3. GEOPHYSICAL SITE SURVEY RESULTS: LEG 88[1]

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ABSTRACT

This chapter describes the underway geophysical data collected near Site 581. Single-channel (sparker) seismic records from all tracklines and selected high-resolution (3.5-kHz) seismic records are presented. Profiles of magnetic data are displayed with associated bathymetric and acoustic basement profiles. The seismic reflection data, combined with data previously collected in the area, were used to make contour maps of bathymetry and acoustic basement. A map showing echo character types observed on the 3.5-kHz records is included.

U.S.N.S. *De Steiguer* left Adak at 0700L on 27 August 1982 and arrived at Site 581 at 2100L, 31 August 1982. Underway geophysical data were collected by *De Steiguer* during the site survey phase of the project, during deployment of ocean bottom seismometers, and while shooting for the seismic-refraction crustal studies. Single-channel seismic reflection data were continuously collected by *De Steiguer* from 0126Z, 28 August to 0528Z, 10 September, with the exception of the 75 hr. from 0240Z, 5 September to 0540Z, 8 September, when typhoon Gordon passed through the area. Seismic records cover more than 3712 km of trackline.

Single-channel seismic reflection data were obtained using a 30-kJ sparker and a 100-m-long hydrophone streamer. Several analog recorders were used. Sweep rates were chosen to obtain both high-resolution records from the upper sediment layers and a complete 10-s (two-way traveltime) sedimentary-acoustic basement section. The seismic records were digitized in the laboratory to obtain bathymetric and acoustic basement depths. Depths are presented in this chapter either as two-way traveltime in seconds or as uncorrected meters assuming a water velocity of 1500 m/s. Final navigation corrections (generally less than 0.5 km) were made by forcing bathymetry and shallow sub-bottom reflectors at track crossings to be in agreement.

Data from the Scripps Institution of Oceanography *Melville* (Antipode cruise, Leg 3), the U.S. Naval Oceanographic Office U.S.N.S. *Hunt* Cruise 931003, and the D.S.D.P. *Glomar Challenger* Legs 86 and 88 were integrated with *De Steiguer* observations to make the contour maps presented in this chapter. The ships' tracklines used for this analysis are presented in Figure 1.

The bathymetric data from the *Glomar Challenger* were provided by D.S.D.P. in digital form. The basement depths were obtained by digitizing tracings made from microfilms of the original *Glomar Challenger* records. The bathymetric and basement data from the *Melville* and *Hunt* cruises were taken from preliminary maps made for the Environmental Report of the Northwest Pacific for the Marine Seismic System (Green and Fleischer, 1980), a comprehensive study of the area which was done to help select a drill site for the deployment of a borehole seismic system during Leg 88.

BATHYMETRIC CONTOUR MAPS

Figure 2 shows a map of the bathymetry within a 1.3° × 1.5° rectangle surrounding the drill site. At about 44°40′N, the dominant feature on that map is the Hokkaido Trough. It is a steep-sided, elongate, sinuous, feature that extends from the Hokkaido Rise eastward to the Emperor Seamounts. Within the mapped area shown in Figure 2 are several abyssal hills with relief of 200 to 400 m. There also are two (possibly three) shallow broad depressions deepening toward the trough.

The drill site location is noted in Figure 3, which is an expanded (10′ × 15′) bathymetric contour map centered at the drill hole. As can be seen in Figure 3, the drill site is located at the edge of one of the broad depressions at the base of a 250-m abyssal hill.

SEISMIC REFLECTION RECORDS

The hachured ship's tracklines (Fig. 4) indicate the tracklines along which the records shown in Figure 5 were collected, and the thick solid lines indicate where the records shown in Figure 6 were collected. The records shown in Figure 5 contain high-resolution (3.5-kHz) data from the upper 0.25 s of sediment. Full seafloor to acoustic basement seismic reflection records are shown in Figure 6.

Patterns showing the areal extent of shallow sub-bottom reflector types which are observed in the high-resolution (3.5-kHz) records are superimposed on a simplified bathymetric map in Figure 7. Type 1 (Fig. 5, Section A–A′) consists of a transparent zone immediately beneath the water bottom reflector. Its measurable thickness ranges from 0.012 to 0.027 s (two-way traveltime) and is generally about 0.02 s. The Leg 88 holes were drilled into sediments which produced this type of transparent reflection zone. Type 1 reflections are also associated with part of a small, narrow bulge in the seafloor surface at 159°48′E, extending from 43°51′N to 43°53′N (Fig. 3).

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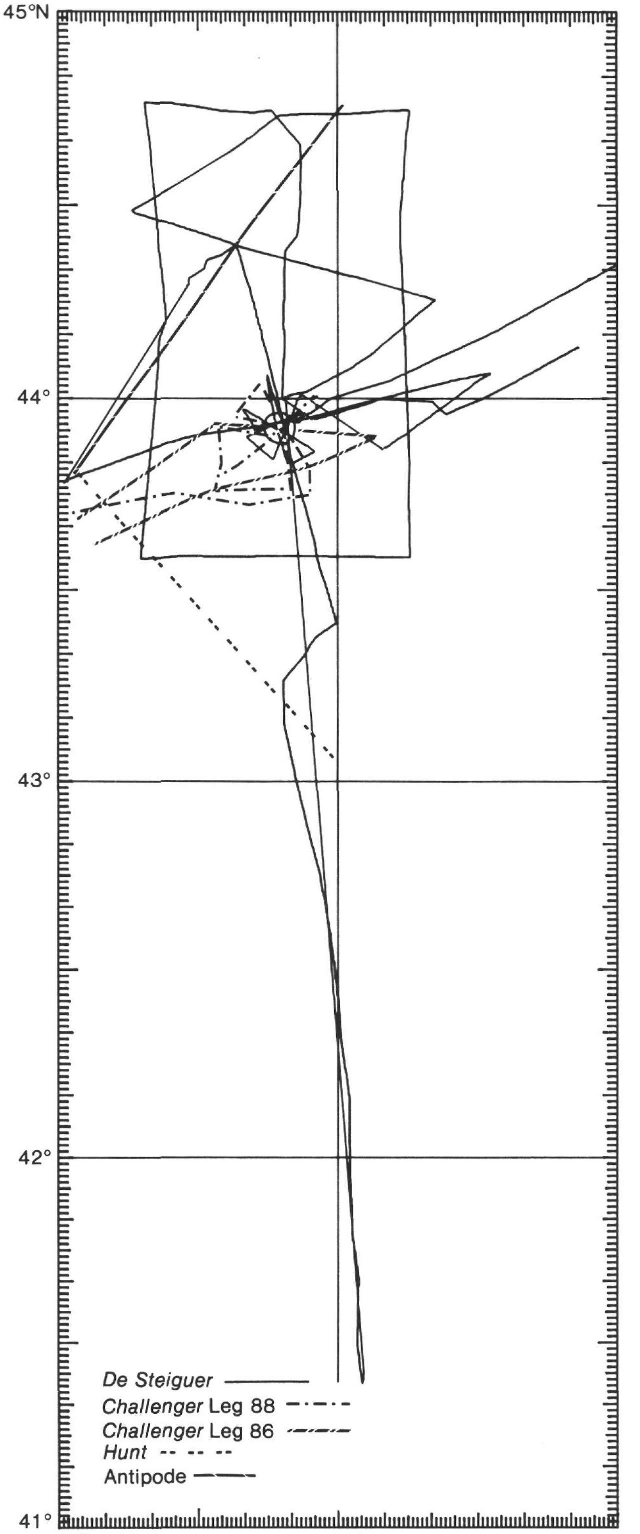

Figure 1. Track chart showing lines along which seismic reflection data were collected by U.S.N.S. *De Steiguer.* Also indicated are tracklines of *Glomar Challenger*, U.S.N.S. *Hunt*, and *Melville* (Antipode 3 cruise) in the survey area. Seismic data collected along these lines were used to compile the contour maps in Figures 2, 3, 7, 8, and 9.

Section Y–Y′ (Fig. 5) is a portion of record extending across the bulge and onto the transparent zone. At the base of the scarp is an apparent slump deposit, producing reflections that are typical of the type IV classification of Damuth et al. (1983) (indistinct, prolonged bottom echoes over fuzzy semi-transparent zone, produced by mass transport deposits from slumping and slides). The adjacent transparent zone may be related to debris-flow deposits.

The second type of reflector (Fig. 5, Section B–B′) consists of a group of five or six parallel reflecting horizons that mimic the acoustic basement topography. They are mostly distinct and continuous, and fall into the IB category of the Damuth et al. (1983) classification scheme (sharp, continuous, numerous parallel sub-bottoms, hummocky terrain). They are observed in an area where the seafloor is composed of low rounded hills (Fig. 5) of about 10 to 30 m relief. This seismic unit appears to be the one labeled seismic Unit II by Heath, Burckle, et al. (1985), who suggest that these reflectors correspond to ash layers.

The third type of reflector is characterized by poor, discontinuous reflections (Fig. 5, Section C–C′) and would be classified as type III in the Damuth et al. (1983) classification scheme (distinct to indistinct bottom echoes with intermittent unconformable sub-bottoms), thus suggesting the presence of reworked sediments. This third type of reflector is observed along some lines, between the areas where the first (transparent) and second (parallel) types of reflectors are found.

The fourth type of reflector shows no clear sub-bottom reflectors (Fig. 5, D–D′). It is associated with the crests and slopes of most of the abyssal hills to the east, southeast, and south of the drill site. On these hills there are some areas, (indicated on the map in Fig. 7) where patches of poorly defined, possibly parallel, reflectors are recorded. However, the records are not clear enough to assign these reflections to one of the reflector types with certainty, so no attempt at classification was made.

ACOUSTIC BASEMENT

Neither the bathymetric contour maps (Figs. 2 and 3) nor the contour maps of acoustic basement (Figs. 8 and 9) show a distinct orientation of features as is seen in the bathymetry around Sites 578 and 576, which are located about 1300 km south of Site 581 (Jacobi et al., 1985). At those sites, the bathymetry is clearly oriented parallel to the strike of the magnetic lineations.

The acoustic-basement surface (Fig. 9) is the deepest reflector clearly visible on the records. In general it produces reverberatory reflections which, on the basis of Leg 86 drilling results (Heath, Burckle, et al., 1985), most likely correspond to a chert layer. Reflections from the upper surface of the basalt often are indistinguishable from those of the overlying chert. Where it was possible to identify the deeper (basalt) reflector, it was picked as acoustic basement; however, the reflector picked and mapped as acoustic basement (Figs. 8 and 9) probably represents the top of the chert layer more often than it does the basalt.

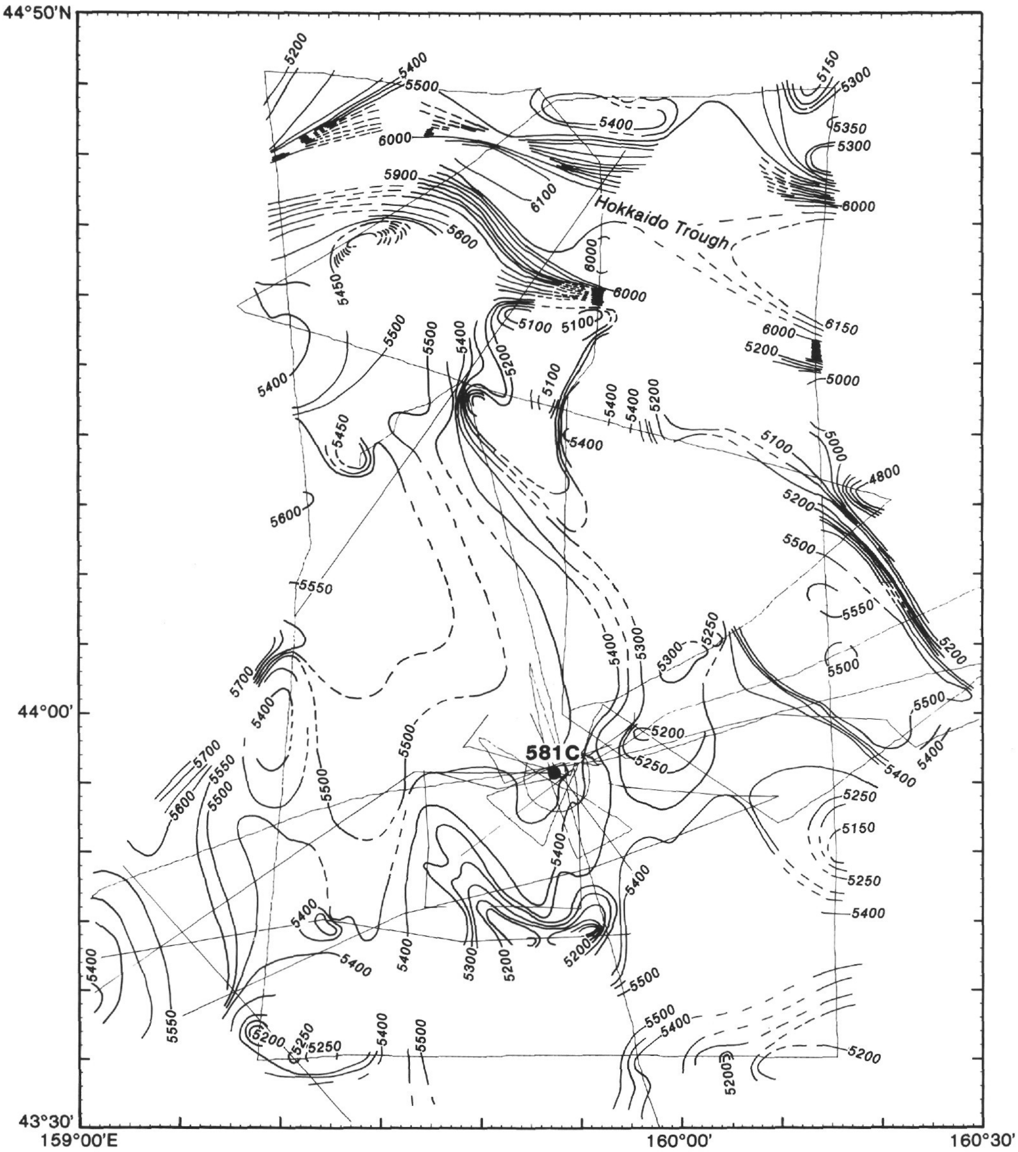

Figure 2. Contour map of bathymetry in the site survey area, with the location of Hole 581C. Contours are in uncorrected meters using a velocity of 1500 m/s. Contour interval is 50 m.

We relate acoustic basement to the chert layer for the following reason. The depth to acoustic basement can be estimated using the average sediment compressional-wave velocity (1720 m/s), determined from data collected by *Glomar Challenger*, and the two-way traveltime depths of 0.33 to 0.38 s observed in *De Steiguer* data from the trackline closest to the drill site. These values give an estimated acoustic-basement depth of 283 to 327 m at a distance of about 1 km from the drill site. In the Leg 86 core from Hole 581, only chert fragments were obtained between 276 and 343 m sub-bottom depth. This depth range is consistent with the calculated depths to the acoustic basement. Further, basalt was drilled at 343 m on Leg 86 and 360, 351, and 357 m on Leg 88, and all of these depths are greater than the estimated depth to acoustic basement.

It is not possible to determine precisely the extent to which the chert, where it occurs as fill between peaks, masks the basement roughness. However, the drill site is located in a basement depression, and if we make the assumption that the thickness of the chert at the drill site is typical of the maximum thickness in the area, then we can estimate that between 50 to 100 m of relief could be masked by the chert in some places.

MAGNETICS

Over 1259 trackline kilometers of proton precession magnetometer data were collected by *De Steiguer* during the period from 28 August 1982 through 4 September 1982. The regional magnetic field was removed from these data using the International Geomagnetic Reference Field (IGRF) for 1980 updated for 1982 (IAGA Division 1, Working Group 1, 1981), with the zero level adjusted for clarity of presentation.

Figure 10 shows the location of six sets of magnetics, bathymetry and acoustic basement topography profiles

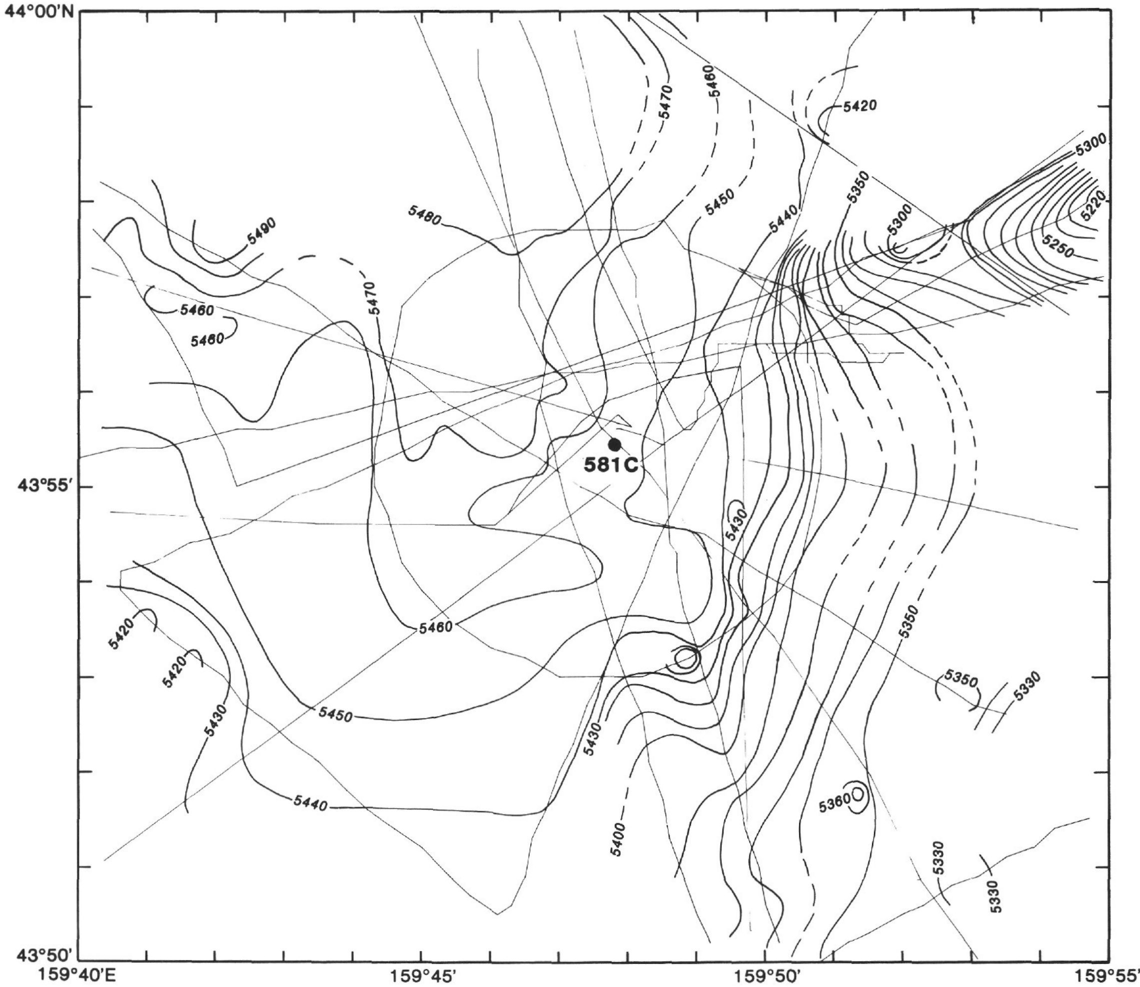

Figure 3. Contour map of bathymetry in immediate vicinity of Site 581. Contours are in uncorrected meters using a velocity of 1500 m/s. Contour interval is 10 m. The location of Hole 581C is shown on the map.

in the survey region. These profiles are shown in Figure 11. Three of these are N-S profiles, labeled A-A′, B-B′, and C-C′ and three are E-W profiles, D-D′, E-E′, and combined profiles F_1-F_1', F_2-F_2'.

Because of the small amount of data from this area, magnetic lineations from the survey site are poorly mapped. The region north of the Hokkaido Trough is presumed to be within the Cretaceous quiet zone (Hilde et al., 1976). Hilde et al. (1976) located the Mesozoic Anomaly CL within the Site 581 magnetic survey area, north of Hole 581, and the Anomaly M-1 to the south of the survey area. All data currently available from the region suggest that Anomaly M-1 is located south of the area. Anomaly CL cannot be identified on the magnetics profiles in Figure 11. If CL is present, an extension of its trend from where it can be identified suggests that it would be located north of the survey area (D. Handschumacher, pers. comm., 1985). Heath, Burckle, et al. (1985) place Site 581 between the M-3 and M-4 anomalies.

Our interpretation suggests a crustal age of between 110 m.y. (Larson and Hilde, 1975, time scale) and 122 m.y. (Harland et al., 1982, time scale). This is consistent with the estimated crustal age of 115 m.y. given by Heath, Burckle, et al. (1985).

Given the disagreement about the location of the anomalies, it is difficult to suggest a spreading rate for the area. Using several different time scales and different locations for the anomalies, we determined that the spreading rate north of 43°30′N should be the same as or greater than that south of 43°30′N. The section of the seismic record indicated by X-X′ in Figure 6 was collected south of 43°30′N. Figure 6 shows that the basement is relatively smooth south of the magnetics survey area and rougher near Site 581. This does not agree with the assumption that the faster spreading zone will produce lower relief than the slower spreading zone. It suggests that the relief around Site 581 is probably related to the Hokkaido Trough tectonism rather than initial formation of the oceanic crust.

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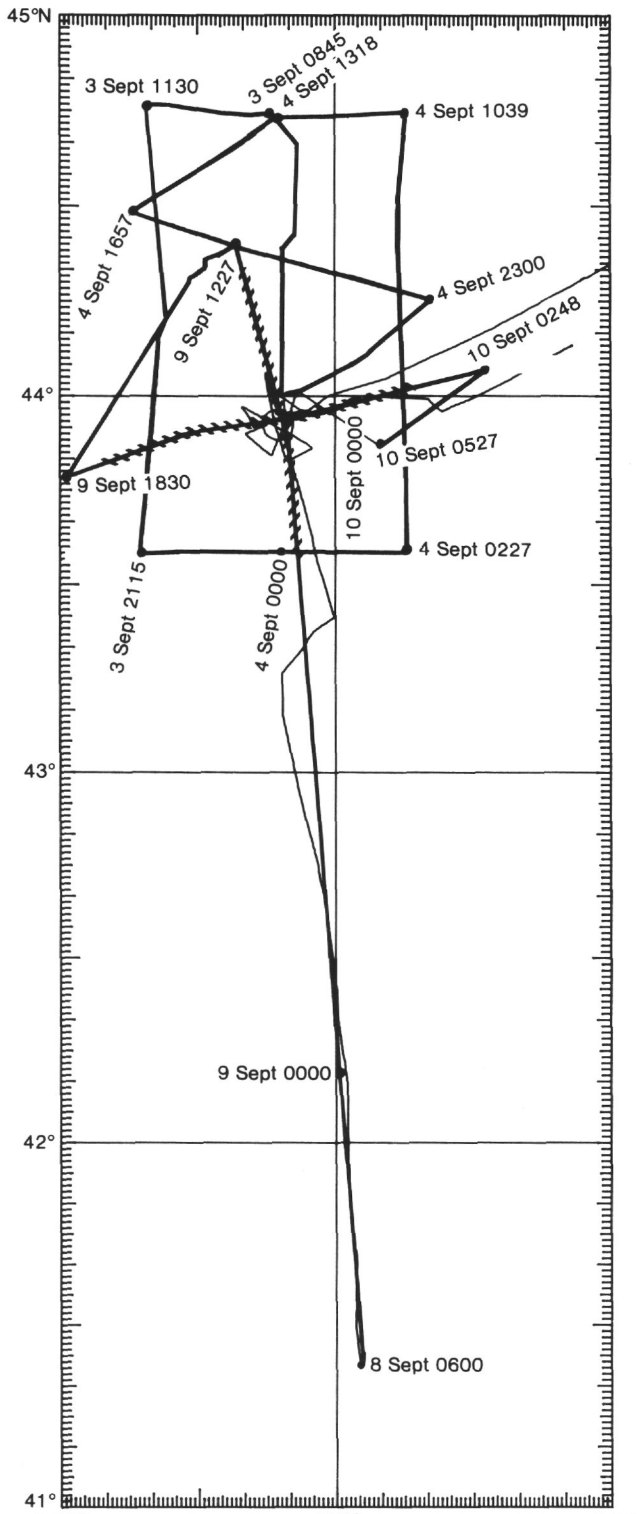

Figure 4. Track chart indicating the locations of record sections shown in Figures 5 and 6. Hachured lines indicate locations where records made with a 1-s sweep rate and displayed in Figure 5 were collected. Thick solid lines show locations of records made with an 8-s sweep rate. They are displayed in Figure 6.

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REFERENCES

Damuth, J. E., Jacobi, R. D., and Hayes, D. E., 1983. Sedimentation processes in the Northwest Pacific Basin revealed by echo-character mapping studies. *Geol. Soc. Am. Bull.*, 94:381-395.

Green, J. A., and Fleischer, P., 1980. *Environmental Report of the Northwest Pacific for the Marine Seismic System (MSS).* Defense Applied Research Agency Order Number 3693, NORDA Report 31, 174 pp.

Harland, W. B., Cox, A. V., Llewellyn, P. G., Pickton, C. A. G., Smith, A. G., and Walters, R., 1982. *A Geologic Time Scale:* Cambridge (Cambridge University Press).

Heath, G. R., Burckle, L. H., et al., 1985. Site 581. *In* Heath, G. R., Burckle, L. H., et al., *Init. Repts. DSDP*, 86: Washington (U.S. Govt. Printing Office), 241-266.

Hilde, T. W. C., Isezaki, N., and Wageman, J. M., 1976. Mesozoic seafloor spreading in the North Pacific. *Am. Geophys. Union Geophys. Monograph*, 19:205-226.

IAGA Division 1, Working Group 1, 1981. International geomagnetic reference fields: DGRF 1965, DGRF 1975, and IGRF 1980. *Eos, Trans. Am. Geophys. Union* 62:1169.

Jacobi, R. D., Hayes, D. E., and Damuth, J. E. High-resolution seismic studies and site survey results near Deep Sea Drilling Project Sites 576 and 578, Northwest Pacific. *In* Heath, G. R., Burckle, L. H., et al., *Init. Repts. DSDP*, 86: Washington (U.S. Govt. Printing Office), 23-49.

Larson, R. L., and Hilde, T. W. C., 1975. A revised time scale of magnetic reversals for the Early Cretaceous and Late Jurassic. *J. Geophys. Res.*, 8:2586-2594.

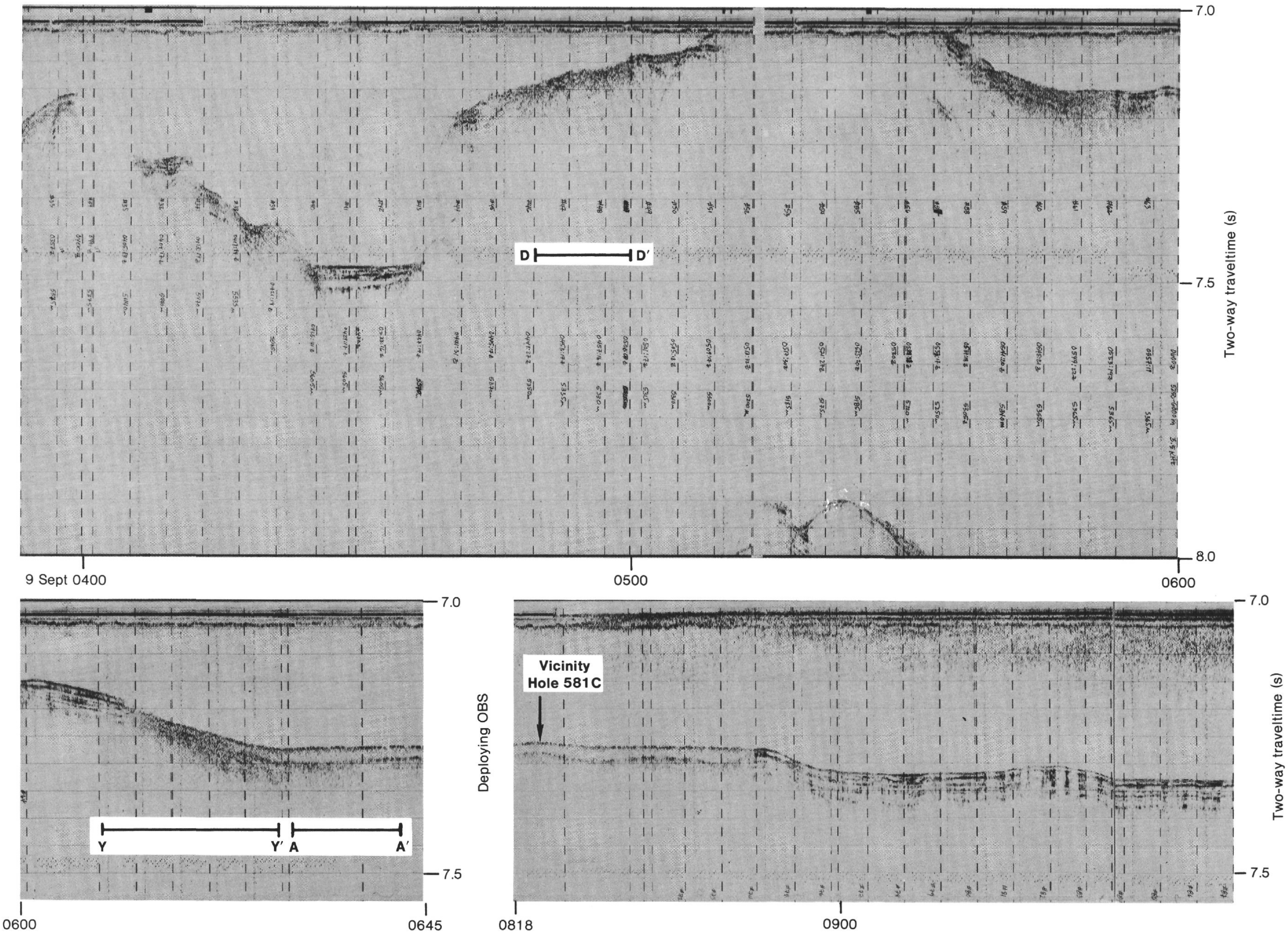
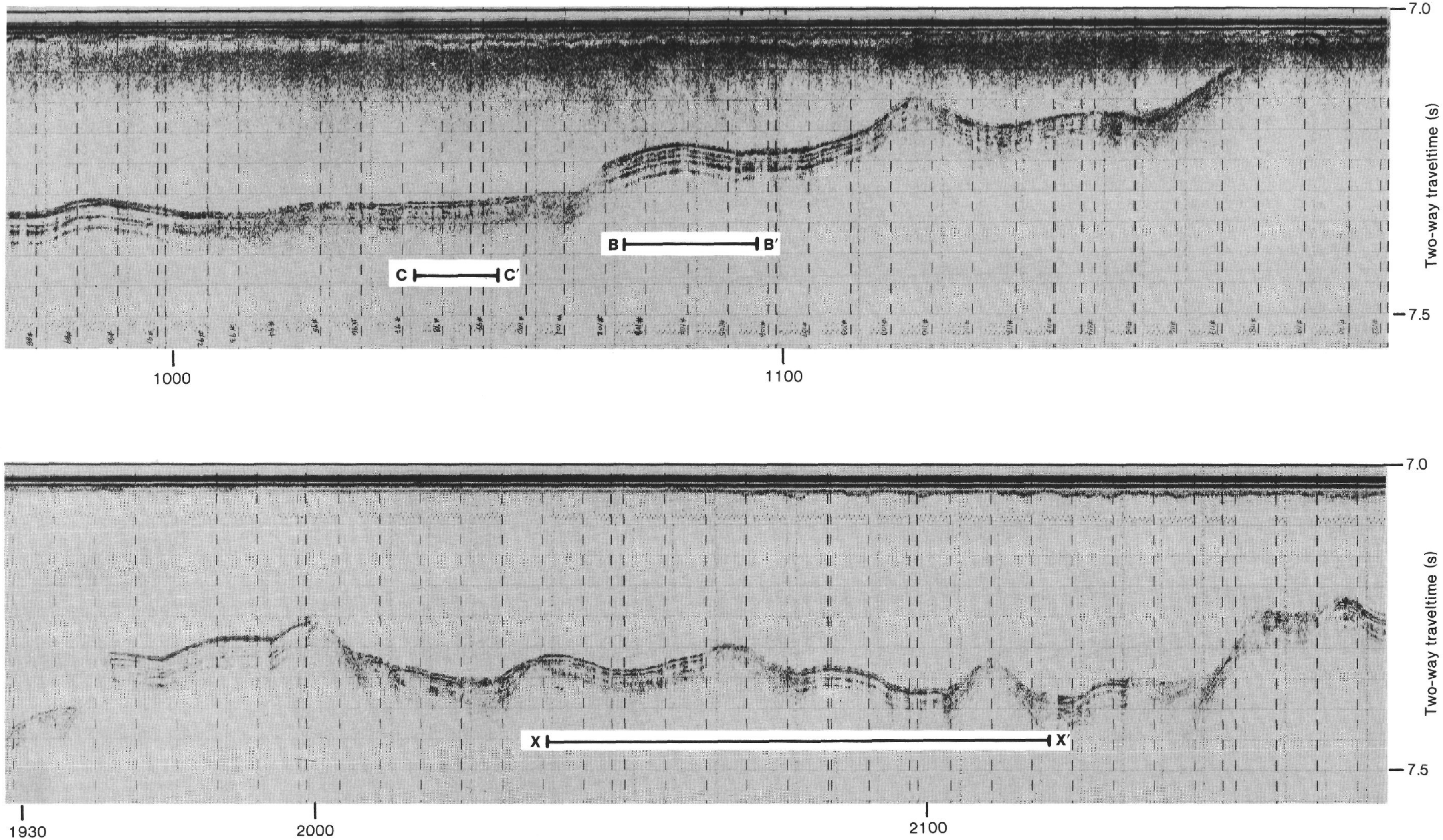


Figure 5. High-resolution records collected along hachured track lines shown in Figure 4. Records were made with a 1-s sweep rate. Samples of the four types of reflections seen on the records are indicated by A–A′ (type 1), B–B′ (type 2), C–C′ (type 3), and D–D′ (type 4). X–X′ indicates an example of the low rounded hills seen on the records. Section Y–Y′ shows reflections which appear to be from a scarp and associated slump and debris-flow deposits. The arrow marks the portion of record that was collected closest to drill Site 581C.



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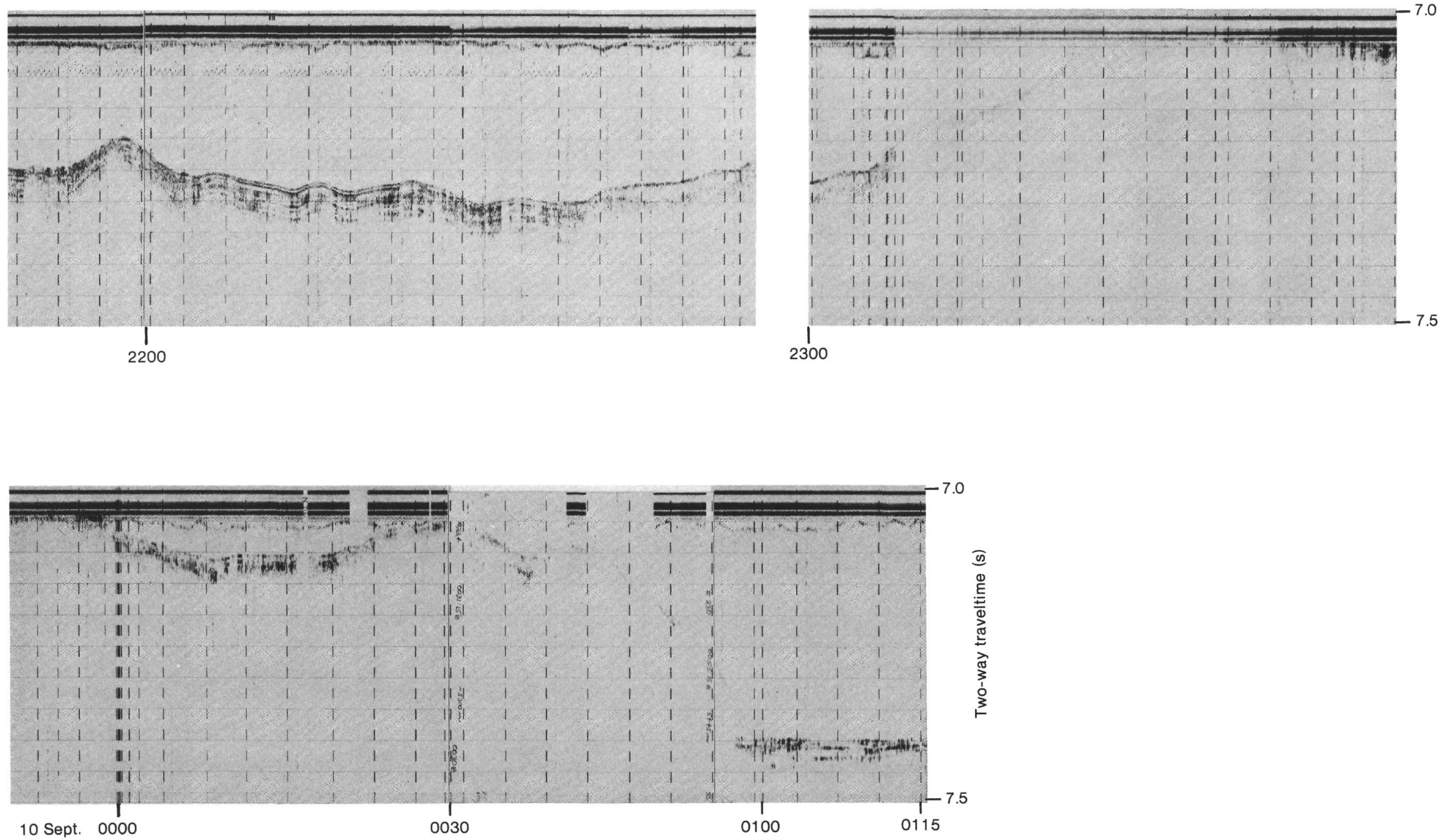

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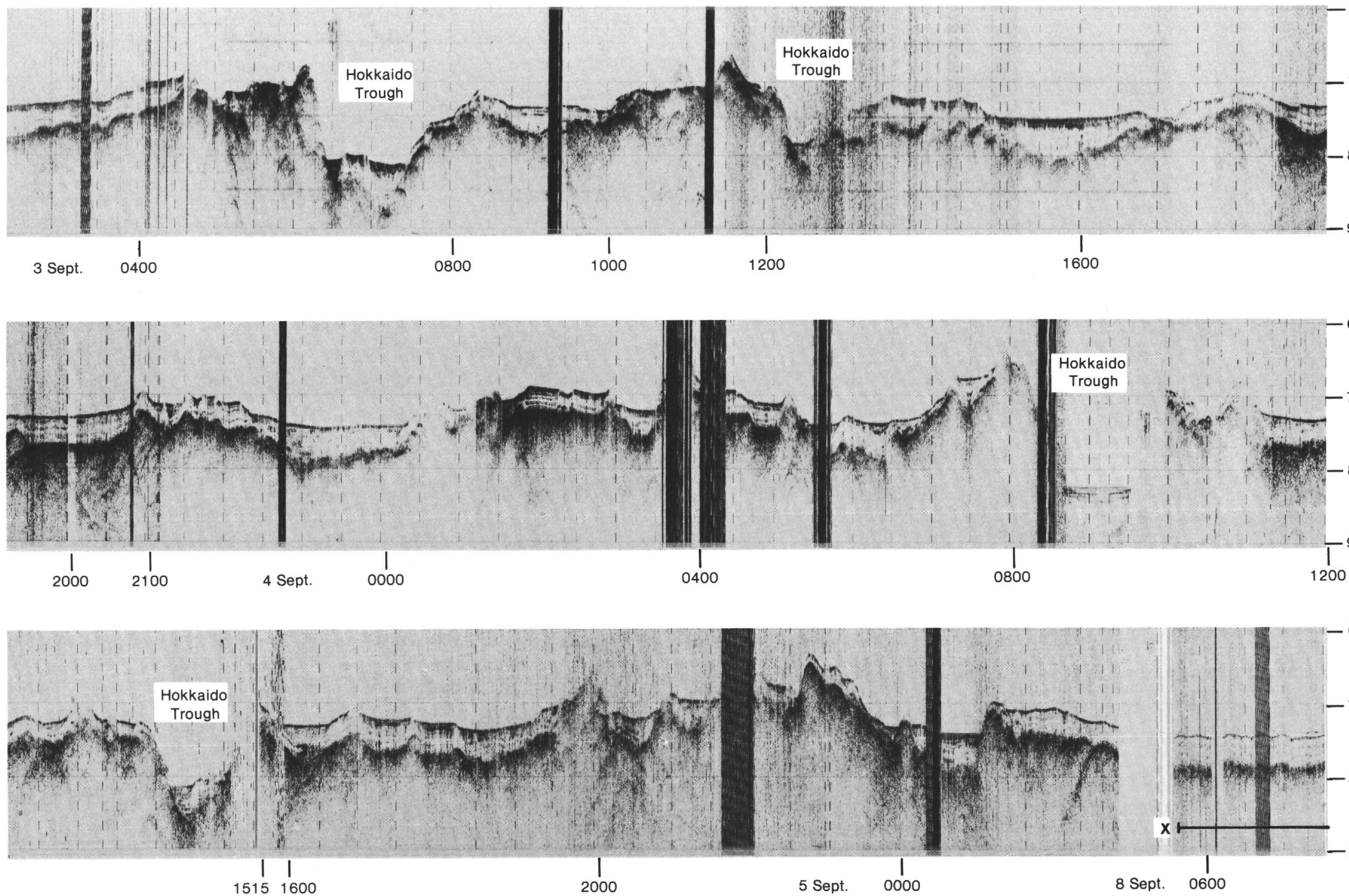
Hokkaido Trough
Hokkaido Trough
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Two-way traveltime (s)
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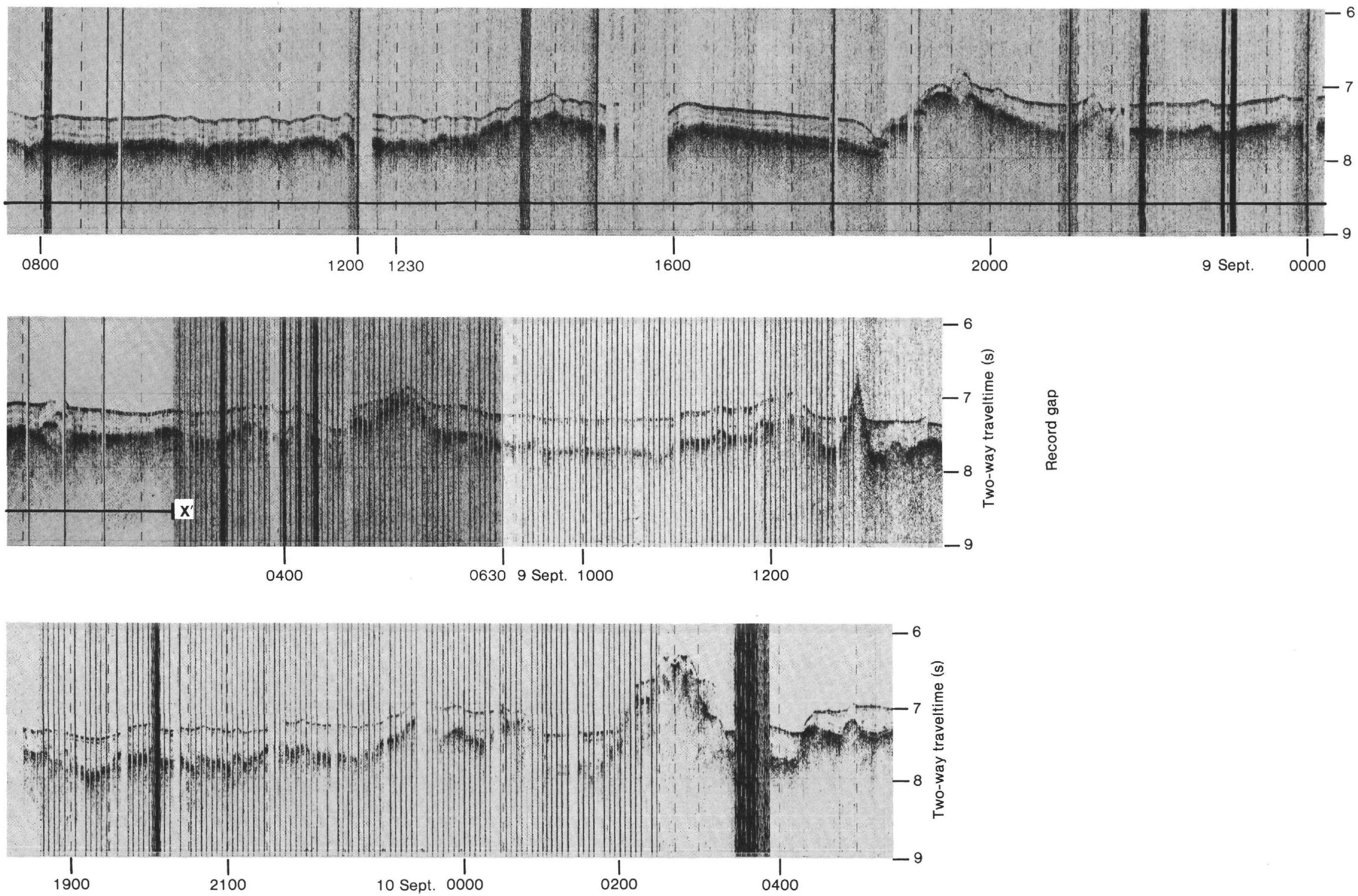

Figure 6. Seismic reflection records along tracks indicated in Figure 4. Record sections were recorded with an eight second sweep rate. X–X′ indicates the portion of record that was collected south of the area where magnetic data were collected.

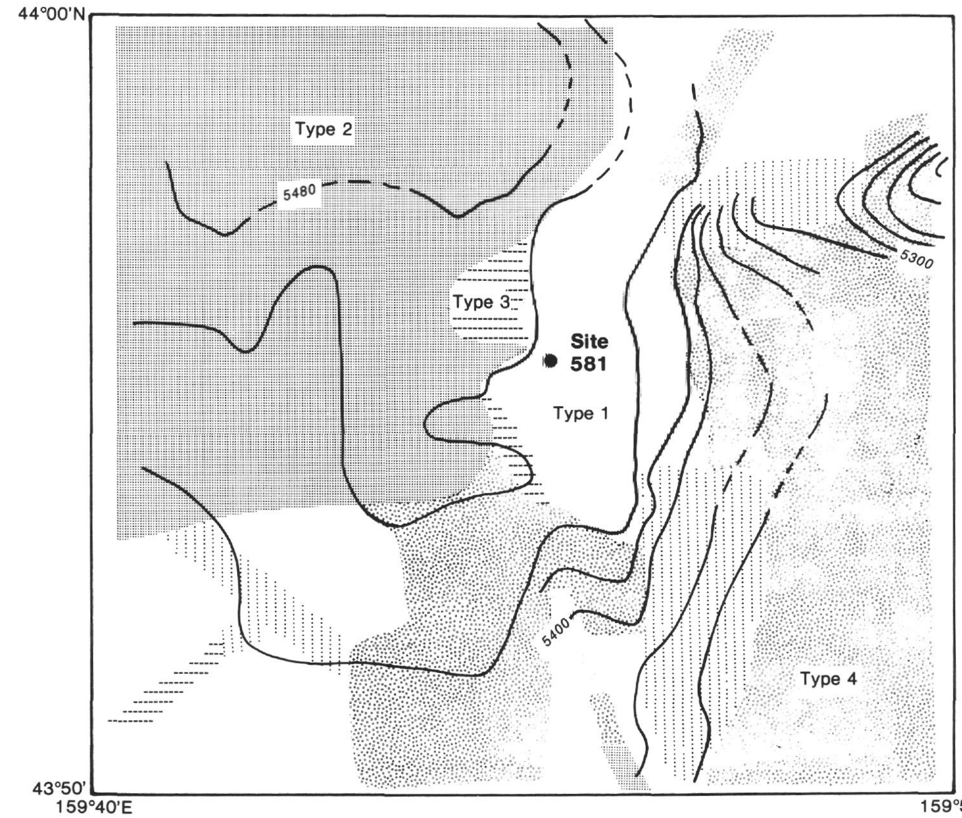

Figure 7. Bathymetric contour map showing the locations of the four types of reflectors which were seen on the records. These are (a) transparent zone immediately beneath water bottom reflector, shown in thin vertical line pattern (type 1); (b) parallel distinct reflectors, shown in small dotted pattern (type 2); (c) discontinuous poor reflectors, shown in thick horizontal dashed-line pattern (type 3); (d) no visible sub-bottom reflectors, shown in various sized dotted pattern (type 4). The fifth pattern, consisting of vertical columns of dots, indicates areas where classification could not be made.

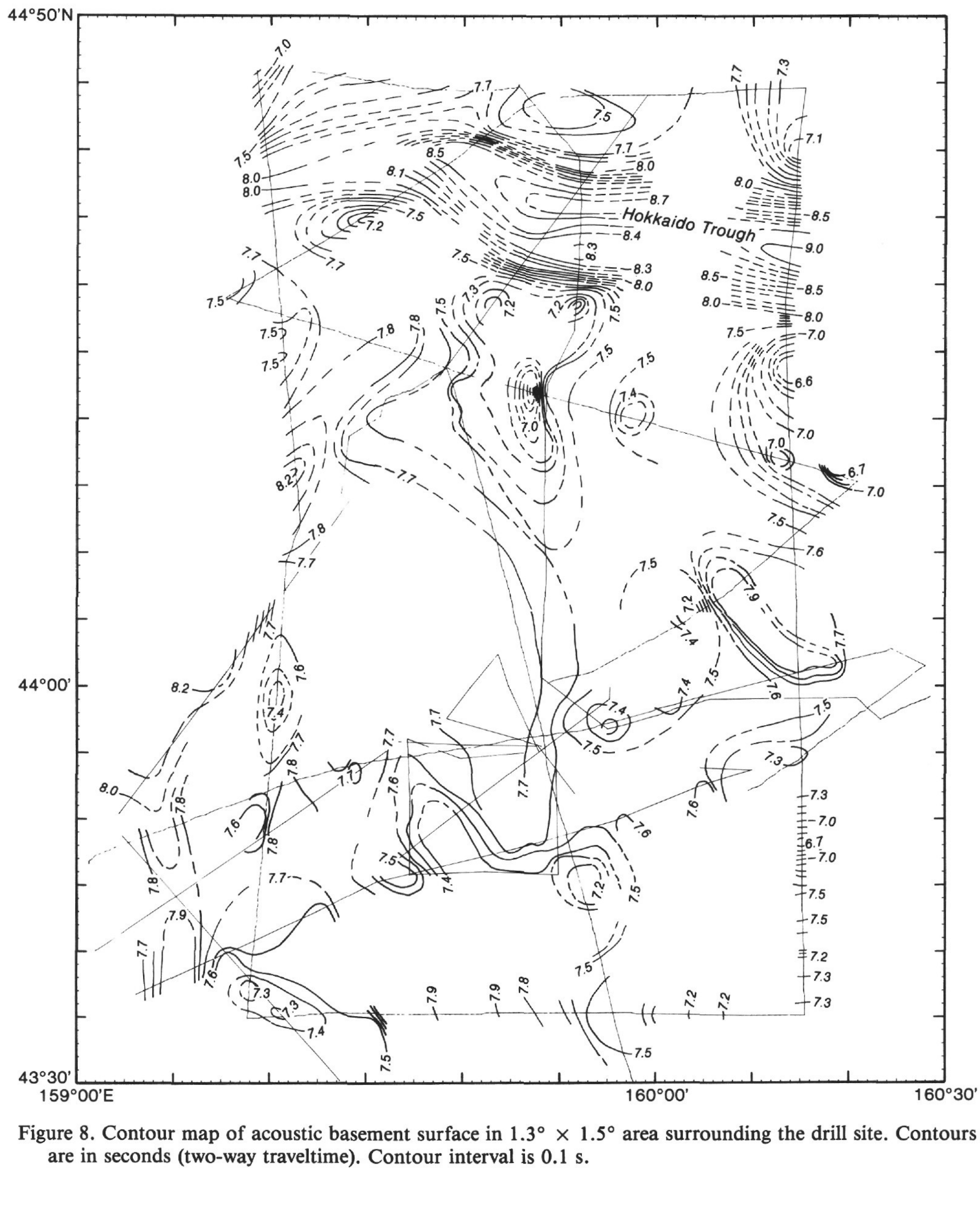

Figure 8. Contour map of acoustic basement surface in 1.3° × 1.5° area surrounding the drill site. Contours are in seconds (two-way traveltime). Contour interval is 0.1 s.

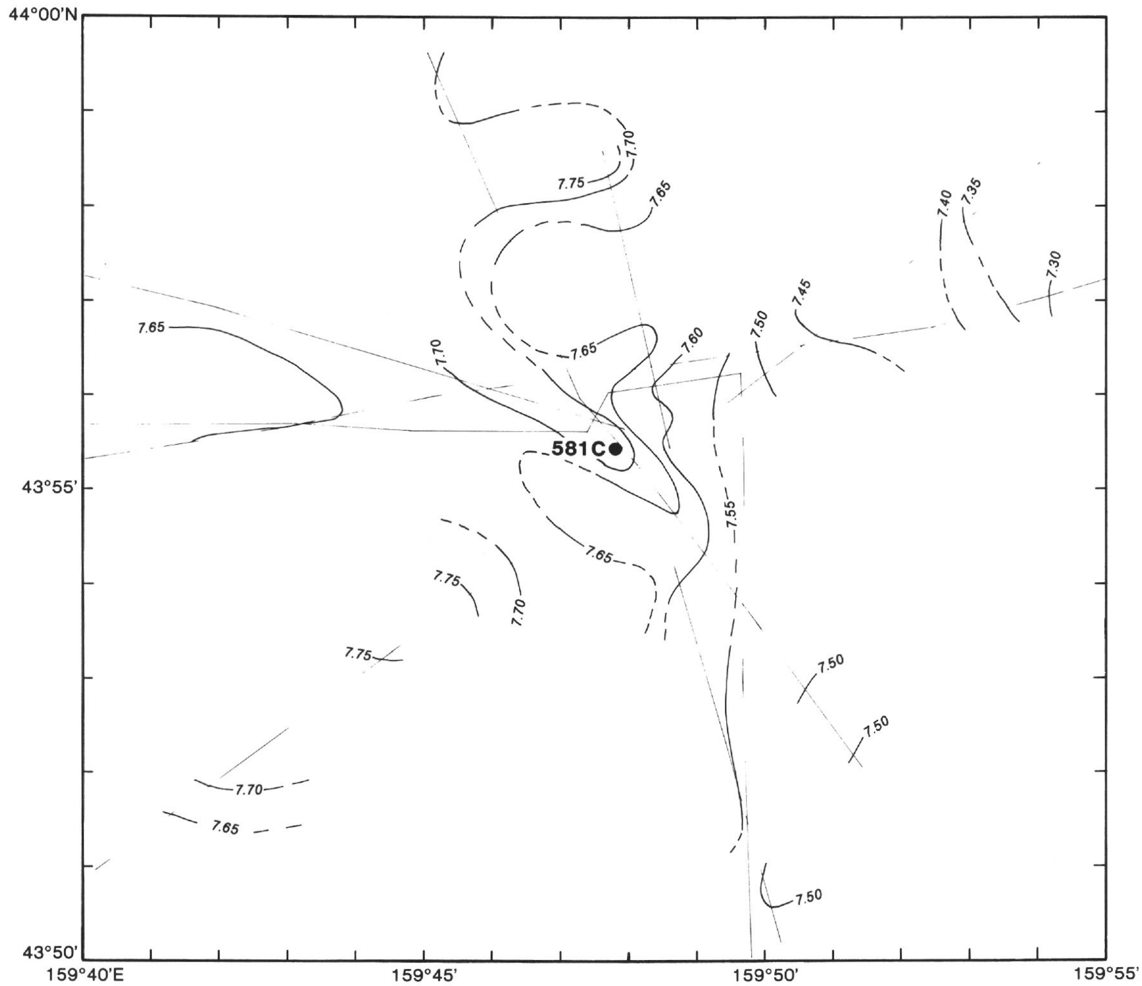

Figure 9. Contour map of acoustic basement surface in immediate vicinity of drill site. Contours are in seconds (two-way traveltime). Contour interval is 0.05 s. Location of Hole 581C is indicated on the map.

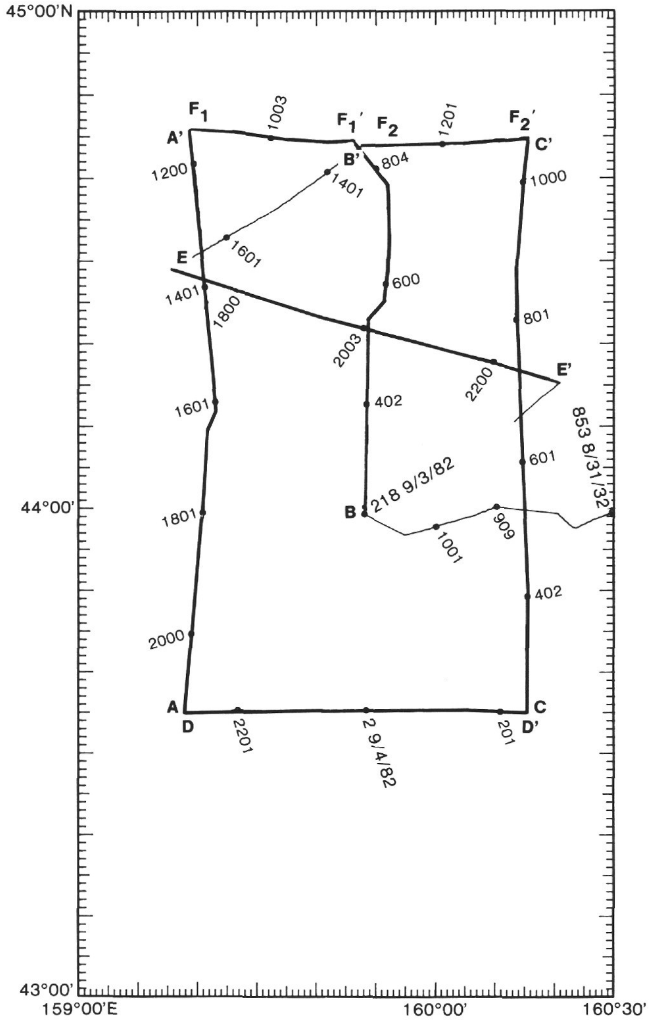

Figure 10. Site survey tracklines along which magnetic data were collected. Locations of profiles shown in Figure 11 are indicated by letters A–A′ through F–F′.

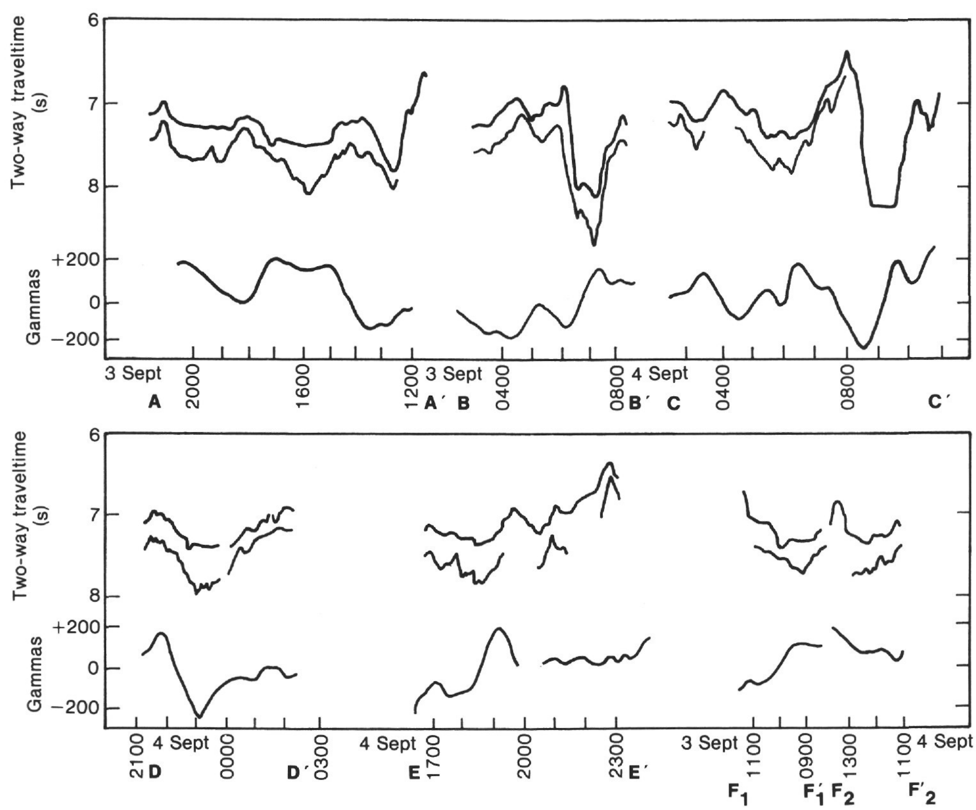

Figure 11. Profiles of bathymetry, acoustic basement, and magnetics along lines indicated in Figure 10. In each set of profiles, the top two lines represent bathymetry and acoustic basement and the magnetic profile is below them.