8. SITE SURVEYS OF DEEP SEA DRILLING PROJECT SITES 608, 610, AND 611[1]

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ABSTRACT

This chapter gives localized geological overviews around three of the DSDP Leg 94 drill sites. Difficulties in comparing sites qualitatively are shown to be caused by differences in the site survey data bases.

INTRODUCTION

This chapter gives details of site surveys carried out around Sites 608, 610, and 611 prior to drilling on Leg 94. Each site is dealt with separately in sections describing (1) the regional location and objectives of drilling at the site, (2) the data used in selection of that site, and (3) an interpretation and discussion of the data. The locations of the sites are shown in Figure 1. Two of the sites (608 and 610) had previously been surveyed using the long-range sidescan sonar GLORIA (Somers et al., 1978).

SITE 608

Regional Location and Objectives

Site 608 is situated approximately 120 km south of the WNW-ESE-trending basin and ridge complex known as King's Trough (Searle and Whitmarsh, 1978; Kidd et al., 1982), and approximately 220 km northwest of the southern part of the Azores-Biscay Rise (Whitmarsh et al., 1982) (Fig. 2). The objectives of drilling at the site were to detect changes in the surface- and bottom-water paleocirculation by analysis of the core samples, and to obtain a reference stratigraphic section for tectonic studies of King's Trough and the Azores-Biscay Rise.

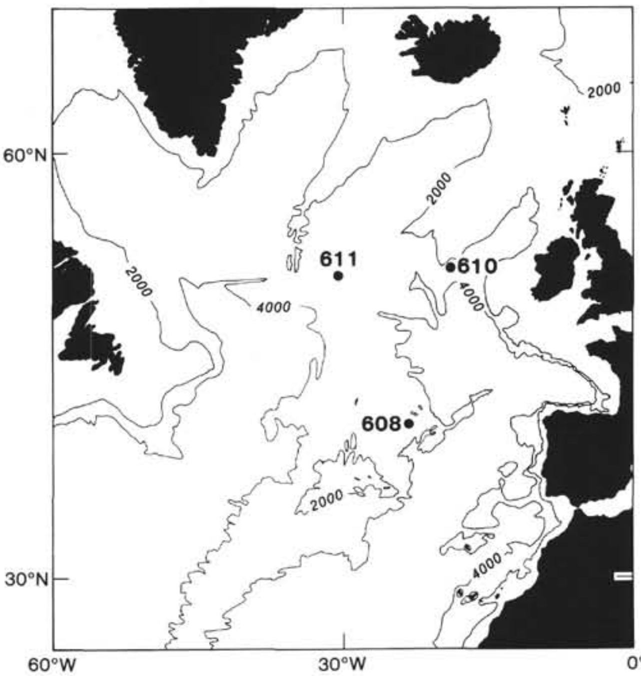

Figure 1. Locations of Sites 608, 610, and 611, with bathymetry (meters) simplified from General Bathymetric Chart of the Oceans, sheets 5.04 and 5.08 (GEBCO, 1978, 1982).

Site Survey

Selection of the site location was originally based upon early single-channel air-gun profiles obtained by the Institute of Oceanographic Sciences (IOS), U.K., on *Discovery* Cruises 33 and 54 (Laughton, 1971; Laughton, 1973) (Fig. 3). In 1982 these profiles were augmented by data collected on *Farnella* Cruise 9 (Revie, 1983). These new data included bathymetry, magnetics, single-channel air-gun profiles, gravity, and GLORIA data. In early 1983, a high-resolution near-bottom profiler station was run on *Discovery* Cruise 134 (Francis, personal communication, 1983).

Interpretation and Discussion

Figures 4 and 5 are maps showing depth to basement and total sediment thickness, compiled from seismic reflection data collected along the tracks shown in Figure 3. The contours show a general north-south trend, reflecting the structural lineaments of the ocean crust in this part of the North Atlantic (Kidd et al., 1983). The positive features (e.g., at 42°35′N, 23°21′W and at 42°55′N, 23°14′W) represent the peaks of faulted basement blocks formed at the Mid-Atlantic Ridge axis. GLORIA data were used to identify fault scarps (e.g., at 43°54′N, 23°15′W) and outcropping basement rocks (e.g., at 42°37′N, 23°02′W) (Fig. 5). GLORIA data were also used to define the shape of the abyssal hills (Fig. 3); the fault trends and basement outcrop were used as a guide to contouring.

One of the more interesting features of Figure 5 is the change in azimuth of the fault trends as mapped from the GLORIA data. The three faults in the north of the area, near 42°53′N, 23°15′W, have trends of 018°, subparallel to the normal "spreading fabric" (010°) seen on GLORIA records near the Mid-Atlantic Ridge at this latitude (Searle and Laughton, 1977). A second group

[1] Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., *Init. Repts. DSDP*, 94: Washington (U.S. Govt. Printing Office).

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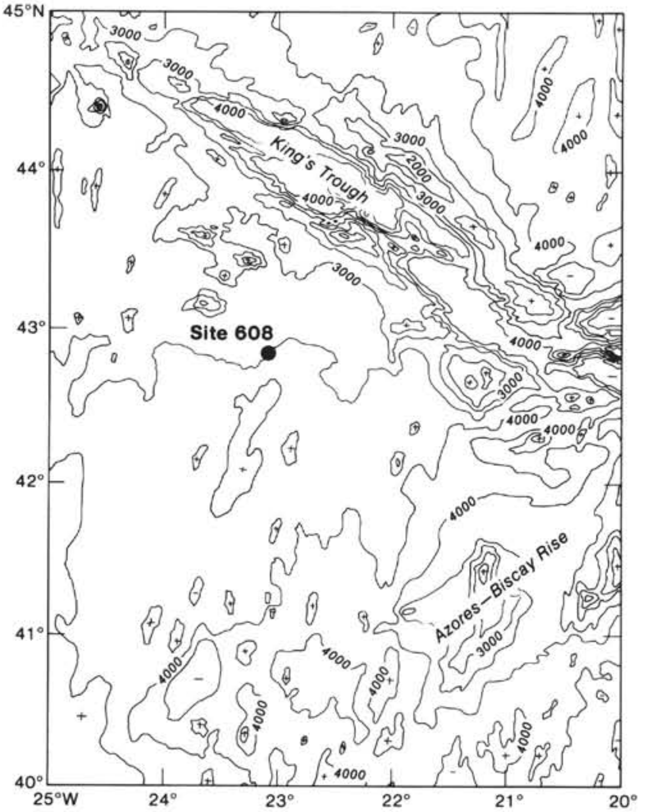

Figure 2. Bathymetry of King's Trough and the Azores-Biscay Rise, from General Bathymetric Chart of the Oceans, sheet 5.08 (GEBCO, 1982). Contour interval 500 m.

of faults, concentrated around the outcrop of acoustic basement at 42°36′N, 23°00′W, shows a trend of 050°, oblique to the normal spreading fabric and almost perpendicular to Fracture Zone "A" of Miles and Kidd (this volume). Searle and Laughton (1977) have suggested that faults with northwesterly trends correlate with regions of dextral offset, and their observation is reflected in Figure 5. In addition, the outcrop of acoustic basement at 42°36′N, 23°00′W, mentioned earlier, is apparently truncated where it intersects Fracture Zone "A." Site 608 is located on ocean crust that just predates or is of Anomaly 18 age (Miles and Kidd, this volume). Berggren et al. (in press) show this to be approximately 42 Ma. The sediments will therefore reflect the evolution of King's Trough, which began with uplift of an aseismic ridge at about 32 Ma (Kidd et al., 1982).

Figure 6 shows a two-channel seismic reflection profile across Site 608.

SITE 610

Regional Location and Objectives

The site is approximately 6 km southeast of the axis of the Feni Ridge, a major sediment drift along the western margin of Rockall Trough (Fig. 7). The site location was southwest of that originally planned, to place it in an area covered by GLORIA sonographs (Roberts and Kidd, 1979). The original objectives of drilling at the site were to record isotopic and faunal responses to deepwater overflow from the Norwegian Sea, and to monitor warm currents along the coast of Europe during the late

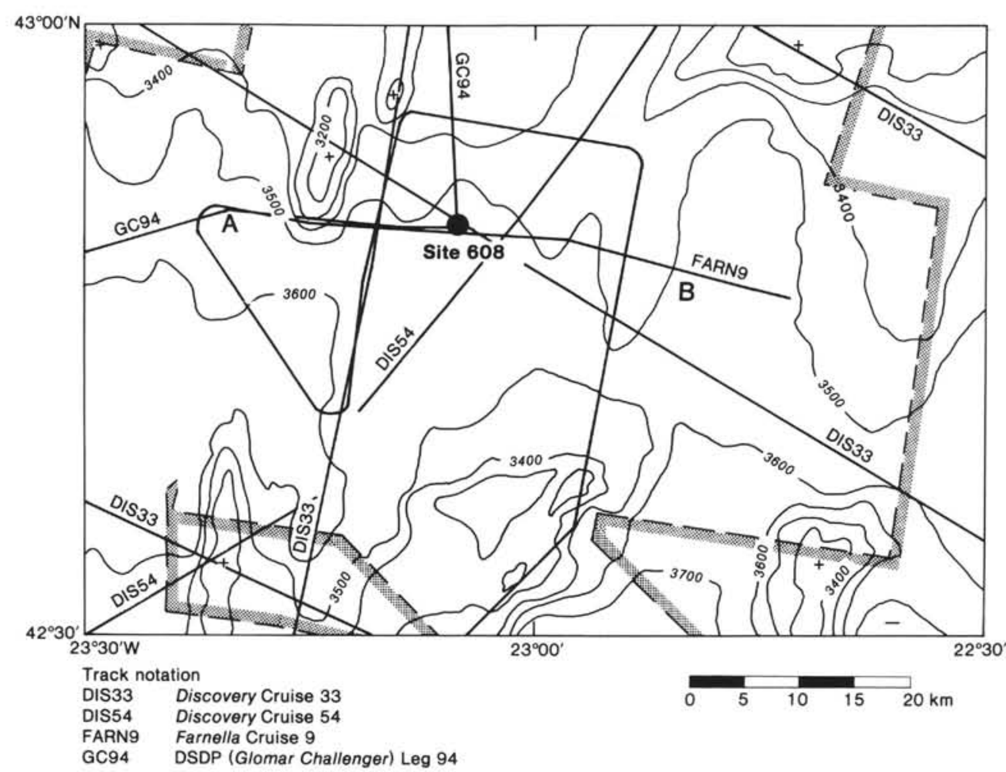

Figure 3. Bathymetry and geophysical data tracks around Site 608. Depths in corrected meters, contour interval 100 m. Dashed line represents limit of GLORIA insonification from *Farnella* Cruise 9. Stippling indicates area beyond range of GLORIA. A–B indicates location of seismic reflection profile in Figure 6.

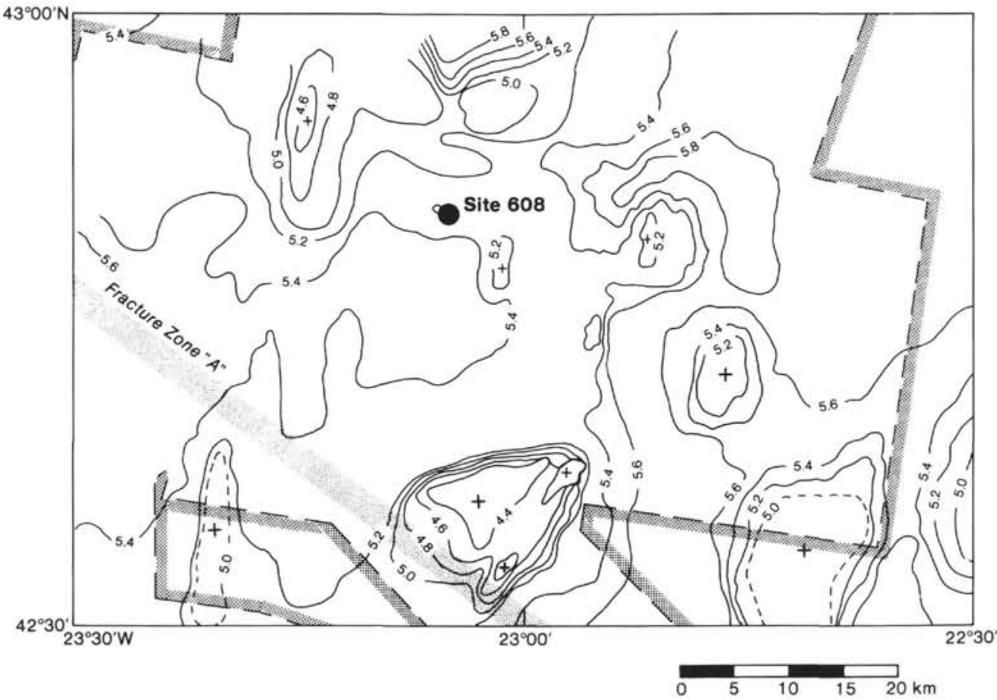

Figure 4. Total depth to basement (in seconds two-way traveltime) in the area around Site 608. Also shown: Fracture Zone "A" of Miles and Kidd (this volume). Contour interval 0.2 s. Dashed line represents limit of GLORIA insonification. Stippling indicates area beyond range of GLORIA.

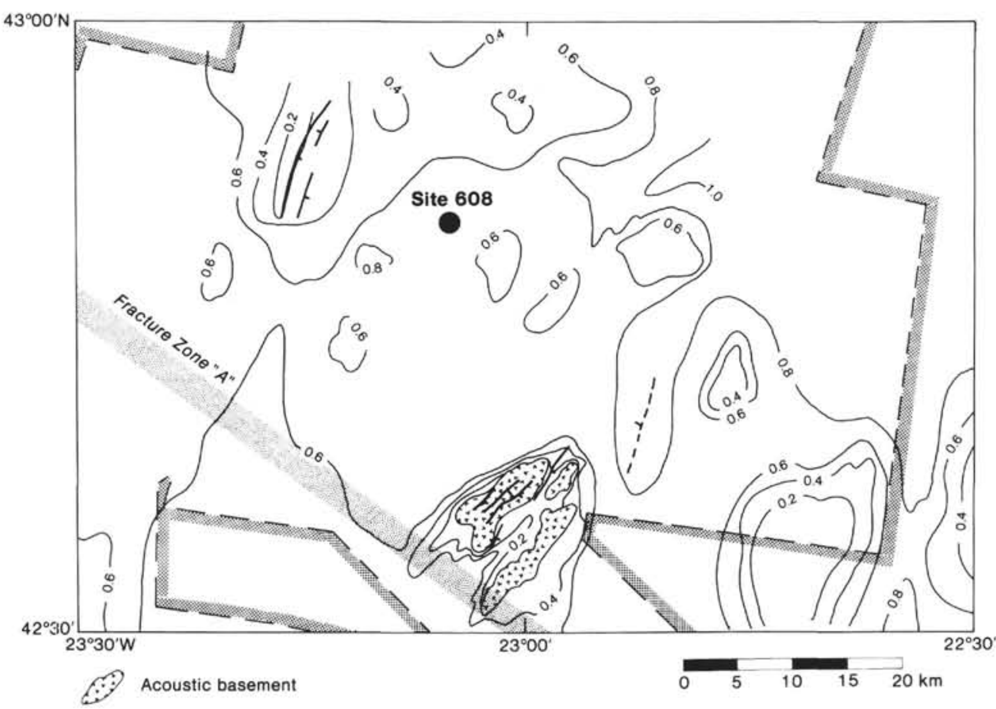

Figure 5. Sediment thickness (in seconds two-way traveltime) in the area around Site 608. Also shown: acoustic basement outcrop and Fracture Zone "A" of Miles and Kidd (this volume). Contour interval 0.2 s. Faults are taken from GLORIA data. Dashed line represents limit of GLORIA insonification. Stippling indicates area beyond range of GLORIA.

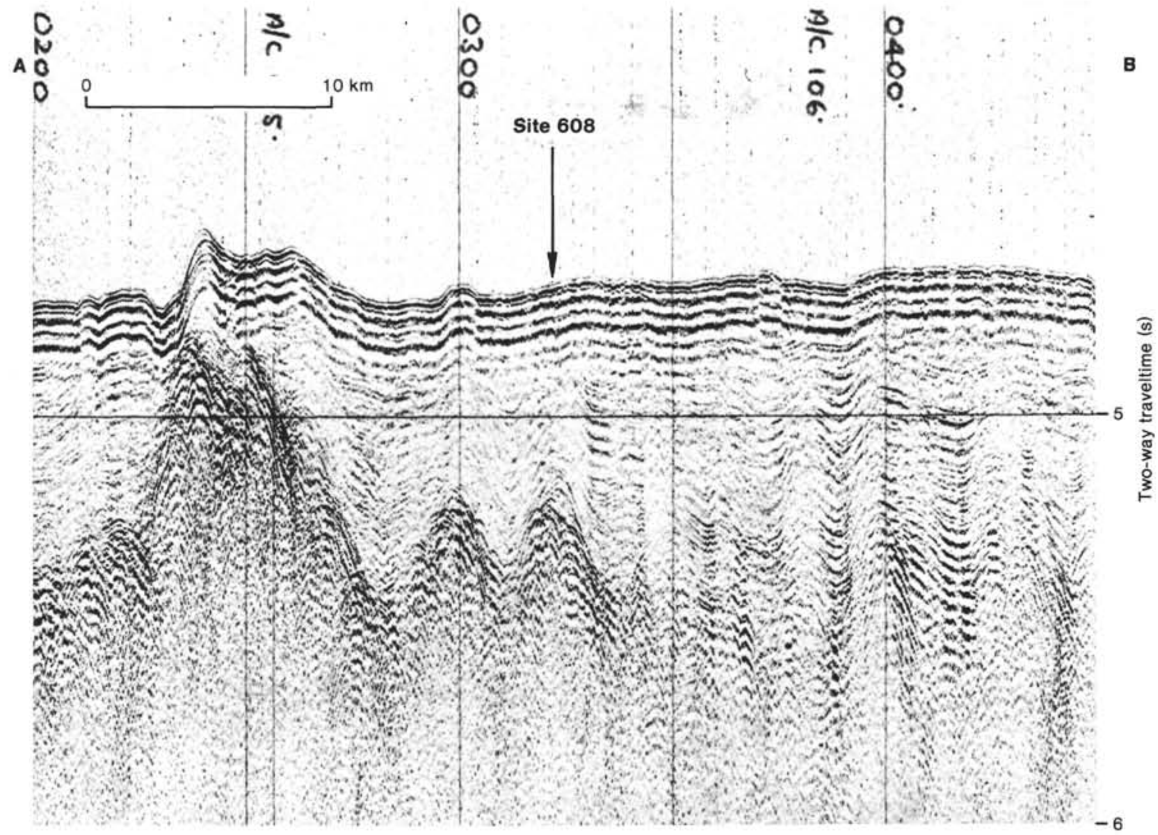

Figure 6. Two-channel seismic reflection profile across Site 608, obtained on *Farnella* Cruise 9. Location of section shown by line A–B on Figure 3.

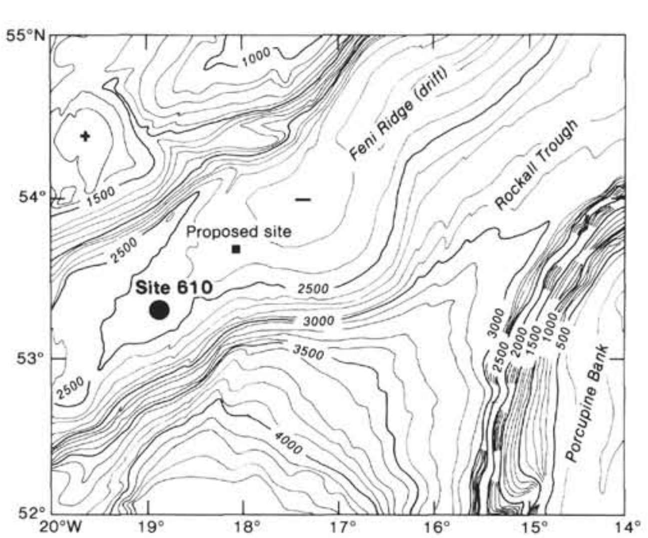

Figure 7. Bathymetry of southern Feni Ridge (drift) and southern Rockall Trough. From Laughton et al. (1982). Contour interval 100 m.

Neogene. Further objectives related to the development of sediment wave fields and the geological history of the Feni Ridge sediment drift were pursued after the change in site location.

Site Survey

The southern Rockall Trough has been the subject of intensive research activity (e.g., Scrutton and Roberts, 1971; Roberts, 1975; Kristofferson, 1978; Roberts et al., 1981), and a large quantity of seismic reflection data is available. Originally it was planned to locate Site 610 on the multichannel seismic reflection profile WI-32, but the site position was revised at sea, as already stated. The new position selected is near the intersection of single-channel seismic reflection profiles from *Discovery* Cruise 84 (Laughton, 1977) and DSDP Leg 12 (Laughton, Berggren, et al., 1972). Other useful profiles include a *Jean Charcot* single-channel seismic reflection profile and the multichannel profile WI-32, located some 65 and 90 km northeast of the site, respectively. GLORIA coverage over the site was obtained on *Discovery* Cruise 84. These data and their interpretations have been presented by Roberts and Kidd (1979), and will not be repeated here.

Interpretation and Discussion

Interpretation of seismic reflection profiles in this area is complicated by the difficulty in correlating reflectors between adjacent profiles obtained using different seismic acquisition systems. Only multichannel lines, such as WI-32, and a limited number of high-quality single-channel profiles (e.g., *Discovery* Cruise 84 and *Jean Charcot* 04) provide significant penetration and resolution to allow reasonable track-to-track correlation of reflectors. Figure 8 shows three examples of seismic reflection profiles, all obtained using different data acquisition systems. One of the most obvious features is the lack of penetration from the water-gun profiles of DSDP Leg 94 (this probably results from the filter settings of the data acquisition system): only the first major reflector, at 0.6–0.8 s sub-bottom, was detected. This compares with more than 3.0 s sub-bottom penetration from the *Discovery* Cruise 84 profile, which for a time runs subparallel to and less than 500 m from the Leg 94 profile (Fig. 9). Depth-to-basement and sediment-thickness maps have not been compiled, because there are not enough high-quality data available in the immediate vicinity of the site to allow construction of a meaningful map.

Roberts and Kidd (1979) show that over much of the Feni Ridge the sediment waves display two trends, one parallel and one orthogonal to the regional contours. Kidd and Hill (this volume) show that these trends continue around Site 610. Many of the waves are of limited extent (< 10 km long) and have mean wavelengths of approximately 4 km. The *Discovery* Cruise 84 seismic profile in Figure 8 shows that the waves can be traced to a sub-bottom depth of more than 0.5 s (two-way traveltime), which equates with a middle Miocene age (Site 610 report, this volume). Figure 10 shows a section of water-gun record from Leg 94 which displays the complex internal structure of the sediment waves down to approximately 415 m sub-bottom.

This area contains a number of lava flows and sill complexes of early Tertiary age (Roberts, 1975; Roberts et al., 1981). These lavas and sills tend to obscure deeper reflectors, so that the acoustic basement seen on the seismic reflection profiles in this area may not represent "true basement" (or crust). Using the data of Roberts et al. (1981), we located the *Discovery* Cruise 84 and DSDP Leg 94 profiles over continental crust, with the continent/ocean crustal boundary located at approximately shot point 2480 on the WI-32 multichannel profile. No expression of this is seen in Figure 8, possibly owing to blanketing of any deeper reflectors by the aforementioned lavas and sills.

The large number of seismic reflection profiles in this area will allow widespread extrapolation of dated seismic reflectors away from the drill site, enabling a detailed history of the Feni Ridge sediment drift to be worked out (Masson and Kidd, this volume).

SITE 611

Regional Location and Objectives

The site is near the southern end of Gardar Ridge, approximately 90 km north-northwest of the intersection of Charlie Gibbs Fracture Zone with the Mid-Atlantic Ridge (Fig. 11). The objectives of drilling at the site were to document the paleoenvironmental history related to late Neogene changes in bottom- and surface-water circulation, linked to overflow of Norwegian Sea water over the Iceland–Faroe ridge. Further objectives were to record changes in deep-water flow through Charlie Gibbs Fracture Zone and to study the overall history of sediment wave formation.

Site Survey

The site was originally chosen using *Vema* Cruise 27-06 and *Discovery* Cruise 131 (Whitmarsh, 1982) single-channel seismic reflection profile data and a 10-m core obtained during *Vema* Cruise 27-06. Other data available for the area were a single-channel seismic reflection profile from *Vema* Cruise 30-12 and 3.5-kHz profiles from *Vema* Cruises 27-06 and 30-12 and part of *Discovery* Cruise 131 (Fig. 12). Soundings were available from the *Gibbs* and *Discovery* tracks.

Interpretation and Discussion

Figure 13 shows a single-channel seismic reflection profile from *Discovery* Cruise 131, across Site 611. The depth-to-basement map (Fig. 14) was constructed using data obtained from the cruises mentioned above, with the addition of the DSDP Leg 94 seismic reflection profiles. The most obvious of the two main structural lineaments is the series of basement highs and lows, trending NNE–SSW; these represent the peaks and troughs of the faulted ocean crust developed at the Mid-Atlantic Ridge axis (Searle, 1981). The second, less obvious, trend runs approximately east–west and manifests itself as an inflection in the contours at 52°49′N, 30°20′W, and also in the basement low at 52°53′N, 30°11′W. It can also be seen in the east–west elongation of the basement low at 52°49′N, 30°29′W. This east–west trend represents the buried part of the northern transform domain of Charlie Gibbs Fracture Zone. The ocean crust beneath Site 611 just predates Anomaly 13 (Vogt and Avery, 1974), with an age of approximately 35 Ma (Berggren et al., in press). Figure 15 is a sediment-thickness map compiled from the data used for Figure 14.

Figure 16 shows a 3.5-kHz profile across Site 611. This profile indicates little or no sediment wave migration, and has two prominant reflectors at approximately 12 and 30 m sub-bottom. Figure 17 is a map of sediment wave crests picked principally from 3.5-kHz profiles. The trend of the waves changes from subparallel to the regional contours at 52°52′N, 30°15′W to oblique to the contours south of 52°48′N, reflecting the change in direction of bottom-current flow from northeast–southwest to approximately east–west (Jones et al., 1970). The position of the drill site near the toe of the sediment drift should allow determination of changes in the direction of bottom-water flow through the Charlie Gibbs Fracture Zone, as well as determination of the overall history of sediment drift formation.

It is interesting to compare the sediment waves at Sites 610 and 611. At Site 610, the sediment waves are near the axis of the sediment drift, whereas at Site 611 the sediment waves are near the toe of the sediment drift (Site 610, 611 reports, this volume). Kidd and Hill (this volume) show that at Site 610 the sediment waves display two trends, individual waves being of rather limited extent (along-axis) and sometimes bifurcating. At Site

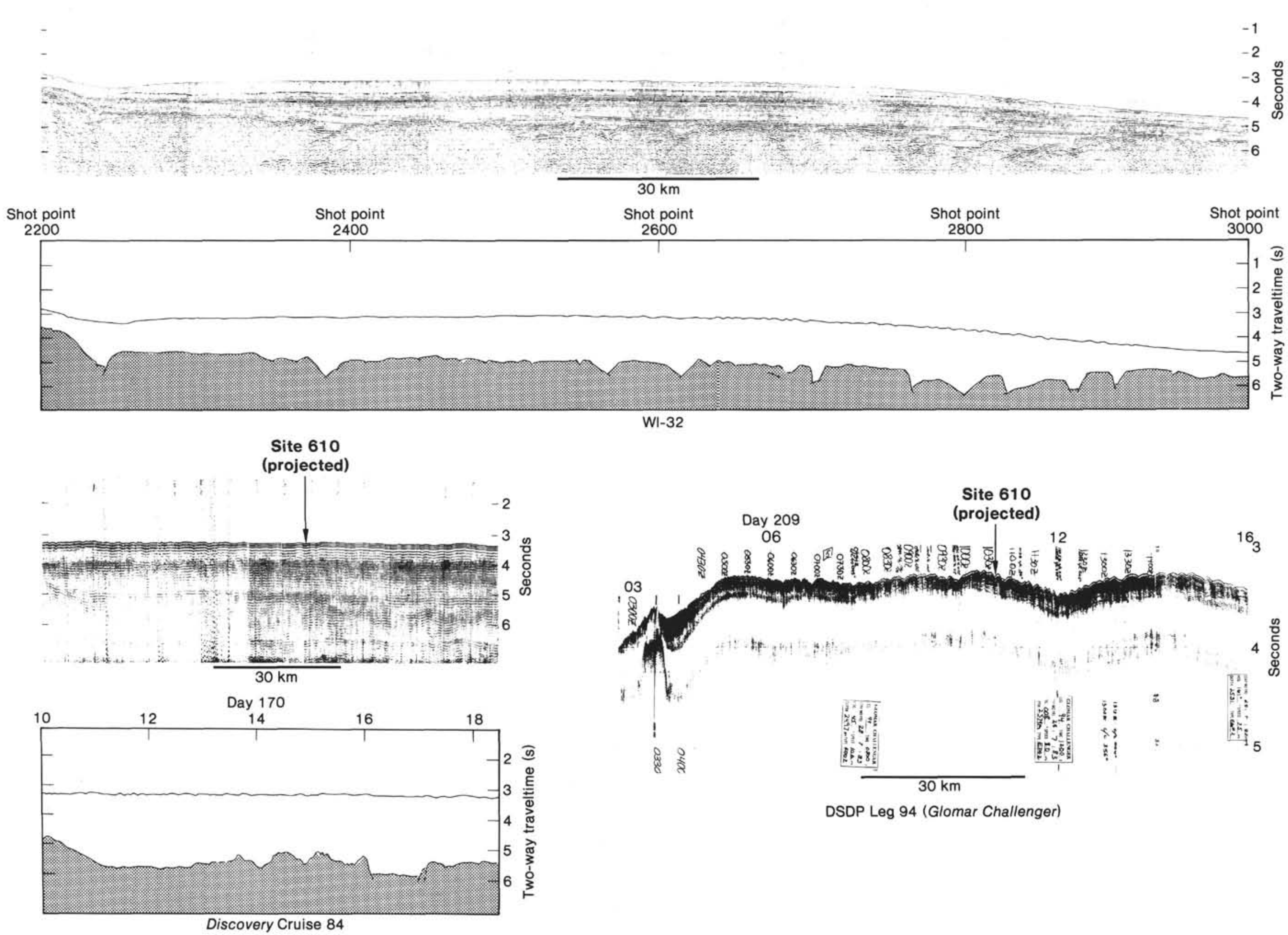

Figure 8. Examples of seismic reflection profiles, with interpretations, from near Site 610. Acoustic basement is stippled. Locations of the profiles are shown in Figure 9.

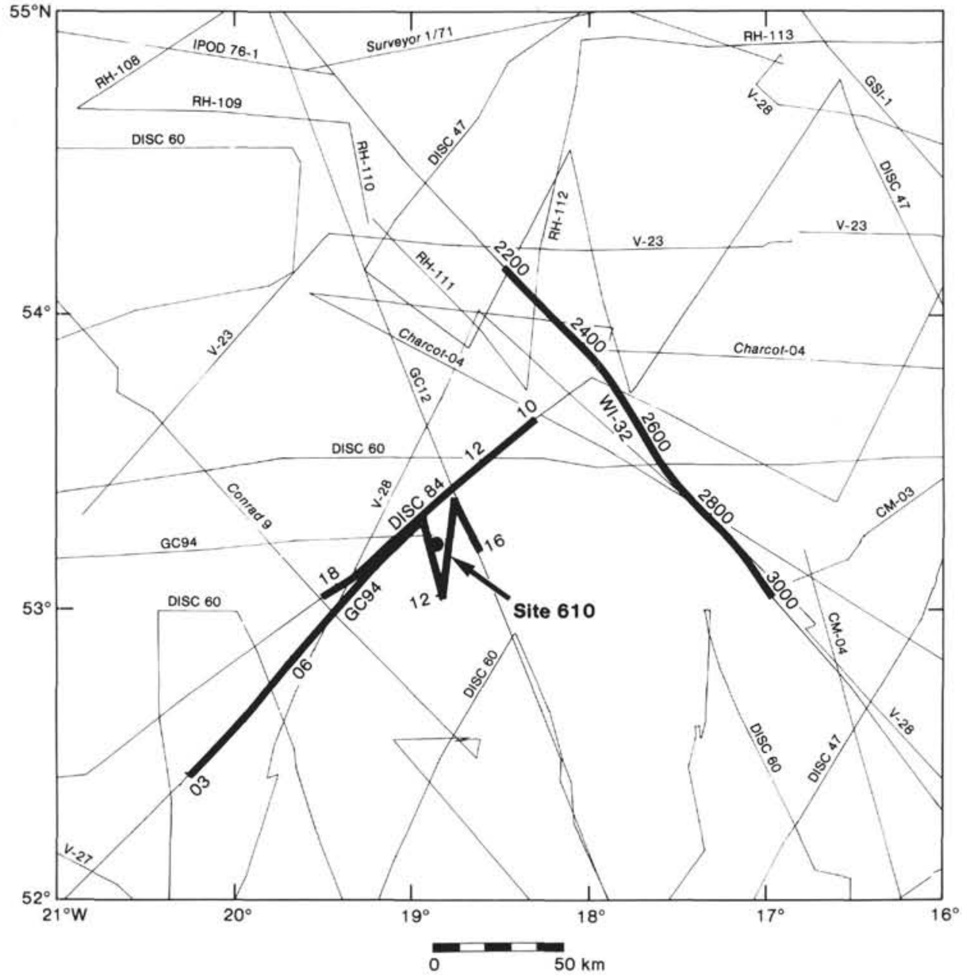

Figure 9. Locations of seismic reflection profiles near Site 610. Heavy lines represent profiles shown in Figure 8.

611 only one trend is seen (although this does change direction downslope), with no direct evidence of bifurcation or interference. If, however, some of the crest trends on Figure 17 were extrapolated away from the tracks—for example, at 52°49′N, 30°22′W—then interference and bifurcation would be apparent.

CONCLUSIONS

This chapter describes how pre- and post-cruise underway geophysical data have been used to produce a geological overview of the site areas. Several inconsistencies are highlighted, the most notable being those arising from the difficulty of comparing sites that have been surveyed using different techniques and survey tools.

The use of GLORIA at Site 610 has provided a view of the true interrelationship of adjacent sediment waves (Kidd and Hill, this volume); at Site 611, the wave trends can only be inferred by correlation between adjacent profiles. This leads to obvious difficulties when trying to compare qualitatively the sediment wave patterns at the two sites. The poor quality of many single-channel seismic reflection profiles around Site 610 has shown a need for the site survey data acquisition to be planned more carefully.

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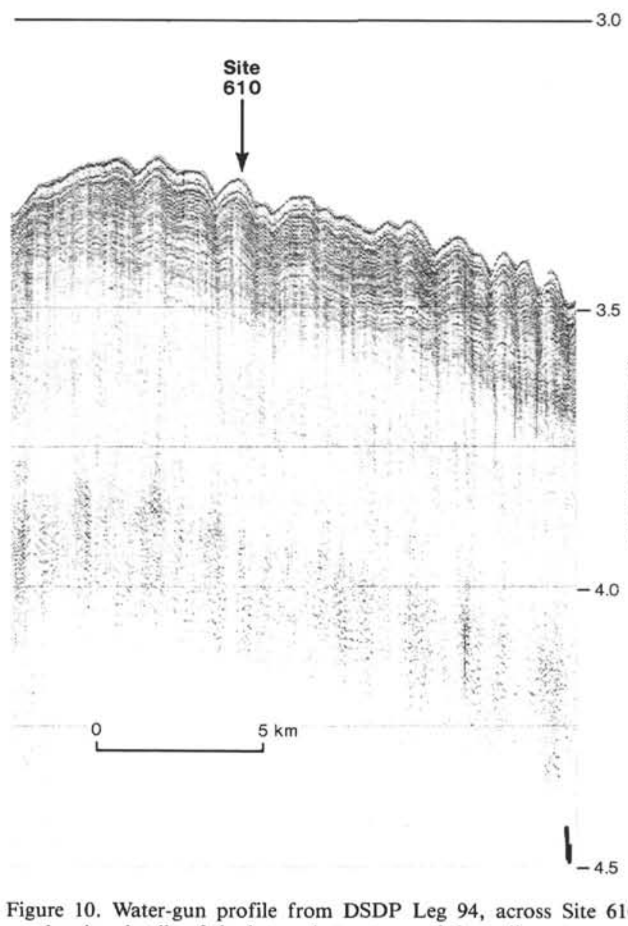

Figure 10. Water-gun profile from DSDP Leg 94, across Site 610, showing details of the internal structures of the sediment waves.

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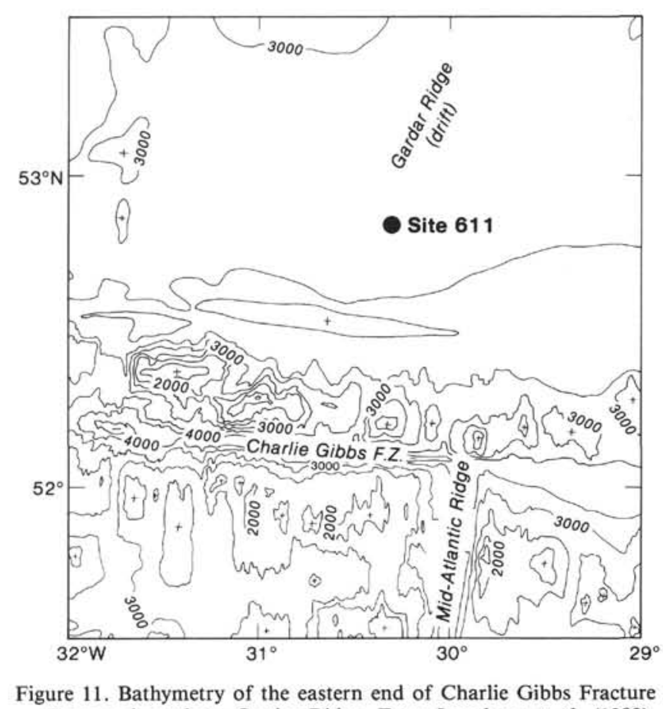

Figure 11. Bathymetry of the eastern end of Charlie Gibbs Fracture Zone and southern Gardar Ridge. From Laughton et al. (1982). Contour interval 500 m.

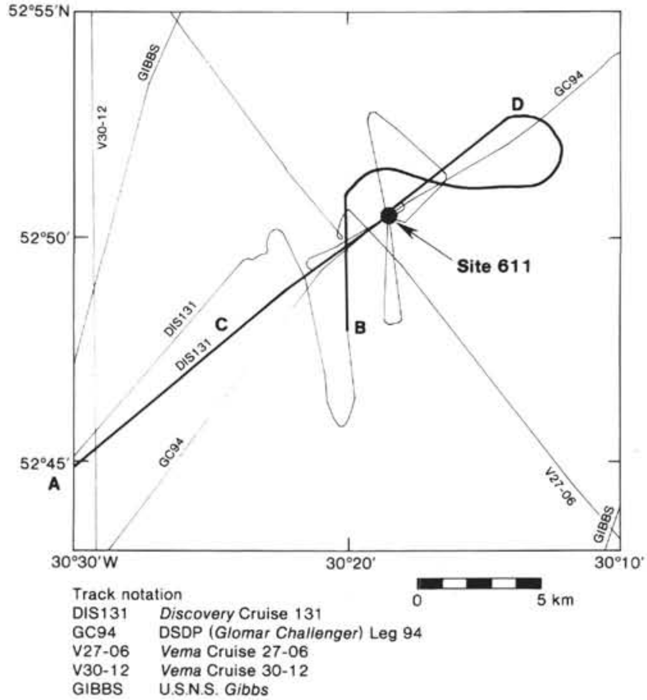

Figure 12. Site survey tracks for Site 611. A–B indicates location of seismic reflection profile in Figure 13. C–D indicates location of 3.5-kHz profile in Figure 16.

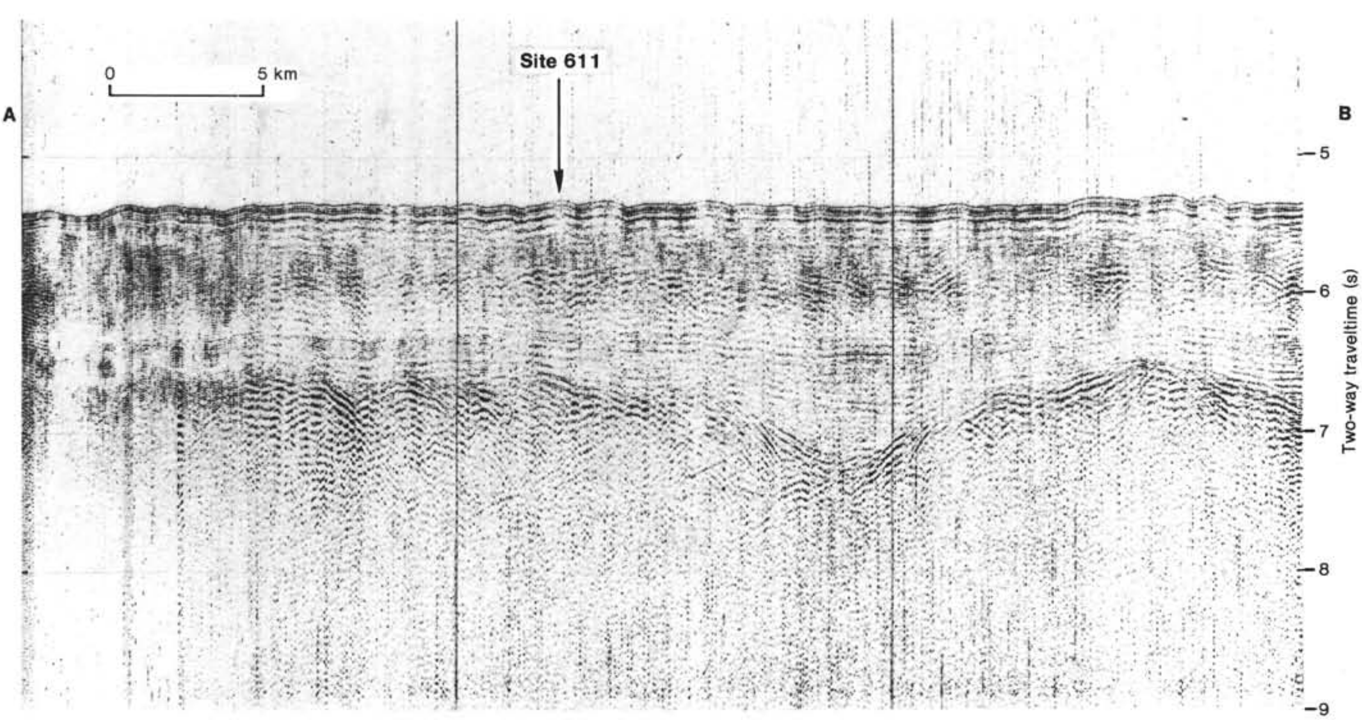

Figure 13. Single-channel seismic reflection profile obtained on *Discovery* Cruise 131, across Site 611. Location of section shown by line A–B on Figure 12.

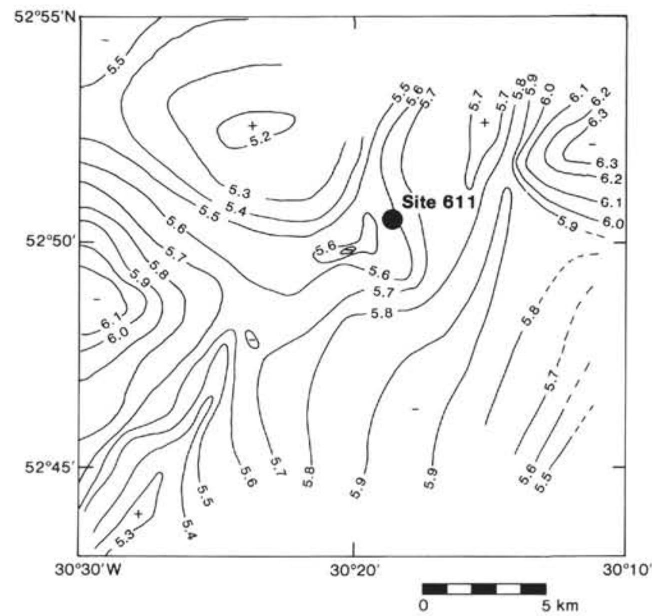

Figure 14. Total depth to basement in the area around Site 611, in seconds two-way traveltime. Contour interval 0.1 s.

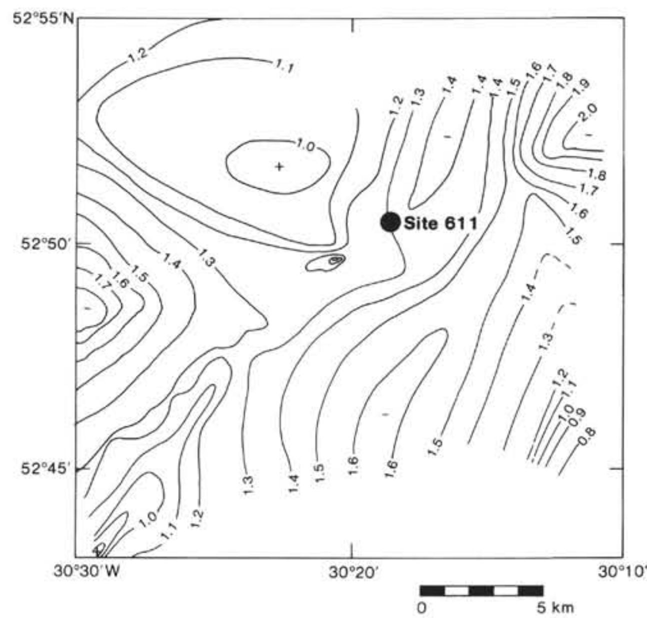

Figure 15. Sediment thickness in the area around Site 611, in seconds two-way traveltime. Contour interval 0.1 s. Location of section shown by line C–D on Figure 12.

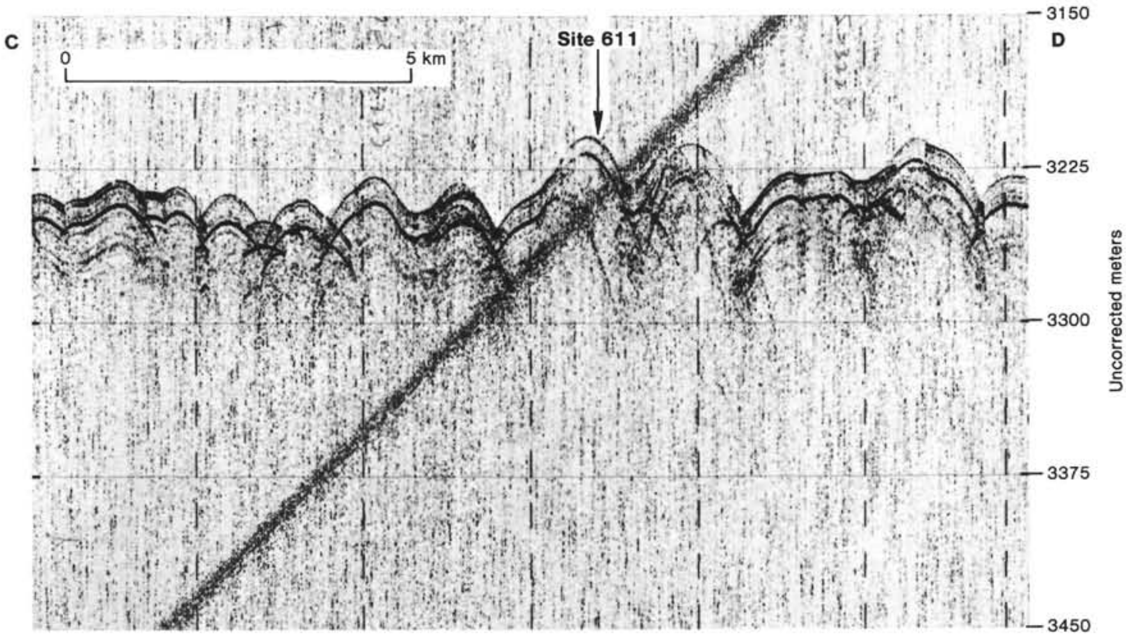

Figure 16. 3.5-kHz profile obtained on *Discovery* Cruise 131, showing the topography and near-surface acoustic stratigraphy of the sediment waves near Site 611.

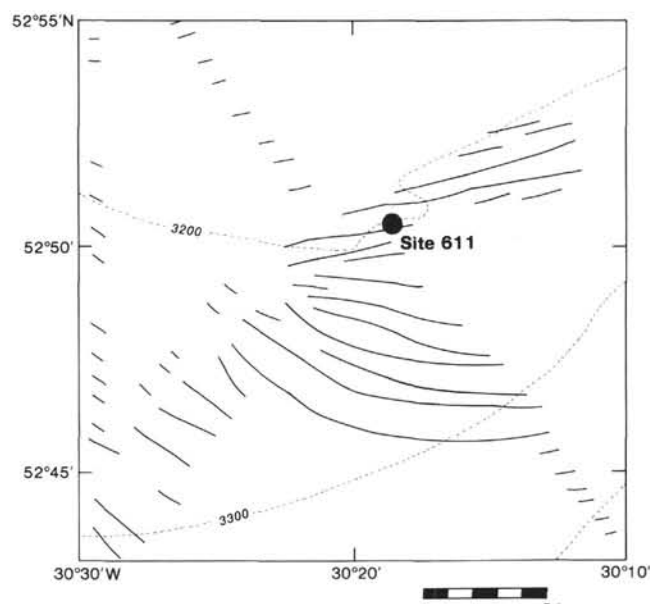

Figure 17. Trends of the crests of sediment waves around Site 611. Data from 3.5-, 10-, and 12-kHz records. Dashed line is bathymetry in corrected meters; contour interval 100 m.