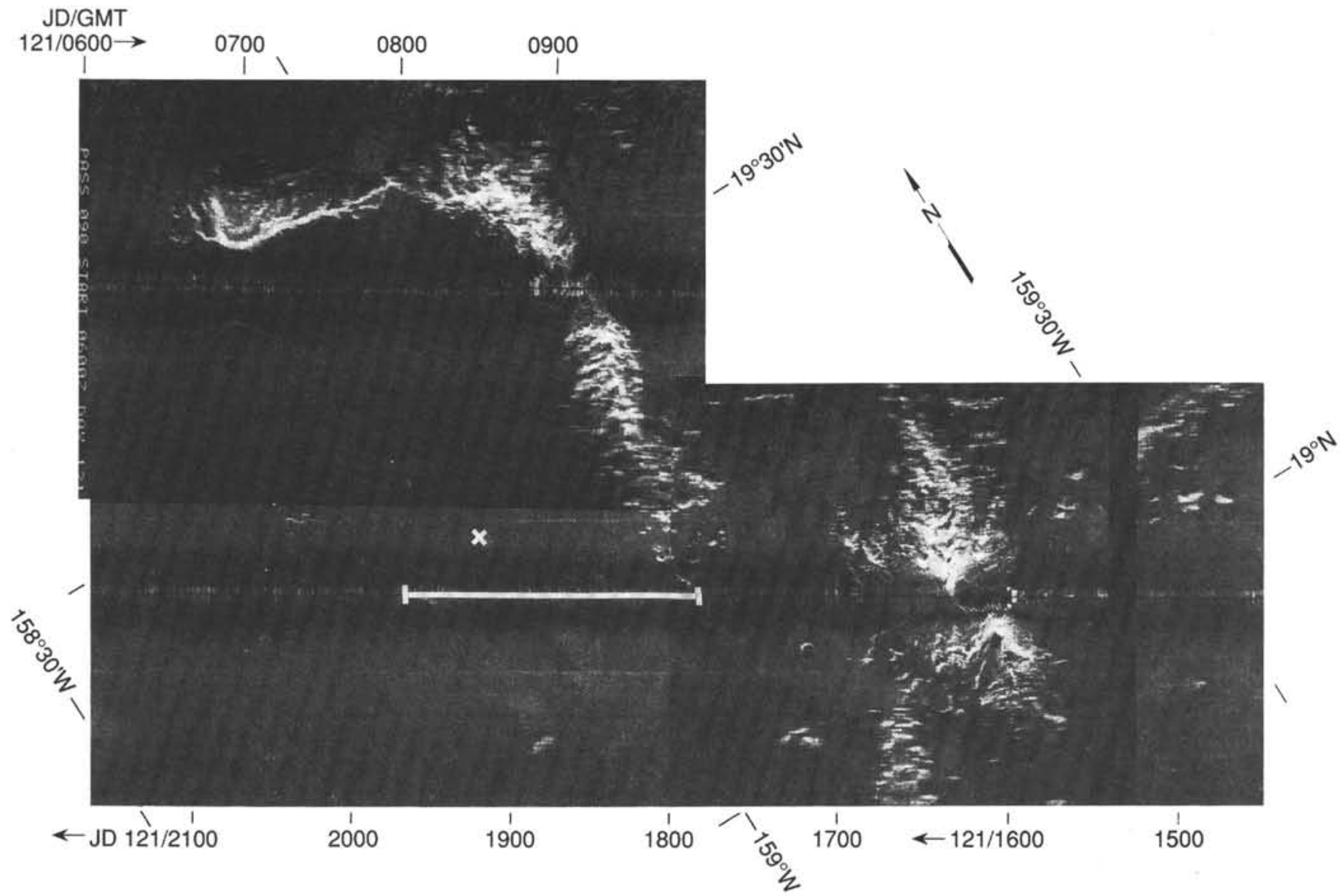

Figure 3. GLORIA image in the immediate vicinity of Sites 842 and 843 (marked by X). The straight line indicates the ship's track (courtesy of M. Torresan, USGS, Menlo Park, CA 94025).

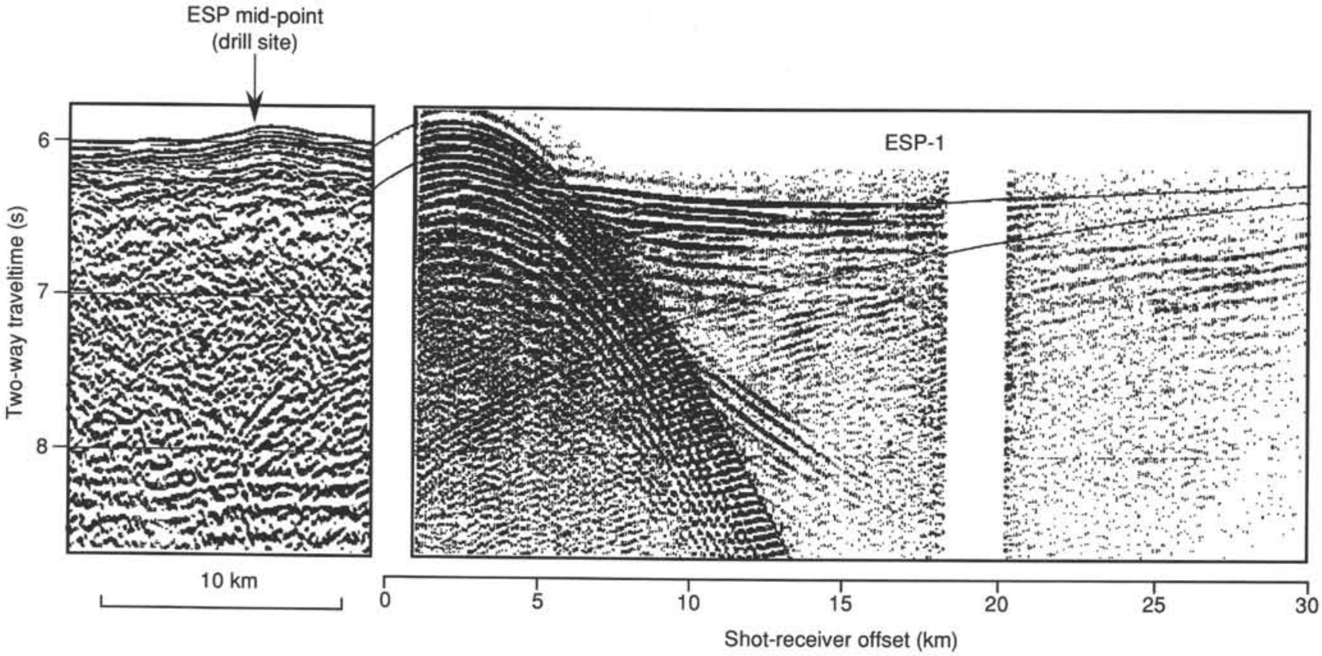

Figure 4. ESP-1, the mid-point of which is within 2 km of Sites 842 and 843 (from Brocher and ten Brink, 1987).

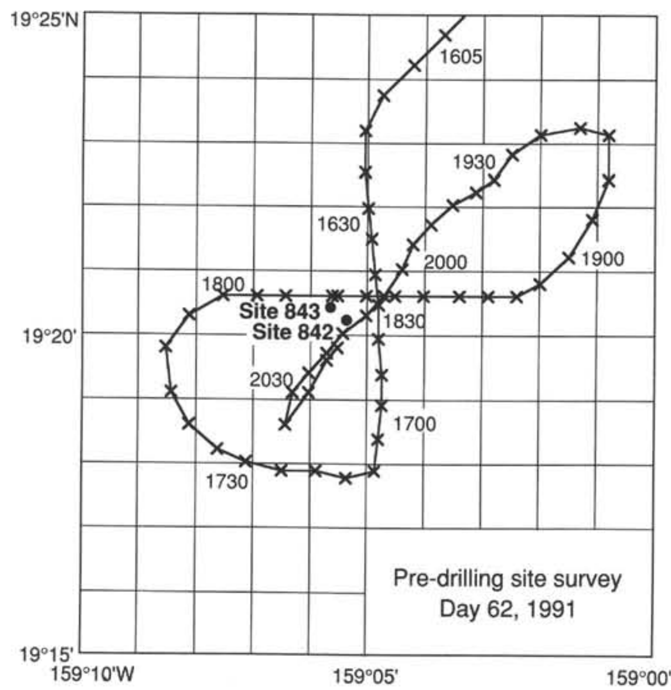

Figure 5. Track lines for the Leg 136 site survey.

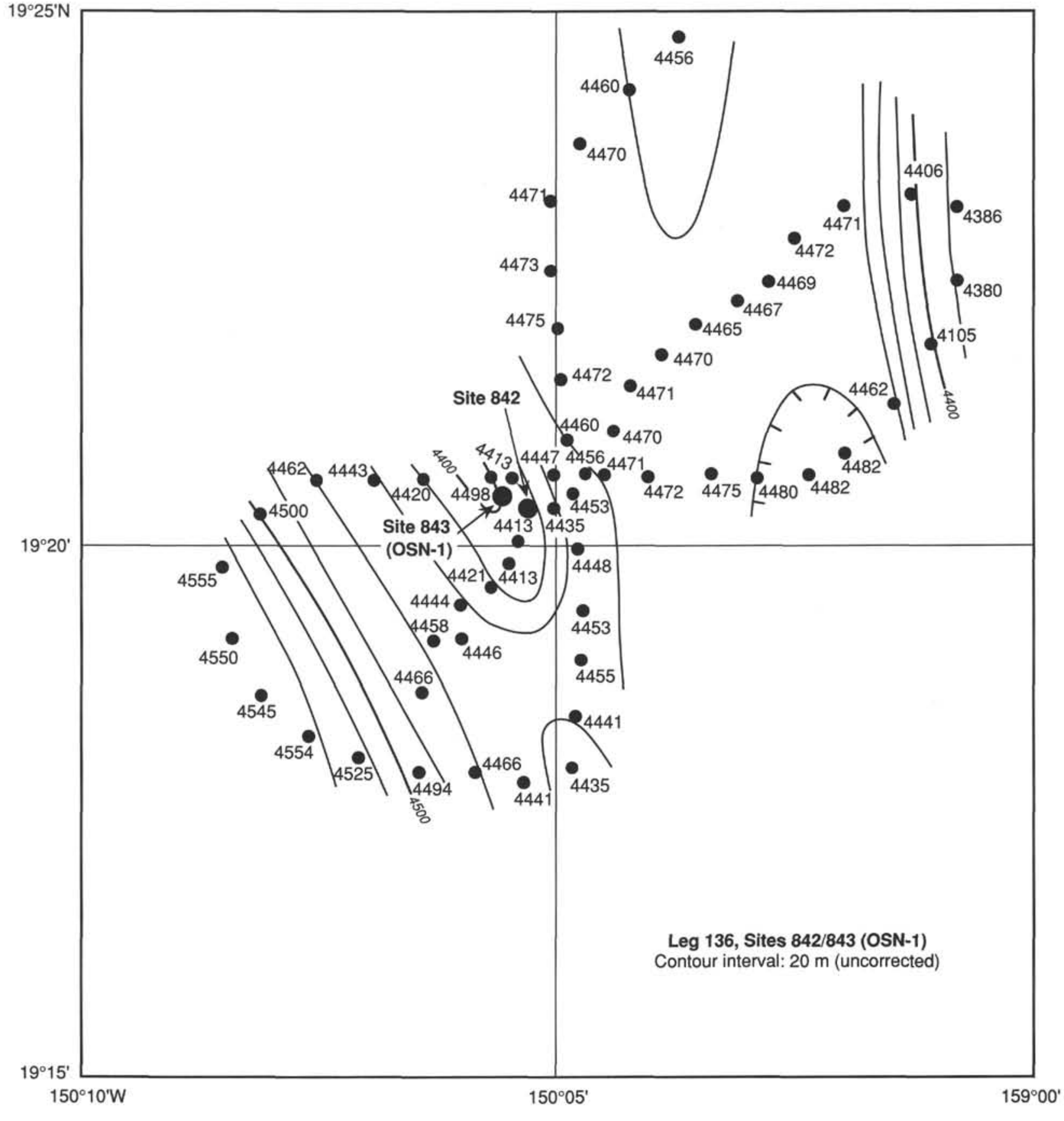

Figure 6. Detailed bathymetry in the immediate vicinity of Sites 842 and 843.

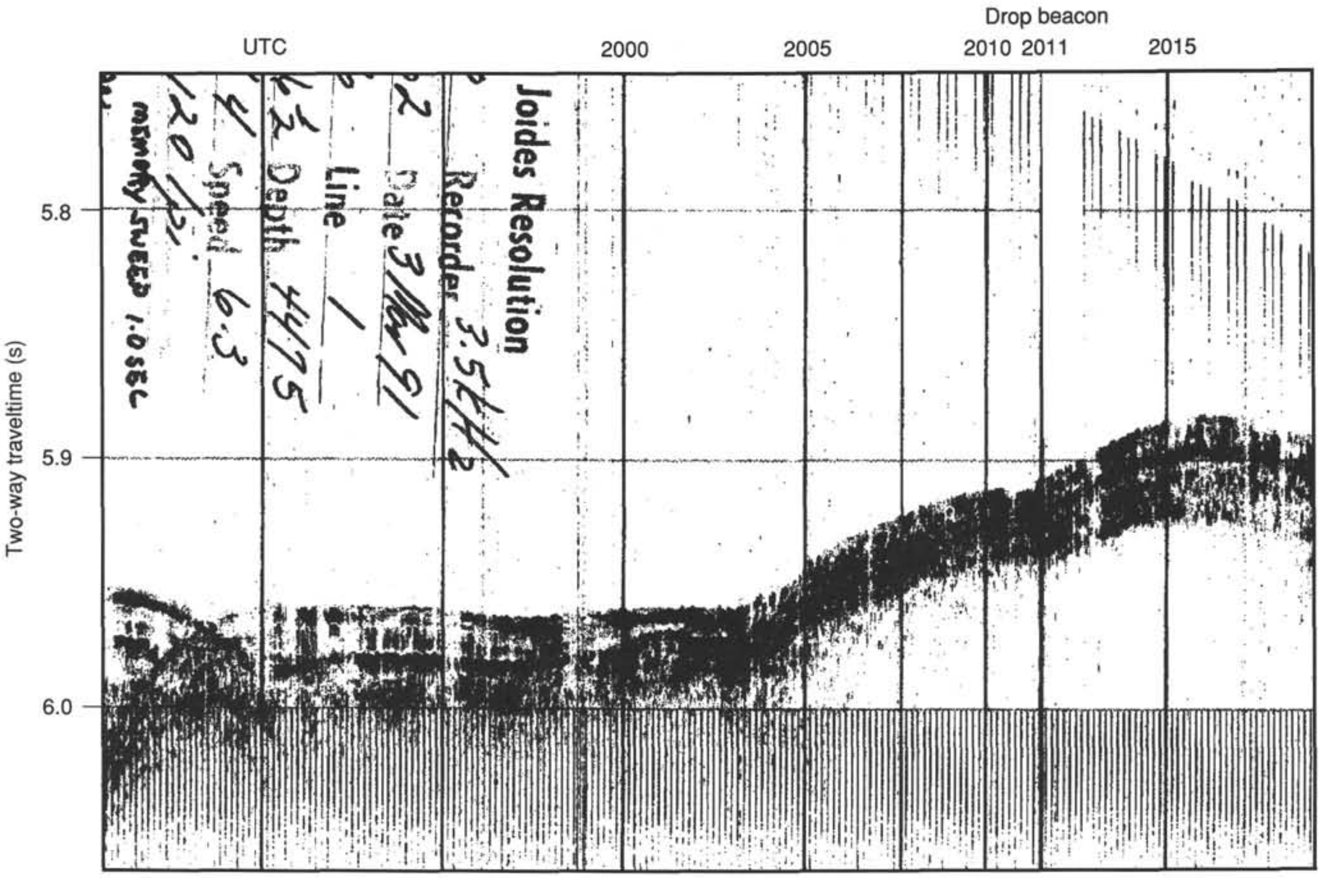

Figure 7. Echo sounder data (3.5 kHz) at Site 842.

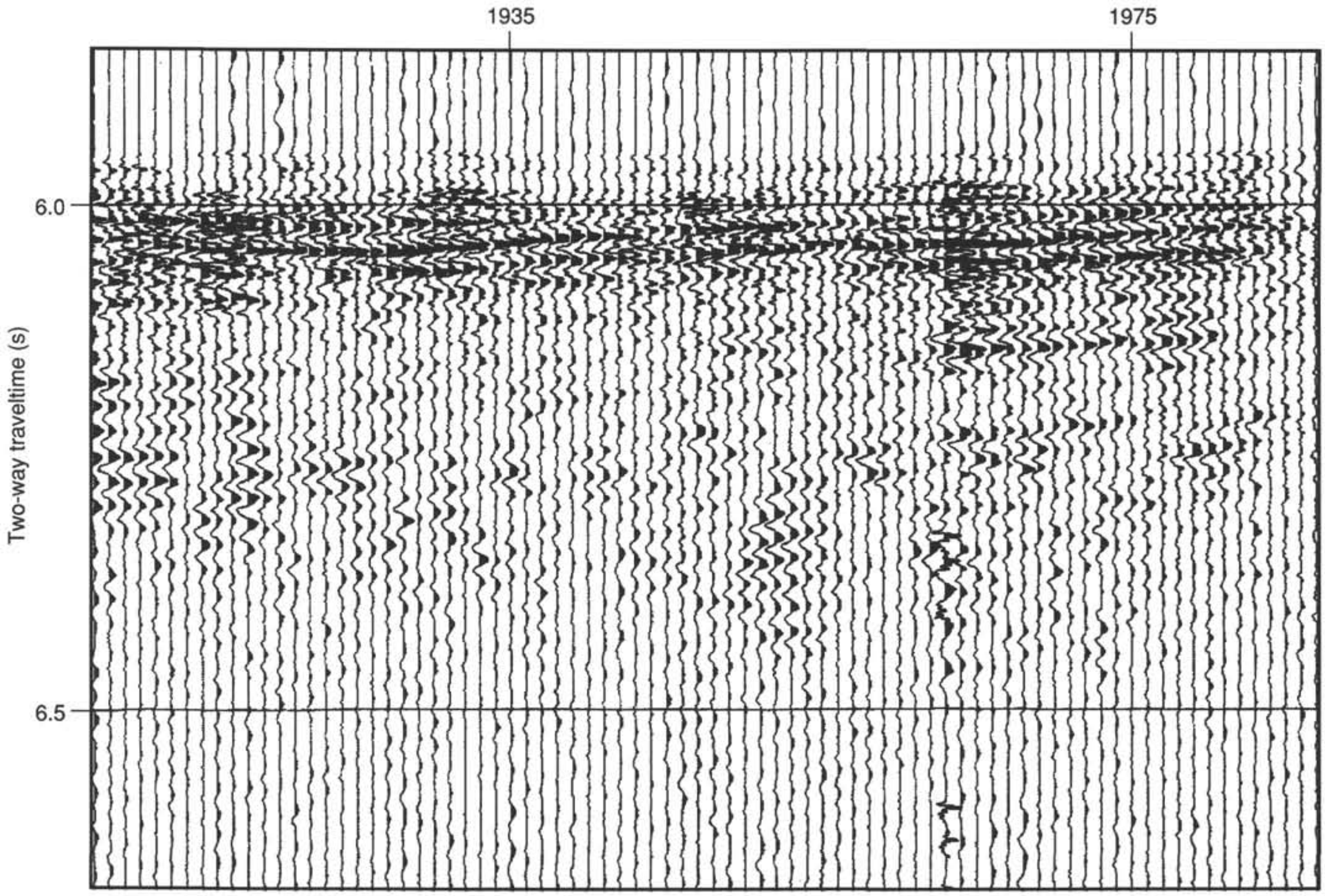

Figure 8. Single-channel seismic reflection profile northwest of Sites 842 and 843.