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3. SEABEAM AND SEISMIC REFLECTION SURVEYS ON THE ONTONG JAVA PLATEAU[1]

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INTRODUCTION

In support of Leg 130 drilling, a site survey program was conducted between 17 and 31 December 1988 aboard the *Thomas Washington* (ROUNDABOUT Cruise 11; E. L. Winterer, T. Shipley, and L. Mayer, Principal Investigators). During this cruise over 3000 km of digitally recorded, single-channel water-gun seismic, magnetic, and SeaBeam bathymetric data were collected in the western equatorial Pacific. Because of the large steaming distances to and from port (Majuro to Majuro), only approximately half of this data set was actually collected on the Ontong Java Plateau (OJP) (Fig. 1).

The goal of the site survey cruise was to find a route from the top of the plateau to the bottom along which the seismic (and thus sedimentary) section would be minimally disturbed by mass wasting and redeposition. Our plan was to identify those areas with the most expanded sedimentary sections and conduct detailed site surveys suitable for drill site selection. Ideally, sites would be at depth intervals of 400–600 m, spanning the depth range of the plateau. In addition to the seismic and SeaBeam surveys, an extra day of ship time was provided by Scripps Institution of Oceanography for the collection of piston cores. We collected four piston cores; their lengths and locations are listed in Table 1.

The site survey cruise was funded specifically to select sites for the Neogene objectives of the Leg 130 drilling program. Thus, ship time constraints precluded surveying a region 300 km west of Sites 289/586 where it is thought that an expanded Mesozoic section might be found. We were, however, well aware of the important pre-Neogene and lithosphere objectives associated with OJP drilling and attempted to accommodate these objectives with the little flexibility that we had. Our approach was to review all existing OJP seismic data, select a route that would provide the best chance of finding undisturbed sections, and then parallel that route as we left Majuro and began to climb up the plateau.

A review of existing seismic data revealed that, although disturbance on the plateau is nearly ubiquitous, at certain depth intervals it is especially pronounced. Complications are common near 3000–3500 mbsl where there is commonly a sharp break in slope, and near 4000 mbsl where there seems to be significant disturbance in the deeper part of the section (Fig. 2). Based on existing seismic data, the best hope for finding a desirable path up the plateau was near the track taken by *Vema* Cruise 24-05 in 1967. This air-gun record (single-channel 40 in.^{3}) showed little disturbance (bearing around 250°) over a large portion of the plateau. We departed Majuro on 17 December and began our survey up the plateau, paralleling the *Vema* track on the 20th of December (Fig. 1).

The traverse up the plateau with the high-resolution water-gun seismic reflection system revealed that the section was more complex than originally thought. Scattered throughout the plateau are examples of mass wasting, scour and channel fill, and complex tectonic and possibly igneous activity. Particularly difficult was the 3000–3500 mbsl depth interval (which is, interestingly, the approximate depth of the lysocline in this region; Berger and Mayer, 1978). The difficulty in finding appropriate sites at this depth range forced us to deviate from the *Vema* track after tying our line to Sites 289/586. We chose to head northeast so that we could follow a bathymetric promontory that might be free of mass wasting and have an expanded older section. Also, surveys to the north would cover sites that are off the isochron of Site 289 and thus be beneficial to lithosphere objectives.

Despite the complexities of the plateau (which make for an interesting story in their own right), the preliminary analysis of the seismic data led us to think that we could find potential sites through which the seismic stratigraphy could be traced (and thus provide a general idea of our location in the section) as well as sites that experienced a minimum amount of disruption. The sedimentary cover on the plateau thins from ~1200 m in thickness at 2200 m water depth to <450 m at 4300 m water depth (averaging about 100 m loss in thickness for every 200 m of water depth; Figs. 2 and 3). The determination of the manner in which this thinning takes place is one of the important goals of the drilling.

During our traverse from the top of the plateau (Sites 289/586) to Majuro, five detailed site surveys were conducted, and, in the spirit of the season, these were named after Santa's reindeer. Surveys were conducted at the following depth intervals: 2600–2800 mbsl (A = Dasher, OJP-1, Site 806); 3040–3180 mbsl (C = Prancer); 3100–3300 mbsl (D = Vixen, OJP-2, Site 805); 3400–3600 mbsl (B = Dancer, OJP-4, Site 803); and 4120–4200 mbsl (E = Comet, OJP-3) (Fig. 1). A preliminary bathymetric chart was produced for each survey area as well as an "avoidance" chart, that is, a chart that details areas avoided in the site selection process. Criteria used to select potential sites included the avoidance of those sites with evidence of modern or past erosion (i.e., hyperbolae or channel structures), displacement or disruption in the sediment column, major faulting and seismic anomalies (Figs. 4 and 5).

Also included as targets to be avoided were the strongly reverberant layers that commonly occur mid-section at water depths greater than 3000 m. These mid-section reflections have a seismic character similar to the chert and basement found near the bottom of Site 289 (Reflectors "F" and "G"; see below and Fig. 6), and may be related to basement complexities, tectonic disruption, igneous intrusion, erosion and early chertification, or some combination of these. Their origin is not yet understood, but certainly they will be the subject of future investigation. Preference was given to those sites with expanded sections and with high-quality seismic images.

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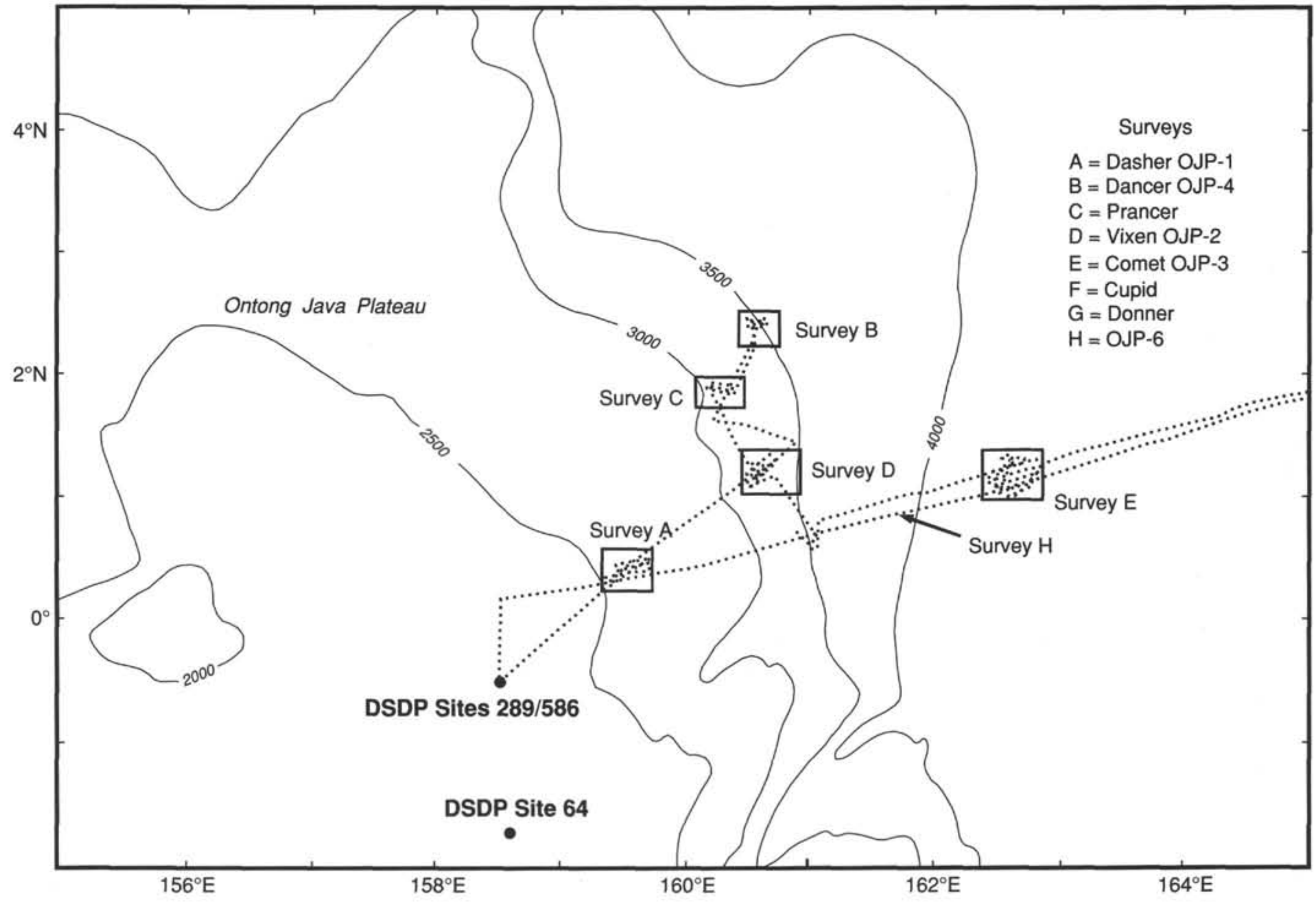

Figure 1. Bathymetry of northeast Ontong Java Plateau and ship track of ROUNDABOUT Cruise 11 with the locations of the detailed site survey areas for the Leg 130 drill sites.

Table 1. Locations of piston cores collected during ROUNDABOUT Cruise 11.

Core	Latitude	Longitude	Water depth (m)	Length (m)
PC 74	00°20.48′N	159°22.49′E	2547	8.5
PC 75	01°53.15′N	160°11.49′E	3078	8.5
PC 76	01°10.10′N	160°40.20′E	3290	7.6
PC 77	00°35.64′N	161°00.66′E	3490	8.5

METHODS

Seismic data were collected with an SSI, 80-in.^{3} water gun fired at 2000 psi. The seismic records were digitized aboard the research vessel at a 1-ms digitization rate by the data acquisition systems of the Scripps Institution of Oceanography as well as the University of Texas. All records presented in this chapter were band-pass filtered at 70–250 kHz and displayed at the same (constant) gain. Navigation was provided by transit satellite and, when available, the global positioning system (GPS).

An NGDC77 data tape, microfilm of analog seismic data, and the cruise report are on file with the Ocean Drilling Program (ODP) Site Survey Data Bank. Data tapes shipped back from Majuro were received at the University of Texas in February 1989, and Tom Shipley and Dave Mosher completed preliminary processing (filtering and display optimization) by early March.

Bathymetric data were collected with SeaBeam, a 16-narrow-beam echo sounder that collects detailed depth information in a swath parallel to the ship and with a width of about 80% of the water depth (Renard and Allenou, 1979). A 20-m contour interval was used for all surveys presented here. The SeaBeam data were adjusted on board the ship to reconcile it with the "best" available navigation for a given survey. The maps presented here are hand-contoured, based on the SeaBeam maps.

SURVEY AREAS

DSDP Sites 289/586

The starting point for our analyses of the site survey data for the Ontong Java Plateau was the line collected over Deep Sea Drilling Project (DSDP) Sites 289/586 (Fig. 7). With the results from DSDP Legs 30 and 89 (Fig. 8) (Shipboard Scientific Party, 1975, 1986) and ODP Leg 130, it is possible to make a preliminary interpretation of the seismic record and assign approximate ages to some of the major reflectors. Seven reflectors were chosen for mapping (A through G; Fig. 3), the deepest two representing the recovery, at Site 289, of chert (F) and basaltic basement (G), respectively. By attempting to trace these seismic horizons throughout the Ontong Java Plateau survey data, we hoped to gain some idea of the stratigraphy within the detailed survey areas.

It must be noted that this sort of seismic interpretation is subjective and, considering the complex nature of the Ontong Java Plateau seismic stratigraphy, a time-consuming task. Given

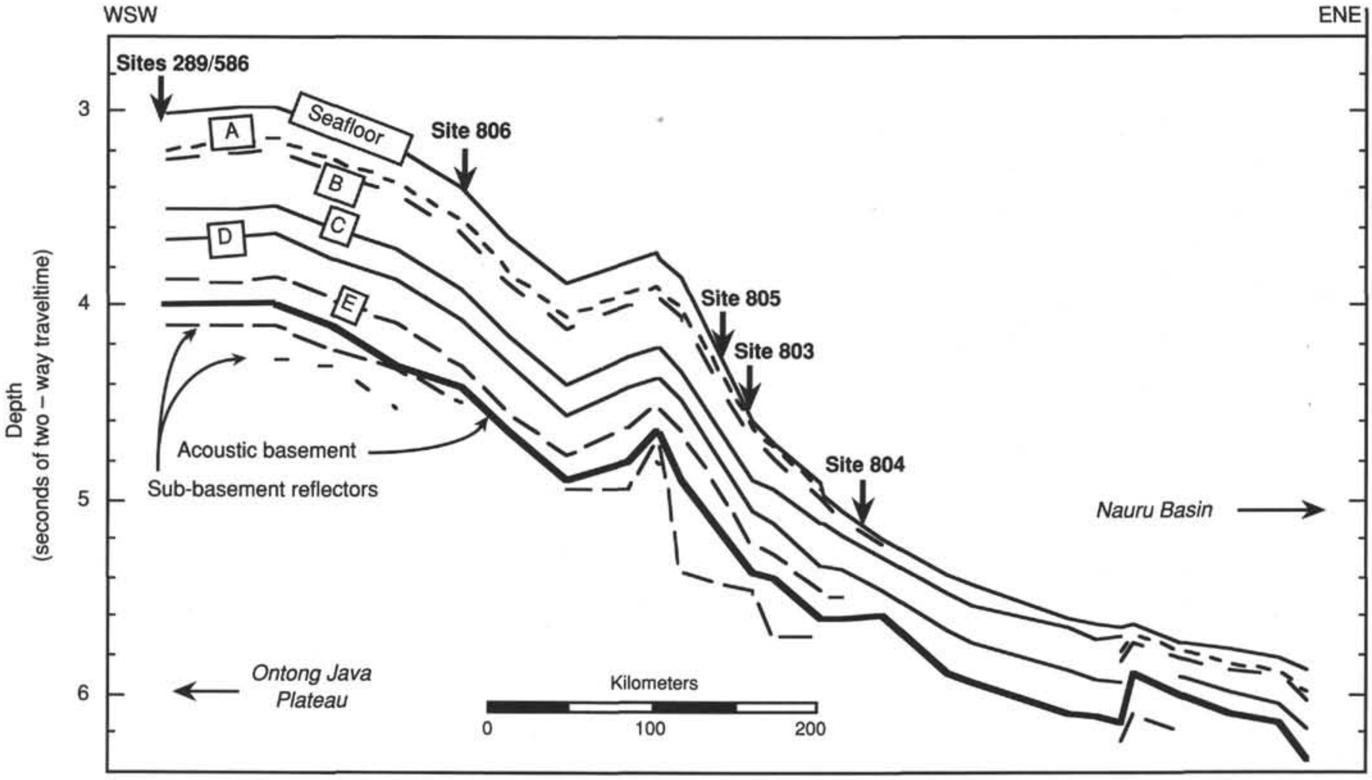

Figure 2. Line interpretation of seismic stratigraphy of the northeastern flank of the Ontong Java Plateau. See Figure 1 for location of profile.

the limited time that we have had to analyze these data, we emphasize the preliminary nature of our interpretations.

Dasher, 2600–2800 mbsl (OJP-1)—Site 806

Using Sites 289/586 (at 2200 m) as an upper plateau reference point, the traverse from Sites 289/586 to the Dasher region is quite straightforward. The "layer-cake" like, seismic stratigraphy of the upper plateau remains virtually constant; individual reflectors can be traced directly along the approximately 139 km between the sites (Figs. 2 and 3). There is virtually no reduction in the thickness of the section between Site 289 and proposed Site OJP-1 except for the deepest part of the section. Bathymetry in the Dasher survey region shows a fairly gentle but steady increase in depth from about 2500 mbsl in the southwest quadrant to 2860 mbsl in the northeast (Fig. 9); a channel-like feature is found in the northern part of the survey area. Areas avoided for site selection in this area consisted mostly of regions of surface erosion (hyperbolic echoes; Figs. 10, 11, and 12). Site OJP-1 (Site 806), in the southwest corner of the survey area, was selected as a primary target because it showed a slightly expanded section and was removed from apparent modern erosion (Fig. 13).

Prancer, 3040–3180 mbsl

The fairly continuous stratigraphy of the upper plateau continues on from Dasher until approximately the 2850-m contour. At this point there is a 150-m drop in the bathymetry (bringing the plateau to depths >3000 m; Fig. 2). Associated with this bathymetric step is a loss of about 0.2 s in the seismic section (Fig. 3). Reflectors are difficult to trace at this point, but it appears that most of the loss is in the upper part of the section (although all of the marker reflectors are still present). Soon after crossing this bathymetric step, the mid-section reverberations (MSRs) discussed earlier were observed. The MSRs continue between the 3000- and 3500-m contours along with extremely rugged surficial topography and much surface erosion. The Prancer region appears to be a small window with no MSR and only minor (though ubiquitous) surface erosion.

The Prancer area is gently sloping to the southeast with a large, deep depression in the northeast section (Fig. 14). Areas avoided in site selection included those that displayed faulting and surface erosion (Figs. 15, 16, and 17). Sites were difficult to select, but OJP-16 (Figs. 16 and 17) was proposed as a first priority site in this region and OJP-17 was suggested as an alternative. The regional seismic correlation (Fig. 3) indicates that the section has thinned by almost 30% between 2600 and 3050 mbsl and that most of the thinning has taken place between about 8 and 20 Ma and in the very deepest part of the section. Because of time constraints, OJP-16 and OJP-17 were not selected as drilling targets.

Vixen, 3100–3300 mbsl (OJP-2)—Site 805

The surface topography in the Vixen area is a bit more complex than that in the other areas (Fig. 18). A zone of rough surficial topography associated with an MSR and possible basement roughness is found in the southeast section of the survey area (Figs. 19, 20, and 21). Targets that were avoided in site selection included the numerous MSRs in the western portion of the survey area, surface erosion in the south (Figs. 21 and 22), and faulting in the northeast (Fig. 21). The seismic section is similar to that found in the Prancer survey area (though of better quality here) with the section appearing to be slightly thinner from 0 to about 8 Ma, and somewhat expanded between 8 and 20 Ma (Fig. 3). The deeper part of the section may also be thicker here than at Prancer. Site OJP-2 (Site 805) is located in the eastern part of the survey area in a region that shows an expanded and complication-free section.

Dancer, 3400–3600 mbsl (OJP-4)—Site 803

The bathymetry in the Dancer area is flat (Fig. 23), with several regions of very rugged topography (northeast and southwest) that appear to be related to basement features (Figs. 24

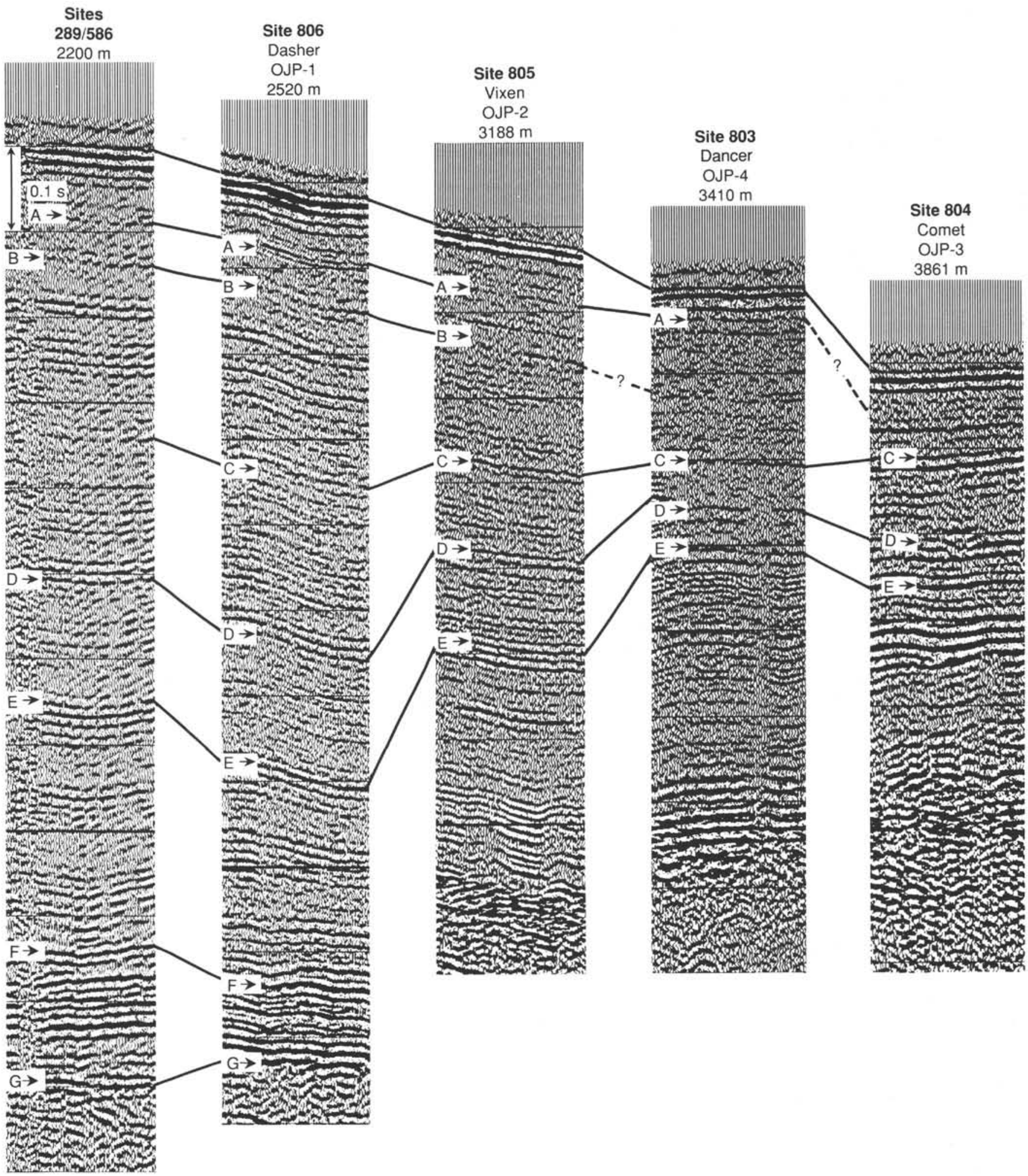

Figure 3. Relationships of seismic sections and marker reflectors down the northeastern edge of the Ontong Java Plateau. Horizontal lines within each section represent 0.1 s (two-way traveltime). Seven major reflectors (A through G) were chosen at this site for correlation throughout the survey area.

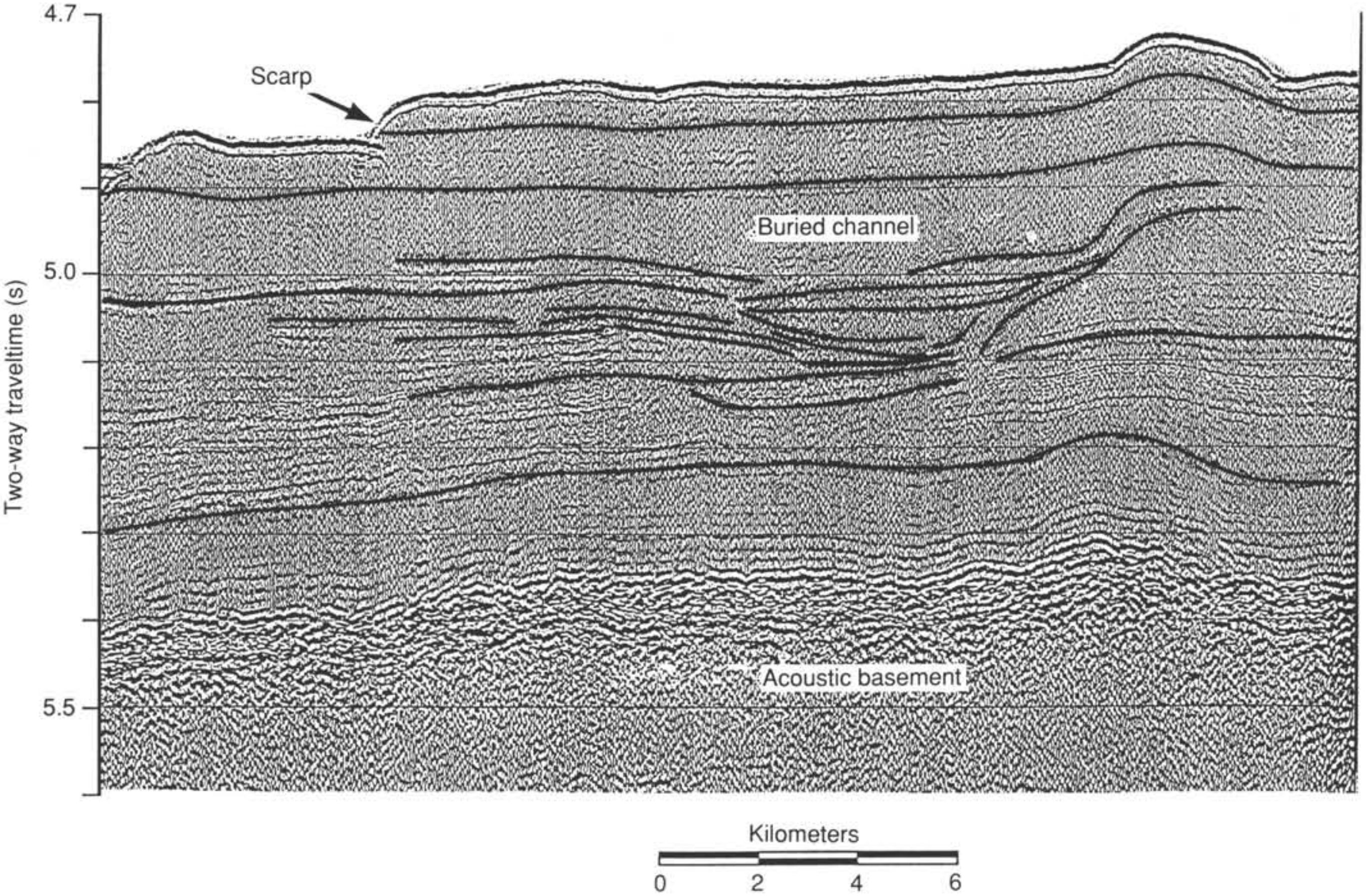

Figure 4. Sample seismic profile with examples of internal structures and surface erosional features that are considered to be undesirable for drill sites.

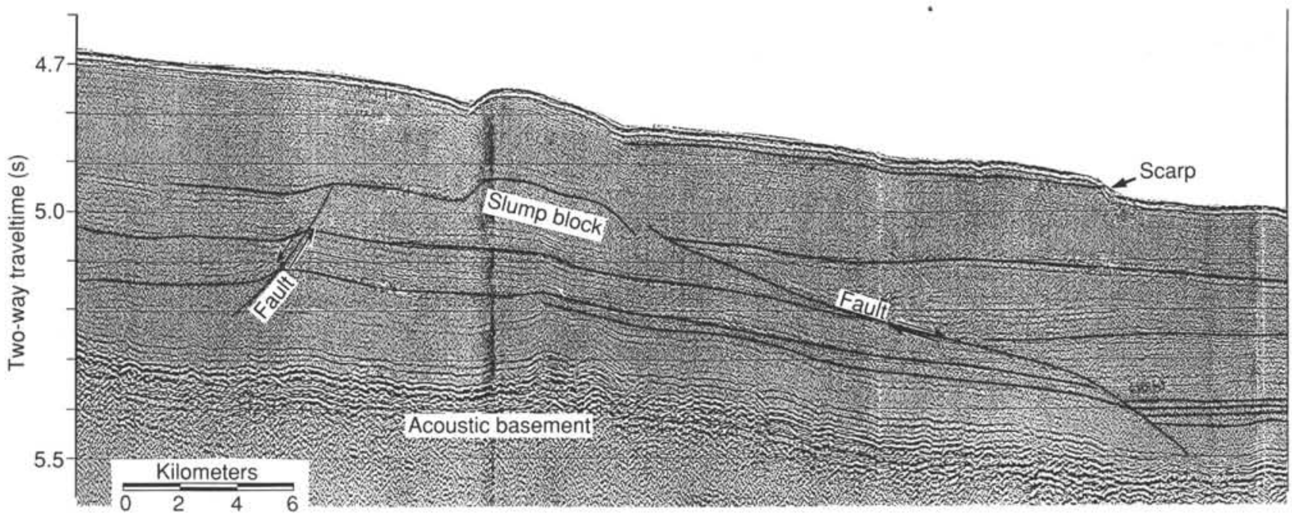

Figure 5. Sample seismic profile with evidence of faulting and slump structures.

and 25). Targets that were avoided in site selection included numerous MSRs (the site is located between two MSRs; Fig. 25), rough basement, and numerous small faults (Fig. 26). These small faults do not appear to disrupt the seismic stratigraphy. At this depth the section is 60% thinner than it was at Sites 289/586 (Figs. 2 and 3). We also can no longer trace, with confidence, the upper two marker reflectors (A and B). That we can no longer pick up these reflectors does not necessarily mean that this part of the section is missing. It may be that the section is compressed to the point that the seismic character is now substantially different. Site OJP-4 (Site 803) is located in the middle of the survey area in a fairly expanded section, close to an MSR.

Comet, 4120–4200 mbsl (OJP-3)

At depths greater than 4000 mbsl, the sediment column on the Ontong Java Plateau thins substantially and evidence for

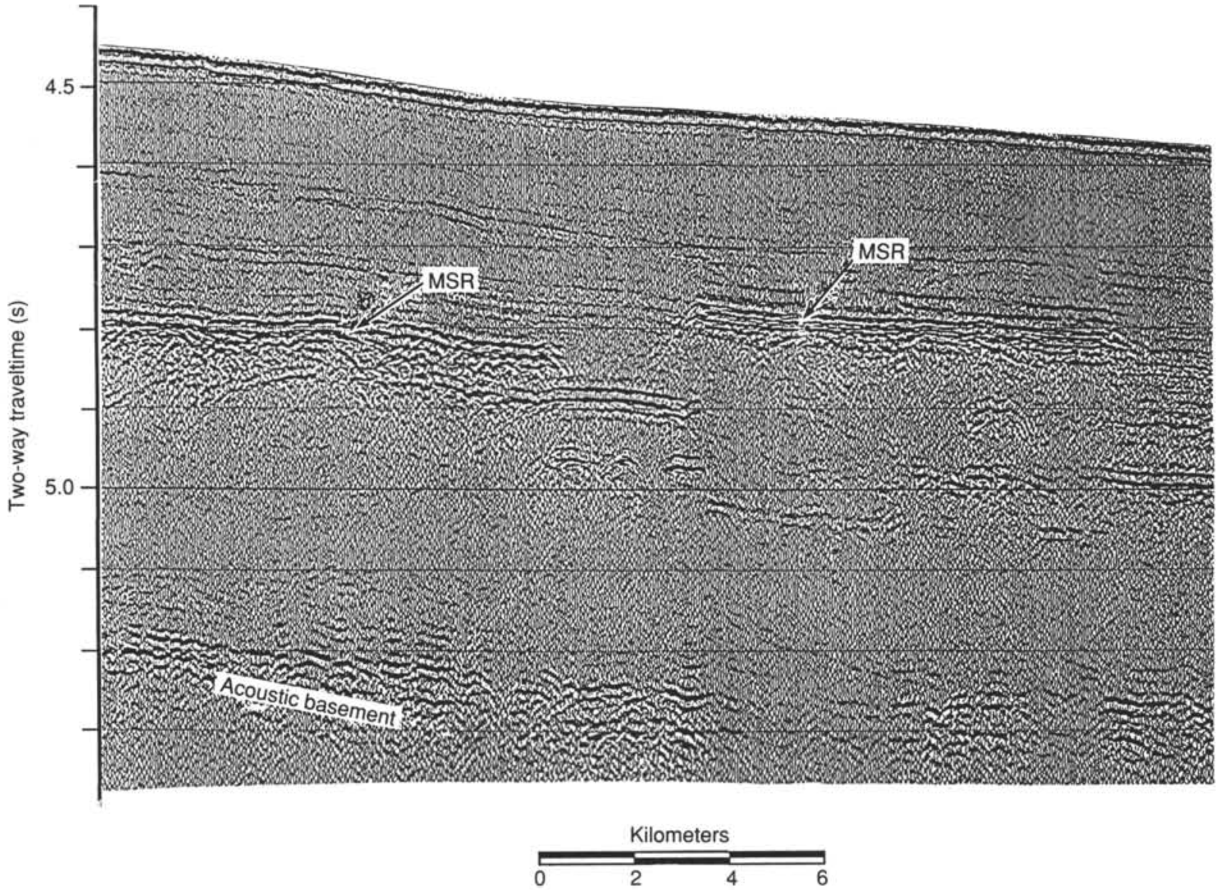

Figure 6. Sample seismic profile with examples of strongly reverberant, mid-section layers (MSRs), which are common between 3000 and 3500 m water depth.

strong erosion is common. In the vicinity of survey area Comet, however, we found, amid a region of extremely complex (and interesting) structures, an almost enclosed basin (graben?) containing a thick sedimentary fill. At first we thought that this fill might represent redeposited material from surrounding highs, but the seismic character of the fill appears to correlate with the section outside of the basin, indicating that the section should be predominantly pelagic. The basin itself is very flat (Fig. 27); rough topography can be found outside of it (to the northeast), associated with the outcrop or near outcrop of basement(?) (Fig. 28). Figure 29 shows the boundaries of the fill. Proposed Site OJP-3 (Figs. 30 and 31) was selected at the point of thickest fill.

The section here is significantly less than half of what it was at 2200 mbsl (Figs. 2 and 3). Most of this thinning appears to take place above Reflector "C," estimated to be about 10 Ma. This is quite consistent with the record of equatorial Pacific carbonate stratigraphy, which shows a major change in the nature of carbonate chemistry in the Pacific at about the middle/late Miocene boundary (Mayer et al., 1985, 1986). In sediments older than the middle/late boundary, carbonate values remain generally high, even in the deep Pacific, but younger sediments typically show major fluctuations in carbonate content.

DISCUSSION

The site survey data from the Ontong Java Plateau reveal a picture of the complex interactions among the processes of pelagic sedimentation, carbonate dissolution, tectonism, and redeposition. Although a detailed understanding of this picture will have to wait on a careful analysis of these data, several preliminary observations can be made.

The top of the northeast quadrant of the Ontong Java Plateau is characterized by a thick (~1200 m) sediment cover with numerous, closely spaced, parallel seismic reflectors. Individual reflectors can be correlated easily over large distances with only rare, small vertical displacements observed. Seafloor topography is generally flat, with rugged topography only in those regions where basement shows substantial relief. In general, the acoustic basement (probably chert overlying basalt) shows moderate relief. The parallel reflectors draping over basement topography indicate that this portion of the plateau is dominated by pelagic sedimentation processes. Although a full understanding of the origin of the closely spaced seismic events must await the analysis of drilling results, we can speculate that the reflectors in this portion of the plateau are the result of physical property contrasts caused by subtle changes in grain size (winnowing and dissolution), carbonate content (winnowing and ocean chemistry), and original microfossil assemblages (productivity). As such, they represent a record of paleoceanographic change that, on the top of the plateau, should be fairly continuous for the Neogene (Figs. 2 and 3).

The parallel, "layer-cake" like seismic stratigraphy of the upper plateau continues beyond the slope break between the plateau and the flank (at about 2250 m) to a depth of about 2800 m. At this depth there is a sharp break in the continuity of the reflectors, with reflectors on the downslope side having a hum-

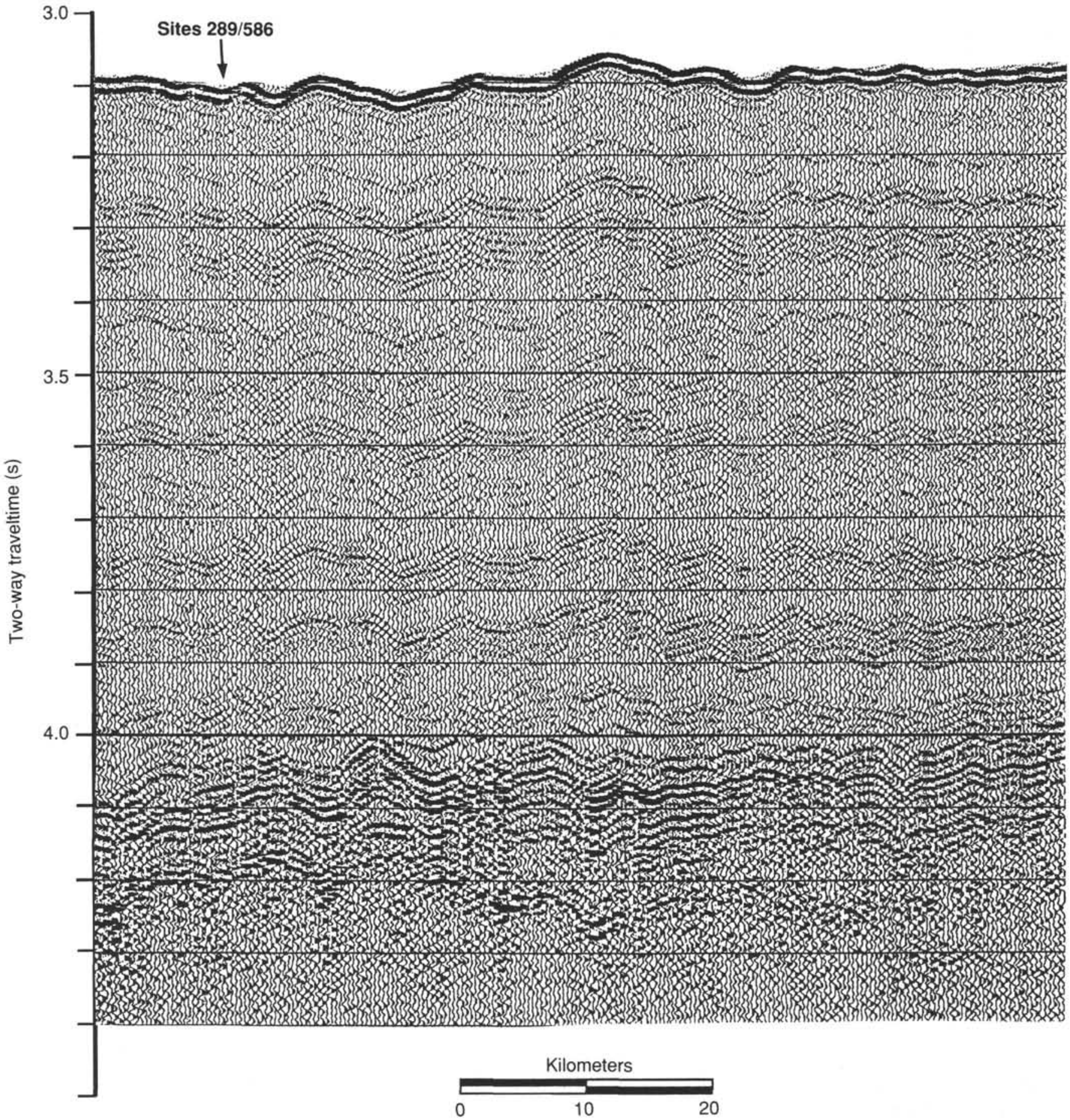

Figure 7. Single-channel seismic profile over Sites 289/586.

mocky character with numerous small offsets. Surficially, this transition is expressed by a steplike bathymetric drop of almost 150 m (Fig. 2). At about 2900 m water depth, the seafloor topography becomes steep and rough, and individual reflectors are very difficult to trace. By about 3000 mbsl, the sediment column has thinned approximately 35%; seismic correlations indicate that, although a small amount of thinning has taken place in the younger part of the section (post 5 Ma), the majority of thinning has taken place in the middle to lower Miocene and in the pre-early Oligocene section (Fig. 3).

The disrupted seismic character described above continues down the plateau to a water depth of about 3400 m; below this depth the seismic record becomes more coherent. We attribute the section thinning and change in seismic character to the effect of dissolution through the lysocline. Berger and Johnson (1976) have described the effects of increased dissolution on the stability of Ontong Java Plateau sediments and noted that at the depth of the lysocline there is evidence for significant internal deformation. The 2800–3400 m depth range also represents the depth interval over which the vertical dissolution gradient is the

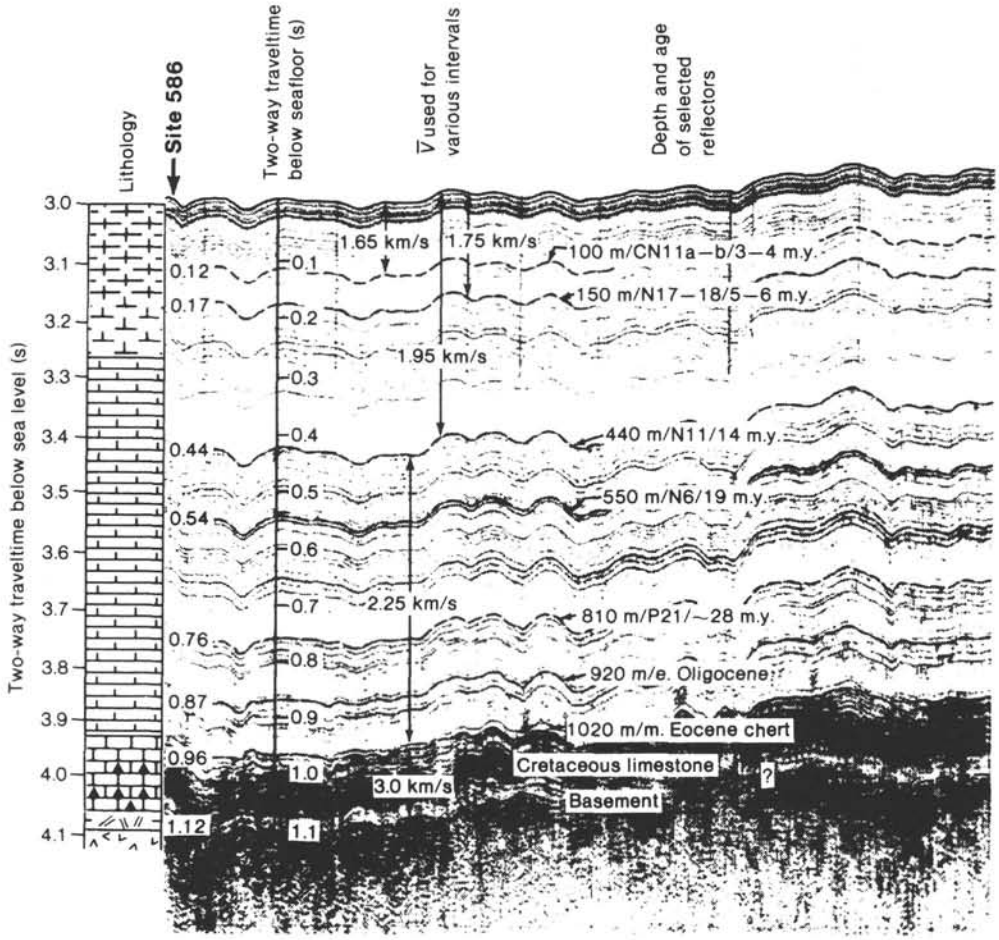

Figure 8. Interpretation of seismic profile over Sites 289/586 based on the drilling results of Leg 89 (Moberly, Schlanger, et al., 1986). Based on Leg 130 seismic stratigraphy, the ages of the 0.42- and 0.54-sbsf events have been reinterpreted to be ca. 11 and 16 Ma, respectively.

steepest. Thus, changes in the depth of the lysocline over time would tend to result in significant vertical changes in the state of preservation of the accumulating sediment. The superposition of sediments with significantly different states of preservation may contribute to the instability of the sediments in this depth range.

Deeper than about 3400 mbsl, the sediment section once again changes character. At this depth range, we begin to see more evidence of tectonic disruption of the sedimentary section (faults), as well as evidence of buried channels (Figs. 4 and 5). The reflection profile also takes on a characteristic appearance with several horizontal low-amplitude zones (relatively transparent sections) bounded by high-amplitude reflections. The most pronounced of these zones occurs in the lower Oligocene sediments. Also at this depth range is the first occurrence of the MSRs, the high-amplitude reflections that typically occur between 0.2 and 0.5 s below seafloor (sbsf). Features of this type have been observed before and have been interpreted as sills (Kroenke, 1972), lithified carbonates, and diagenetic "hardgrounds" associated with erosive events (Shipley et al., 1985). The restriction of the MSRs to certain stratigraphic intervals and depth ranges implies that they may be associated with periods of increased tectonic activity related to the subduction of the southwest portion of the plateau. The grabenlike features that are found at the base of the plateau (see discussion of OJP-3) and are restricted to between 3800 and 4200 mbsl may be a flexural response to this subduction.

The preliminary interpretation of the seismic stratigraphy on the Ontong Java Plateau indicates that the sedimentary section has thinned from ~1200 m on the crest to about 450 m at the base (4300 m water depth). Although there is a general decrease in sediment thickness at all time intervals, the nature of the thinning varies with time interval and depth range. In the younger part of the section (post Miocene), the majority of thinning takes place deeper than about 3500 m. The Miocene and pre-early Oligocene sections, on the other hand, begin to thin at depths as shallow as 2800 mbsl, whereas the middle to late Oligocene section remains remarkably constant in thickness throughout the entire depth range of the plateau. Even these rough correlations present a picture of the history of the equatorial dissolution surfaces that is consistent with the carbonate-compensation depth (CCD) history presented by van Andel et al. (1975). From the results of drilling, logging, and seismic modeling, we hope to put together a detailed picture of the temporal and spatial history of carbonate dissolution in the western equatorial Pacific.

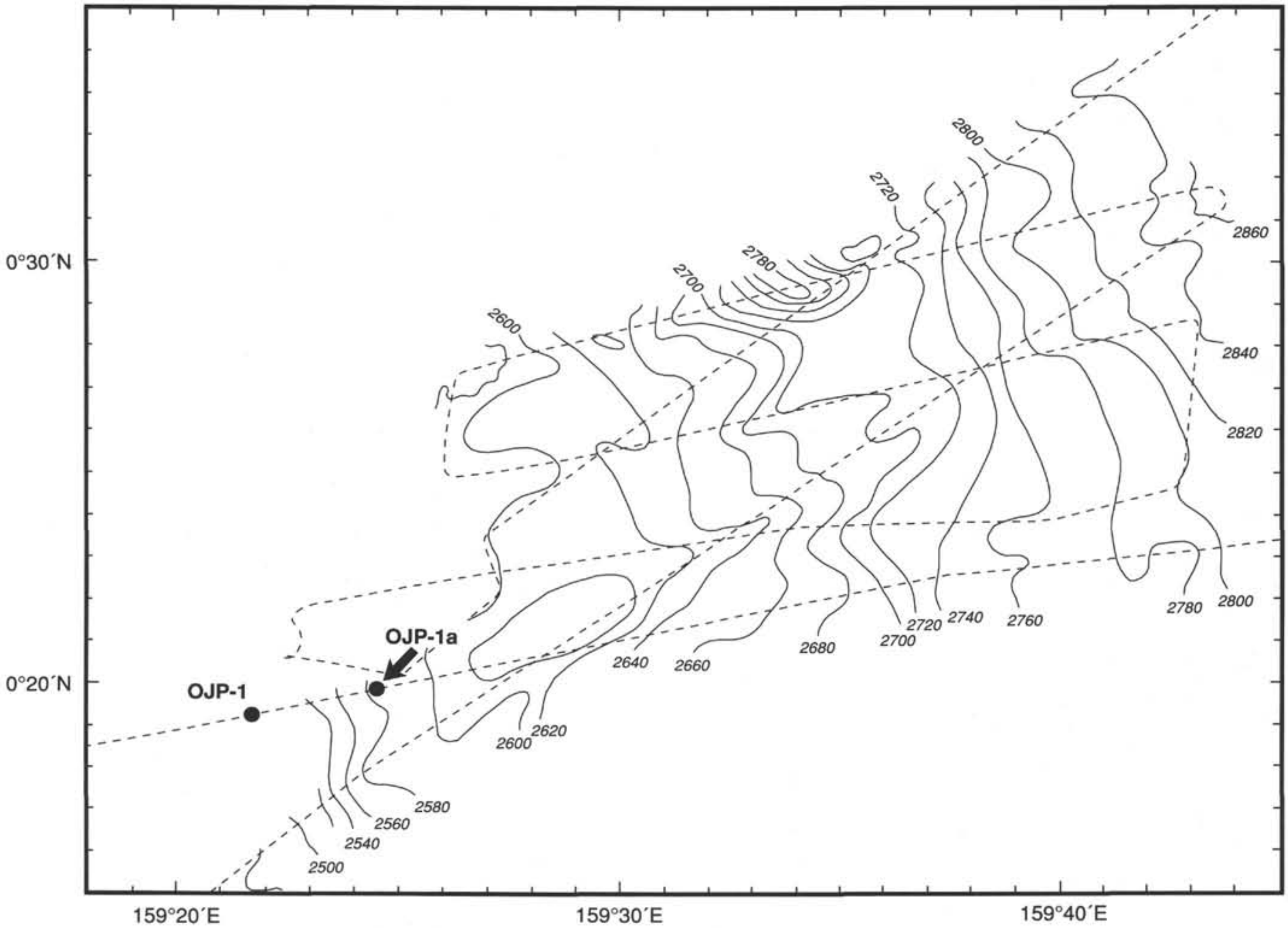

Figure 9. SeaBeam bathymetry in the Dasher survey area. Contour interval is 20 m. Dashed line is ROUNDABOUT Cruise 11 ship track. Proposed Sites OJP-1 and 1a are shown.

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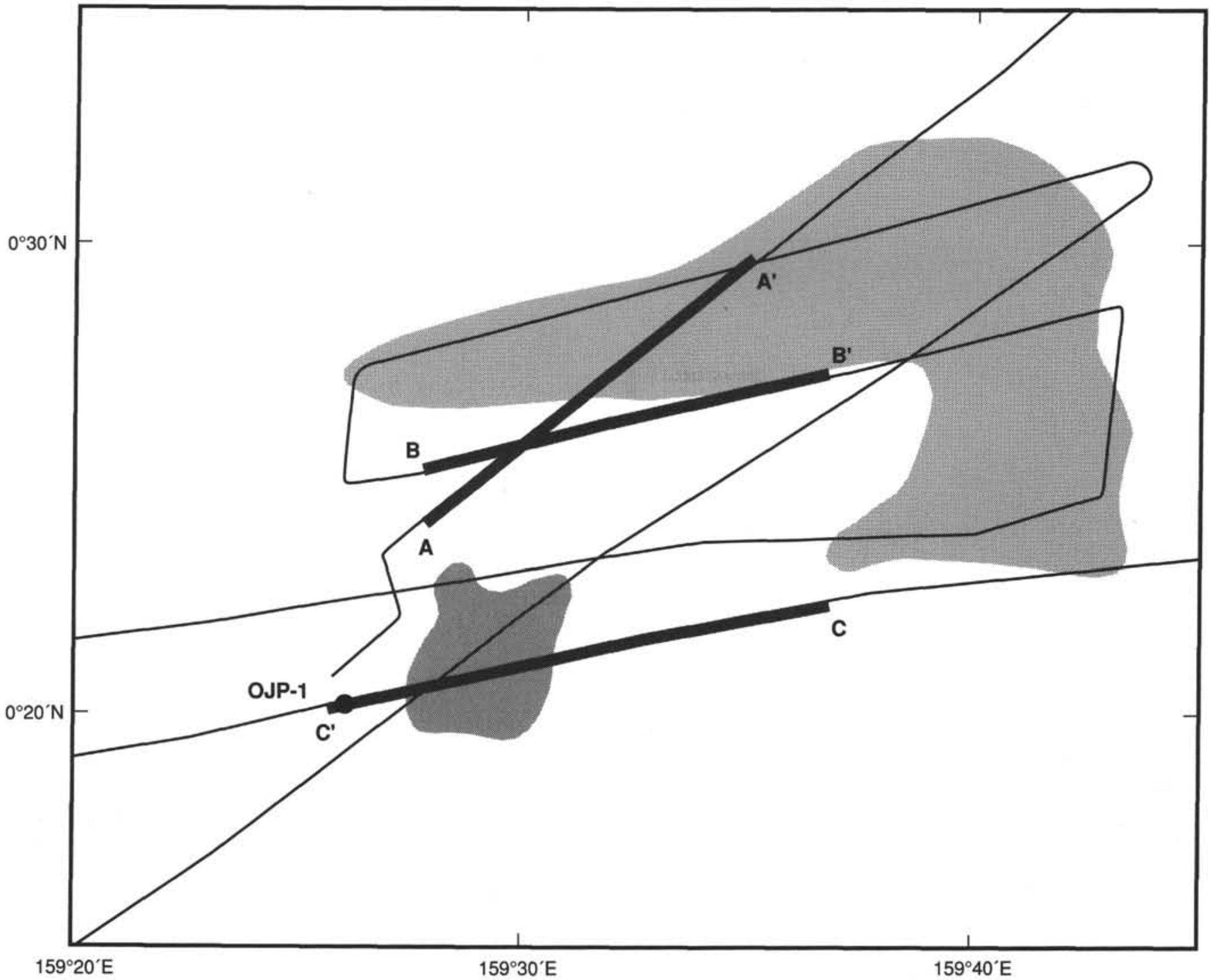

Figure 10. Drilling "avoidance" map of the Dasher survey area based on seismic reflection profiles. Stippled areas were avoided for site selection.

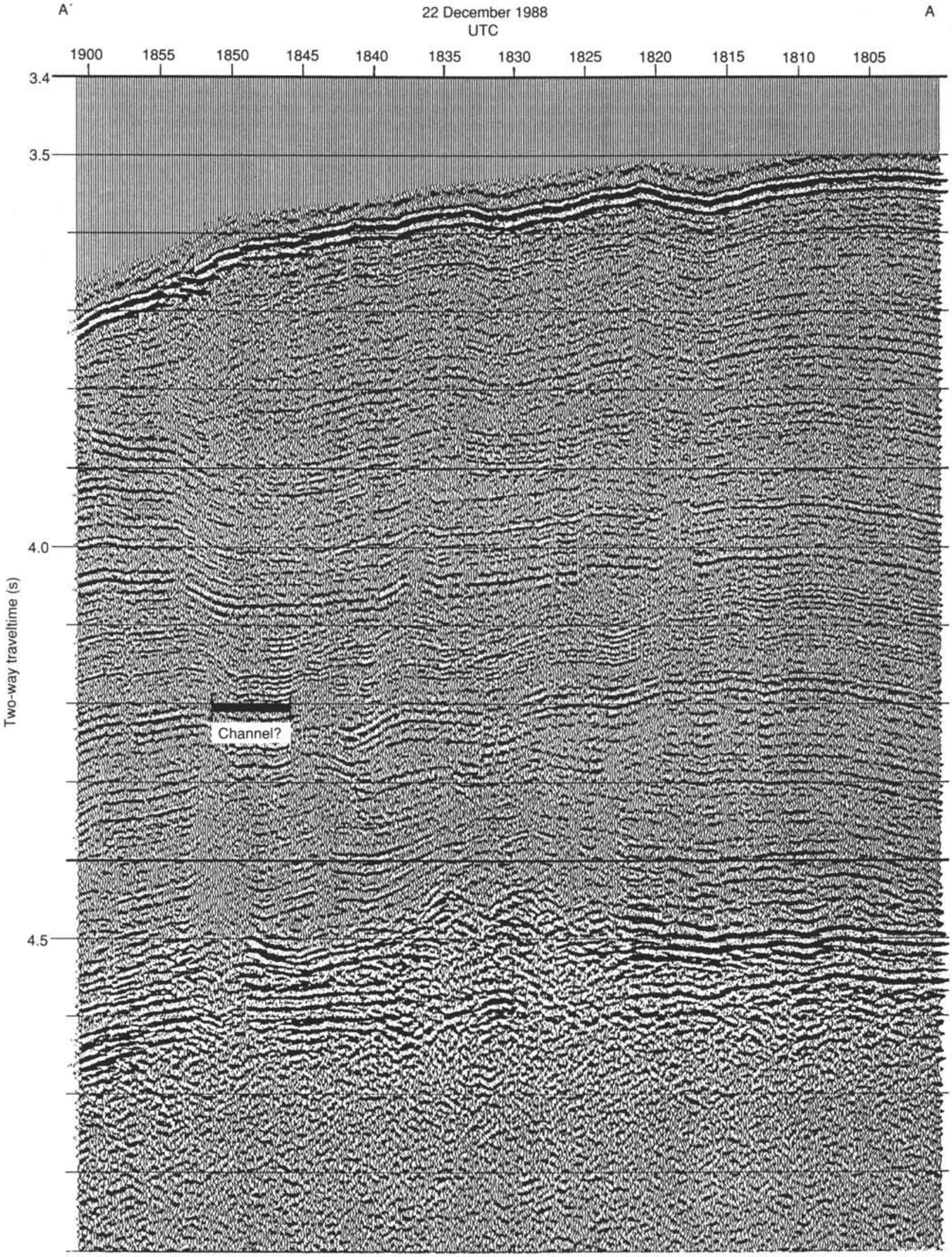

Figure 11. Single-channel seismic profile A-A′ in the Dasher survey area. Reflectors A through G are all present at this site. An erosional channel is visible at the left of the figure. See Figure 10 for location of line.

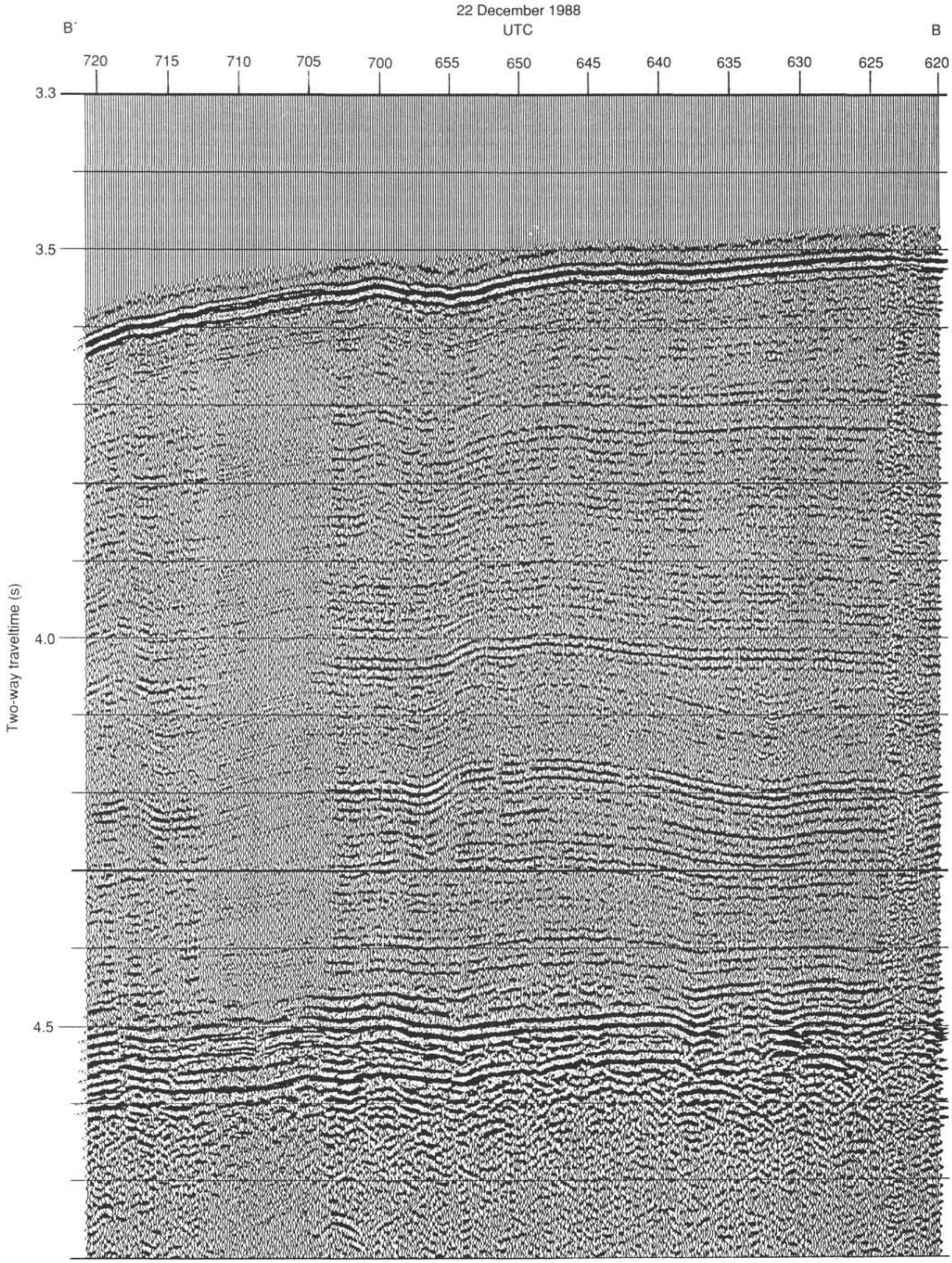

Figure 12. Single-channel seismic profile B-B′ in the Dasher survey area. See Figure 10 for location of line.

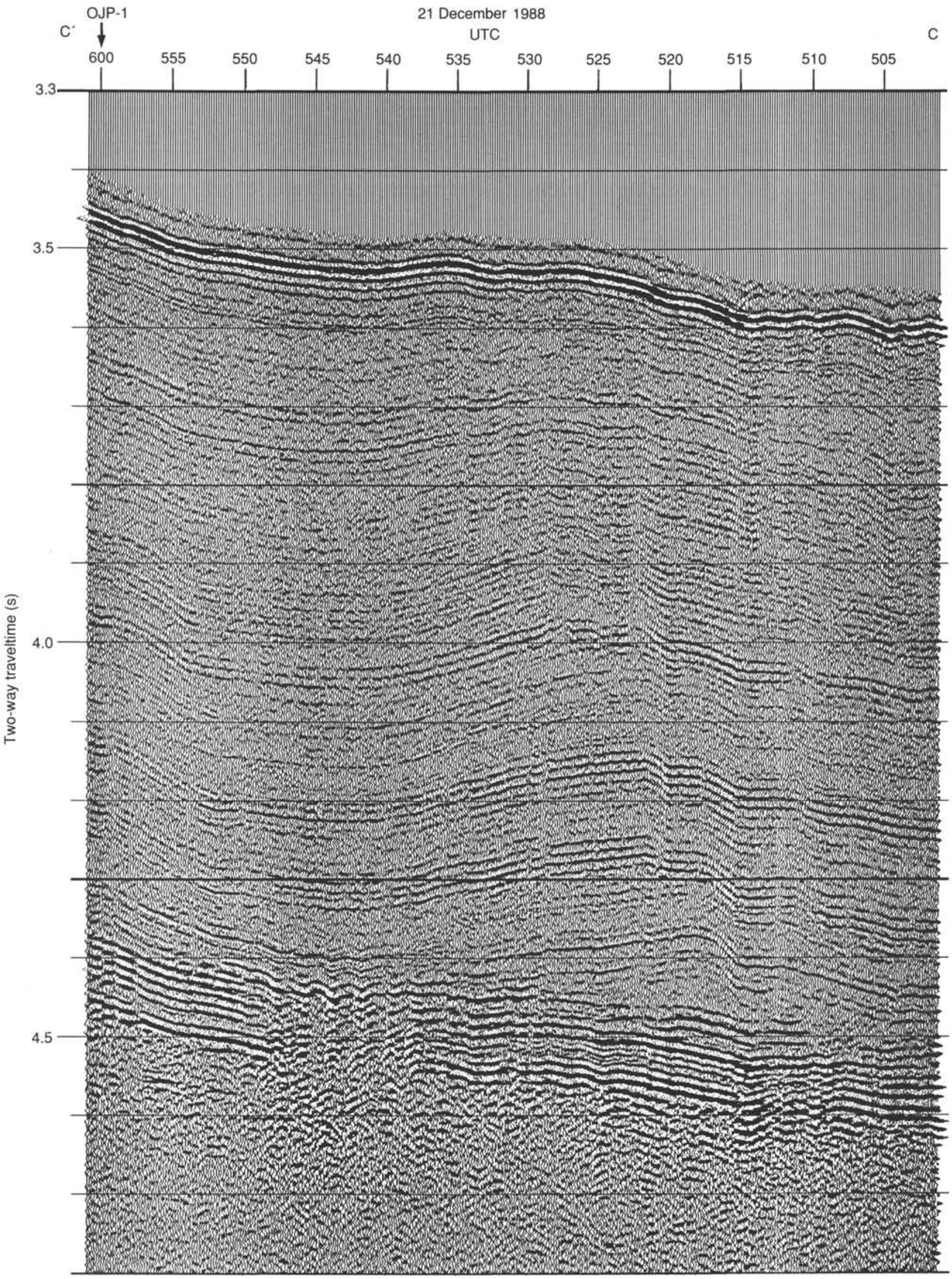

Figure 13. Single-channel seismic profile C-C′ in the Dasher survey area. See Figure 10 for location of line.

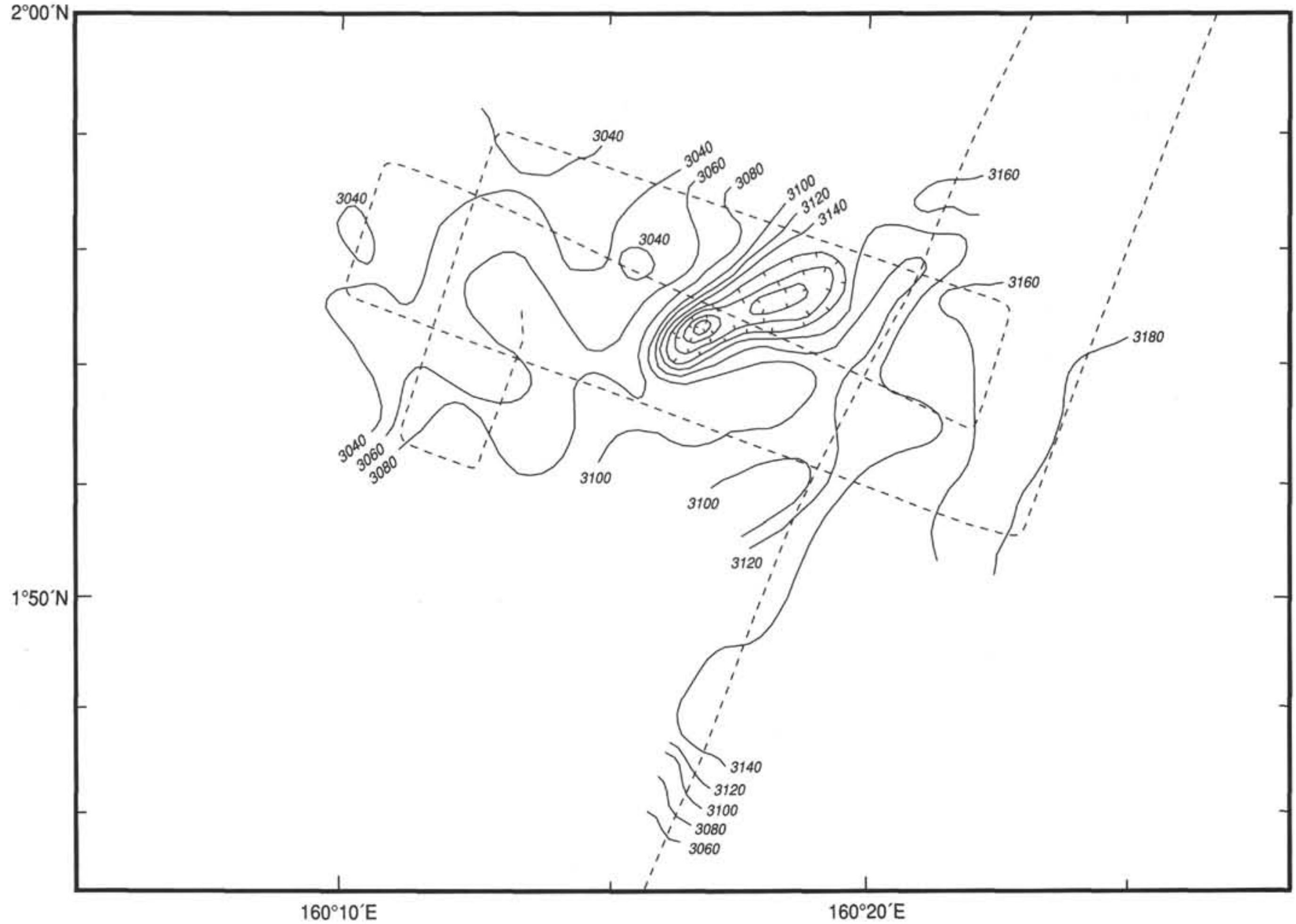

Figure 14. SeaBeam bathymetry in the Prancer survey area. Contour interval is 20 m.

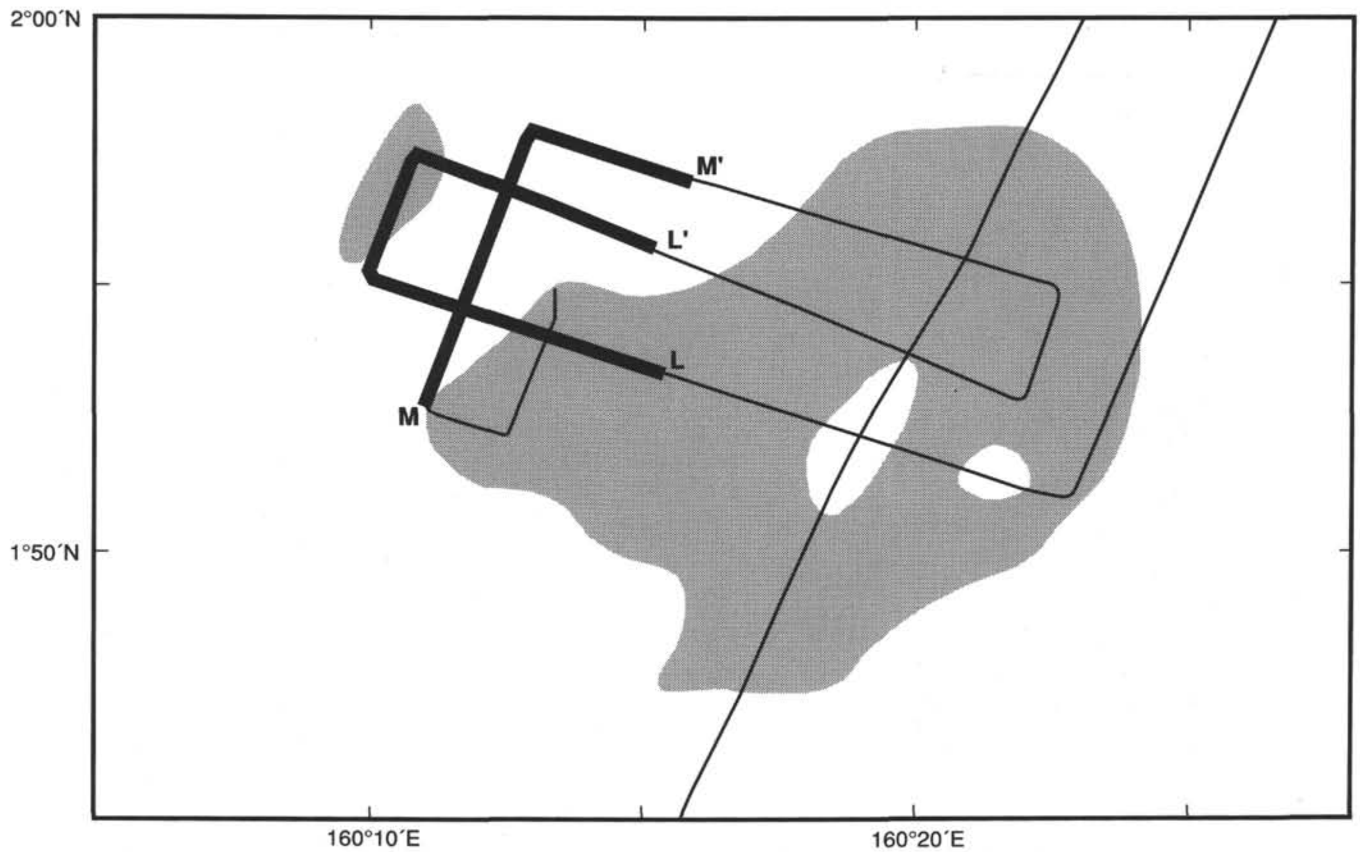

Figure 15. Drilling "avoidance" map of the Prancer survey area based on seismic profiles. Stippled areas were avoided for site selection.

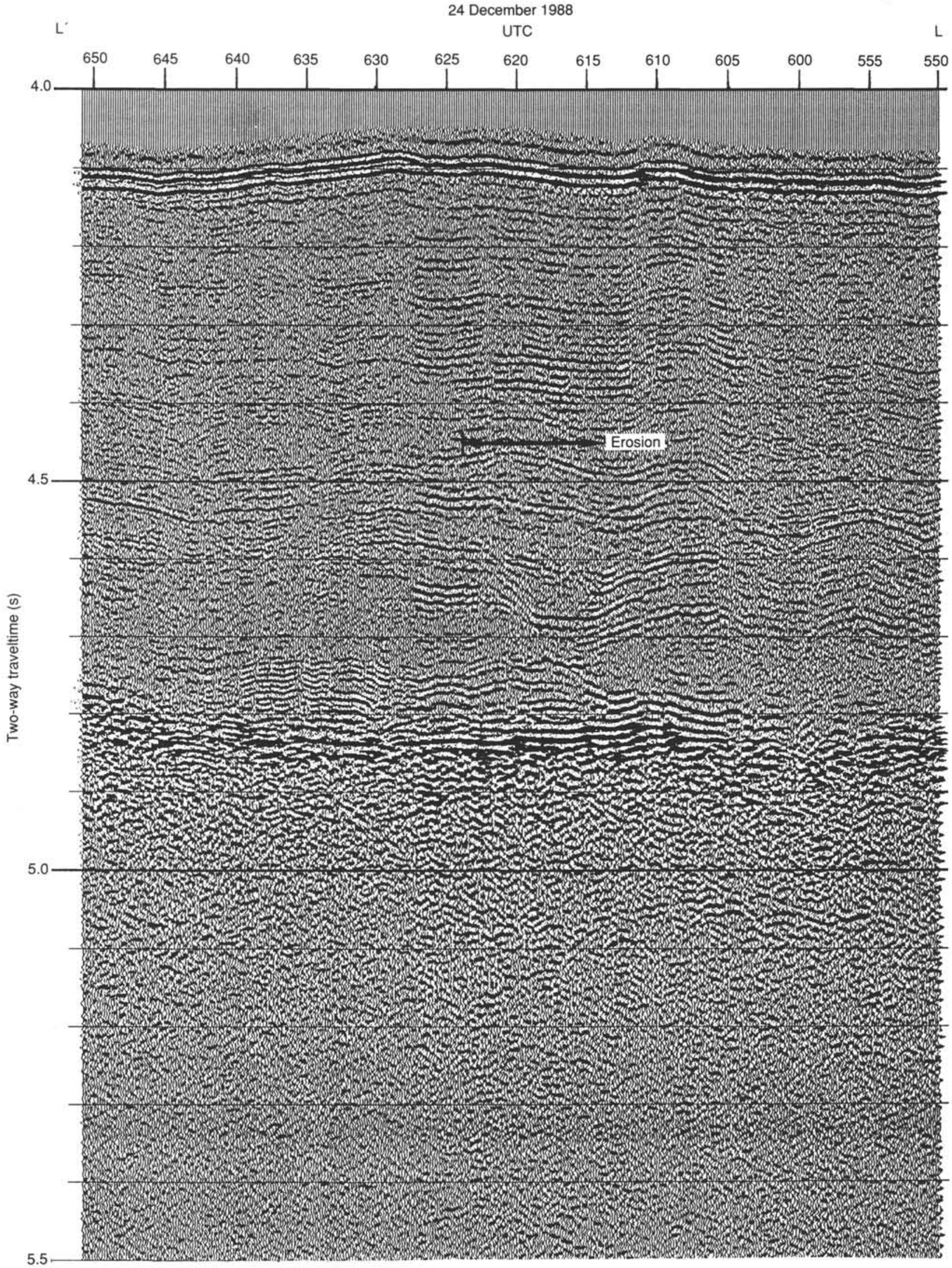

Figure 16. Single-channel seismic profile L-L′ in the Prancer survey area. A possible buried channel structure is visible near the center of the figure. See Figure 15 for location of line.

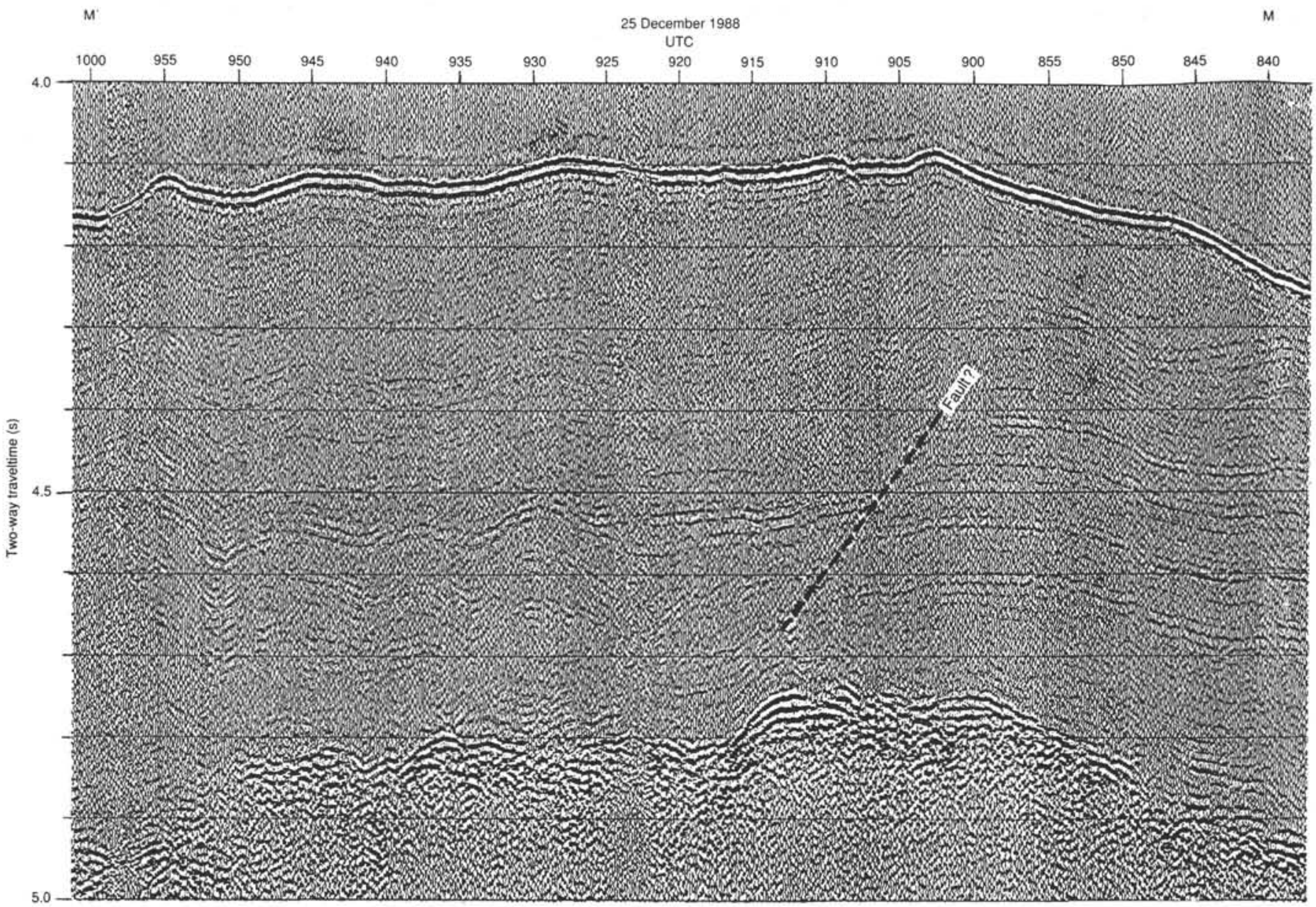

Figure 17. Single-channel seismic profile M-M′ in the Prancer survey area. See Figure 15 for location of line.

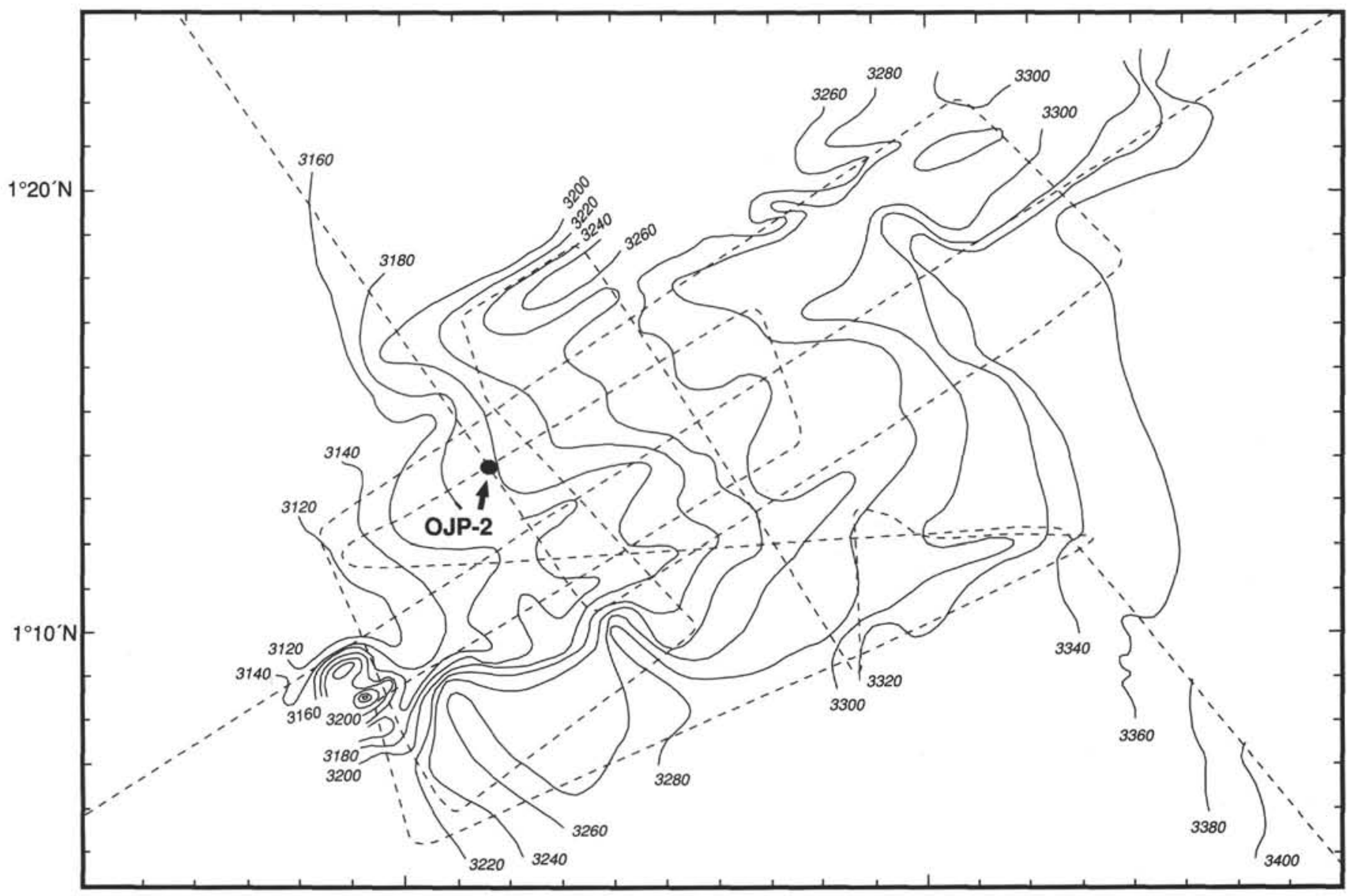

Figure 18. SeaBeam bathymetry of the Vixen survey area. Contour interval is 20 m. The location of proposed Site OJP-2 (Site 805) is shown.

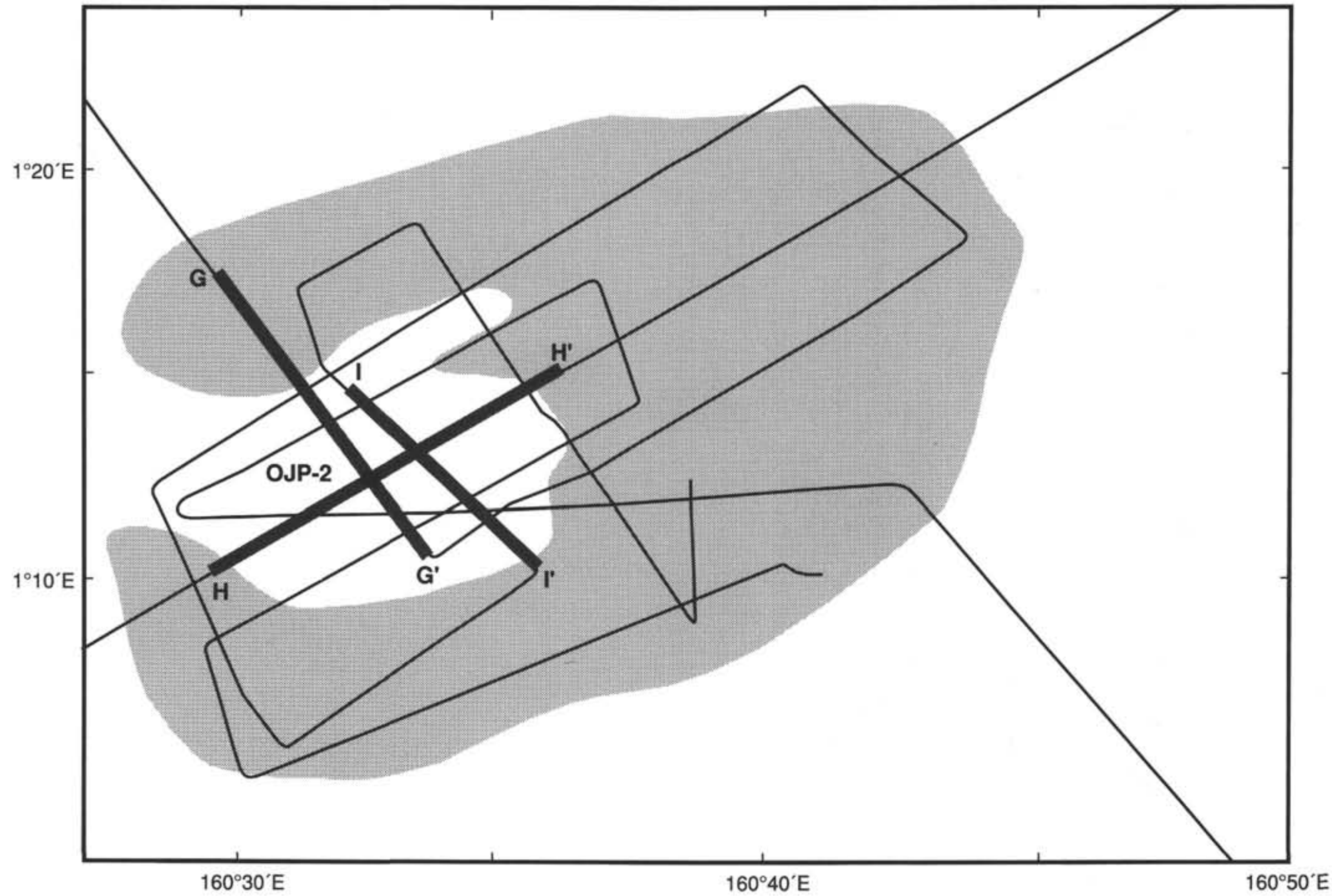

Figure 19. Drilling "avoidance" map of the Vixen survey area based on seismic profiles. Stippled areas were avoided for site selection.

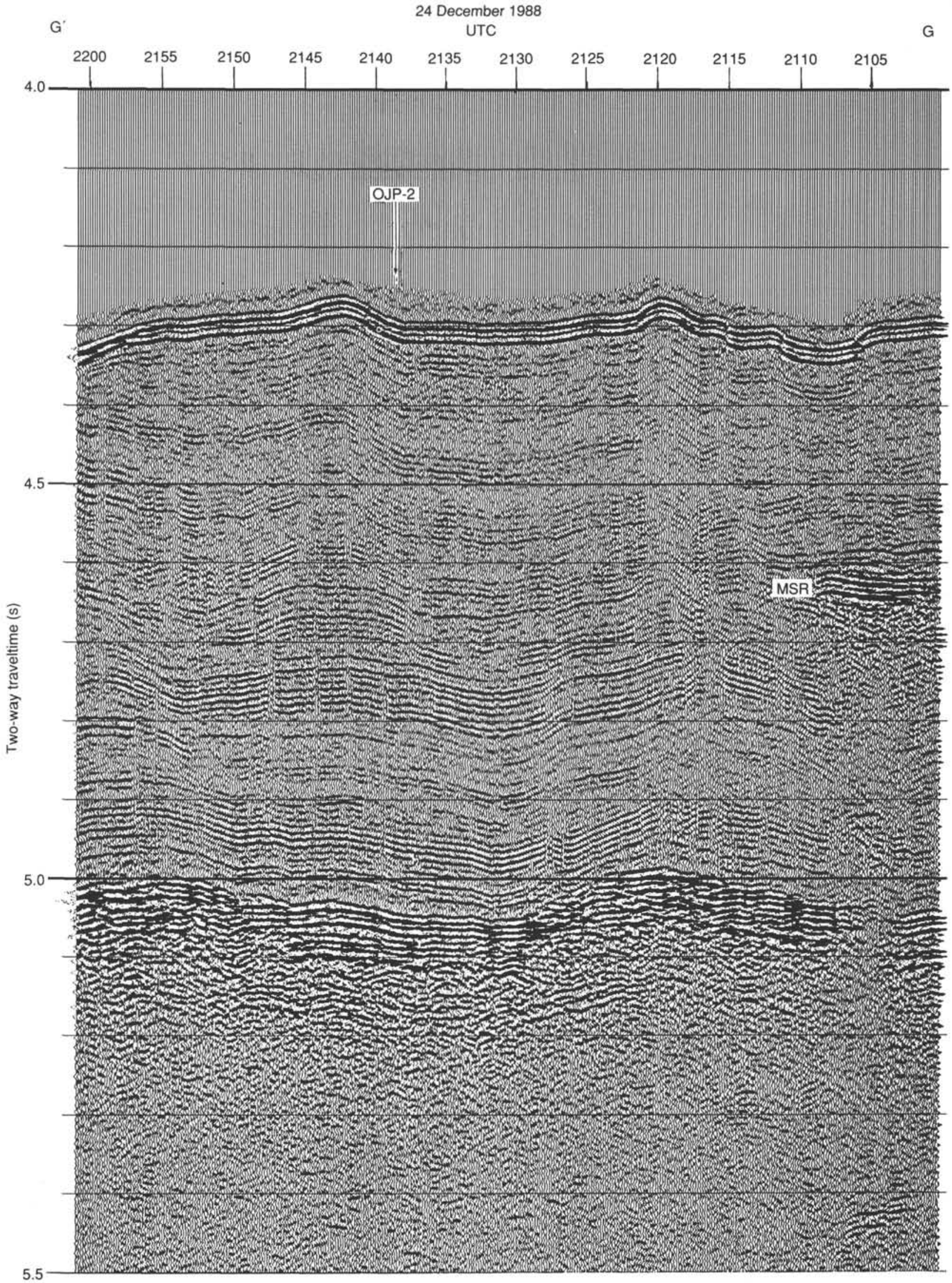

Figure 20. Single-channel seismic profile G-G′ in the Vixen survey area. An MSR is visible on the right side of the figure. See Figure 19 for location of line.

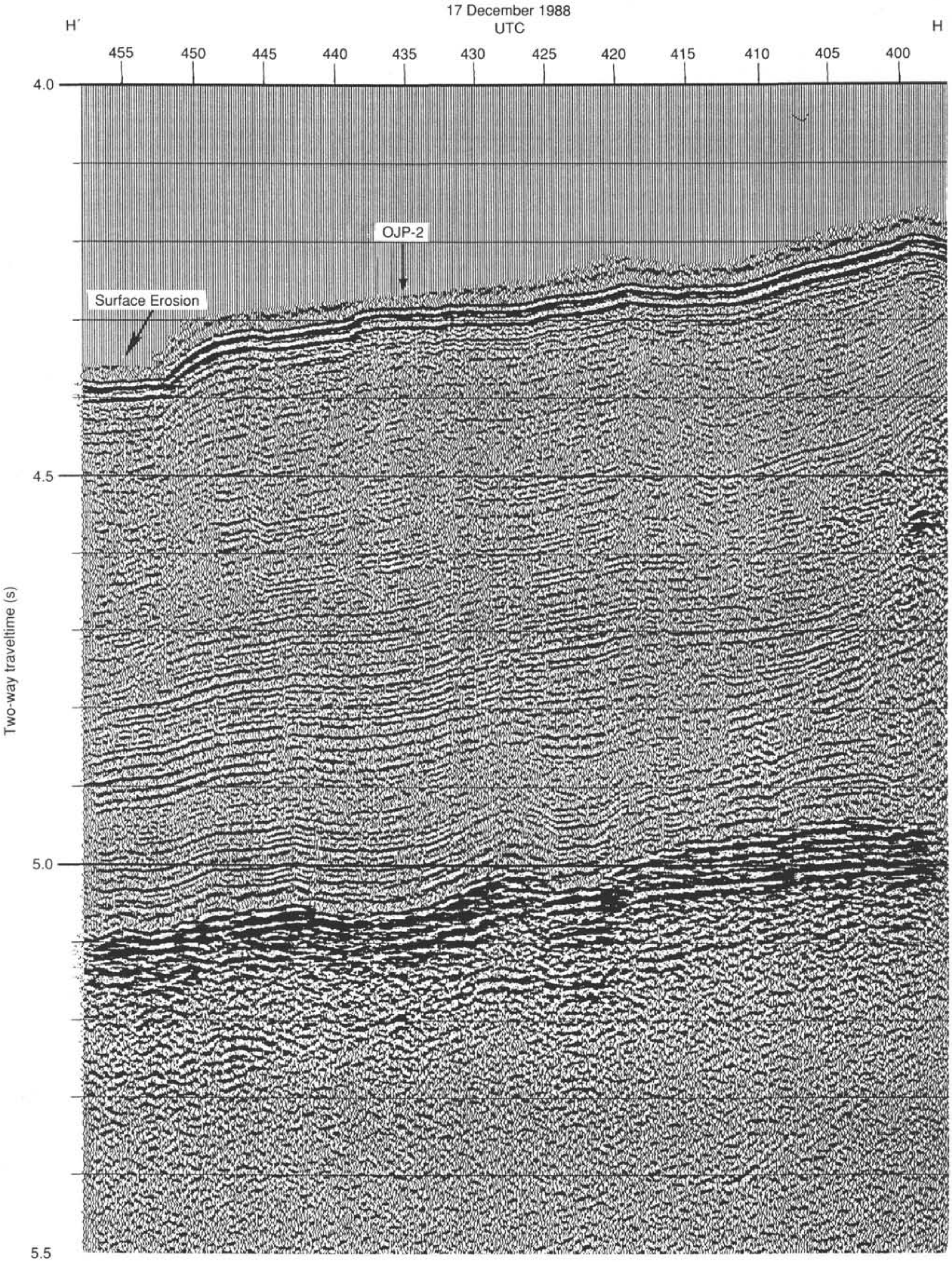

Figure 21. Single-channel seismic profile H-H′ in the Vixen survey area. The MSR on the right side of the figure is associated with surface erosional features. See Figure 19 for location of line.

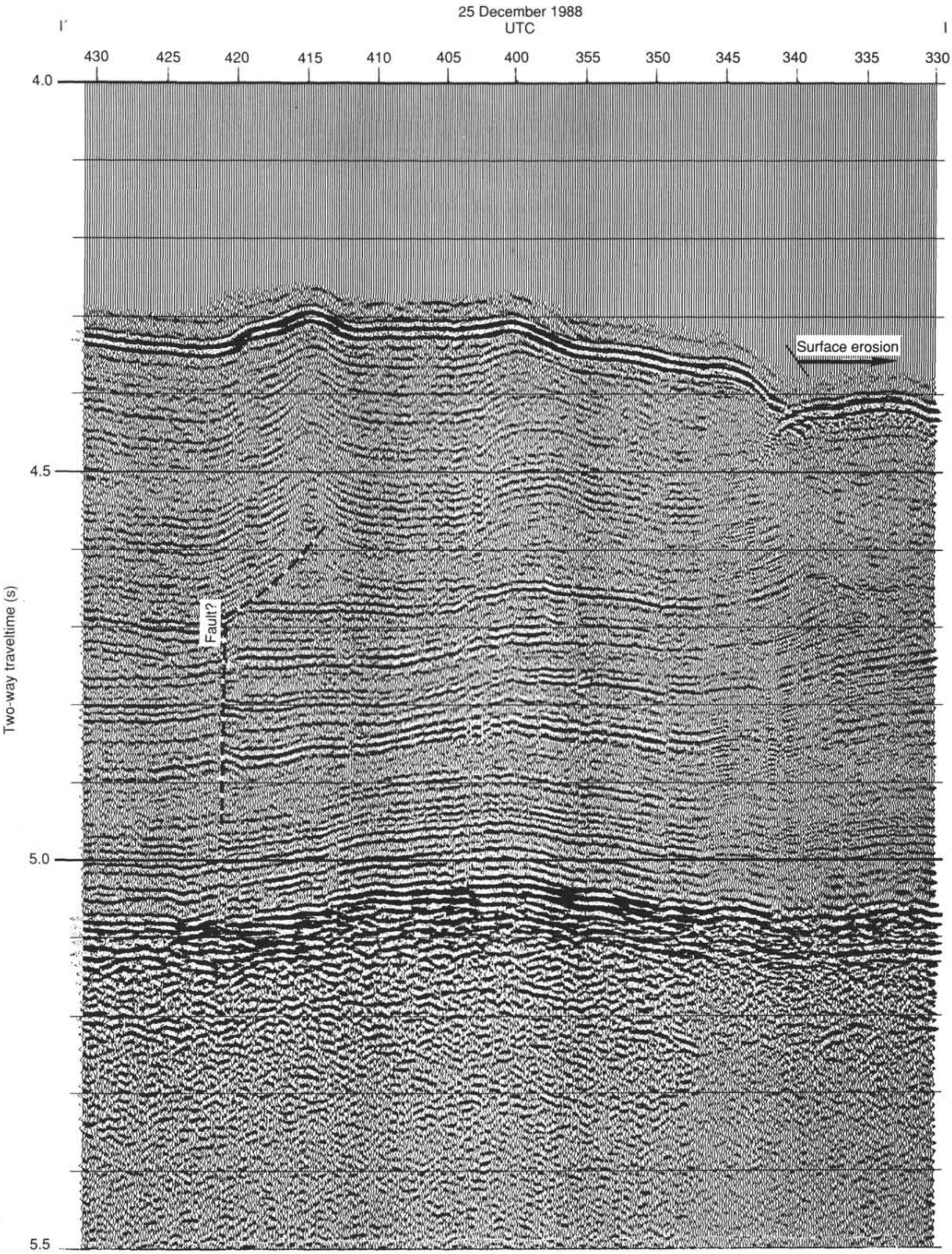

Figure 22. Single-channel seismic profile I-I′ in the Vixen survey area. See Figure 19 for location of line.

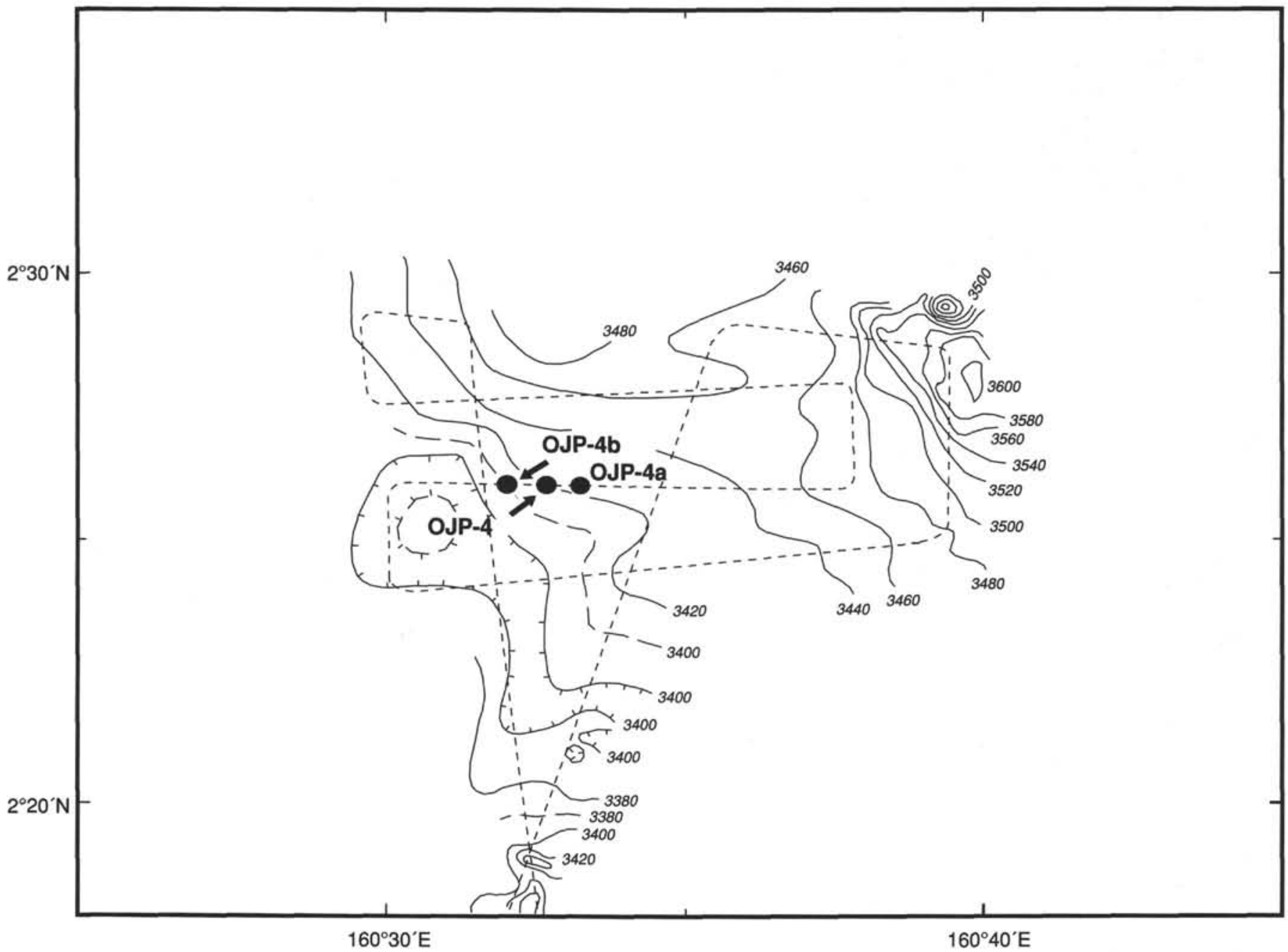

Figure 23. Sea Beam bathymetry in the Dancer survey area. Contour interval is 20 m. Proposed Sites OJP-4, 4a, and 4b are shown.

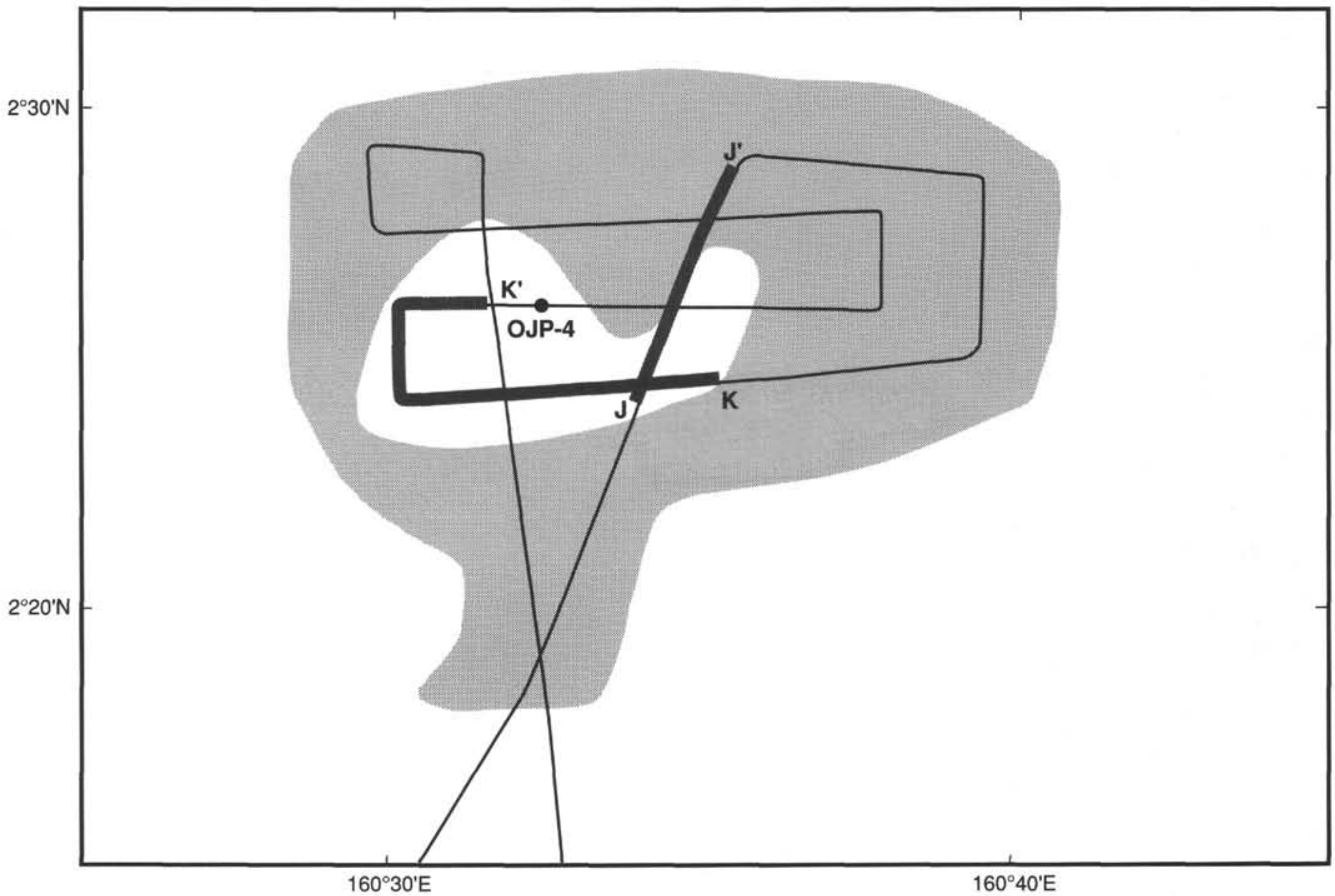

Figure 24. Drilling "avoidance" map of the Dancer survey area based on seismic profiles. Stippled areas were avoided for site selection.

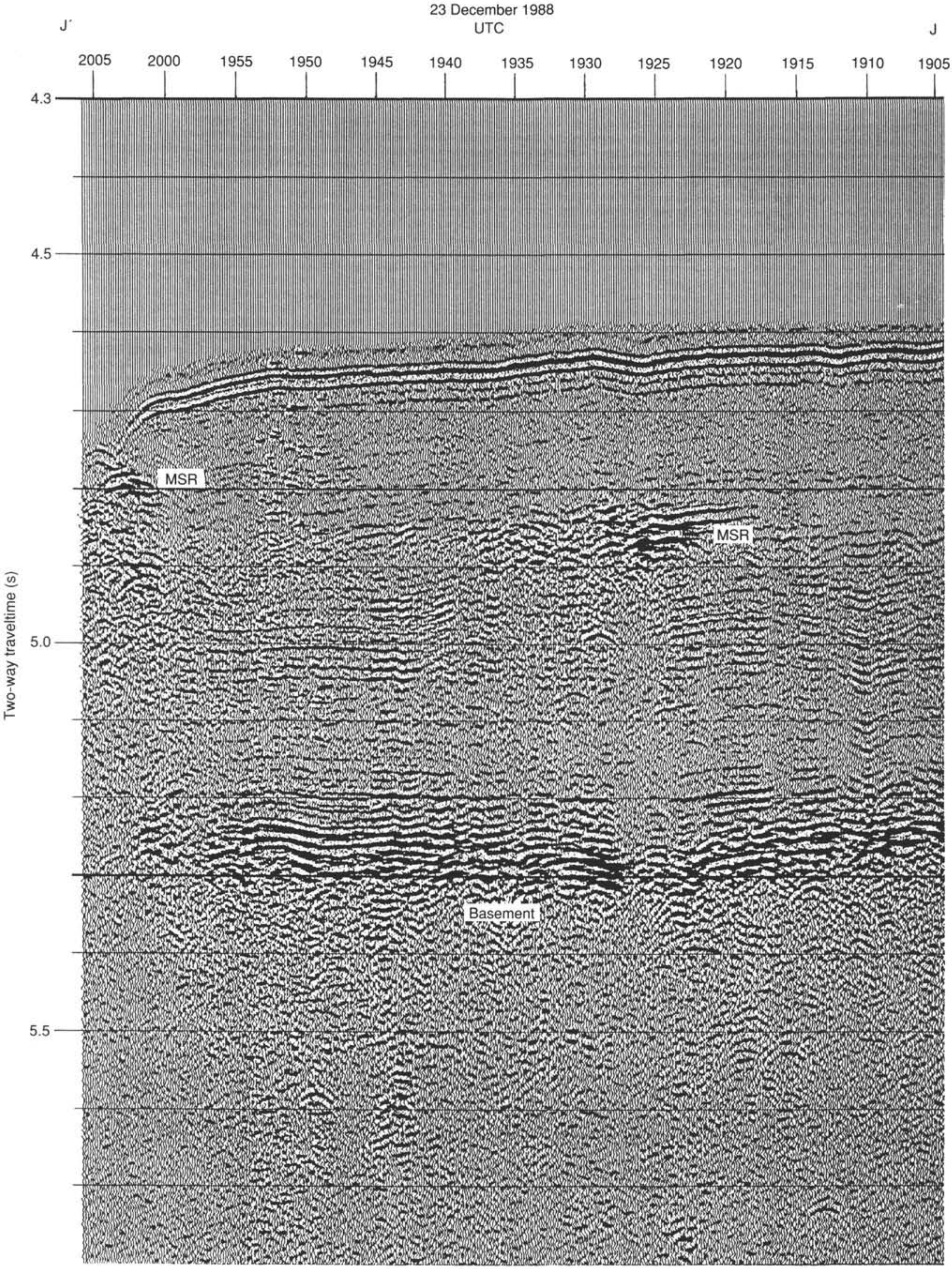

Figure 25. Single-channel seismic profile J-J′ in the Dancer survey area. MSRs are clearly visible on this profile, and the one on the left appears to outcrop at the surface. See Figure 24 for location of line.

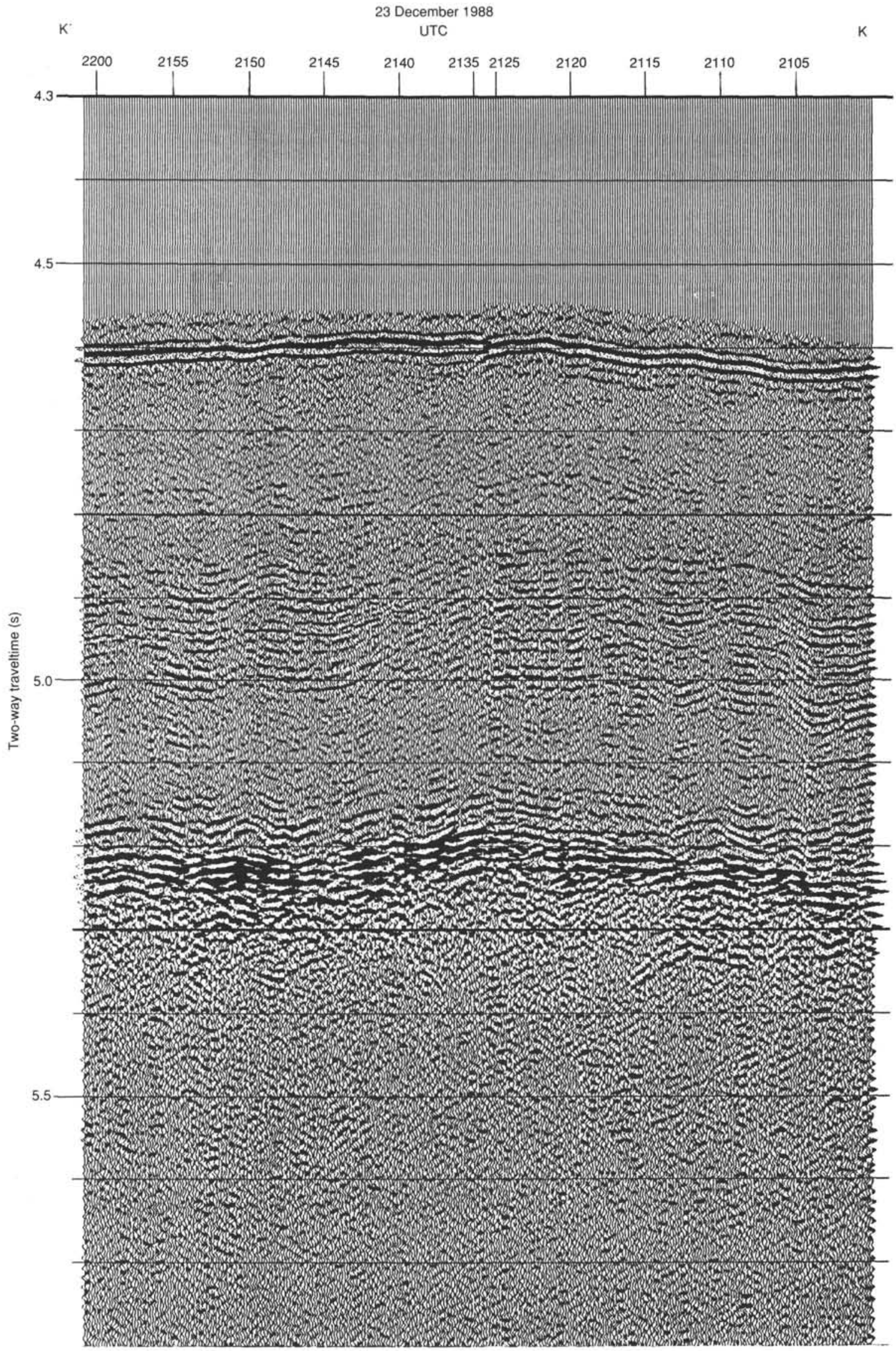

Figure 26. Single-channel seismic profile K-K′ in the Dancer survey area. See Figure 24 for location of line.

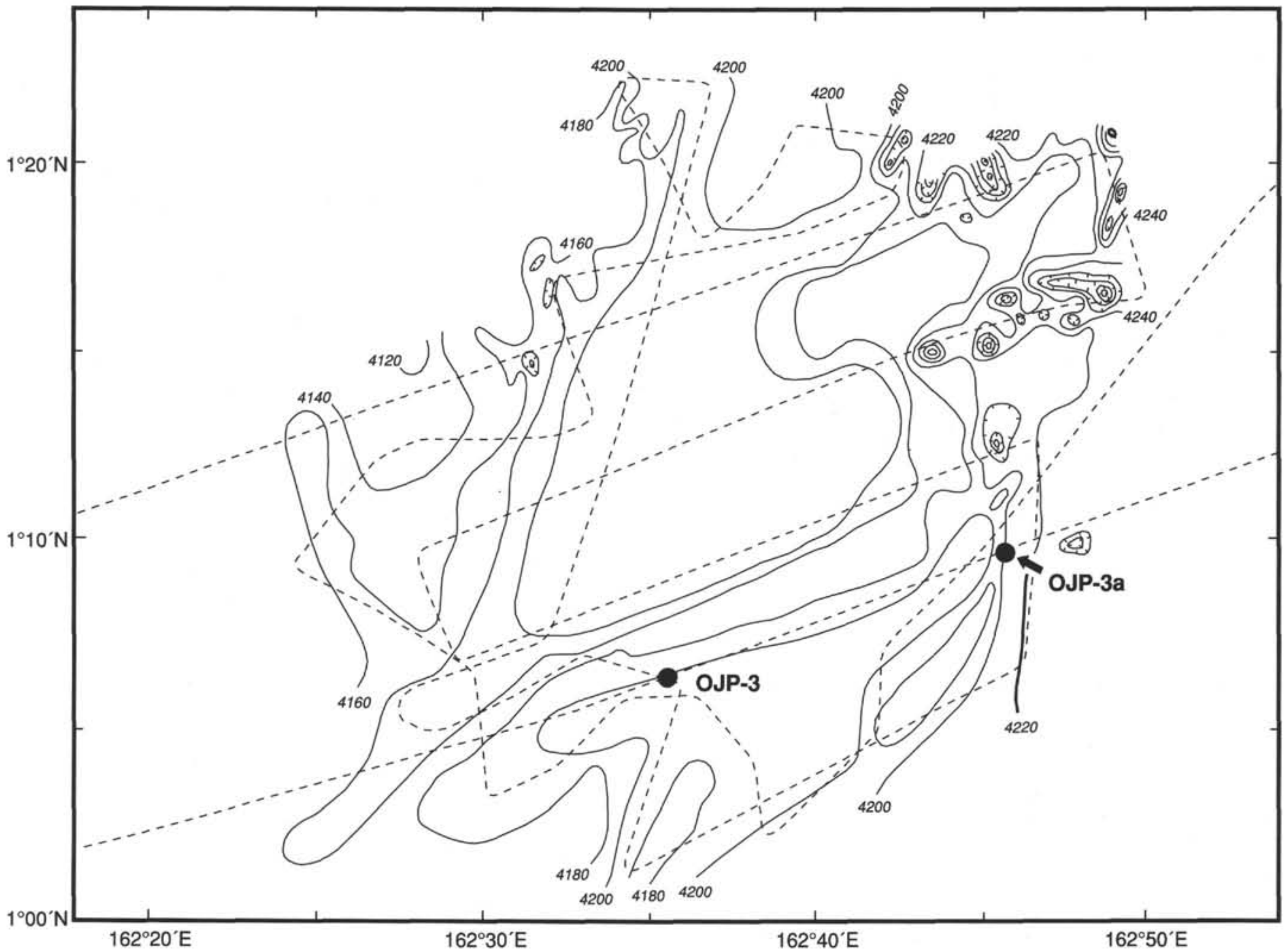

Figure 27. SeaBeam bathymetry in the Comet survey area. Contour interval is 20 m. Proposed Sites OJP-3 and 3a are shown.

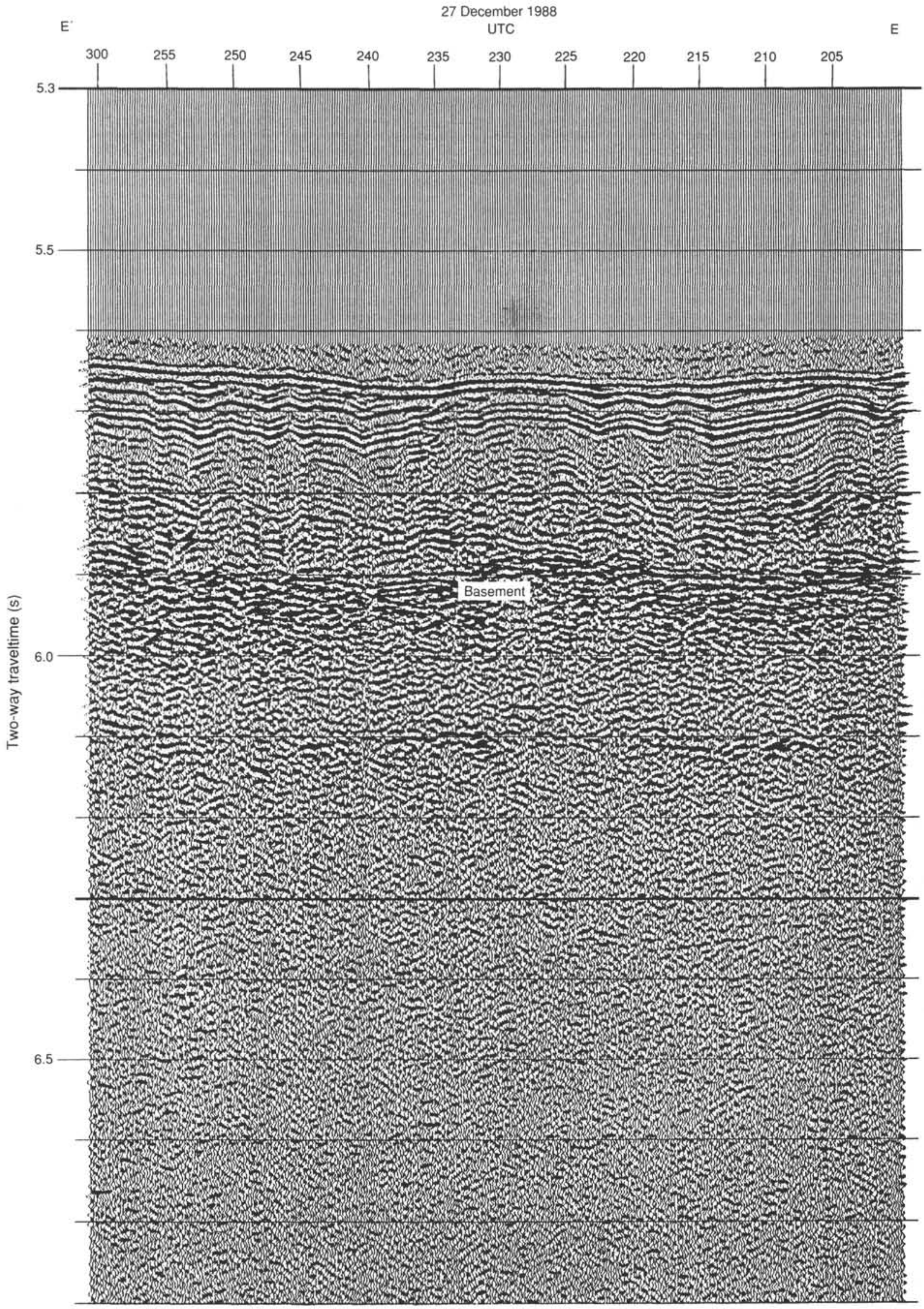

Figure 28. Single-channel seismic profile E-E′ in the Comet survey area. The uplift(?) of basement in this area has caused erosional truncation of surface layers and rough bathymetry. See Figure 29 for location of line.

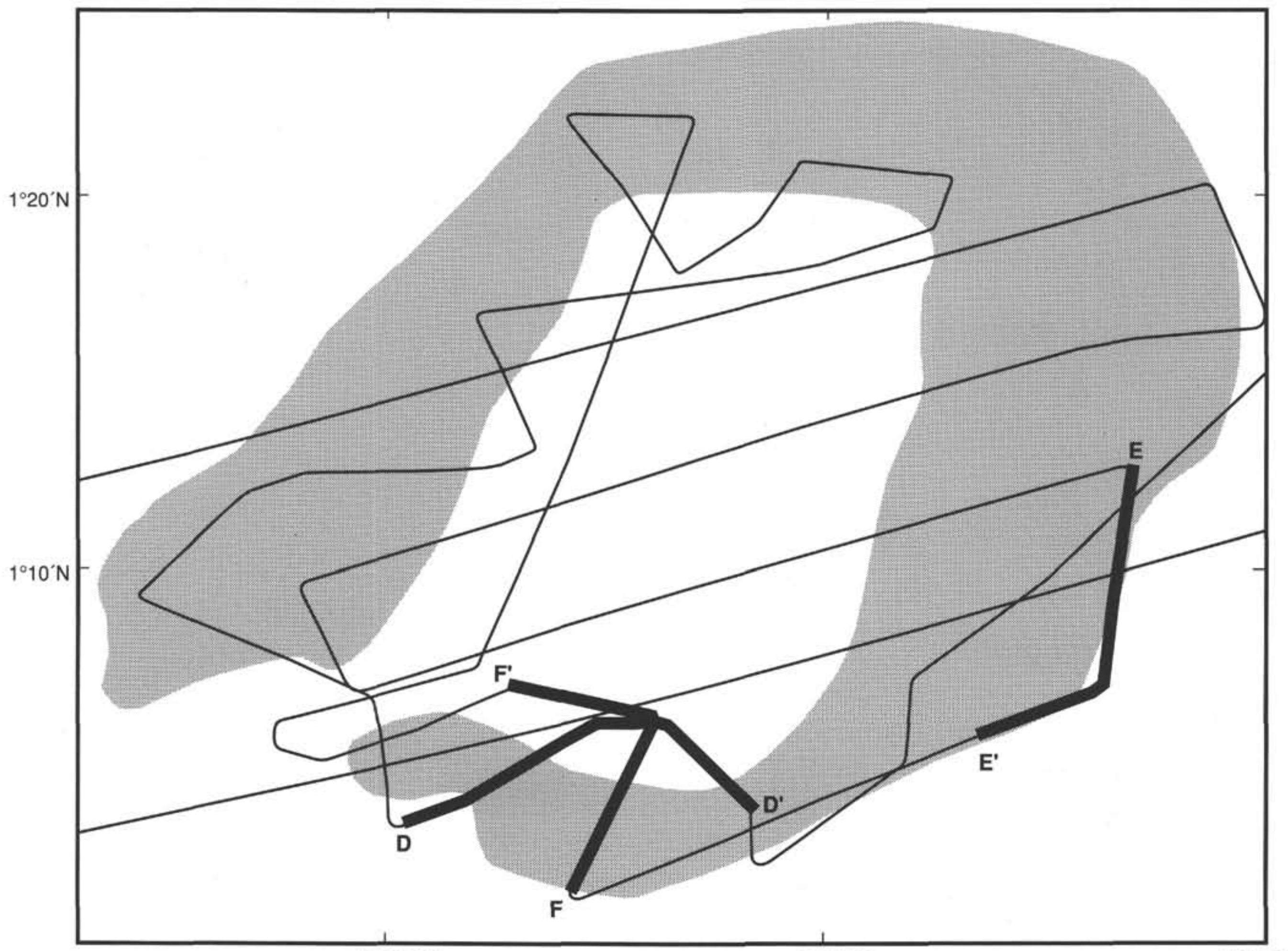

Figure 29. Drilling "avoidance" map of the Comet survey area based on seismic profiles. Stippled areas were avoided for site selection.

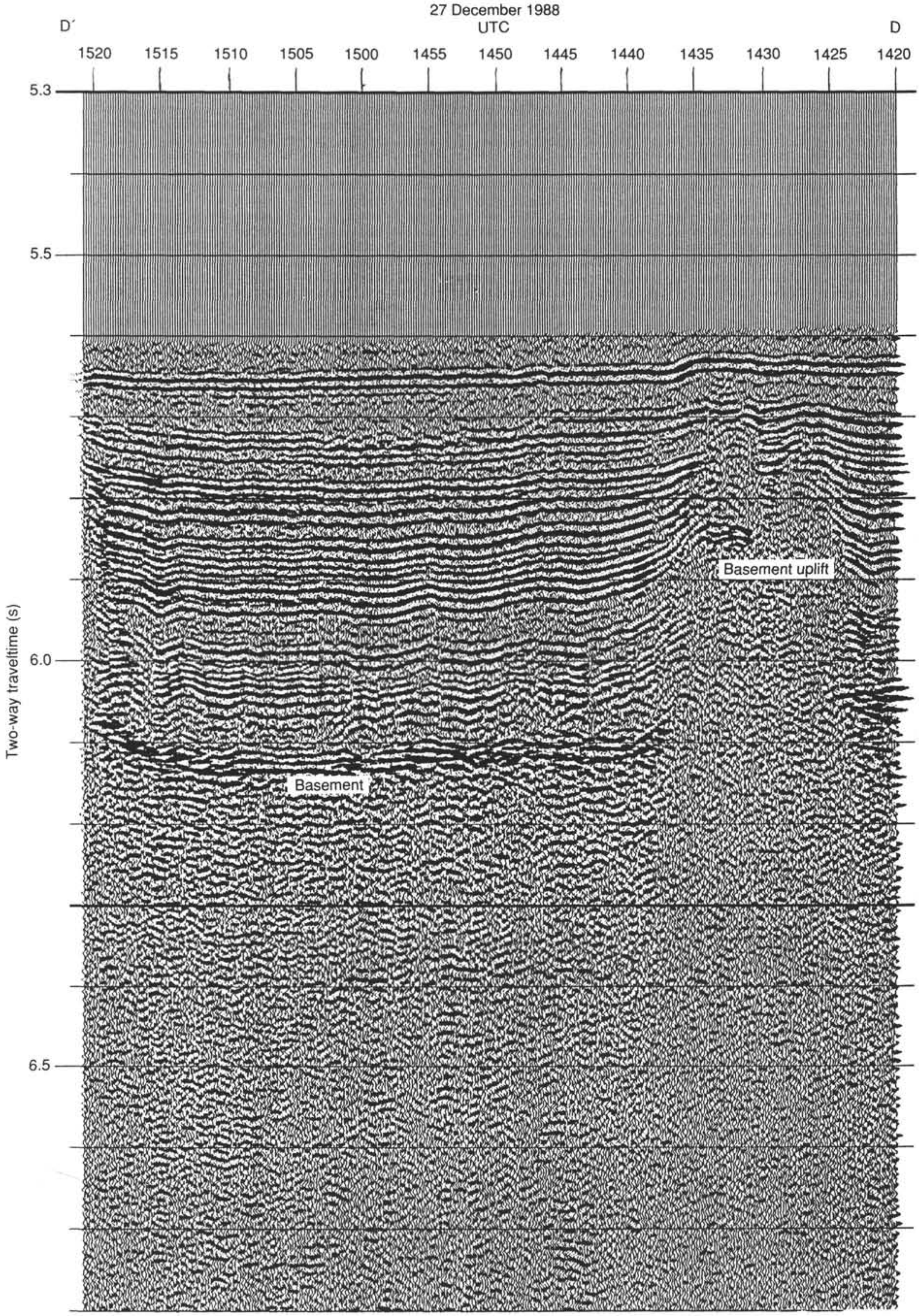

Figure 30. Single-channel seismic profile D-D′ in the Comet survey area. A thick sedimentary section occurs in a small graben structure. See Figure 29 for location of line.

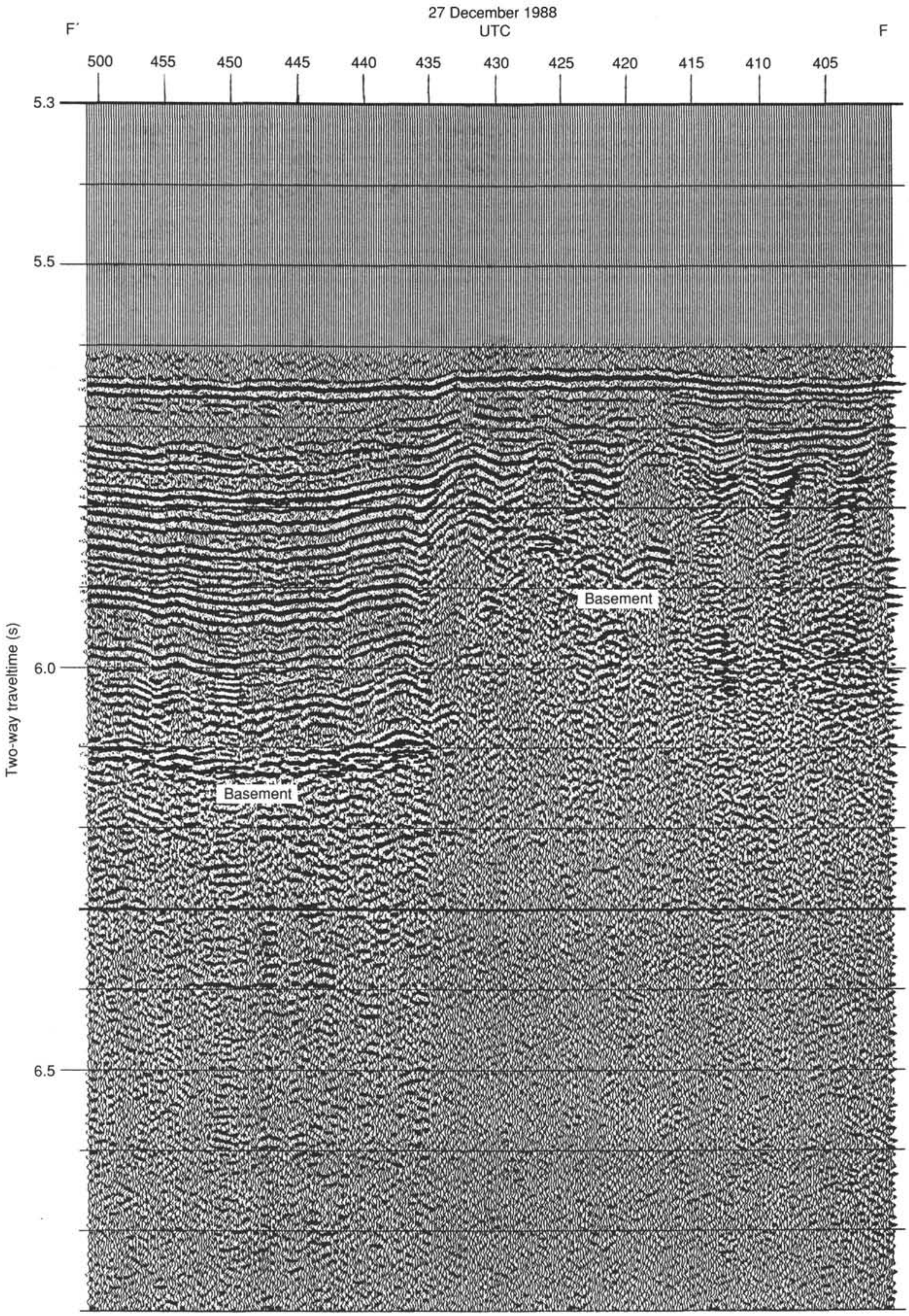

Figure 31. Single-channel seismic profile F-F′ in the Comet survey area. See Figure 29 for location of line.