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2. BASEMENT STRUCTURE OF THE NORTHERN ONTONG JAVA PLATEAU[1]

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ABSTRACT

Site surveys conducted in conjunction with Leg 130 on the Ontong Java Plateau reveal a strong seismic reflector at 0.8 to 1.0 s below the seafloor that drilling at Sites 803 and 807 confirmed is Cretaceous basalt. This reflector is generally smooth, except for the northeastern margin of the plateau, where it forms a series of small, irregularly shaped depressions. Correlatable reflectors present at the bottom of the depressions are also present on the adjacent highs, suggesting that these depressions are original volcanic topography.

A strong sub-basalt reflector occurs on many seismic profiles on the northeastern portion of the plateau. This reflection may be caused by a density and velocity contrast between pillow lavas and flood basalt flows or it may result from interbedded sediment and thus may represent significant lulls in volcanic activity. The presence of sub-basalt reflectors near Site 803 may indicate that later volcanic episodes occurred there, in contrast to Site 807, where this reflector was not observed and where older basalt ages were obtained.

INTRODUCTION

Detailed drill site selection surveys conducted before and during Ocean Drilling Program (ODP) Leg 130 provide new data on the structure of the northern and northeastern portions of the Ontong Java Plateau. These areas are of interest because they should preserve a record of processes and structures that occurred early in the history of the plateau. They are also relatively unaffected by volcanism and deformation associated with the collision of the plateau and the North Solomon subduction zone in late Oligocene time and the subsequent overthrusting of the arc by plateau crust in the late Miocene–early Pliocene (Kroenke, 1972, 1984; Kroenke et al., 1986).

Digital single-channel seismic data and SeaBeam bathymetry were collected during the December 1988 site-survey cruise of the *Thomas Washington* (Roundabout Cruise 11). The site surveys were located on the northeastern portion of the plateau, in water depths ranging from 2600 to 4200 m (Mayer et al., 1991). Seismic lines tie these sites with Deep Sea Drilling Project (DSDP) Sites 289/586 to the southwest as well as provide a continuous profile across the eastern margin of the plateau. Seismic data collected during Leg 130 by the *JOIDES Resolution* supplement the seismic coverage in this area as well as provide additional tracks on the northern part of the plateau (Fig. 1) (Hagen et al., 1991).

METHODS

Seismic data acquired by the *Thomas Washington* were generated by an SSI 80-in.^{3} water gun fired at 2000 psi. The seismic data were anti-alias filtered at 3–250 Hz, digitized at a 1-ms sample interval, and stored on tape for later reprocessing. The seismic source used aboard the *JOIDES Resolution* during Leg 130 consisted of two 80-in.^{3} SSI water guns or a single 80-in.^{3} SSI water gun and a 200-in.^{3} HAMCO water gun. The seismic data collected on Leg 130 were bandpass filtered at 25–250 Hz, digitized at a 1-ms interval, and logged to tape. The quality of the digital seismic data collected during these cruises is relatively high, with the result that little reprocessing of the data was necessary. A three-trace, 1:3:1 weighted mix and a 2-s AGC window were applied to all records presented in this paper.

Navigation during both of these cruises was by transit satellite and global positioning system satellites when available. The quality of the navigation is generally good; comparisons of intersecting seismic lines revealed no significant crossover errors.

Seafloor and basement horizons were digitized on selected profiles, merged with the navigation data, and plotted and contoured on a computer grid. Sediment thickness isochrons were also derived from the gridded seafloor and basement data. This information was then combined with a velocity-depth function to arrive at "true" basement depths and sediment thicknesses. The velocity-depth function used in this conversion is a simple linear increase of velocity with depth (Fig. 2) that provides a close approximation to the log velocities measured during Leg 130.

DATA DESCRIPTION AND INTERPRETATION

Northeastern Ontong Java Plateau

The northeastern flank of the Ontong Java Plateau rises smoothly from the floor of the Nauru Basin (>4000 m) to the summit of the plateau (<2000 m). The sedimentary cover on the plateau thins from >1200 m at a depth of 2200 m to <450 m at 4300-m depth (Mayer et al., 1991). The acoustic basement of the northern Ontong Java Plateau is relatively smooth and gently undulating. In the vicinity of Site 804 (3920 m water depth), however, basement topography becomes rough, consisting of a series of depressions with basement relief of up to 0.3 s (Figs. 3 and 4).

A network of seismic lines was collected in the "Comet" survey area (Mayer et al., 1991) during the *Thomas Washington* site-survey cruise. During Leg 130, a small seismic survey was conducted to the west-southwest of the "Comet" survey and Site 804 was drilled above one of the small basement depressions in this area (Fig. 5).

The basement depression below Site 804 is the first of many such structures encountered as one descends the flank of the plateau in this area. The depression is irregular in shape (Fig. 6). It is about 5 km wide (east-west) at Site 804 and widens to the south. Basement relief

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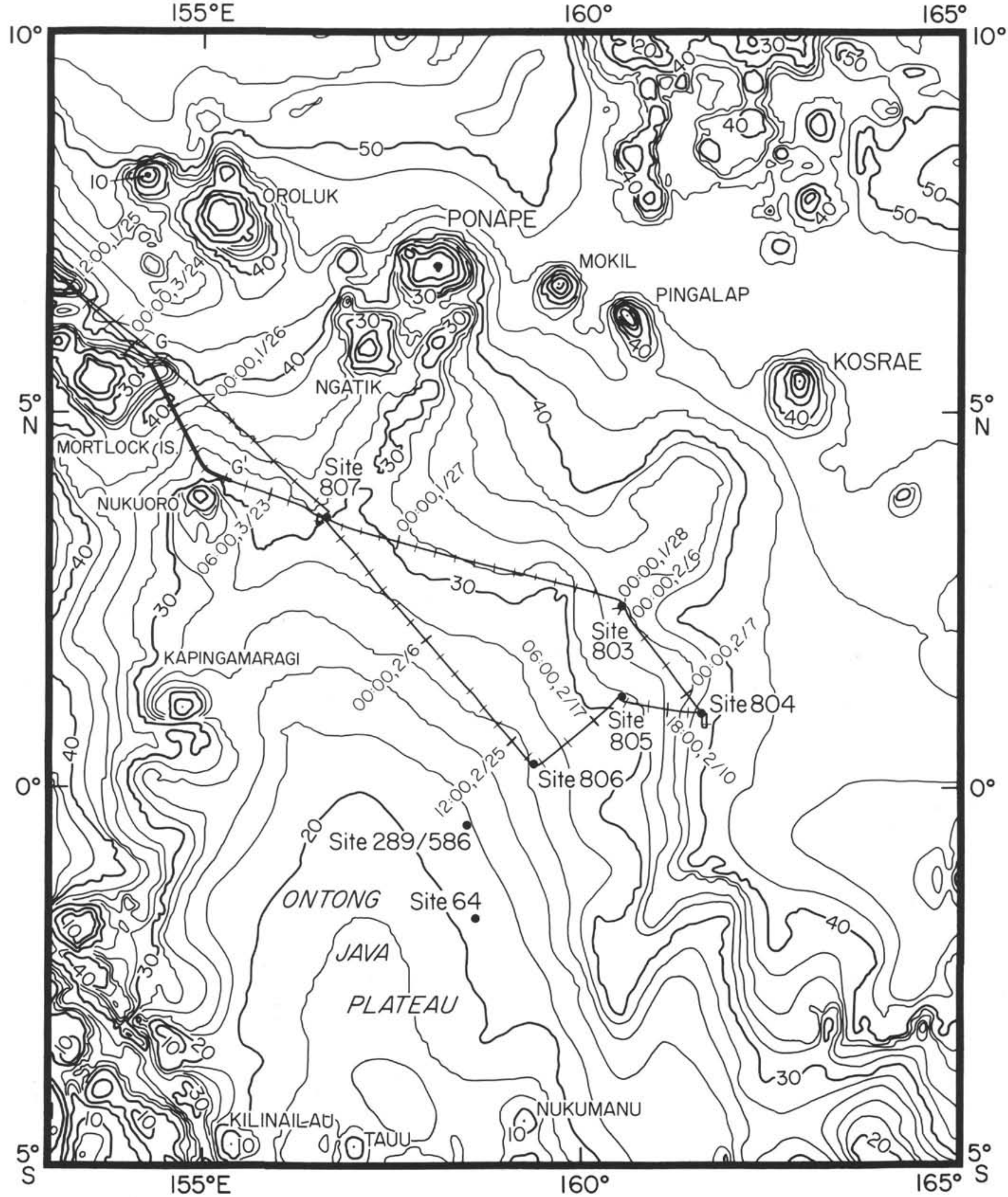

Figure 1. Bathymetric map of the northern Ontong Java Plateau showing DSDP Sites 64 and 289/586, ODP Leg 130 Sites 803–807, and ship tracks for Leg 130. Seismic profile G-G′ is shown in Figure 8. Bathymetry is from the U.S. Navy DBDB5 5-min. gridded data set. Contour intervals are in hundreds of meters.

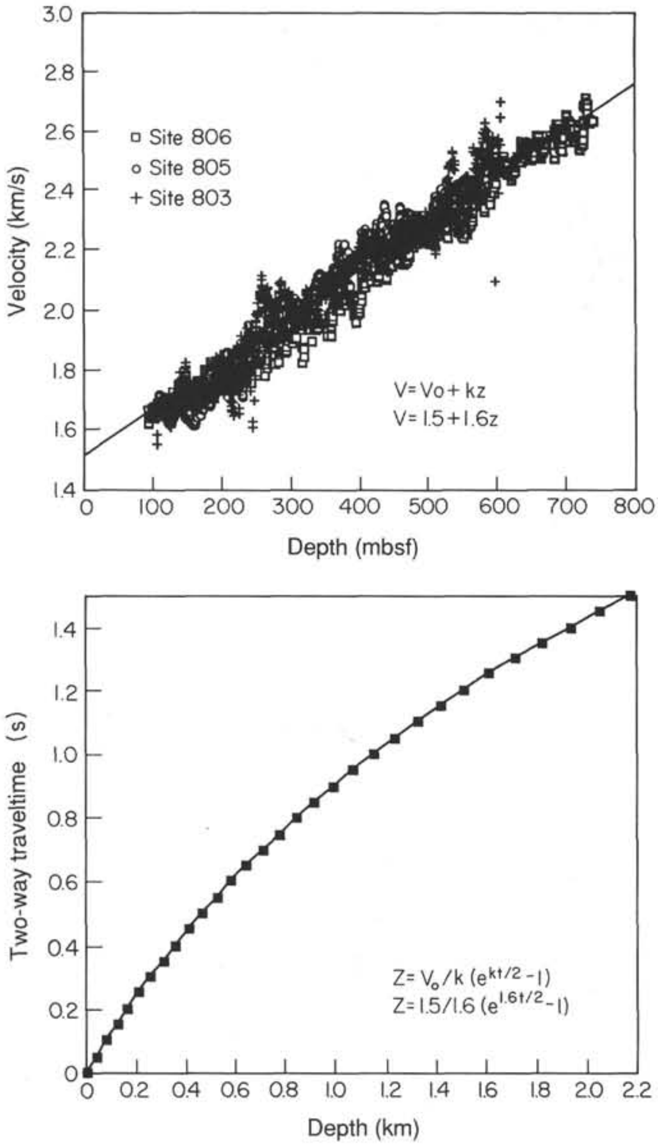

Figure 2. Well-log velocity vs. depth plot for Sites 803, 805, and 806. The straight line $V = 1.5 + 1.6z$ was used to generate the traveltime vs. depth relationship shown in the lower portion of the figure.

is approximately 0.2 s (about 250 m) (Figs. 3 and 4). Reflectors above the level of the bounding basement highs extend continuously throughout the area, paralleling the underlying strata over the depressions and conforming to the undulating surface of the basement highs (Figs. 3 and 4). Sediment disturbance is common over the basement highs and decreases in amplitude upward in the sediment column. We interpret this disturbance as resulting from sediment drape and differential compaction of the sediment over the rough underlying basement topography. Faulting within the sediment cover generally consists of rotational slumps and occasional small-offset normal and reverse faults.

Thick accumulations of older sediment occur within this basement depression. These same sediments are thin or missing on the adjacent basement highs. The sediment layers within the depression are thicker, suggesting that currents and/or mass movement removed sediment from the basement highs and redeposited it in the sheltered depression. Once the depression was full, sediment was deposited conformably across the area. Approximately 450 m of sediment fills the depression whereas about 200 m of sediment overlies the adjacent basement highs (Fig. 6).

A series of similar small basement depressions extends to the east of Site 804 (Fig. 6). These depressions are structurally similar to the depression drilled at Site 804; old sediments are preserved within the depressions and are thin or absent from the tops of the bounding basement highs, which are in some cases directly overlain by younger sediment. Minor normal and reverse faults occur in the section to the east of Site 804 (Fig. 7). These faults offset the entire seismic section and cause small offsets of the seafloor. This suggests that they are recent, or that sedimentation is slow and that bottom currents and sediment flow have not yet smoothed the seafloor.

The "Comet" site survey by the *Thomas Washington* delineated a large basement depression about 110 km east-northeast of Site 804 (Fig. 6). This depression is about 10 km wide (east-west) and approximately 18 km long (north-south). A narrow gap in the western boundary of the depression connects it to a smaller low on the west. Basement relief between the depression floor and the bounding basement highs is approximately 0.3 s (about 275 m), and the depression is overlain by about 0.5 s (400 m) of sediment. This depression is the lowest encountered on the profiles descending the plateau. Basement to the east of this depression is covered by a sequence of old sediment (Fig. 7). The seafloor to the east has been eroded by bottom currents, resulting in a thin sedimentary section consisting mostly of old sediment.

Drilling at Sites 803 and 807 confirmed that the strong, reverberant reflection found throughout the northern plateau at 0.8–1.0 s below the seafloor is caused by basaltic lava flows. In several areas of the northeastern Ontong Java Plateau, seismic profiles show a fairly strong and continuous reflector beneath this plateau basalt reflection (B) (Fig. 4). This sub-basalt reflector (SBR) generally parallels the B reflector but occasionally rises and merges into it, divides into several reflectors, or is lost as it becomes deeper. The SBRs were observed in profiles near Sites 803 through 806, but they were not observed on the northern portion of the plateau near Site 807.

Northern Ontong Java Plateau

A seismic line collected across the northern margin of the Ontong Java Plateau during Leg 130 shows basement structures similar to those observed near Site 804 (Fig. 8). The basement in this area is broken into a series of small depressions. The basement structures on this profile have a relief of 0.2–0.3 s (250–400 m), and are overlain by up to 0.9 s of sediment. Sediment thickness in this area is thus almost twice that observed near Site 804, even though both areas are in the same depth range (3300–4000 m). Old sediments are preserved on the basement highs bounding the depressions. These sediments appear as an interval (up to 0.2 s) of moderate amplitude reflectors overlying basement. Although no faulting is observed in the sediment column, this may be a result of the lack of strong continuous reflectors, which makes recognition of fault offset difficult. Seafloor disruption above a few of the basement highs suggests that there has been some recent movement. The seafloor is generally flat or slopes gently to the north. A rapid increase in depth, however, occurs midway through the profile shown, where the seafloor drops more than 500 m over a distance of about 10 km (Fig. 8). This slope break overlies a large basement high that probably represents the flank of nearby Nukuoro Atoll (Fig. 1). A thick (1.3 s) sequence of sediment occurs at the base of this slope break. Such a thick accumulation of carbonate sediment is unusual at such depths (4000 m) on the plateau and probably includes much sediment from the nearby atoll.

DISCUSSION

Rough basement topography on the margins of the Ontong Java Plateau was also observed in earlier seismic profiles (Ewing et al., 1968; Kroenke et al., 1971; Kroenke, 1972; Berger and Johnson, 1976). Kroenke (1972) claimed that many of these basement features are extensional horst and graben structures that predate much of the

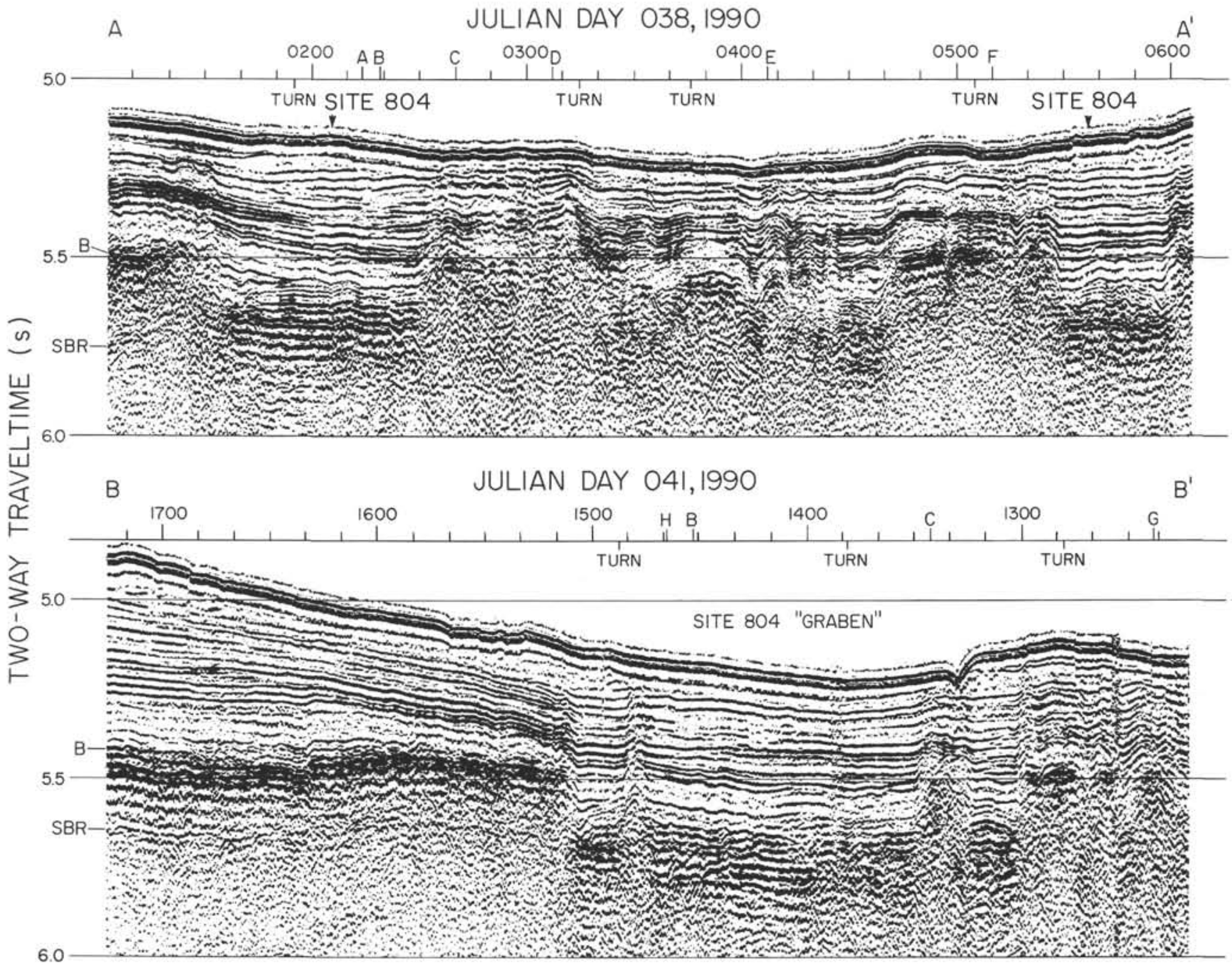

Figure 3. Single-channel seismic profiles A-A′ and B-B′ collected across Site 804 by the *JOIDES Resolution* during Leg 130. The horizontal axes are labeled in time along the ship track. B = basalt reflector, and SBR = sub-basalt reflector. Capital letters on the horizontal axes indicate crossing "tie" points. Profile locations are shown on Figure 5.

Tertiary section, and that others are much younger. Much of the rough basement topography on the southern margin of the plateau is apparently caused by faulting and deformation associated with the collision of the Ontong Java Plateau and the Solomon Arc (Kroenke et al., 1971; Kroenke, 1972).

The basement relief on the northeastern margin of the Ontong Java Plateau increases slightly from west to east, but it is remarkably uniform within the survey area. The margin of the plateau in this area appears to consist of a smooth, descending basement, broken by a series of depressions (Figs. 3 and 4). Basement topography on the northern edge of the plateau is more irregular, consisting of a descending series of narrow depressions and a large basement high on the margin of the plateau that is probably associated with a nearby atoll (Fig. 8).

The limited amount of data available makes it difficult to clearly determine the origin of the rough basement topography observed on the northern and northeastern margins of the plateau. A possible interpretation of basement structure on the northeastern Ontong Java Plateau is that the basaltic lava flows forming the strongly reverberant layer that we have called basement actually overlie a thick (up to 275 m) section of sediment, and that "real" basement is represented by the SBR. In this case, the depressions along the northeast margin of the plateau would actually be windows in an upper layer of lava flows through which additional sediment and "real" basement (the SBR) can be seen. A problem with this interpretation, however, is that this proposed mid-section layer of lava flows appears to form a continuous layer throughout the plateau and out into the Nauru Basin to the east. This would be a truly enormous sill or flow, probably requiring multiple vents of which no evidence has yet been observed. In addition, the SBR appears to be present beneath the depressions as well as the rest of the area (Fig. 7), indicating that the floors of the depressions are not formed by the SBR. Finally, profiles B-B′ (Fig. 3) and F-F′ (Fig. 7) show examples of lower sedimentary layers that are present both within the depressions and on the adjacent basement high. This is strong evidence that the lower sediment section in the "grabens" is not present beneath an upper layer of lava flows adjacent to the depressions.

The rough basement structure on the northern and northeastern margins of the plateau, therefore, appears to be predominantly original basement topography, created during or slightly after the plateau formed. This rough topography probably was formed by constructional volcanism; a faulting origin is unlikely because of the irregular, interconnected shapes of the depressions. These basement depressions were then filled by pelagic carbonate sedimentation. Thin or missing sediment layers on the horsts and thickened layers in the grabens indicate that syndepositional current erosion and/or sediment slides were active in redistributing sediment.

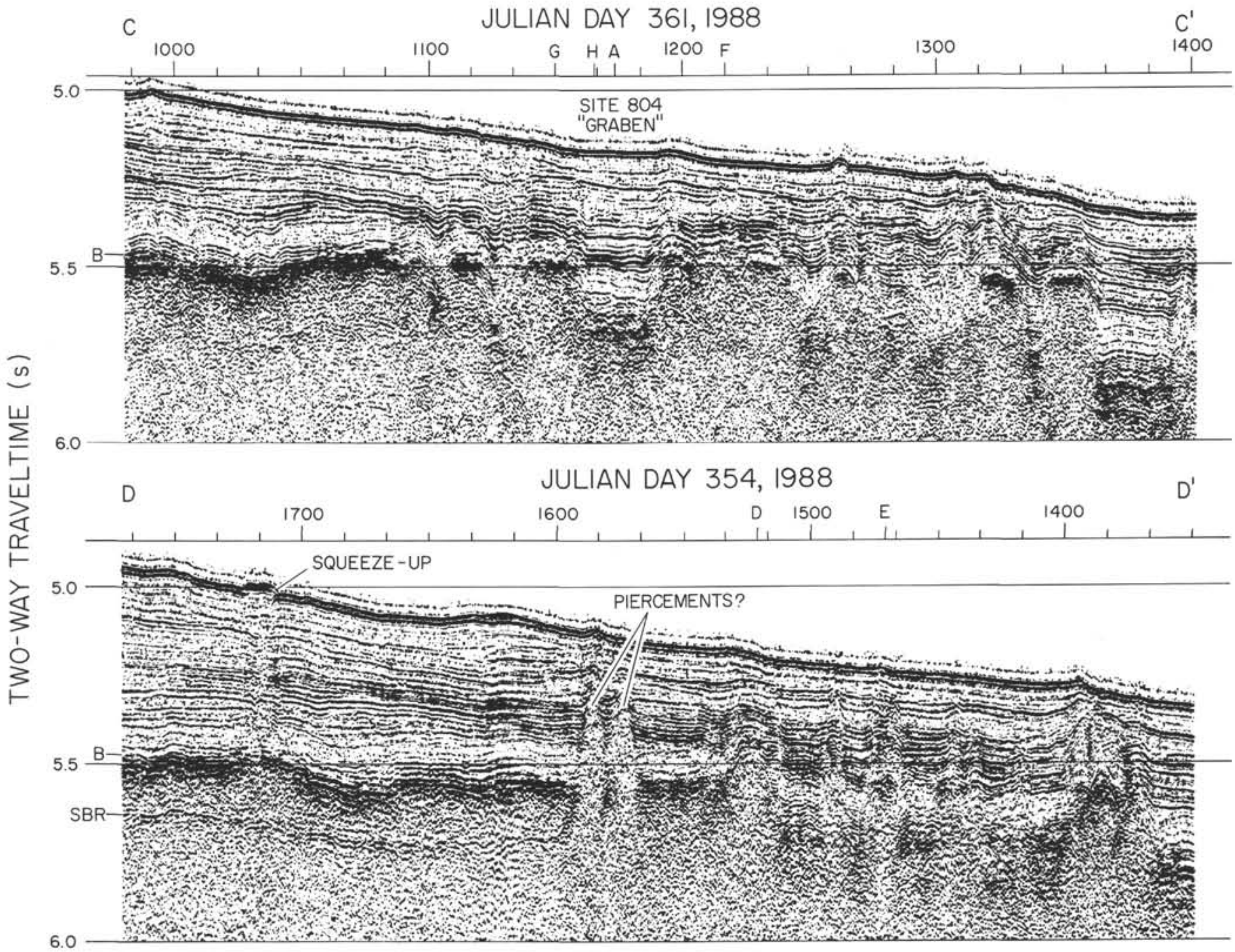

Figure 4. Single-channel seismic profiles C-C′ and D-D′ collected near Site 804 by the *Thomas Washington* during Roundabout Cruise 11. The horizontal axes are labeled in time along the ship track. B = basalt reflector, and SBR = sub-basalt reflector. Capital letters on the horizontal axes indicate crossing "tie" points. Profile locations are shown on Figure 5.

The SBRs that occur in the northeastern portion of the plateau may represent an impedance contrast between thin pillow flows and underlying, massive flood basalts. Alternatively, the SBRs may result from interbedded sediment layers, indicating nonvolcanic periods in the volcanic history of the plateau. Volcanism probably varied in space as well as in time because the SBRs are apparently not present everywhere on the northern plateau. This may account for the apparent discrepancy in basement ages between Sites 803 and 807 (Mahoney et al., this volume). Site 803, which yielded younger ages than Site 807, was drilled in an area of the plateau where SBRs are common, possibly indicating later stages of volcanism there and suggesting that true basement was not reached. Site 807 was drilled in an area where no SBRs were observed, consistent with the sampling of plateau basement.

CONCLUSIONS

The rough acoustic basement terrain revealed by seismic surveys on the northeastern Ontong Java Plateau appears to be caused by original volcanic topography. The depressions are too irregularly shaped to have formed by faulting. An alternative hypothesis, that they are actually windows through a plateau-wide (and Nauru Basin-wide) layer of sills or lava flows is possible. However, source vents for such an extensive vent have not yet been observed. In addition, several seismic profiles appear to show correlatable reflectors present in the bottoms of the depressions as well as on the bounding basement highs—a stratigraphic relationship that is incompatible with the sill/flow model.

Sub-basalt reflectors, seen on seismic profiles in the northeastern portion of the plateau, may be caused by interbedded sediment layers and therefore may indicate significant periods of time between volcanic episodes. The absence of these layers at Site 807 may indicate that later volcanic stages did not occur there and may account for the older basement material drilled there.

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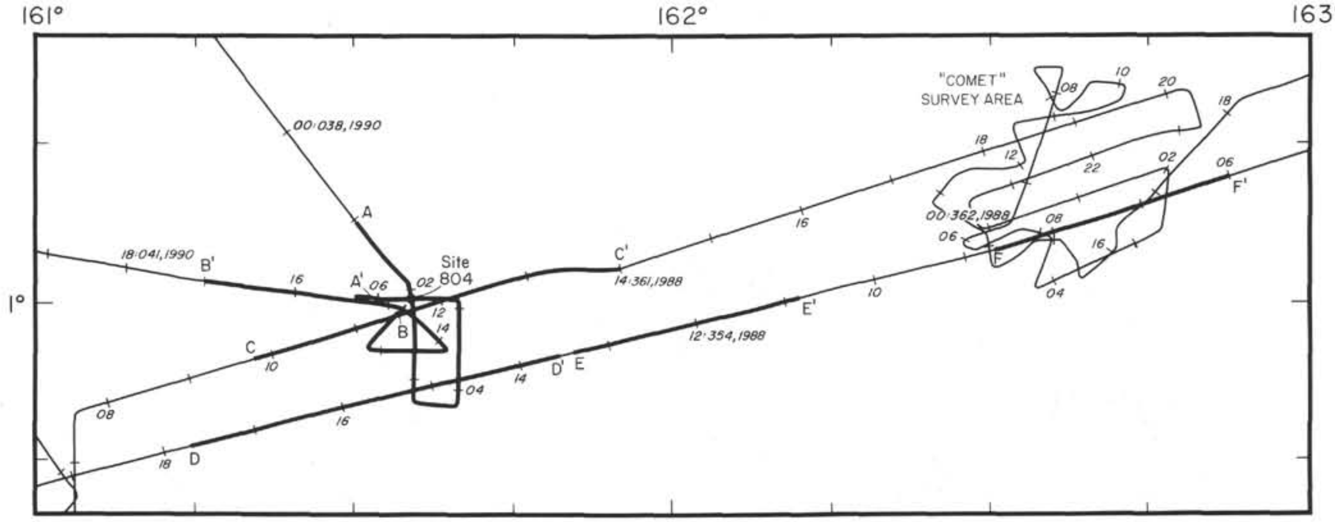

Figure 5. Leg 130 and Roundabout Cruise 11 navigation near Site 804 and in the "Comet" survey area. Seismic profile locations are indicated by the heavy lines.

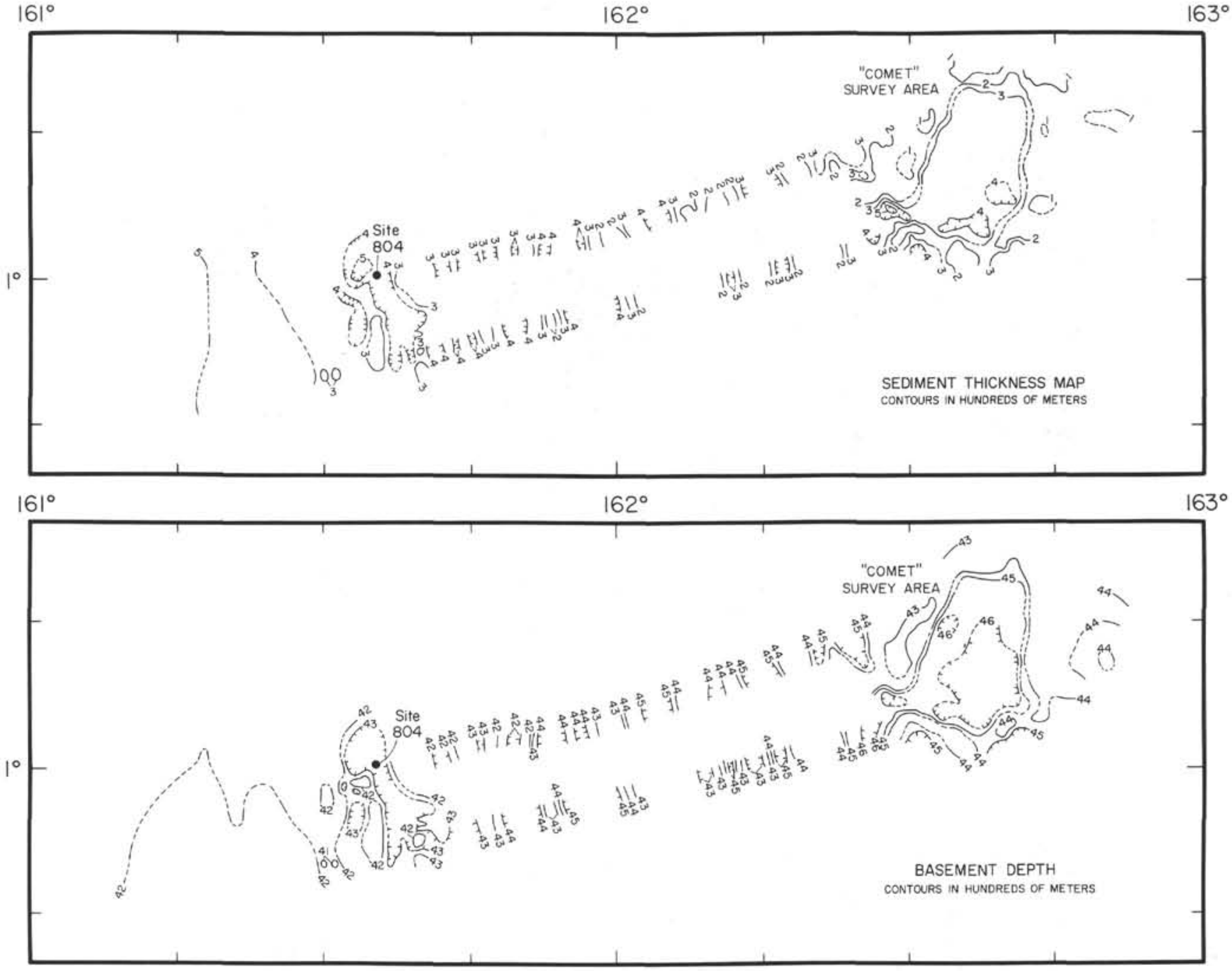

Figure 6. Contour maps of sediment thickness and basement depth near Site 804 and in the "Comet" survey area on the northeast margin of the Ontong Java Plateau.

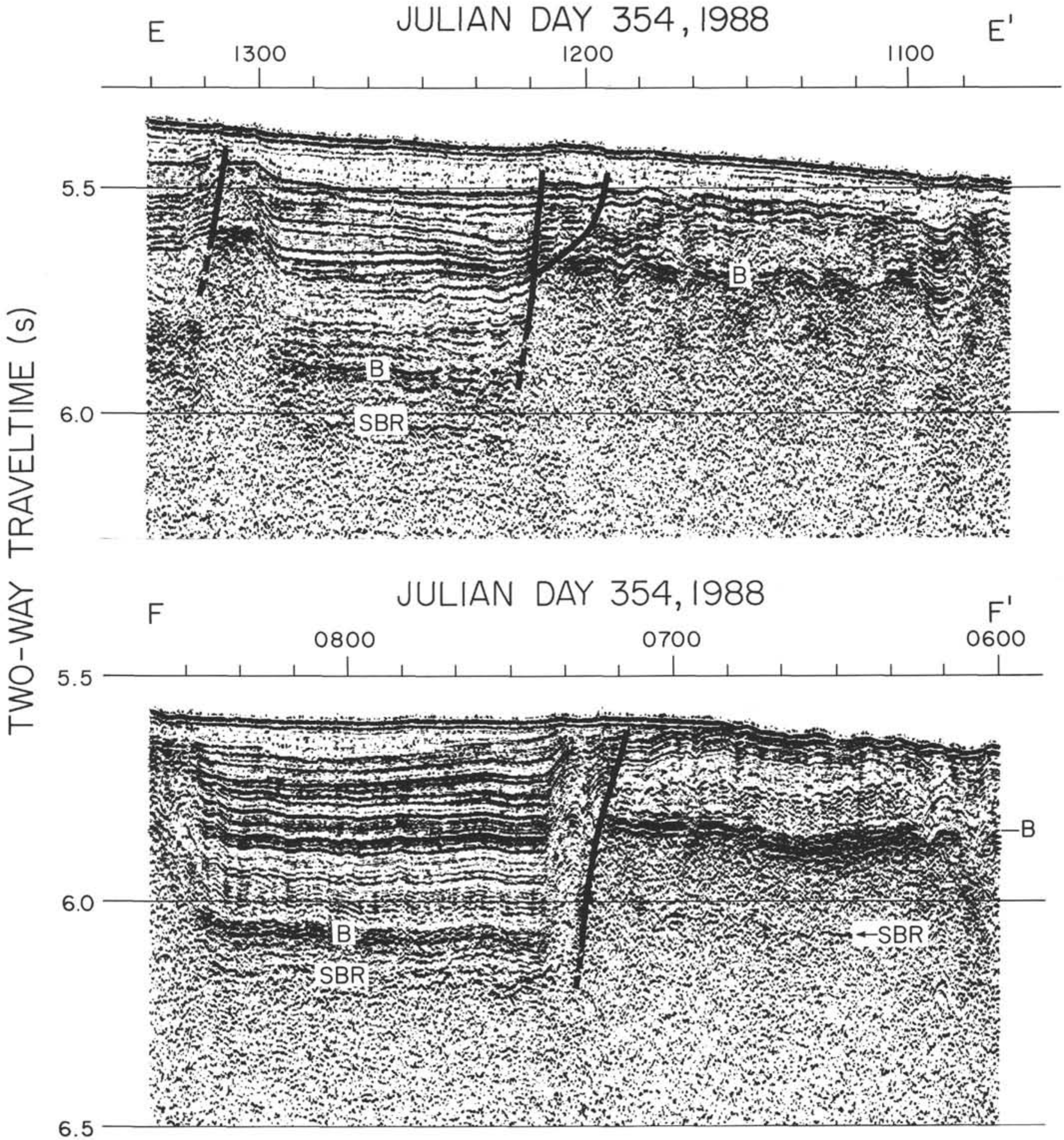

Figure 7. Single-channel seismic profiles E-E′ and F-F′ in the "Comet" survey area collected by the *Thomas Washington* during Roundabout Cruise 11. Small faults can be seen offsetting reflectors on the margins of the small graben-like structures. B = basalt reflector, and SBR = sub-basalt reflector. Profile locations are shown on Figure 5.

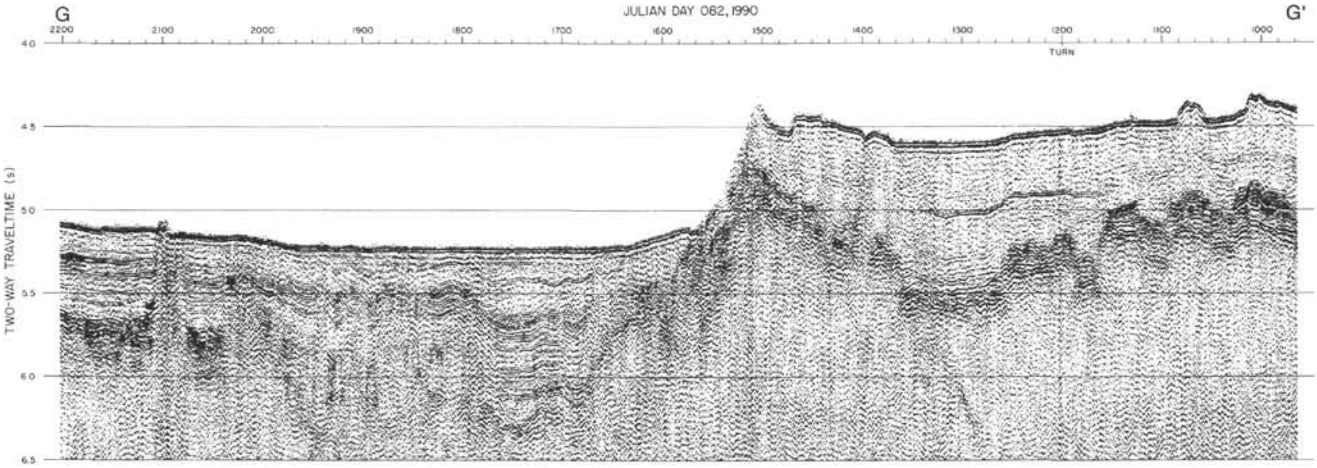

Figure 8. Single-channel seismic profile G-G′ collected across the northern margin of the Ontong Java Plateau (near Site 807) by the *JOIDES Resolution* during Leg 130. Profile location is shown on Figure 1.