8. SITE SURVEYS IN THE SOUTH PACIFIC WITH A SEABEAM SWATH-MAPPING SYSTEM[1]

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ABSTRACT

Four 500-km^2 areas along latitude 19°S were surveyed to help select drill sites for DSDP Leg 92. Three were areas of abyssal hills on the west flank of the East Pacific Rise. The fourth was on older crust that had accreted at the ancestral Pacific–Farallon spreading center. Principal survey tools were a Seabeam multi-narrow-beam echo sounder, which mapped highly lineated fault-block terrains with local volcanic relief, and seismic profilers, which allowed an estimate of sediment thickness. Magnetic profiles in and between the surveys established the crustal age at each site.

INTRODUCTION AND METHODS OF STUDY

Most of the drill sites for Leg 92 were targeted in a remote and relatively unexplored region between the Tuamotu Archipelago and the crest of the East Pacific Rise. The objective was to sample typical sections of crust that had accreted at fast-spreading rises during the past 30 m.y. and had not been overprinted by off-axis seamount volcanism. Site surveys were required to identify such areas and to establish their age and the thickness and continuity of sediment cover. These surveys also indicated the structural setting of the heat flow and pore water measurements used to define precise drilling targets.

The systems used on the survey vessel *Thomas Washington* were a newly installed Seabeam multi-beam echo sounder, a 3.5-kHz acoustic profiler, a single-channel seismic profiler using a 40-in^3 air gun as the sound source, and a proton-precession magnetometer. Navigation was by transit satellite, with the track interpolated between fixes by a sophisticated dead-reckoning program. For the survey areas this interpolation was improved by matching swaths of Seabeam contours where they overlap on adjacent or crossing tracks.

The Seabeam system (Renard and Allenou, 1979) provides a swath of 16 narrow-angle (2.7°) sonar beams which cover a cross-track distance equal to about two-thirds of the water depth. On this first cruise of the Scripps system we experienced some problems with data from the outer beams. In particular, the system frequently tracked and displayed the sidelobe response of the central beam instead of the signal from the outer beams. The result was a well developed "tunnel effect" (Moustier and Kleinrock, in press), in which flat, smooth seafloor is represented as a trough with the ship's track along its axis. This failure of the system's sidelobe rejection scheme, which depends on the correct setting of echo-processing thresholds, was caused mainly by operator inexperience; artifacts are most marked on our first two surveys (Sites I and II), where considerable post-cruise processing and the elimination of spurious data were required to produce the final charts. As we learned more about the operational characteristics of the system and moved into rougher terrain, this problem was overcome, and the raw data from Sites III and IV are much cleaner. The seismic records also contain numerous instrumental artifacts from bubble-pulses and multiple echoes, but these are more familiar and easily recognized.

Our survey strategy was to run an east–west survey line from the Tuamotus to the crest of the East Pacific Rise, monitoring the crustal age along this transect by identifying measured magnetic anomalies with the reversal time scale and anomaly nomenclature of Ness et al. (1980). As our track crossed crust of the age desired for drilling (30, 10, 5, and 2 Ma), our contour swath and profiles were scanned for a suitable site; when we found one, a survey pattern was run to cover a 500-km^2 area straddling the west–east transect. At the end of this survey, acoustic transponders were deployed to serve as navigational benchmarks for the subsequent drilling. We completed four surveys, on crust aged 27.6, 8.0, 4.7, and 2.0 Ma; only the three oldest sites were eventually drilled on Leg 92.

REGIONAL SETTING AND TECTONIC HISTORY

At the latitude of our surveys the age of the East Pacific Rise is less than 20 Ma. Older crust accreted at a segment of the Pacific–Farallon plate boundary called the Mendoza Rise (Mammerickx et al., 1980). The breaking of the Farallon Plate was followed by (1) the reorientation of the spreading center so that it was orthogonal to a new direction of relative plate motion, and (2) a westward jump of the spreading center that abandoned the Mendoza Rise as a fossil on the new Nazca Plate. On our Seabeam transect (Fig. 1), the boundary between these spreading regimes, referred to as the "J-line" by Okal and Bergeal (1983), is at 129°W, where it is readily identified by a change in abyssal-hill orientation and by a topographic step which is caused by the absence, at this latitude on this west flank, of crust aged between about 27 and 19 Ma. This location is more than 500 km west of the location predicted by Okal and Bergeal's (1983) model for the tectonic evolution of the region.

The other major tectonic event recorded by our transect is the growth of a major seamount chain, with an

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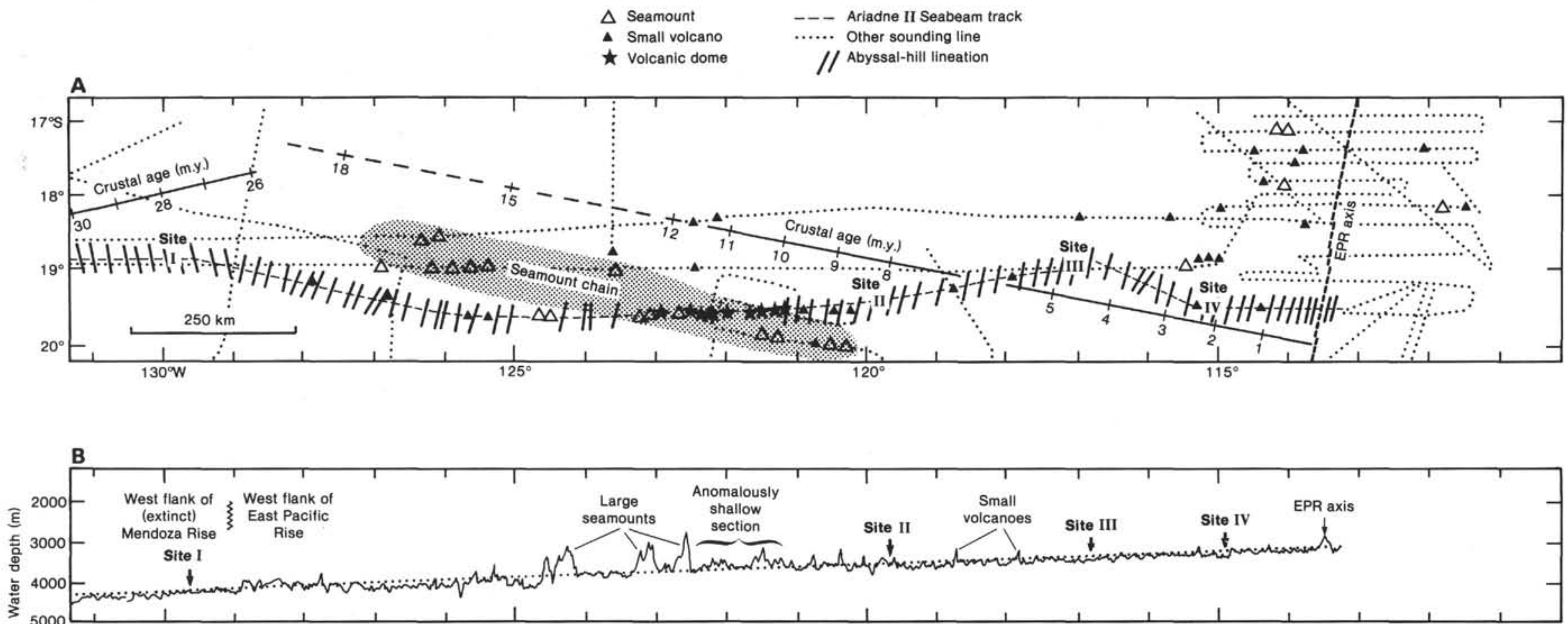


Figure 1. A. Location of survey sites and intervening track, Ariadne Leg II. Crustal ages are inferred from the magnetic anomalies in Figure 2. B. West–east projection profile along the center beam of the Seabeam swath. Dotted line shows subsidence curve in meters, z, calculated by $z = 3000 + 230\sqrt{T}$, where T is estimated crustal age in millions of years. Vertical exaggeration is $\times 60$.

orientation appropriate for a hot spot chain, across the older part of the East Pacific Rise flank. Our oblique crossing of this chain between 124.5° and 121°W (Fig. 1) included several 1-km-high seamounts and numerous low, circular domes that may result from laccolith intrusions (Lonsdale, 1983). No lineated abyssal hills were mapped in this region, presumably because the plate fabric has been buried by subsequent volcanism. A few of the domes have small parasitic cones with very fresh, apparently unsedimented, craters (Lonsdale, 1983, fig. 3), features that indicate that the part of the chain we crossed, which seems to be near its southeast end, may be quite young. Because of the likelihood that the thermal regime and hydrothermal circulation have been perturbed by off-axis volcanism, this area was considered unsuitable for Leg 92 drilling, and no site surveys were conducted.

West-flank spreading rates, derived from an interpretation of magnetic anomalies along our transect and adjacent tracks (Fig. 2), are estimated at 70 mm/yr. for the 33- to 27-Ma crust accreted at the Mendoza Rise, and 77 mm/yr. for 12- to 1-Ma crust accreted at the East Pacific Rise. Unambiguous indentification of anomalies on the older half of the East Pacific Rise is not possible, probably in part because of the effects of off-axis volcanism, but extrapolation of the 77-mm/yr. rate gives an age for the "J-line" of about 19 Ma, the same as the age estimated from other data by Mammerickx et al. (1980). Except for the area overprinted by the seamount chain, the west flank of the East Pacific Rise has subsided very regularly as its lithosphere cooled; the topographic profile is fitted well by a single $\sqrt{T}$ curve (Fig. 1), where T is estimated crustal age in millions of years.

SITE SURVEYS

Site I (DSDP Site 597)

This site survey (Fig. 3A) straddles the young margin of Anomaly 9 (Fig. 2); that is, crustal age is 27.6 Ma (time scale of Ness et al., 1980). In terms of topography, the area is a slightly rolling plain with a 50-m abyssal-hill relief lineated with a strike of 355°. In the southern part of the area there are a few small (100-m) volcanic peaks (e.g., those on line G–H in Fig. 3B).

There is a rather uniform blanket of unconsolidated sediments, with an average thickness of about 0.07 s (estimated to represent 50 to 60 m). Acoustic basement is very strong and unusually smooth. Steep volcanic peaks rise above this smooth reflector (e.g., those near B and C, Fig. 3B). Outcrops exposing igneous rock at the seafloor probably occur near G. Immediately west of the survey, near A in Figure 3B, the sediment cover thins rapidly and disappears; presumably it has been removed by erosion. Since the presence of a fairly uniform blanket was a requirement for the drill site, a slightly younger area was chosen in preference to the 30-Ma site originally targeted.

Site II (DSDP Site 599)

This survey site lies on the young half of Anomaly 4.1′ (Fig. 2) and is therefore estimated to be 8 Ma in age. This crust is younger than that originally targeted (10 Ma); it was chosen as a survey site to avoid the seamount chain that occupies 10-Ma crust at this latitude. The site has a typical abyssal-hill topography (Fig. 4A), with lineated fault-block hills striking 010°, on which small volcanic hills have been superimposed. The hills have been smoothed by sedimentation. Normal abyssal-hill relief in this region is up to 200 m (see line A–B, Fig. 4B), but in the central part of the survey, between the ends of overlapping fault blocks, there is a 20-km^2 smooth patch with less than 25 m of relief.

The steep sides of many of the fault blocks seem, on the 3.5-kHz and air gun profiles (Fig. 4B), to expose basement rocks. The central flat patch has a fairly uniform blanket of unconsolidated sediment cover about 0.05 s (35 to 40 m) in thickness. Sediment estimated to be as much as 50 m thick occurs in the floors of some abyssal-hill troughs (e.g., those near A and D, Fig. 4B).

Site III (DSDP Sites 600 to 602)

This site is situated on Anomaly 3.4 (Fig. 2), which has an estimated age of 4.8 to 4.6 Ma. It includes a region of unusually smooth relief within a typical lineated abyssal-hill terrain, best mapped in the southern and western parts of Figure 5A, which strikes 015°. The flatter area is divided by an 80- to 150-m scarp, also striking 015°, into a 6-km-wide basin and a 6-km-wide plateau. The transponders were deployed on this plateau. The lineated hills east of the transponder array are somewhat unusual in that they are narrow and sharp-crested and look more like constructional volcanic ridges than the abyssal-hill horsts characteristic of the region.

A substantial sediment cover, estimated at 20 to 30 m from both the 3.5-kHz and seismic reflection profiles (e.g., Fig. 5B), occurs only on the plateau. It is rather surprising, but the adjacent basin has less sediment, a maximum of only about 10 m being inferred from 3.5-kHz records. Basement no doubt crops out over extensive areas of the sides of abyssal hills, especially on the steep ridges east of the transponders. It probably also crops out along the step between the basin and the plateau.

Site IV (not drilled)

This youngest survey site occupies the older margin of Anomaly 2, which is dated 2.1 to 1.9 Ma. It has typical young lineated abyssal-hill terrain with about 250 m of fault-block relief (Fig. 6), except that near 19°30′S, 114°58′W, where most of the heat flow and gravity-coring stations were made, there is considerable nonlineated volcanic relief. At the east side of the survey there is an anomalously shallow ridge rising above 3000 m; the ridge was probably also built by volcanic construction.

The 3.5-kHz records indicate that there are abundant rock outcrops, with significant patches of sediment occurring only as shallow ponds in the troughs. The thickest ponds tend to be near the greatest relief: in the vicinity of the heat flow and coring survey, maximum thickness is 10 to 15 m, but farther west, beside the shallow ridge, there is a pond with 20 to 30 m of sediment.

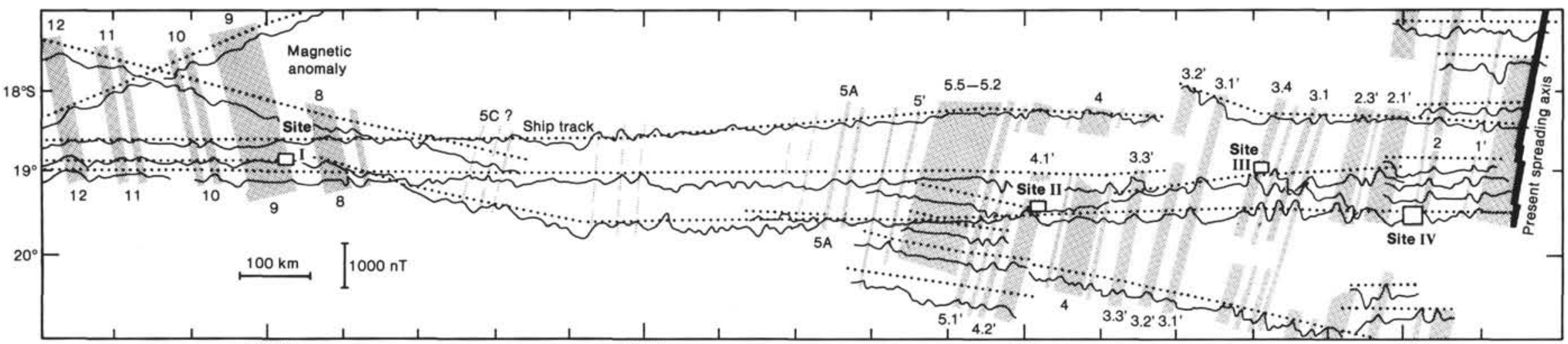


Figure 2. Magnetic anomalies along the Ariadne II and adjacent tracks, with an interpretation in terms of the magnetic reversal time scale (shaded strips are positively magnetized crust).

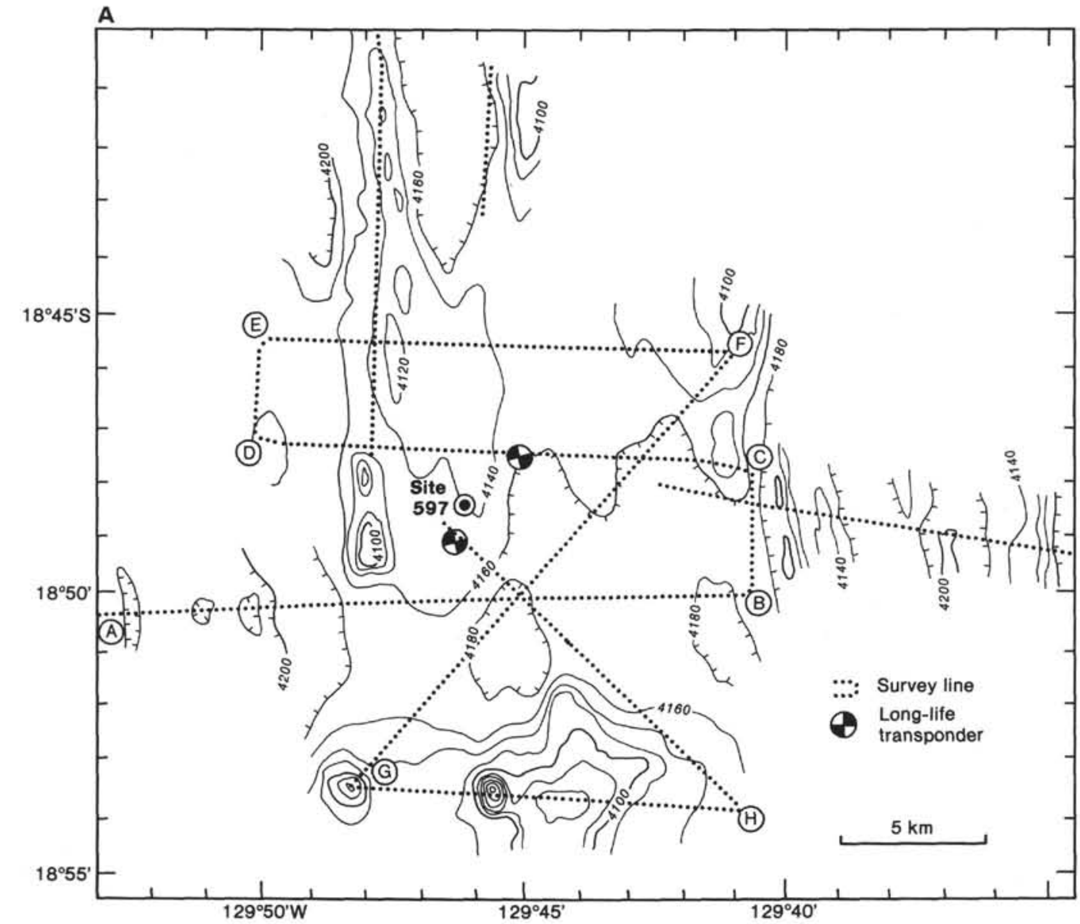
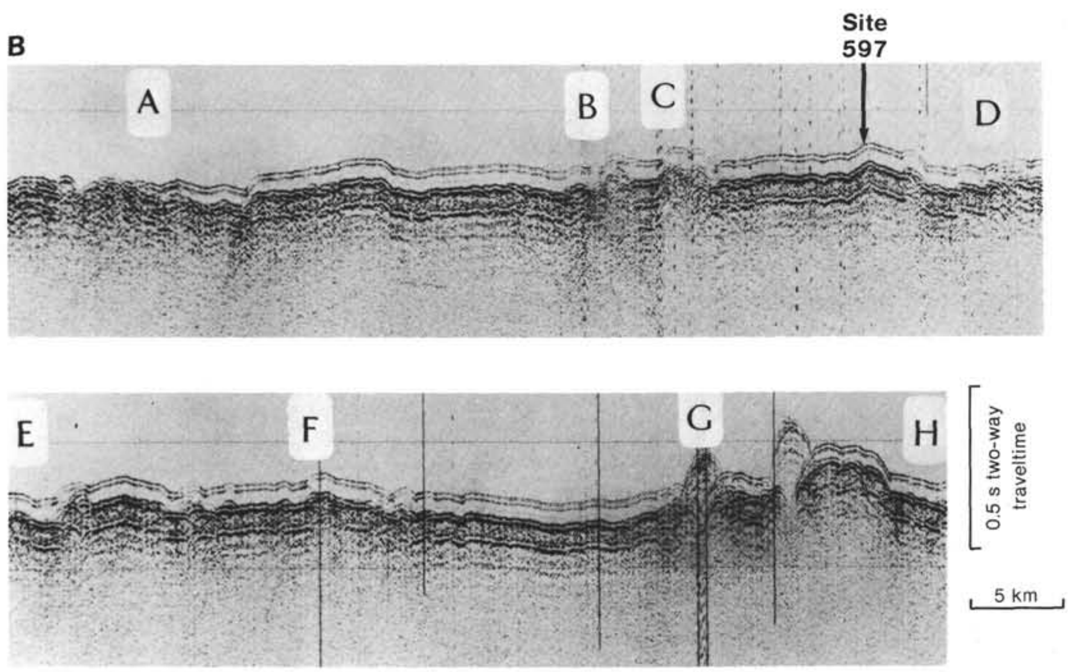


Figure 3. A. Bathymetry of Site I, from Seabeam site survey data. Contour interval is 20 m. Lettering shows location of profiles in (B). B. Seismic reflection profiles, from a single-channel 40-in.^{3} air gun system, at Site I.



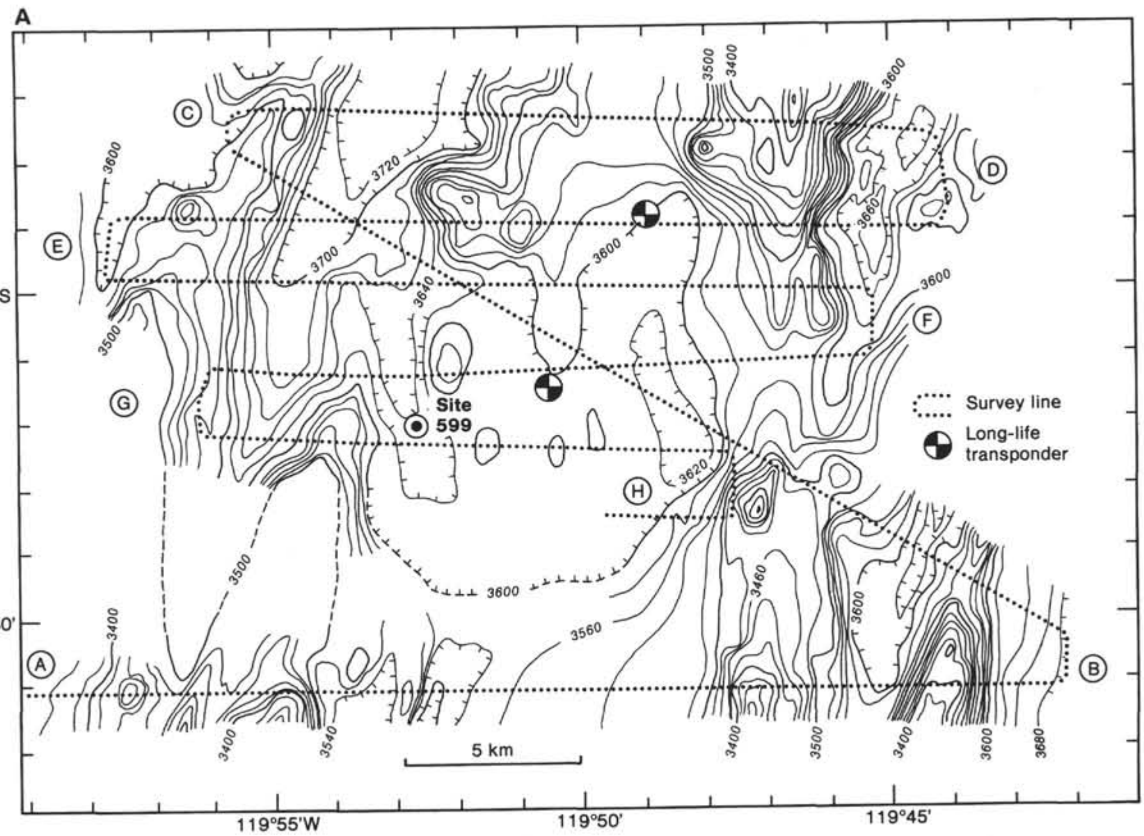


Figure 4. A. Bathymetry of Site II, from Seabeam site survey data. Contour interval is 20 m. Lettering shows location of profiles in (B). B. Seismic reflection profiles, from a single-channel 40-in.^{3} air gun system, at Site II.

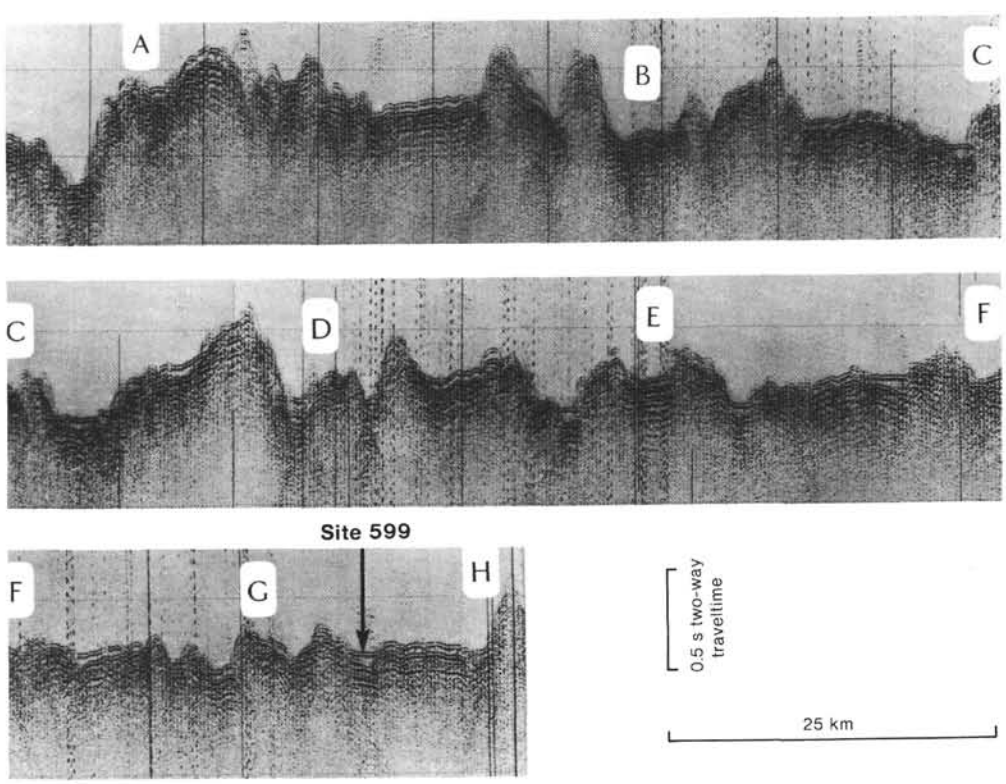


Figure 4 (continued).

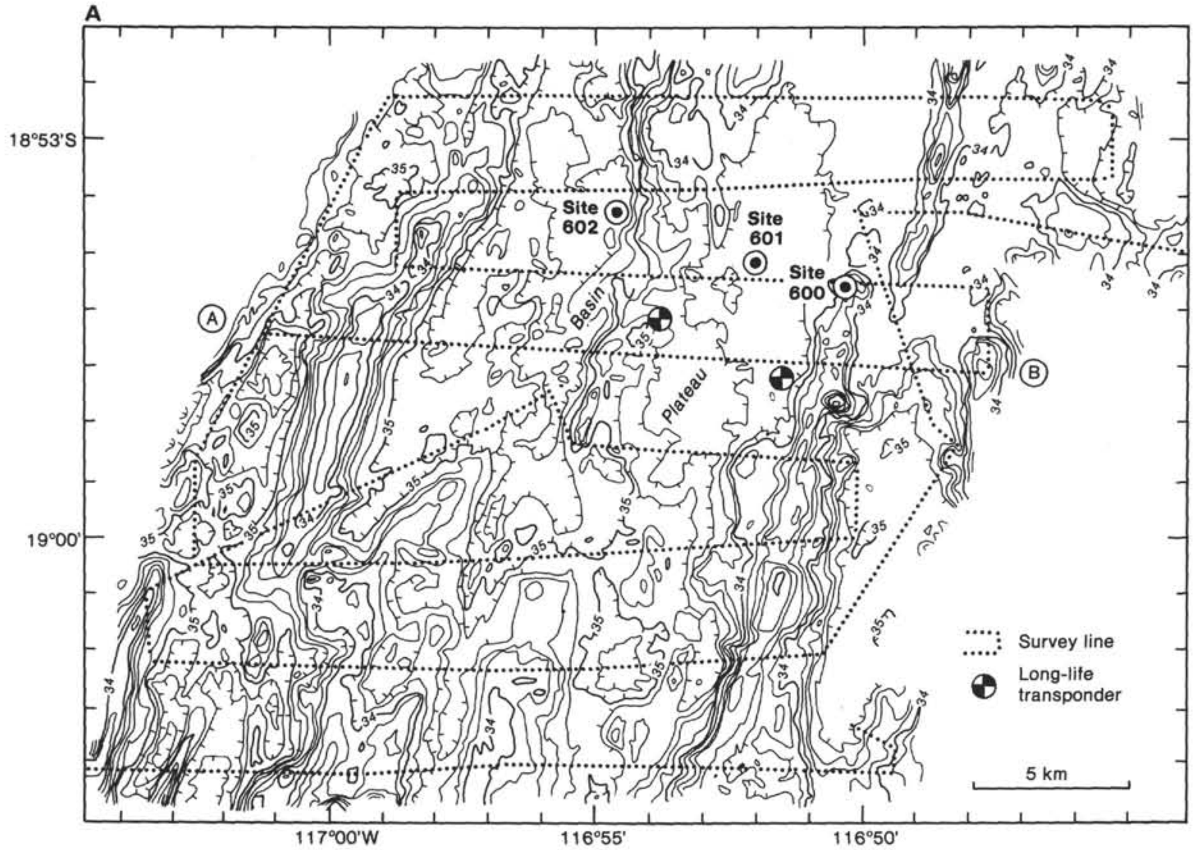


Figure 5. A. Bathymetry (in hundreds of meters) of Site III, from Seabeam site survey data. Contour interval is 20 m. Lettering shows location of profile in (B). B. Seismic reflection profile across the center of Site III.

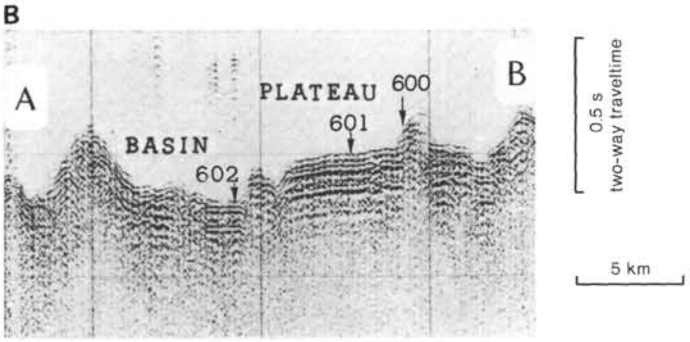


Figure 5 (continued).

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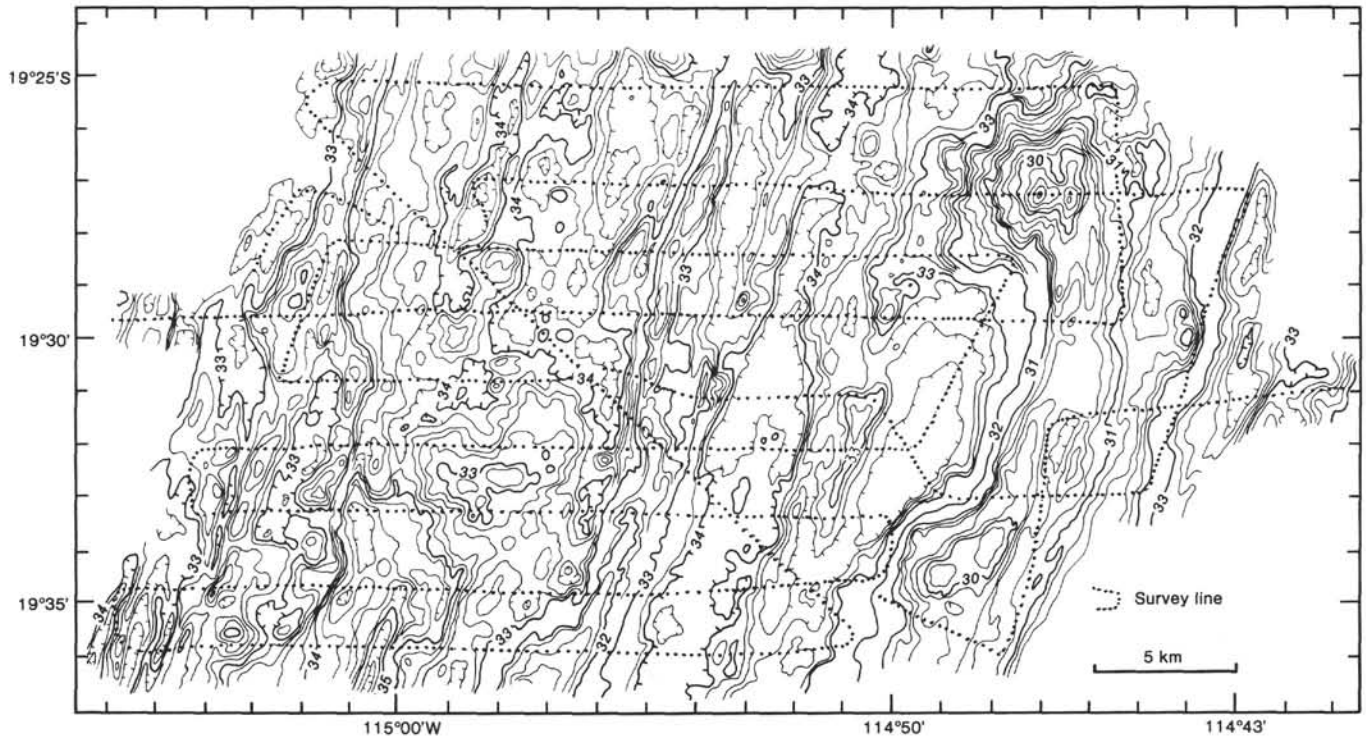

Figure 6. Bathymetry (in hundreds of meters) of Site IV, from Seabeam site survey data. Contour interval is 20 m.