8. BASEMENT LOGS FROM THE MOUTH OF THE GULF OF CALIFORNIA, DEEP SEA DRILLING PROJECT LEG 65[1]

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ABSTRACT

Geophysical logs run in Holes 482C, 483, and 485A on Deep Sea Drilling Project (DSDP) Leg 65 demonstrate that interlayered sediments represent a substantial portion (up to 63%) of the upper levels of the basement in the mouth of the Gulf of California. The rest of the sections consist of massive basalts and minor pillow basalts. The thickness of the interlayered sediments in Hole 483, together with the sediment accumulation rate, imply that late-stage volcanism persisted at Site 483 for at least 490,000 years after most of the crust had formed.

The lack of washouts in the sediments immediately overlying and underlying several of the basalt units in Holes 483 and 485A implies hardening resulting from baking or diagenesis. High natural gamma-ray counts in the uppermost basalts in all three holes are attributed to neutron activation of elements introduced by alteration.

INTRODUCTION

Although geophysical logging has now been conducted in numerous DSDP holes in the ocean basins, relatively few holes have been logged to significant depths in basement. Nonetheless, the data from these holes have enabled us to deduce a great deal about the crust which could not otherwise be known, such as the water to rock ratio, the relative abundance of massive basalts, pillow basalts, and sediments, and the *in situ* formation properties of the crust.

One of the first and most important findings of the basement logging program was the discovery on Leg 46 that the upper few hundred meters of crust at Site 396 on the Mid-Atlantic Ridge has an extremely high formation porosity (15% to 20%). This is consistent with the low seismic velocities reported for young crust near the ridge crest by Houtz and Ewing (1976) and was interpreted as resulting from the presence of numerous water-filled joints, fractures, and interpillow voids near the top of the section (Kirkpatrick, 1979). Lower, but still surprisingly high porosities (10%–15%), were subsequently deduced from logs run in the uppermost levels of the basement at Site 417 in 110 m.y. old crust in the western Atlantic on Leg 51 (Salisbury et al., 1979), suggesting that the crust never entirely anneals with age.

At other sites in old crust, however, such as Site 462 in the Nauru Basin, the basement formation properties determined by logging were almost indistinguishable from those determined in the laboratory, suggesting that the basement consists of massive, relatively unfractured flows or sills (Boyce, 1981). Finally, on Leg 64, a series of logs run at Site 474, where the recovery was low, were of considerable importance in distinguishing the relative abundance and position of pillow basalts, massive basalts, and sediments in the section (Curray, Moore et al., in press).

During Leg 65, a series of nine holes were drilled into the basement at four sites across the mouth of the Gulf of California (Fig. 1), and three of these holes (482C, 483, and 485A) were logged by Gearhart-Owen Wireline Services (Fig. 2), nearly doubling the number of basement holes studied by logging. The purpose of this chapter is to review the logs obtained on Leg 65, to compare these logs with the results of coring (Figs. 3–5; site summaries, this volume) and to determine the *in situ* properties of the sections drilled.

DOWNHOLE LOGGING

Hole 482C

A limited program of downhole logging was conducted in Hole 482C between 2025 hours, February 2, and 1030 hours, February 3, 1979. The purpose, in addition to those cited above, was to determine whether or not the *in situ* temperatures in the basement were low enough to permit installation and operation of the Hawaii Institute of Geophysics (HIG) downhole seismometer (Duennebier et al., this volume).

Since the prime objective of drilling Hole 482C was to provide a site for emplacing the HIG instrument, several steps were taken to minimize the chance of losing tools in the hole, and thus the hole itself, before we installed the seismometer package. First, the logging program was limited to two runs. Second, only the base of the basement section was logged open-hole; the sediments and the upper section of the basement were logged through the pipe to prevent bridging.

Before lowering the logging tools, the pipe was run to the bottom of the hole (184 m sub-bottom); the bit was then released and the hole pumped clean with guar gum, borax, and mud. After the end of the pipe had been raised 29 meters off bottom to 155 meters, a combined temperature–gamma density–caliper tool was rigged and pumped to a point 2490 meters below the seafloor and then lowered (without pumping) another 450 meters to 2940 meters, or 60 meters above the mudline.

[1] Lewis, B. T. R., Robinson, P., et al., *Init. Repts. DSDP*, 65: Washington (U.S. Govt. Printing Office).

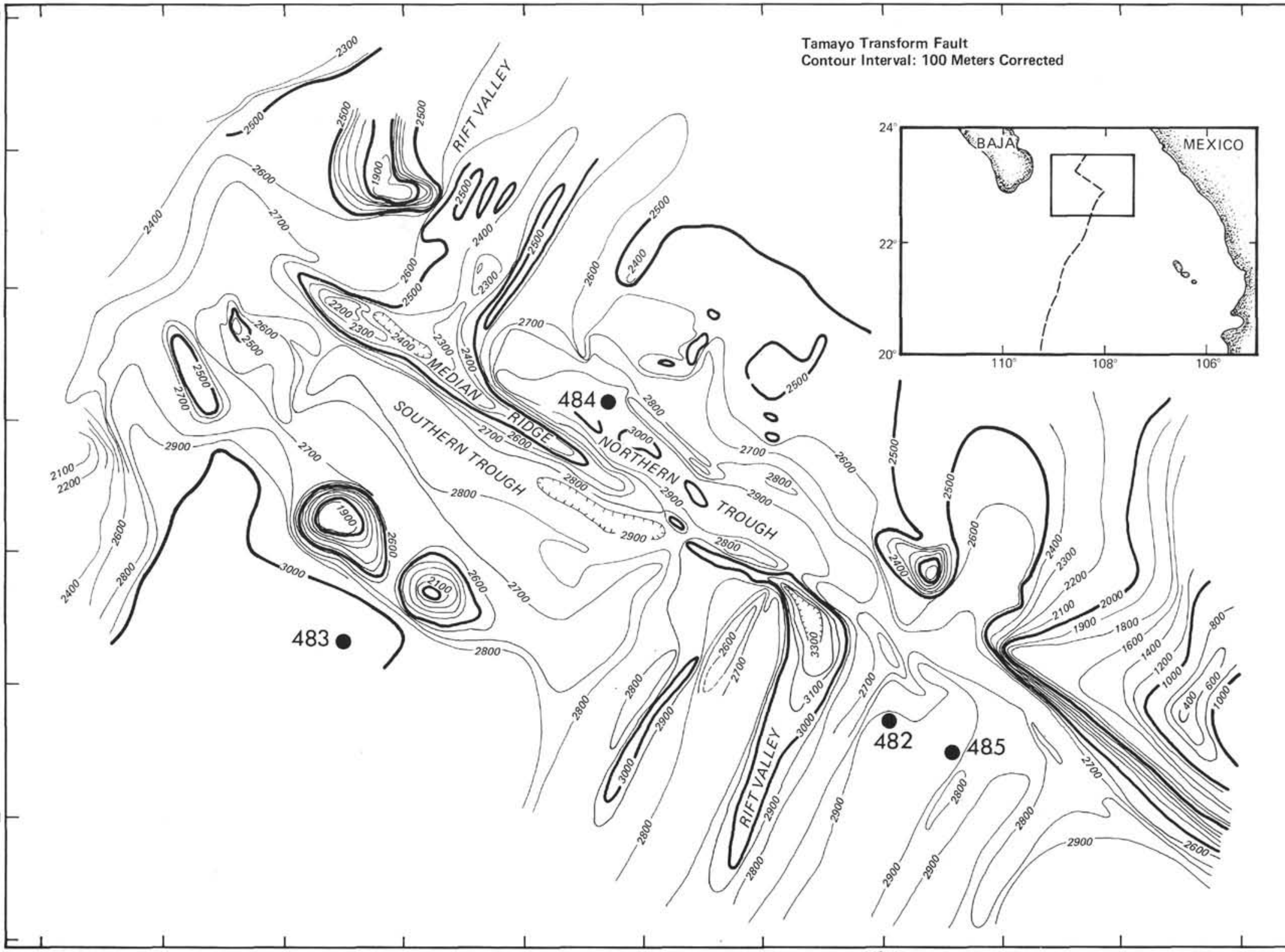

Figure 1. Locations of sites drilled on DSDP Leg 65. (Contours in corrected m.)

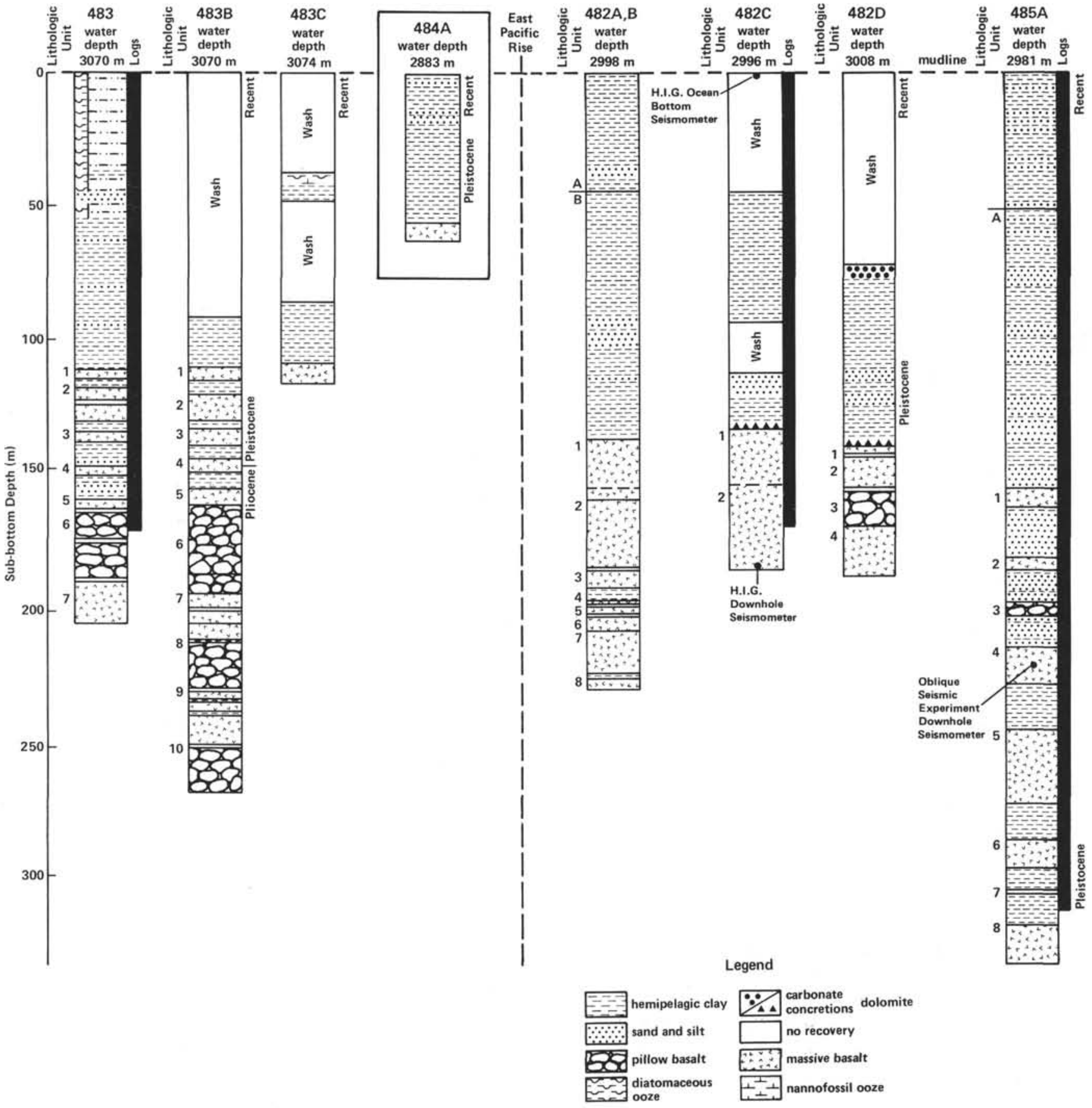

Figure 2. Lithologic columns for holes drilled on Leg 65, showing intervals logged.

After the tool had been calibrated, it was lowered 6 meters past the end of the pipe to confirm the bit release, raised 9 meters above the mudline, and then logged (temperature only) on the way down to a sub-bottom depth of 180 meters. The temperature was then monitored for one hour at 180 meters, after which the hole was logged open-hole between 180 and 160 meters and then through the pipe to a point 10 meters above the mudline. The tool was then pulled to the surface.

A combined neutron porosity-collar log-natural gamma tool was then rigged and lowered to 180 meters. As in the preceding run, the hole was logged open-hole between 180 and 160 meters and through the pipe to 10 meters above the mudline, after which the tool was brought to the surface.

The temperature probe used on the first logging run consisted of a thermistor mounted in a cage at the bottom end of the tool and calibrated to read between 0° and 190°C. The temperature of the water in the pipe was approximately 3°C down to the mudline, below which it rose to 6°C in the upper 6 meters of sediment and then rose monotonically to 12°C at the basalt/sediment contact. Within the basement, the temperature in the pipe rose more rapidly to about 17°C at the end of the pipe and then increased still more rapidly in the open hole to 40°C at 180 meters. Since these temperatures were much lower than those measured by the Uyeda device (Lewis, this volume) in the same hole while drilling the sediments, it is believed that the downhole temperatures had been depressed by mixture with seawater and had not returned to thermal equilibrium. The temperature was then monitored continuously at 180 meters for about an hour (0234–0329 hours, February 2), during which time it increased by 2° to 42°C. A final, independent downhole temperature measurement of 67°C was obtained at 1200 hours on February 3 from the HIG experiment package before the recorder package was lowered to the seafloor.

The density log accompanying the temperature probe on the first run consisted of a compensated gamma density tool with a collimated Ce^{137} source and two detectors spaced 12″ and 18″ from the source along a pad which is pressed against the side of the hole by a scissor jack and a back-up arm mounted on the other side of the tool. The tool measures the electron density and thus, indirectly, the wet-bulk density of the formation to a depth of about 3″ in basalt and 10″ in sediments by monitoring the attenuation (by Compton scattering) of gamma rays directed into the formation. It compensates for borehole irregularities by using two detectors and by being run in combination with a caliper log which measures the borehole diameter by means of a linear tensiometer mounted between the pad and the back-up arm. Unfortunately, the density tool was damaged and the run was aborted when the pad caught under an overhang after only 5 meters of basement between 175 and 180 meters had been logged. The formation densities recorded over this interval average 2.85 g/cm^3, with lower values observed at the lithologic break noted between Cores 14 and 15 (Site 482 summary, this volume).

The neutron porosity tool used on the second logging run consisted of a 3 Curie Be–Am^{241} epithermal neutron source and a thermal neutron detector spaced 13″ from the source. The tool measures the abundance of hydrogen and thus, indirectly, the porosity of the formation to a depth of about 2 ft. into basalt and 6″ into sediments by monitoring the number of low energy or thermal neutrons produced by collisions between epithermal neutrons from the source and hydrogen atoms in the formation. Since the source is nondirectional and the tool is not deliberately centralized, the data are not borehole-compensated and must be regarded as being qualitative.

The natural gamma-tool run in combination with the porosity tool consisted of a nonspectral scintillation counter. Since natural gamma rays tend to be absorbed in the formation by Compton scattering, the tool is sensitive to the presence of radioactive elements (K and, to a lesser extent, U and Th) within 6″ of the borehole.

The collar log, run in conjunction with the porosity and natural gamma tools discussed above, consists of an ac magnetic induction coil, which induces an ac field in the pipe, and a receiver coil, which monitors the induced field. Since the phase lag between the induced field and the field in the induction coil is a measure of the thickness of the pipe and, thus, the position of the drill collars, the tool was used in Hole 482C to determine the *in situ* configuration of the bottom-hole assembly (BHA). Once its configuration had been established, its position in the hole was determined by comparing the collar log with the natural gamma ray and porosity logs, both of which are extremely sensitive to the thickness of pipe between the formation and the tool.

As can be seen in Figure 3, many features of the porosity and natural gamma logs can be attributed to changes in pipe thickness alone. The apparent porosity of the sediments, for example, decreases with increasing pipe thickness, and the natural gamma count increases dramatically in the intervals cased by the relatively thin-walled bumper subs.

It is equally clear, however, that many of the features of the logs are related to the geology of the section:

1) The increase in natural gamma ray activity about 3000 meters below sea level corresponds to the mudline (the sharp spikes higher in the record result from gamma rays emitted during the capture of thermal neutrons produced by the collision of epithermal neutrons from the porosity tool with seawater).

2) The high porosity interval between the mudline and 140 meters corresponds to the silty clays recovered in Cores 1 through 9.

3) The decrease in porosity between 133 and 134 meters corresponds to the basal dolostone recovered in Core 8, Section 1.

4) The low porosity unit logged between 160 and 180 meters corresponds to the fresh, massive basalts recovered in Cores 12 through 15.

Since the average formation density (2.85 g/cm^3) measured between 170 and 175 meters is slightly lower than the density of the basalts from the same interval (2.95 g/cm^3), the unit appears to contain perhaps 5% cracks by volume. The high porosity excursions at 170 and 177 meters probably represent interlayered sediments or open cracks (sediments and/or chilled margins were recovered from the tops of Cores 14 and 15, but the absence of a strong natural gamma spike at 170 meters indicates that the sediments are not volumetrically significant in the upper interval).

5) An intermediate porosity unit characterized by high natural gamma counts between 140 and 160 meters is somewhat more enigmatic. Since the decrease in porosity at 140 meters occurs in the middle of a drill collar, it is unrelated to the configuration of the pipe. The top of the unit coincides with the top of the basement as defined by the ease of drilling and the first recovery of basalt, while the open-hole logs at the base of the unit between 157 and 160 meters clearly indicate the presence of sediments (high porosity, high natural gamma count). The intervening logs seem characteristic of interlayered claystone and basalt (the porosity tool would tend to average out the detailed structure seen by the natural gamma tool) but, in fact, only coarse-grained basalts were recovered from this interval. It is possible that the interlayered claystones were destroyed in drilling, but the absence of glassy or even fine-grained basalt from this interval seems inconsistent with this interpretation.

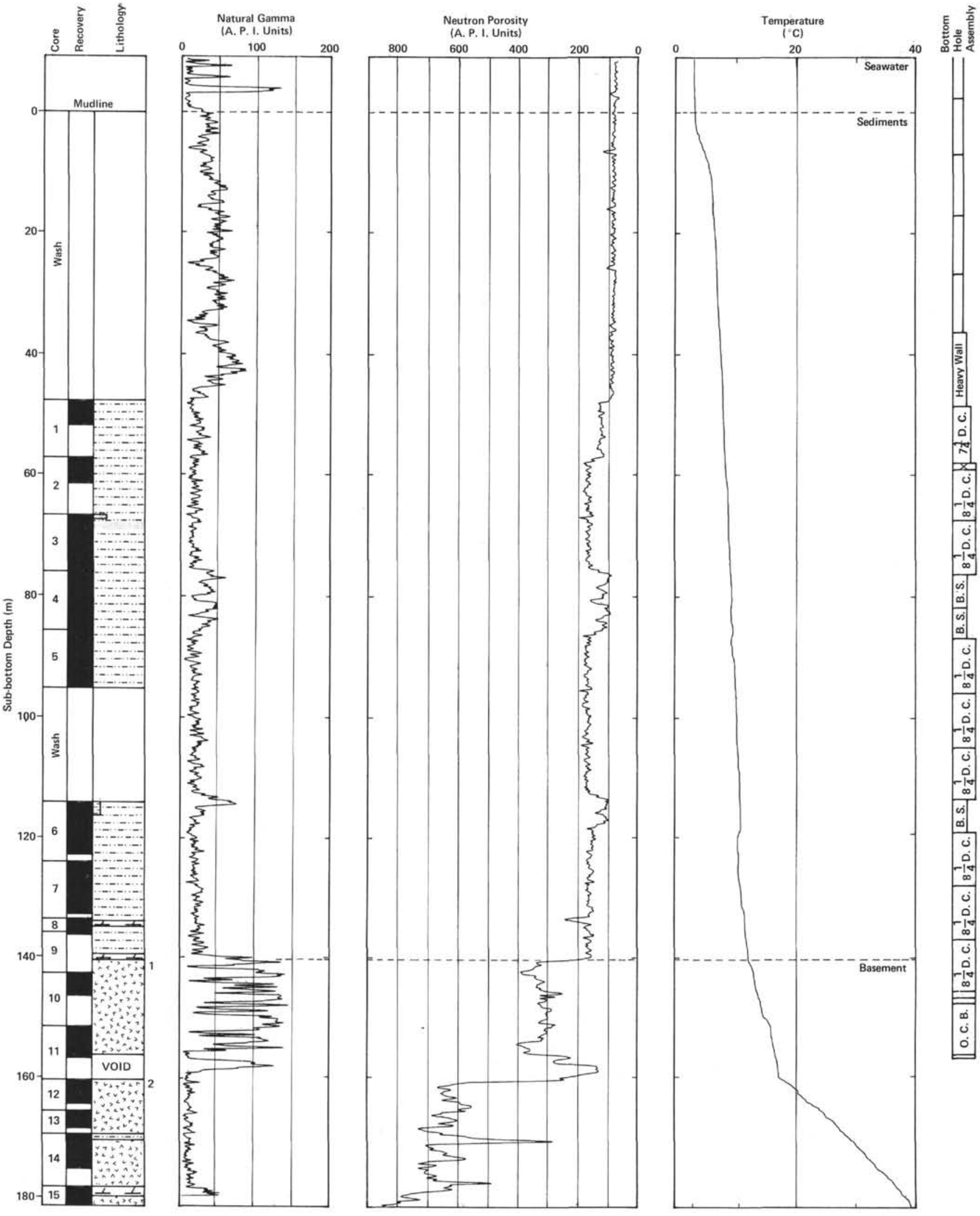

Figure 3. Comparison of lithology and downhole geophysical logs from Hole 482C. The position and configuration of the bottom hole assembly during logging is shown on the right. (O.C.B. = outer core barrel; D.C. = drill collar; B.S. = bumper sub. See Explanatory Notes (this volume) for definition of lithologic symbols.)

A more likely explanation is that the porosity and natural gamma activity observed between 140 and 160 meters can be explained in terms of basalt alteration. The basalts in Cores 9 through 11 are altered in patches to as much as 50% smectite ± chlorite and actinolite, suggesting that the relatively high apparent porosity results from bound water in secondary minerals and that the high natural gamma count results from K, U, and Th. Since the formation was exposed to a high neutron flux during the descent of the combined neutron-collar-natural gamma tool on the last logging run, it is also possible that the high gamma ray count at the top of the basement resulted from neutron activation of the altered basalts.

Hole 483

A full downhole logging program was conducted in the basement in Hole 483 between 1730 hours, February 16 and 0800, February 17. As in Hole 482C, the purpose was to determine the lithology of the section in zones of low recovery and to study the *in situ* physical properties of the upper levels of the crust. Only the base of the section was logged open-hole in order to minimize the chances of bridging; and the sediment/basement contact was only logged open-hole with the combined guard–neutron porosity–natural gamma tool on the last logging run when the pipe was pulled above the basement. The sediments were logged through the pipe using the natural gamma tool.

Before the first logging run, the hole was cleaned with 30 barrels of mud, the bit was released, and the pipe lowered 11 meters into basement. A combined temperature–natural gamma–gamma density–caliper tool was then rigged and lowered to a point 6 meters above the mudline. After calibration, the tool was lowered without pumping and the temperature logged through the pipe and then open-hole to 198 meters sub-bottom. The basement section between 198 and 126 meters was then logged open-hole using the gamma density, natural gamma, and caliper tools, after which the caliper was closed, the tool pulled into the pipe and the sediments logged through the pipe to the mudline at 3074 meters using the natural gamma tool.

After the first logging tool was brought to the surface, a combined natural gamma–sonic velocity–caliper tool was rigged and lowered to 2487 meters below sea level before instrument problems forced us to return the tool to the surface and rig a new one. A second tool was prepared and lowered to 191 meters sub-bottom, at which point the tool was stopped by cavings. Although the tool had been checked and calibrated near the mudline, the velocity tool failed once again at the bottom of the hole and had to be pulled to the surface. As a result, the only velocity data from Hole 483 was obtained open-hole between 11 and 60 meters subbasement while monitoring the tool as it was lowered to the bottom of the hole with the caliper closed and the tool uncentralized.

On the final logging run, a combined natural gamma–neutron–guard log was lowered to 183 meters sub-bottom, at which point the tool was stopped by cavings about 18 meters higher than on the preceding run. After the tool had been raised off bottom for calibration and lowered again to 183 meters, the hole was logged open-hole from 183 to 116 meters (i.e., across the sediment/basalt contact) by raising the pipe two stands at the rig floor. The tool was then dragged into the end of the pipe through collapsing sediments and brought to the surface without further incident.

The temperature probe used on the first logging run was identical to that used in Hole 482C. The temperatures increased monotonically from about 2.7°C at the mudline to 4°C at the end of the pipe at a subbasement depth of 11 meters and then increased slightly more rapidly in the open hole in basement to about 7°C at 87 meters subbasement. As in Hole 482C, the temperatures measured seem anomalously low, suggesting mixing with seawater.

The natural gamma tool used in the sediments was set up with high trigger levels and short counting times so that it could be used for open-hole logging in conjunction with the gamma density tool. As a consequence, the tool was not suited to logging through the pipe and the data were poor. Within the basement section, however, the natural gamma logs were more informative, both because they were run open-hole and because on the second and third runs, they were run at higher sensitivity (Fig. 4).

As expected, the sediments display relatively high natural gamma counts (60-105 API units) while the basalts tend to display relatively low counts (0-30 API units). As in Hole 482C, the basalts in the top of the basement section provide a striking exception to this pattern by displaying the highest counts (≥ 150 API units) in the entire logged interval. While it could be argued that the high natural gamma counts in the top of Hole 482C result either from altered basalts or from interlayered sediments, the case here is unequivocal; the high counts in Hole 483 are coincidental with intervals having formation densities typical of massive basalt, which suggests that the phenomenon is due to alteration. Since the counts were only anomalously high on the third run after the formation had been exposed to a high neutron flux, it is probably the result of neutron activation.

The density tool used in Hole 483 was the same as that used in Hole 482C. As in the case of the natural gamma data, the density log displays a bimodal distribution of values corresponding to sediment and basalt, respectively. Where the caliper tool was not fully extended in washouts but was engaged against the sediments, the density tool gives corrected wet-bulk density values of 1.7-1.9 g/cm^3—in reasonable agreement with measured values in the interlayered sediments (1.76 g/cm^3 in Core 18). The corrected densities of the basalts, on the other hand, range from about 2.5-3.0 g/cm^3. The formation densities are consistently high (average 2.85 g/cm^3) in the basalt layers drilled between 124 and 161 meters sub-bottom. Since the measured formation density is only slightly lower than the average measured density of samples from this interval (2.92 g/cm^3), the basalts are interpreted as being massive with relatively

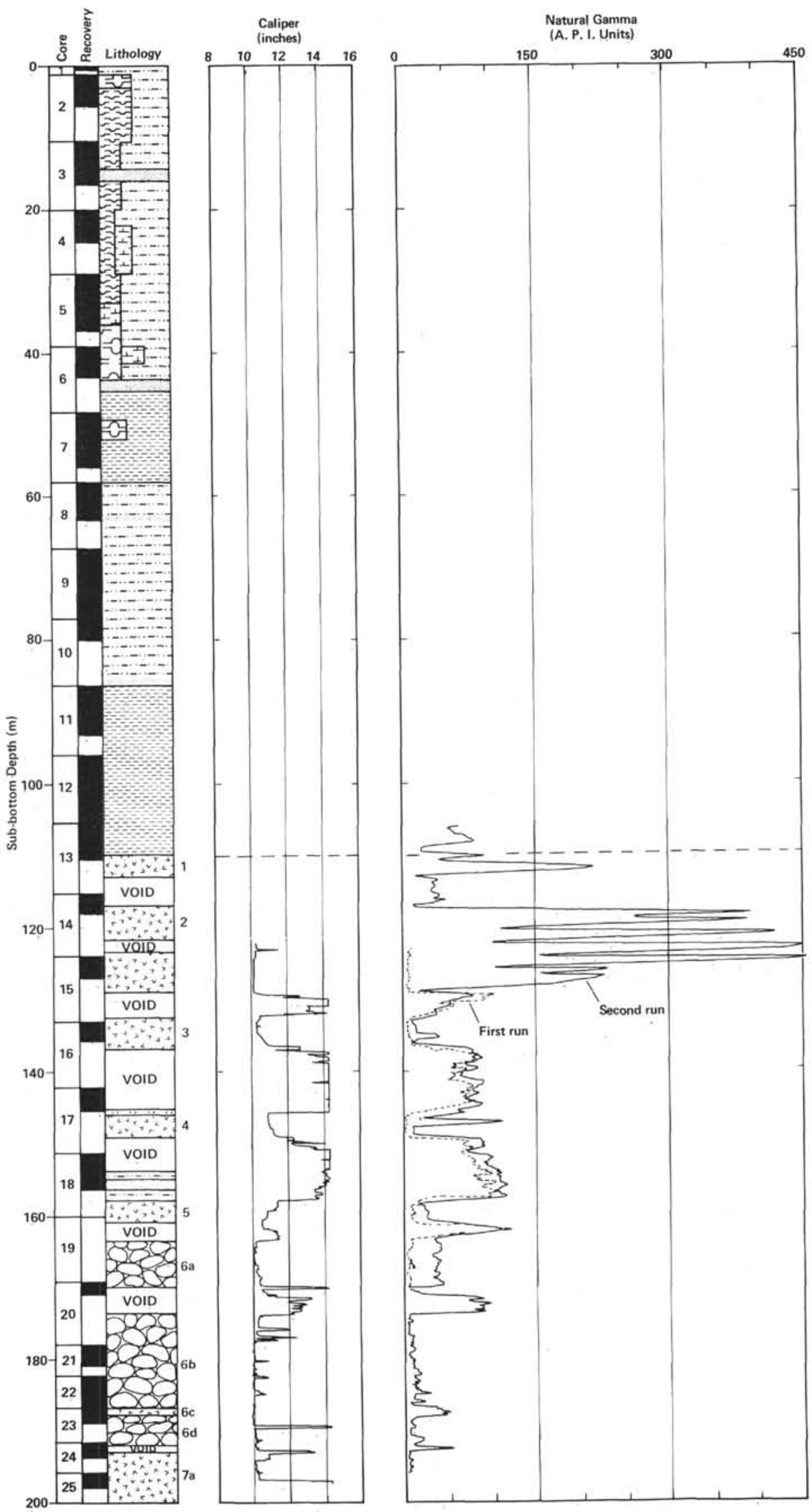

Figure 4. Comparison of lithology and downhole geophysical logs from Hole 483. See Explanatory Notes (this volume) for definition of lithologic symbols.

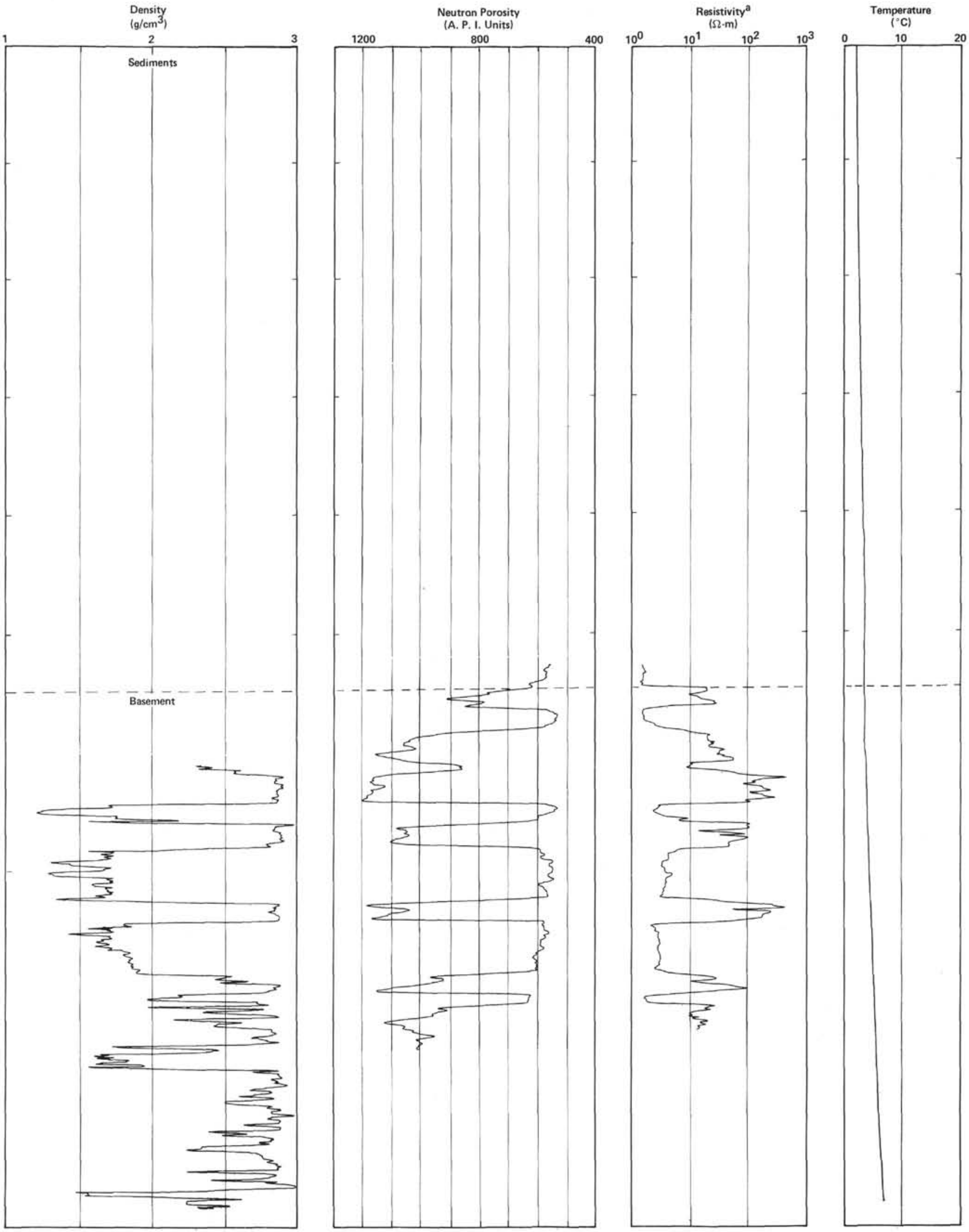

Figure 4. (Continued).

few cracks (4% by volume). Between 161 meters and the base of the hole, however, the formation properties of the basalt are distinctly different from those higher in the section: the densities range erratically between large extremes (2.5–3.0 g/cm^3), the values cannot be reproduced in detail, and both the natural gamma and caliper logs show considerable spiking, all of which are suggestive of logging in pillow basalts or thin flows.

As in the case of the natural gamma and density data discussed above, the porosity values shown in Figure 4 display a bimodal distribution that is directly related to lithology. Although the data are only qualitative (the tool is uncompensated), the porosity of the interlayered sediments ranges between 950 and 775 API units (approximately 45% to 60%) over the limited intervals in which the caliper tool was not fully extended in washouts. The porosities of the basalts, on the other hand, range for the most part between 2700 and 2175 API units (2%–5%), with higher values of 1800 and 1400 API units (10%–20%) observed in the uppermost unit. A comparison of the average formation porosity of the massive basalts logged between 124 and 149 meters sub-bottom (225 API units or 4.5%) and the average porosity of the basalts recovered from this interval in Cores 15, 16, and 17 (3.5%) gives a crack porosity of about 1% by volume, in reasonable agreement with the value derived above from density relationships.

The resistivity data were obtained using a guard or laterolog tool with a vertical resolution of about one foot and a depth of investigation of between 2 and 6 feet, depending on the nature of the formation. The tool measures the resistivity of the formation by injecting a thin sheet of constant current into the formation by means of focusing electrodes in the sonde and monitoring the drop in potential between a sensing electrode near the source and the armor of the cable. The resistivities obtained by this means are very low (2–5 ohm-meters, uncorrected) in the sediments, but increase to 10–30 ohm-meters in the pillow basalts and to values as high as 250 ohm-meters in the massive basalts. Since the average resistivity of dry basalts at room temperature ranges from 10^3 to 10^6 ohm-meters and borehole corrections will only increase these values by a factor of 4 to 5, it is likely that the basalts are saturated *in situ* with seawater.

The sonic velocity tool used consisted of two 20 kHz transmitters spaced 12 ft. apart along the tool and two receivers spaced one ft. apart midway between the transmitters. By measuring the difference in travel times between the first transmitter and the two receivers and averaging the result with the difference in travel times from the second, the velocities are corrected for the tilt of the sonde and irregularities of the hole in a manner analogous to that of a reversed refraction line. Normally the tool is centralized by means of a caliper tool, but in the present case the log was run while lowering the tool with the caliper closed. Since the log was only qualitative and showed evidence of cycle skipping, the data will neither be shown nor discussed further.

From the preceding discussion, it is clear that all of the tools except the sonic log functioned properly in Hole 483 and that the logs obtained appear to be of high quality. The results prove what can only be inferred from drilling rates and hinted at from the recovery, namely that interlayered sediments are an important component of the upper levels of the crust. As can be seen from the lithologic section derived from the logging results and shown in Figure 4, interlayered sediments constitute 36% of the logged section below the first basalt layer. Both the logging data and the recovered material indicate, however, that the sediments and the massive basalts decrease in abundance below 163 meters sub-bottom (53 meters subbasement) and pillow basalts increase.

It should also be noted that the average formation density of the pillow basalts (about 2.7 g/cm^3) is lower than that of the massive basalts (2.85 g/cm^3). If the interstitial voids between the pillows are not entirely filled with sediments, then the formation porosity and thus the permeability of the pillow sequence will be greater than that of the overlying sequence of massive basalts and interlayered sediments. This in turn suggests that water circulation at the site is now controlled by a relatively impermeable cap but that initially the system was open to seawater.

Hole 485A

A full logging program was run in Hole 485A between 9030 and 2230 hours, March 10. As in the previous holes, the hole was logged open-hole below the uppermost basalt unit to reduce the chances of bridging.

After a 34 hour hiatus during which the oblique seismic experiment was conducted (Stephen, this volume), a final logging run was conducted between 0830 and 1136 hours, March 12, in order to determine the temperature in the basement after equilibration.

The tools used, with the exception of the VDL (variable density log), were identical to those described for Holes 482C and 483. The VDL is obtained using the sonic velocity tool reprogrammed to display the full wave train as function of depth instead of the *P*-wave travel time. Second arrivals and changes in signal amplitude on such a display may be used to determine shear-wave velocities and to locate fractures in the formation.

After the hole had been cleaned with mud and the bit released, the bottom of the pipe was raised to a point 8 meters below the top of the basement. A combined temperature–natural gamma–gamma density–caliper tool was then pumped down to within 7 meters of the mudline, after which the temperature was logged to the bottom of the pipe and then open-hole to a sub-bottom depth of 328.5 meters with the pump off. After monitoring the temperature at the bottom of the hole for 10 minutes, we logged the basement section open-hole to 253 meters sub-bottom using the natural gamma, gamma density, and caliper tools. The tool was then lowered to 310.5 meters sub-bottom (at which point the tool was blocked by new cavings) and the section logged open-hole to the bit. The tool was then pulled into the pipe and brought to the surface.

On the second logging run, a combined sonic velocity–natural gamma tool (minus caliper) was rigged and lowered to 308.5 meters where the tool was stopped by cavings. The section was then logged open-hole using the sonic velocity and natural gamma tools to 249.5 meters, after which the tool was lowered to 295.5 meters and the hole logged again to the bit. The tool was then lowered a final time to 292.5 meters, programmed for VDL operation, and the hole logged 9 meters into the end of the pipe to 152.5 meters.

After the sonic tool was brought to the surface, a combined natural gamma-gamma neutron-guard log was lowered to the bit, calibrated, and then lowered to 271.5 meters where the tool was stopped by new cavings. The hole was then logged to 195.5 meters, after which the tool was lowered to 265.5 meters and the section logged open-hole to the bit. The tool was then withdrawn into the pipe and returned to the surface without incident.

On the final logging run, conducted after completion of the oblique seismic experiment, the temperature probe was pumped down to within 5 meters of the mudline and then lowered without pumping past the end of the pipe into the sediment fill in the bottom of the hole at 238.5 meters. Thus the temperature was logged in the pipe from about the mudline to a point 8 meters below the top of the basement depth of 238.5 meters. After the temperature of the sediments had been monitored for about 10 minutes, the tool was returned to the surface.

Data from all of the logging runs described above (except for the sonic velocity and variable density logs which were of poor quality due to lack of centralization) are shown in Figure 5. From an examination of the logs, the following conclusions can be drawn concerning the nature of the section:

1) Although the downhole temperatures recorded on the first logging run were clearly depressed by seawater introduced during pumping (the temperature at the base of the hole increased from 22° to 29°C over a period of ten minutes during the static test), the temperature of the sediment fill remained unchanged at 36.5°C for 10 minutes during the second run, suggesting that the base of the hole had reached or was approaching thermal equilibrium, even though the temperatures in the uppermost basalts were still perturbed by seawater.

2) As in Hole 483, the combined gamma density-natural gamma log proved invaluable for bed definition. Although the logs indicate a total sediment thickness of 97.9 meters below the uppermost basalt/sediment contact (versus 85 meters of basalt), the total duration of igneous activity at or near the site after the formation of the underlying crustal sequence cannot be clearly established from accumulation rates because the pillow sequence was never reached.

3) The caliper log indicates that the sediments interlayered in basement were for the most part washed out beyond the limits of the tool. Thus the density data shown for most of the sediments in the section cannot be used quantitatively. The only exception to this appears to be in the sediments below 294.5 meters, in the sediments immediately adjacent to (protected by?) the basalts, and in the basalts themselves; in these specific cases, the density values are in good agreement with laboratory values. The symmetry of the high density sediments adjacent to the basalts is an interesting phenomenon in itself, incidentally, in that it may reflect baking or localized diagenesis.

4) The porosity data, like the density data, are only in reasonable agreement with the laboratory data in zones displaying relatively little washout. Nonetheless the low porosities observed in several of the basalt units indicate that the crack porosity of the basalts is low. The formation porosity in the vicinity of Section 23-3, for example, is identical to the laboratory value (3%) measured in a sample from a continuous, two-foot long core from the same interval.

5) As in Holes 482C and 483, the basalts from several intervals in Hole 485A show anomalously high natural gamma ray counts. Since the phenomenon was only observed when the natural gamma tool was run in conjunction with the gamma-neutron tool, it is probably due to neutron activation of altered basalts.

DISCUSSION AND CONCLUSIONS

The sections logged on Leg 65 consisted of 110 to 153 meters of rapidly deposited silty clays and turbidites underlain by interlayered massive basalts, pillow basalts, and sediments. Since the sediments overlying the basalts were generally unconsolidated, only the intervals below the uppermost sediment/basalt contacts were logged open-hole to prevent caving. As a consequence, the only logs which can be used quantitatively are those obtained in the basement.

As can be seen in Figures 3, 4, and 5, the logs obtained in Holes 482C, 483, and 485 are nearly ideal for bed-resolution studies: The basalts display markedly higher density and resistivity values and lower caliper, natural gamma, and porosity values than the sediments. In general, the logs are consistent with the results of coring but allow the thicknesses of the units to be defined with greater precision since the drill recovery was low. The only major discrepancy occurs in Hole 485A where the logs failed to confirm the existence of a thin basalt layer (Unit 3) defined on the basis of recovery between 195.8 and 201 meters sub-bottom. Although the density log shows two narrow spikes in this interval, the lack of a response on the resistivity log indicates that the basalt is volumetrically insignificant and may simply be the result of caving from above.

The logs also allow a clear distinction between massive and pillow basalts. As can be seen in Figure 4, the massive basalts typically display a high, relatively uniform formation density of 2.85 g/cm^3, whereas the density of the pillow basalts varies erratically between 2.3 and 2.9 g/cm^3 in response to the presence of interpillow voids.

One of the most interesting and unexpected features of the Leg 65 logs is the high natural gamma count observed in the basalts near the top of the basement in all three holes. Although this was originally thought to result from the presence of U, K, or Th introduced during alteration, it is more likely due to neutron activation since the phenomenon only appeared when the neutron and natural gamma ray tools were run together. The elements activated remain unknown but are still assumed to be associated with alteration since in one instance (the massive basalt between 244 and 271 meters sub-bottom in Hole 485A) the high gamma counts are only observed in the upper half of the unit.

Although the sediments interlayered in the basement were generally too washed out either for recovery or quantitative logging (the caliper was fully extended), the sediments immediately overlying and underlying the basalts were often preserved, particularly toward the base of Hole 485A. Although the increase in preservation with depth may be the result of consolidation (the sediments become increasingly hard with depth and increase in density from 1.75 to 2.05 g/cm^3), the preservation against the basalts, particularly along the upper surfaces, would appear to result from baking or at least diagenesis against intrusions.

Finally, and most importantly, those logs obtained from Hole 483 make it possible to place constraints on the duration of late-stage volcanism at individual sites in the ocean basins. If it is assumed that all of the basalts observed are extrusive and that the deepest sediments in the section were drilled, then the thickness of interlayered sediments determined by logging (30.7 m) together with the average sediment accumulation rate determined for the overlying sediments (62 m/m.y.) suggest that volcanism continued at or near the site for at least 490,000 years after the bulk of the crust had been formed.

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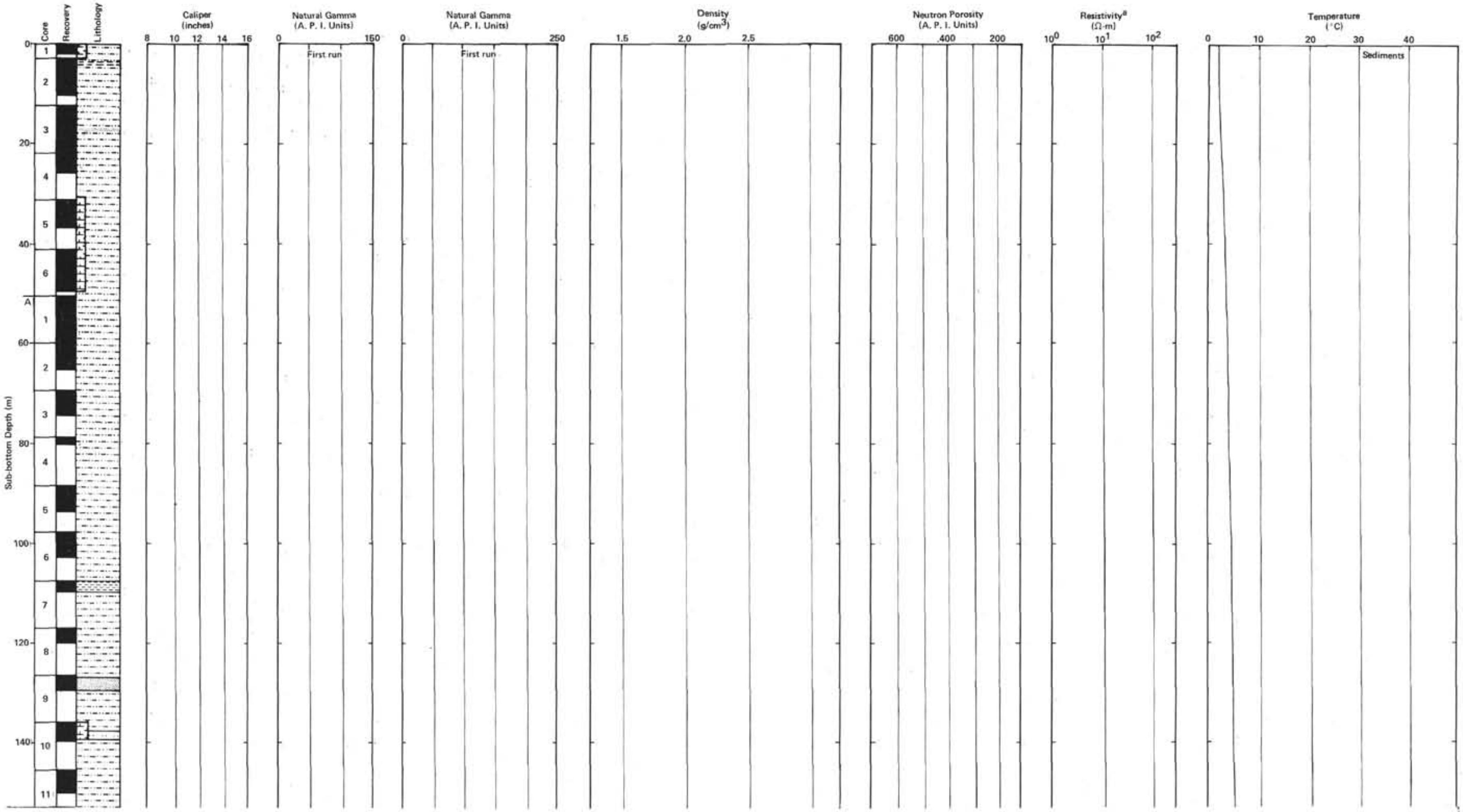
Core
Recovery
Lithology
Sub-bottom Depth (m)
0
20
40
60
80
100
120
140
A
Caliper (inches)
8 10 12 14 16
Natural Gamma (A. P. I. Units)
0 150
First run
Natural Gamma (A. P. I. Units)
0 250
First run
Density (g/cm3)
1.5 2.0 2.5
Neutron Porosity (A. P. I. Units)
600 400 200
Resistivity (Ω-m)
10^0 10^1 10^2
Temperature (°C)
0 10 20 30 40
Sediments

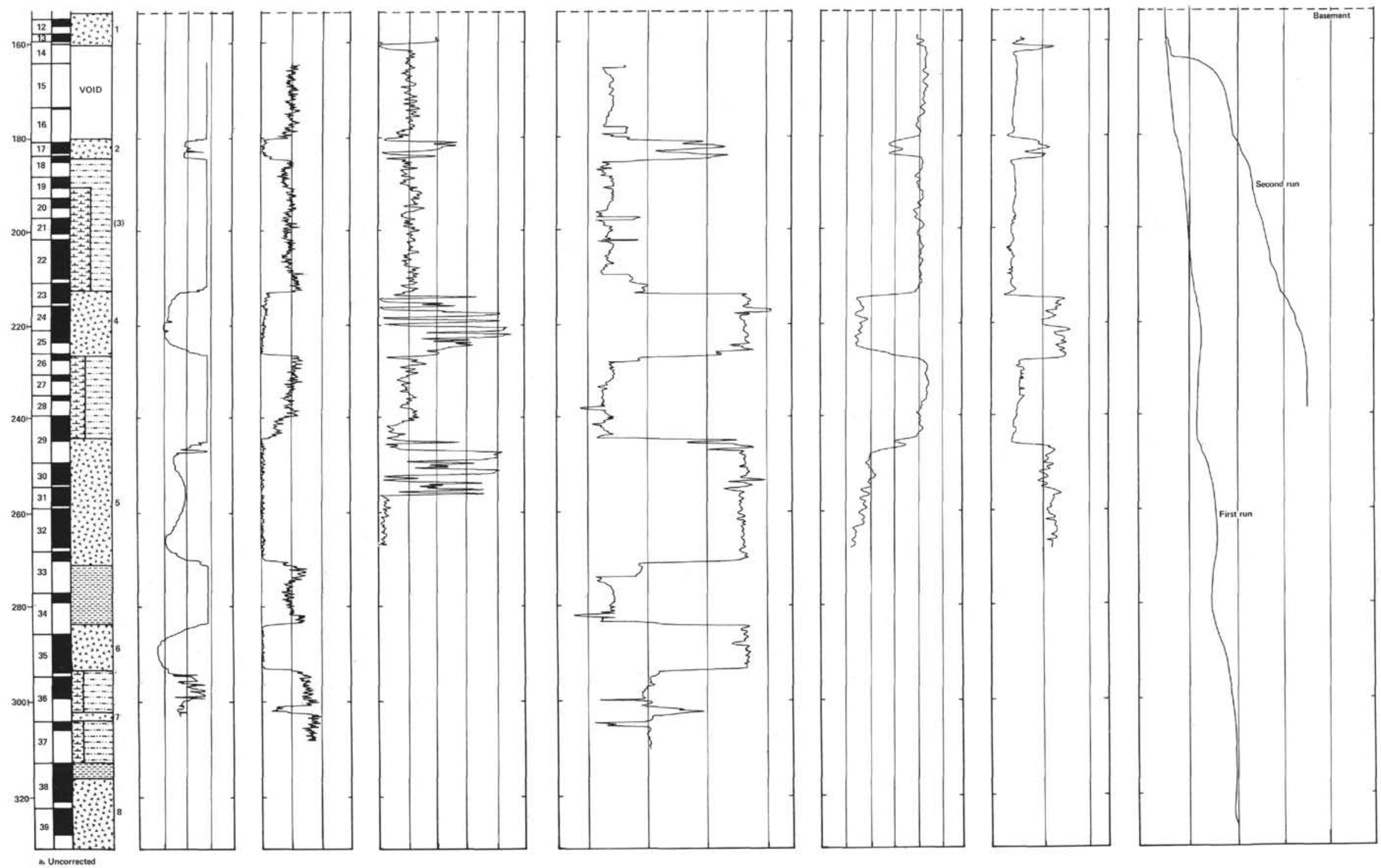

Figure 5. Comparison of lithology and downhole geophysical logs from Hole 485A. See Explanatory Notes (this volume) for definition of lithologic symbols.