Moore, J.C., Klaus, A., et al., 1998
Proceedings of the Ocean Drilling Program, Initial Reports, Vol. 171A

7. SITE 1048[1]

Shipboard Scientific Party[2]

HOLE 1048A

Position: 15°32.0284′N, 58°40.5800′W

Date occupied: 2115 5 January 1997

Spud hole: 0100 6 January 1997

End hole: 0300 7 January 1997

Time on hole: 1 day, 5 hr, 45 min

Seafloor depth (drill-pipe measurement from rig floor, m): 5064

Distance between rig floor and sea level (m): 11.0

Water depth (drill-pipe measurement from sea level, m): 5053

Total depth (from rig floor, m): 5401

Penetration (m): 337

Total core recovered (m): 0

Comments: Logging while drilling (LWD). No coring done. Seafloor depth identified from LWD data.

Principal results: Site 1048 was drilled into the sedimentary section incoming to the northern Barbados accretionary prism at 2.1 km east of the deformation front and 3.8 km west-southwest of collocated Sites 672 and 1044. At Site 1048, LWD gamma-ray, resistivity, density, caliper, photoelectric effect, and neutron porosity logs were acquired from the surface to 337 m below seafloor (mbsf) across the proto-décollement zone. Excluding neutron porosity, all logs are of excellent quality.

Traditional visual and multivariate statistical analyses define four log units (Fig. 1) that can be lithologically interpreted by correlation with Site 672. Log Unit 1 (0–105 mbsf) is characterized by increasing density, resistivity, and photoelectric effect with depth. These log signatures are consistent with a normally compacted, carbonate-rich lithologic unit that occurs from 0–123 mbsf at Site 672. Log Unit 2 (105–187 mbsf) shows a general decrease with depth in resistivity, density, photoelectric effect, and gamma-ray values. Comparison with Site 672 suggests that these log responses probably signify a downhole transition to an increasingly underconsolidated clay-rich unit. An interval of very low density values and low resistivity, photoelectric effect, and gamma-ray values defines log Unit 3 (187–207 mbsf). This interval probably correlates with a lower Miocene radiolarian mudstone that lies in the proto-décollement zone at Site 672. Log Unit 4 (207–324 mbsf) is characterized by increases in the density, gamma-ray, and photoelectric effect values. The spiky nature of the logs suggests interbedding of contrasting lithologies and correlation with the muddy turbiditic unit beneath the proto-décollement zone at Site 672.

Comparison of the logs from Site 1048 with the more seaward reference Site 1044 shows good correlation, but a slightly thicker section exists at Site 1048. A synthetic seismogram generated from the density log reproduces well the shape and amplitude of the negative polarity reflection from the proto-décollement zone. The location of the proto-décollement zone occurs slightly higher in the upper reflective seismic unit than at Site 1044; thus, the basal surface of this seismic stratigraphic unit is time transgressive. The most important result from Site 1048 is confirmation of the ultra-low-density nature of the proto-décollement zone, with implications for localizing the detachment as the accretionary prism forms to the west.

BACKGROUND AND OBJECTIVES

Site 1048 is on the northern flank of the Tiburon Rise about 2.1 km east of the deformation front and about 3.8 km west-southwest of collocated Sites 672 and 1044 (Fig. 2). Seismic Line 723 through Site 1048 shows the same four seismic units identified at Site 1044, although the units are thicker at Site 1048 (Fig. 3). Site 672 was drilled as an undeformed reference locality to gauge changes in the sedimentary section caused by accretion or underthrusting observed at other Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) sites to the west. Surprisingly, the structural and geochemical anomalies suggest that the section at Site 672 was disturbed by the encroaching accretionary prism (Shipboard Scientific Party, 1988a). Nevertheless, Site 672 provides valuable baseline information on the nature of the sedimentary section that can be compared with the logs at Sites 1044 and 1048.

Good correlation with the 3-D seismic reflection survey allows the extrapolation of information from Site 672 to logs acquired at Site 1048. Cores at DSDP Site 543, located 18 km north on the oceanic plate (see "Faulting, Fluid Flow, and Seismic Imaging of the Northern Barbados Subduction Zone" chapter, this volume; Fig. 1, "Introduction" chapter, this volume), provide clues to the nature of the lower Eocene to Cretaceous part of the section that was not penetrated at Site 672 (Shipboard Scientific Party, 1984). The sedimentary section beneath Site 672 is about 650 m thick and overlies oceanic crust of probable Cretaceous age. The uppermost Pleistocene to lower Miocene hemipelagic unit extends to about 200 mbsf and is equivalent to the section that is incorporated in the accretionary prism. This upper 200-m section correlates with seismic Unit 1 of moderately continuous reflectors. The proto-décollement zone occurs at about 200 mbsf and shows no deformation at the resolution of the seismic data. Below the proto-décollement zone, upper Oligocene to middle Eocene units consist of alternating muddy and calcareous lithologies, with sandstone and siltstone interbeds indicative of terrigenous input. Lower middle Eocene to Cretaceous rocks are siliceous, calcareous, and clay-rich pelagic deposits that overlie pillow basalt.

The principal questions addressed at Site 1048 are these:

1. What is the log signature of the proto-décollement zone? How does the log signature of the proto-décollement zone compare with equivalent intervals at Site 1044 farther seaward and with Sites 1045, 1046, and 1047 within the accretionary prism?
2. What are the overall physical properties, especially porosity, of the incoming section? Equivalents of this sequence are the sources of fluids being expulsed from the accretionary prism and underthrust sequence. Moreover, the effects of the encroaching accretionary prism may have induced a gradient that can be observed by comparison of the physical properties at Sites 1044, 1048, and 1047.

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[1]Moore, J.C., Klaus, A., et al., 1998. *Proc. ODP, Init. Repts.,* 171A: College Station, TX (Ocean Drilling Program).

[2]Shipboard Scientific Party is given in the list preceding the Table of Contents.

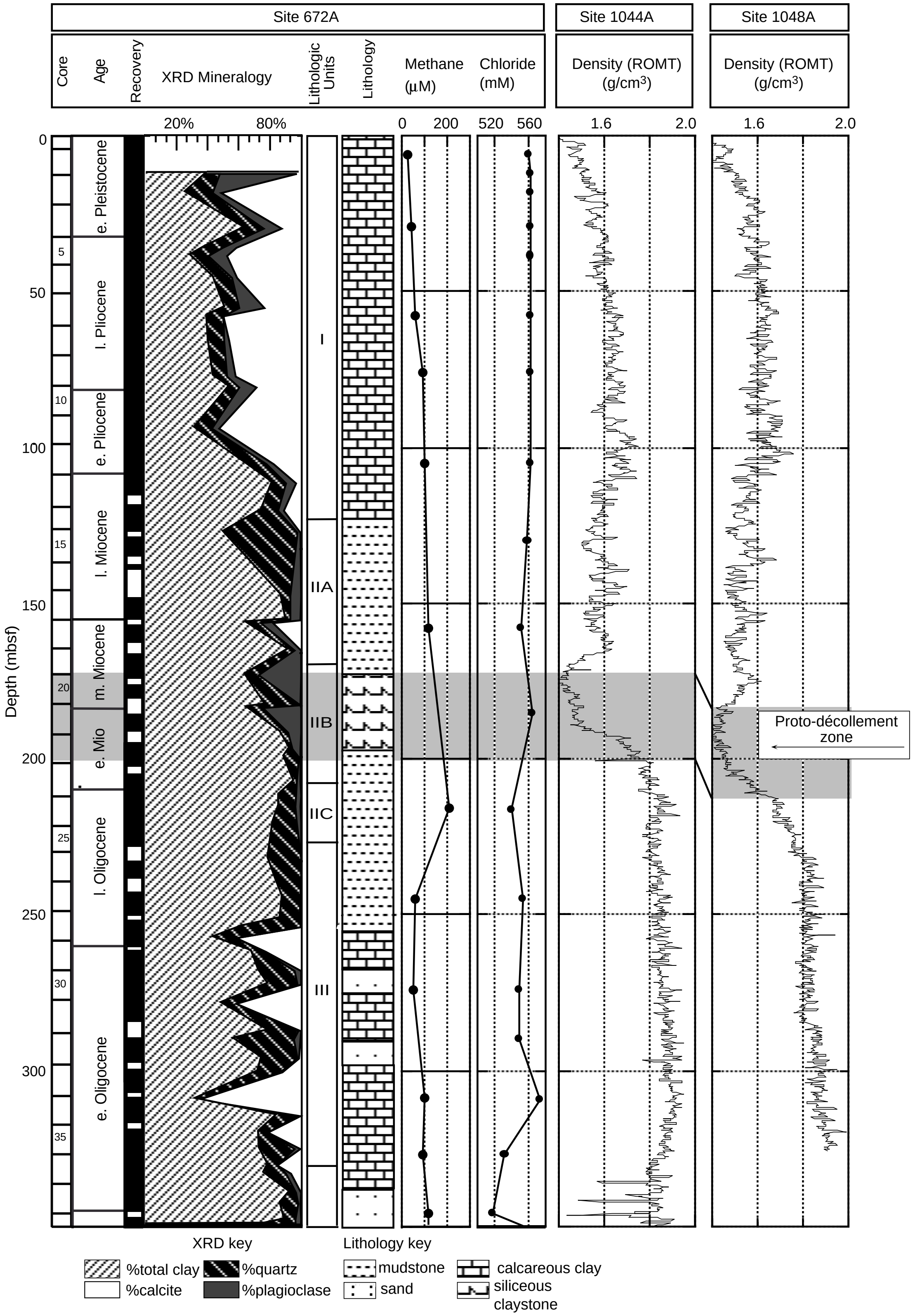

Figure 1. Summary of log data from Site 1048 compared with core data from Site 672 and the density curve from Site 1044. Log units for Site 1048 are shown beside the lithologic units for Site 672. The shaded bar represents the proto-décollement zone, as inferred from cores at Site 672 and projected onto logs at Site 1044. The log signature from Site 1044 is then used to identify the probable depth of the proto-décollement zone at Site 1048, shown here by the shaded bar.

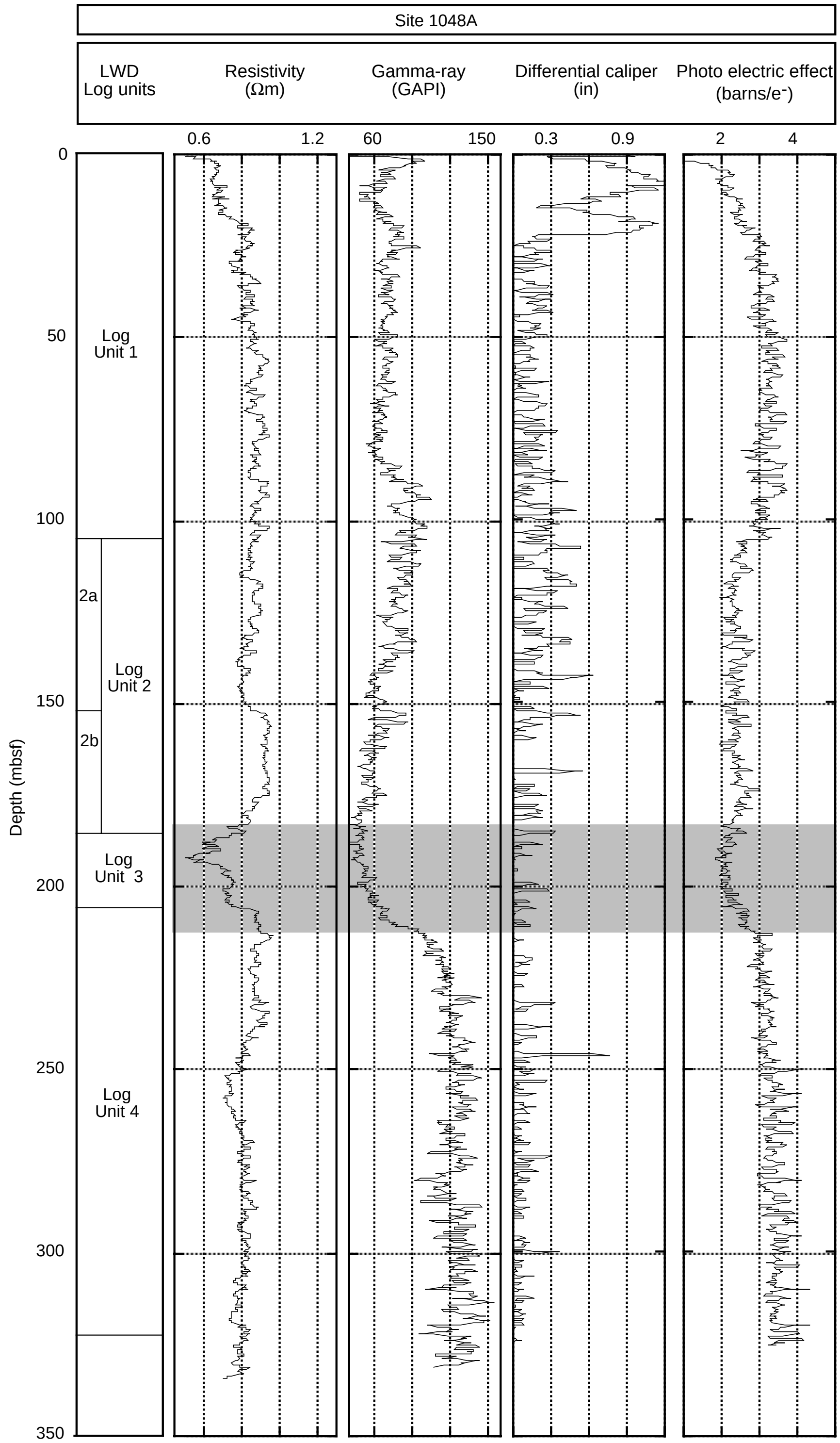

Figure 1 (continued).

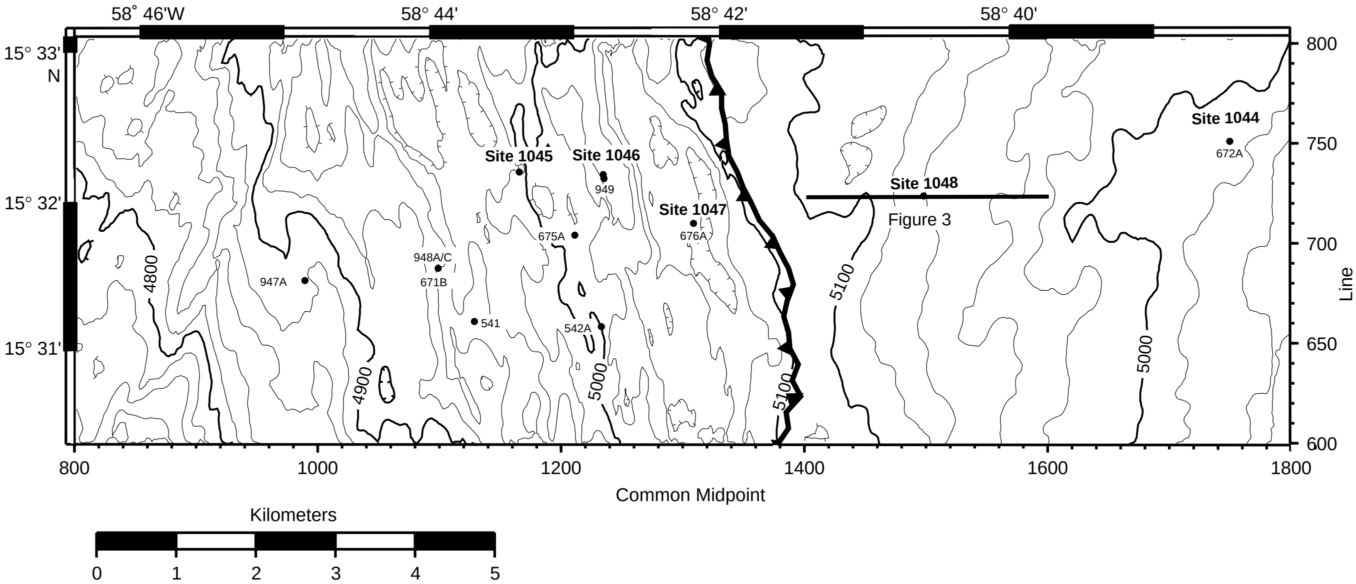

Figure 2. Bathymetric location map for Site 1048 in the Leg 171A drilling area and for previous ODP and DSDP holes in the northern Barbados accretionary prism.

3. How do the observed physical properties determined from LWD account for the seismic reflection signature of this well-imaged incoming sedimentary section?

OPERATIONS

Hole 1048A

The drill string was pulled two stands above the seafloor, and the vessel was offset in dynamic positioning mode at a speed of 2 kt/hr from Hole 1047A to Site 1048. LWD Hole 1048A was located at Global Positioning System (GPS) coordinates 15°32.0284′N, 58°40.5800′W. Hole 1048A was spudded at 0100 hr, 6 January 1997. Drilling was initiated at 35 m/hr at a water depth of 5060 m below rig floor (mbrf), based on the precision depth recorder (PDR) reading. The actual water depth was established at 5064 mbrf (5053 m below sea level [mbsl]), based on analysis of the LWD data.

Drilling continued at 35 m/hr without incident to 5401 mbrf (337 mbsf). When the time allocated for the Leg 171A drilling operations had expired, the drill string was pulled out of the hole. The bit cleared the seafloor at 1830 hr on 6 January 1997. During the pipe trip, the beacon was released and recovered. The vessel was then offset in dynamic positioning mode back to Site 1047, where the beacon from 1047A was released and recovered. The trip continued to the surface, where the nuclear sources were removed, the LWD data from Holes 1047 and 1048 were downloaded, and the LWD collars were laid out. The bit cleared the rotary table at 0300 hr on 7 January 1997 to end Hole 1048A.

While the drill collars were being laid out and secured for transit, the vessel continued offsetting in dynamic positioning mode to Site 1046, where the beacon used at Sites 1046 and 1045 was released but failed to surface. The thrusters and hydrophones were raised, and the vessel was under way to Bridgetown, Barbados, at 1000 hr, 7 January 1997.

Transit From Hole 1048A to Bridgetown, Barbados

The transit to Bridgetown was completed in mild weather and calm seas. Arrival at the anchor buoy outside the Bridgetown harbor was timed to coincide with the scheduled time of 0600 hr, 8 January. Leg 171A officially ended with the first line ashore at 0700 hr, 8 January 1997.

CHARACTERIZATION OF LOGS

Description of Unit Boundaries

The log data, with the log units labeled, are shown in Figure 4. Four log units and several subunits were defined through a combination of visual interpretation and multivariate statistical analysis (Fig. 5; see “Explanatory Notes” chapter, this volume).

Three factors were extracted from the deep resistivity, gamma-ray, thorium, potassium, photoelectric effect, bulk density, and neutron porosity logs. The three factors explain 89% of the variance contained in the data. The cluster analysis shows four prominent clusters. Table 1 summarizes the mean values and standard deviations of the log properties by cluster, each of which shows a distinct set of physical properties. Figure 5 shows the calculated cluster log, together with the log units, gamma ray, and density.

Log Unit 1 (0–105.4 mbsf) is defined at its base by increases in the photoelectric effect and density logs of 0.5 barns/e^- and 0.25 g/cm^3, respectively. There is a positive shift within Unit 1 in the resistivity and gamma-ray logs at 90 mbsf (Figs. 4, 5).

Log Unit 2 (105.4–186.5 mbsf) has a relatively constant density (mean of 1.57 g/cm^3 and standard deviation of 0.62 g/cm^3) and photoelectric effect (mean of 2.6 barns/e^- and standard deviation of 0.4 barns/e^-) and a decreasing gamma-ray trend. The base of Subunit 2a (105.4–152.5 mbsf) is located at the bottom of a decreasing gamma-ray trend, and the base of Subunit 2b (152.5–186.5 mbsf) occurs at the bottom of a second decreasing gamma-ray trend. The Unit 2/3 boundary also represents a decrease in the resistivity log.

Log Unit 3 (186.5–206.5 mbsf) is a zone of low resistivity (mean of 0.69 Ωm for the deep resistivity), bulk density (mean of 1.46 g/cm^3), and photoelectric effect (mean of 2.2 barns/e^-). The base is located at a positive resistivity shift of 0.2 Ωm. Gradual increases in gamma ray, bulk density, and photoelectric effect also occur at the Unit 3/4 boundary.

Log Unit 4 (206.5–323.9 mbsf) is characterized by high gamma-ray, density, and photoelectric effect mean values of 123 GAPI, 1.82 g/cm^3, and 3.3 barns/e^-, respectively.

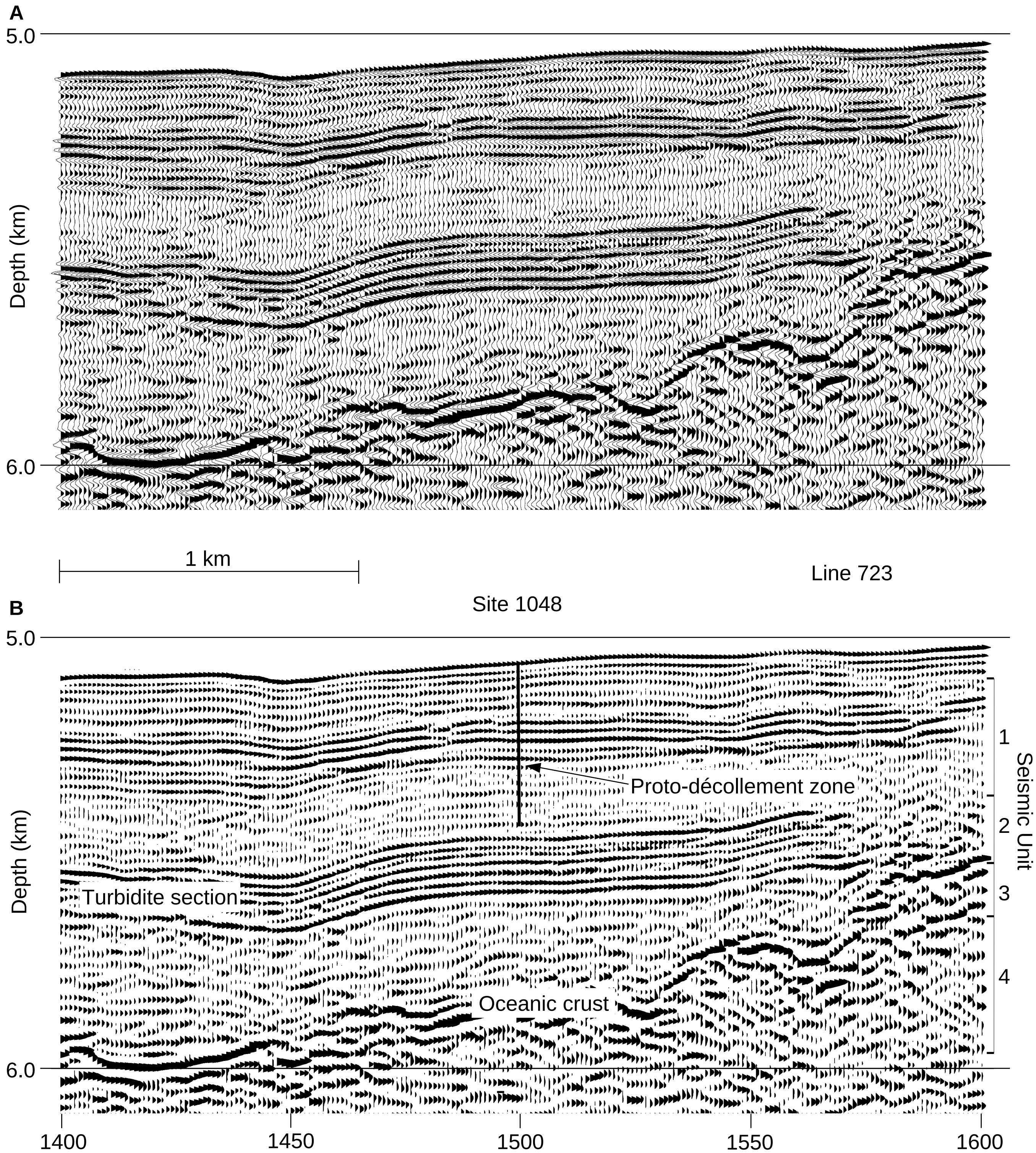

Figure 3. (**A**) Uninterpreted and (**B**) interpreted seismic Line 723 through Site 1048 (see Fig. 2 for location). Black is positive polarity; white is negative polarity.

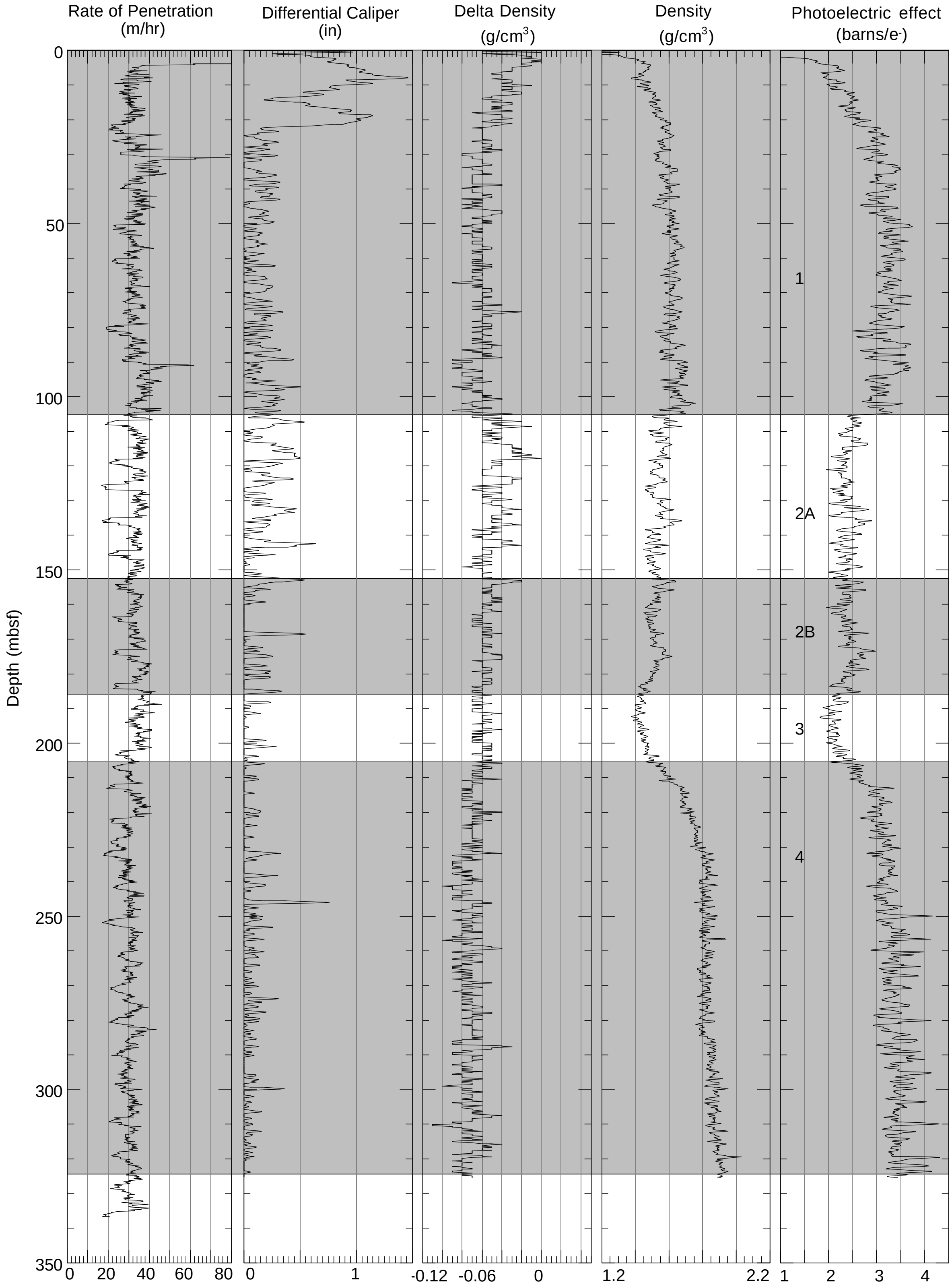

Figure 4. Site 1048 LWD data and the log units. Post-cruise processed log data are available on CD-ROM (back pocket, this volume).

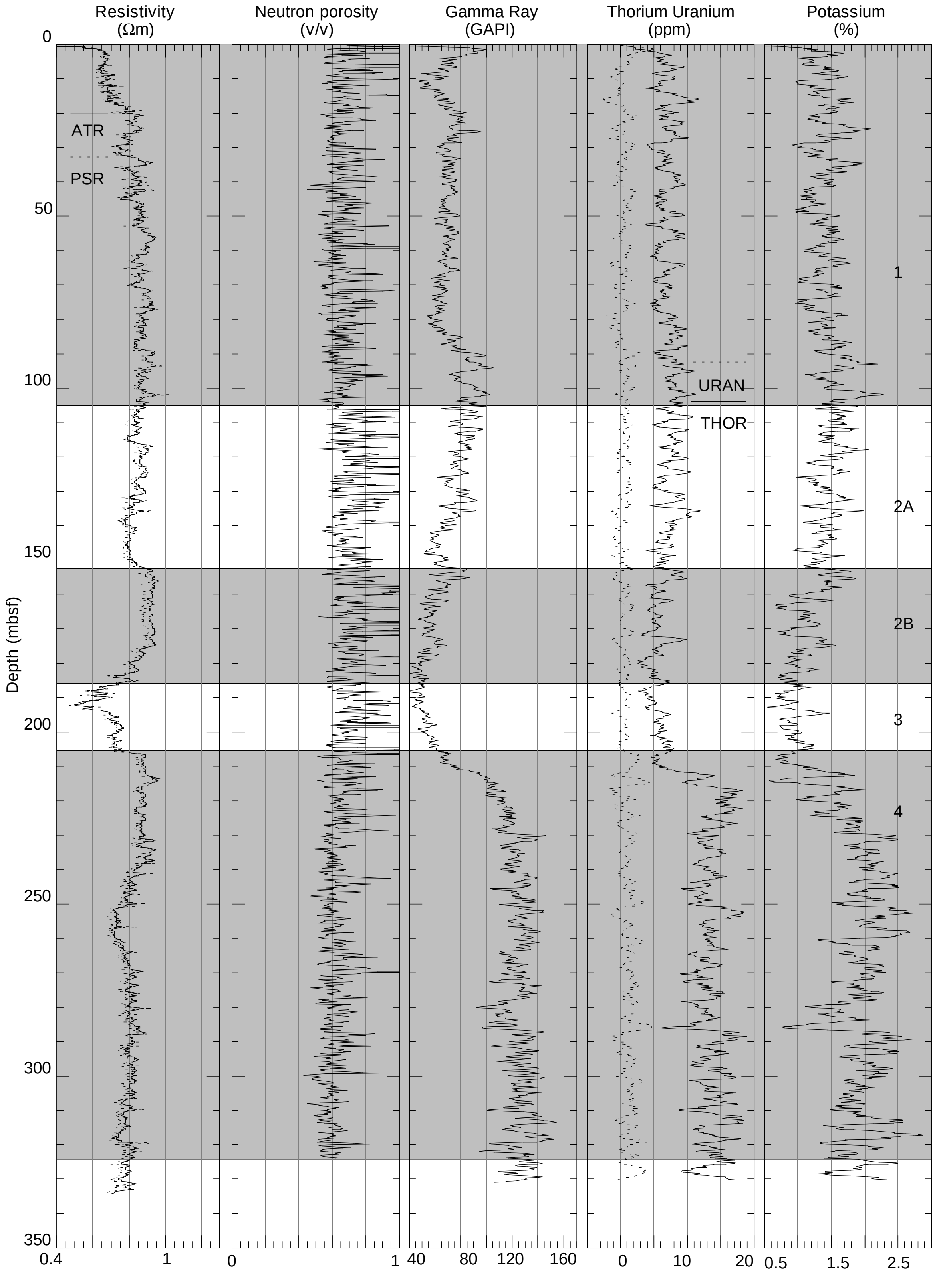

Figure 4 (continued).

Table 1. Mean values and standard deviations of the log properties according to each cluster for Hole 1048A.

	ATR (Ωm)		GR (GAPI)		THOR (ppm)		POTA (%)		PEF (barns/e⁻)		ROMT (g/cm³)		TNPH (v/v)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All	0.83	0.07	87.6	28.6	9.2	3.7	1.53	0.43	2.9	0.5	1.651	0.142	0.66	0.07
Cluster 1	0.69	0.06	55.0	7.4	6.2	1.7	1.07	0.27	2.2	0.2	1.464	0.04	0.7	0.07
Cluster 2	0.89	0.05	73.1	13.6	7.2	1.9	1.38	0.29	2.6	0.4	1.567	0.062	0.74	0.07
Cluster 3	0.85	0.04	70.7	12.6	7.0	1.7	1.35	0.25	3.0	0.4	1.591	0.08	0.64	0.04
Cluster 4	0.82	0.05	123.0	10.9	13.6	2.1	1.96	0.32	3.3	0.2	1.818	0.057	0.62	0.05

Notes: SD = standard deviation. ATR = deep resistivity; GR = gamma ray; THOR = thorium; POTA = potassium; PEF = photoelectric effect; ROMT = density (rotationally processed); TNPH = thermal neutron porosity.

LWD Log Quality

For Hole 1048A, a target rate of penetration (ROP, 1.5 m averaged) of 35 m/hr was chosen because we concluded that the spectral gamma-ray data collected by the natural gamma-ray tool (NGT) at 30 to 40 m/hr penetration rates are reliable in Hole 1044A (see "Characterization of Logs" section, "Site 1044" chapter, this volume). A ROP of ~35 m/hr was maintained throughout Hole 1048A (Fig. 6).

The differential caliper values in Hole 1048A show standoffs of <1 in, except for intervals at 5–8 mbsf (up to 1.46 in) and 9–10 mbsf (1.15 in). The only significant washouts occur during the interval at 0–22 mbsf. Overall, borehole conditions are excellent; 98.2% of the hole showed a differential caliper of <1 in, 93.3% showed values <0.5 in, and 34.1% showed a value of 0 in. The bulk density correction (DRHO) varies from –0.11 to 0 g/cm^3, indicating the high quality of the density measurements that were obtained. Time-after-bit (TAB) measurements are 5–30 min for resistivity and gamma-ray measurements, and 20–50 min for density and neutron porosity measurements.

LOGS AND LITHOLOGY

Drilling east of the deformation front at Site 1048 penetrated 337 m of undisturbed hemipelagic and turbiditic sediments. This section may be correlated with the upper 312 m of reference Site 1044, which includes the top four lithologic units defined at Site 672 (Fig. 7). For a summary of the lithologic units at Site 672 see the "Logs and Lithology" section, "Site 1044" chapter, this volume.

Correlation With Log Units

Log Unit 1 correlates with the calcareous clays and marls of lithologic Unit I at Site 672. The base of this log unit is defined by an abrupt decrease in the density and photoelectric effect logs, which corresponds to the abrupt decrease in calcite observed in X-ray-diffraction (XRD) analyses at Site 672. Relatively low gamma-ray values in the upper part of this interval also suggest high carbonate content. The large increase in gamma ray at about 90 mbsf, which is driven by a slight increase in both thorium and potassium, is also indicative of high clay or ash content.

Log Subunit 2a is defined by decreasing gamma-ray values and low density and photoelectric effect values. This unit correlates with the claystones of lithologic Unit IIA. The decrease in gamma-ray values in this interval may be related to a decrease in ash content, which is apparent in the core data for this unit at Site 672. The transition from Subunit 2a to Subunit 2b is characterized by a stepwise increase in resistivity; however, there is no obvious correlation between this shift and a lithologic change.

Log Unit 3 corresponds to the décollement zone. The gamma-ray and photoelectric effect logs show their lowest values over the entire section within this interval, suggesting a correlation with the siliceous claystone found at this level at Site 672.

Log Unit 4 correlates with the upper part of a thick interbedded sequence. The equivalent lithostratigraphic interval at Site 672 is characterized by claystones, with silt and carbonate interlayers increasing downsection. The increasing photoelectric effect values through log Unit 4 are also an indication of increasing carbonate content. The spiky variability in the logs, particularly in the lower part of this interval, suggests meter- to submeter-scale bedding.

LOGS AND STRUCTURE

Drilling in Hole 1048A penetrated 335 m of the incoming sedimentary section. Although the site was chosen for its lack of apparent structural features on the seismic reflection data, small-scale features similar to those observed at Site 1044 may occur at this site. The LWD log data contain no patterns indicative of structural features.

LOGS AND PHYSICAL PROPERTIES

In this section, the downhole variability of the rotationally processed density, photoelectric effect, and deep and shallow resistivity logs is discussed and compared with the physical properties data at Site 672 and with the logs at Site 1044.

Density

In the uppermost 110 m, the downhole density profile in Hole 1048A (Fig. 8A) is identical to the density profile in Hole 1044A, delineating a normal consolidation trend, which is also described for Site 672 (Shipboard Scientific Party, 1988b). The interval from about 100 to 170 mbsf is characterized by scattered density values between 1.45 and 1.68 g/cm^3 and an unclear trend with depth, with an average density of 1.53 g/cm^3. The estimated proto-décollement zone, an interval of very low density, includes log Unit 3 (187–207 mbsf). The density pattern across this zone and the zone below (207–230 mbsf) shows good agreement with the one observed in Hole 1044A (see "Comparison of the Décollement Zone at Sites 1044 and 1048," this section). From 230 mbsf to total depth, the normal downhole consolidation trend matches that detected in Hole 1044A.

Photoelectric Effect

As expected, the characteristics of the photoelectric effect downhole profile closely match the trends observed in the density log (Fig. 9). Therefore, the divisions defined for the density log also apply to the photoelectric effect log.

Resistivity Logs

The resistivity trend above the proto-décollement zone at Site 1048 is similar to the resistivity trend above the décollement zone at Sites 1046 and 1047 (Fig. 8B). There is a gradual increase to about 0.9 Ωm at 100 mbsf in log Unit 1, followed by a slight decrease to 0.8 Ωm in log Subunit 2a. The resistivity increases to 0.9 Ωm immediately above the proto-décollement zone (log Subunit 2b) and then decreases abruptly to as little as 0.5 Ωm in the proto-décollement zone (log Unit 3). The resistivity varies from ~0.68 to 0.97 Ωm in the upper portion of log Unit 4 and then varies only slightly around 0.8 Ωm

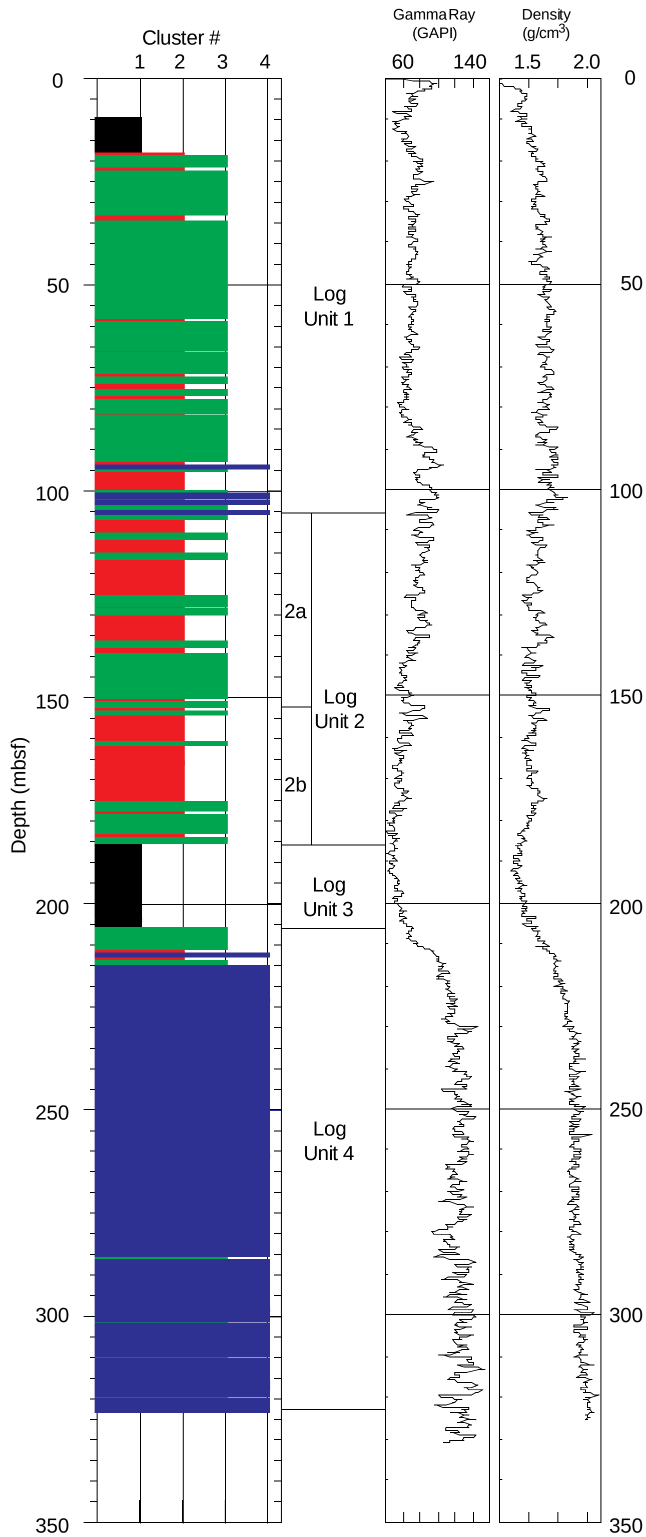

Figure 5. Definition of log units for Site 1048. Four clusters were derived from three factor logs that account for 88% of the total variance observed in the data. Boundaries between first-order log units correspond to changes in log character related primarily to lithology that are clearly visible on the logs (e.g., gamma ray, density, photoelectric effect, and resistivity). Second-order units represent subtle changes in log character that are observed in only a few curves and that may not be related to lithology.

below 270 mbsf. The resistivity trend does not closely resemble the character of the bulk density or gamma-ray trend below the décollement zone.

The deep and shallow resistivity curves are generally similar, with a few noteworthy exceptions. The most prominent separation occurs between 155 and 175 mbsf, where the deep resistivity is about 0.06 Ωm greater than the shallow resistivity. Smaller separations of about 0.02 Ωm, with the deep resistivity systematically higher than the shallow resistivity, include the intervals at 120–155 and 205–230 mbsf.

Comparison of the Proto-Décollement Zone at Sites 1044 and 1048

To better define the physical properties of sediments coming into the subduction zone, the density and resistivity logs from the décollement zone at Site 1048 were compared with those at Site 1044 (Fig. 10). Because no core data were obtained at Site 1048, correlation with the reference site was made visually. The top of the proto-décollement zone is at ~170 mbsf at Site 1044 and at ~185 mbsf at Site 1048 (approximately the top of log Unit 3). In general, the densities and resistivities of the proto-décollement zone at Site 1048 are similar to those at reference Site 1044. There is a slight difference in density from 205 to 230 mbsf in Hole 1048A (190–215 mbsf in Hole 1044A), but this may be an artifact of depth-shifting or lithologic change between the two sites.

Summary

1. The density, resistivity, and photoelectric effect logs are very similar to those from the reference site (Site 1044), which was also seaward of the deformation front.
2. In particular, the log signatures of the proto-décollement zone at the two sites are almost identical.

LOGS AND INDICATORS OF FLUID FLOW

At Site 1048, LWD was used to collect continuous data through the proto-décollement zone at a location between reference Site 1044 and the deformation front. Because this site was not previously cored, no chemical or thermal data are available. The proto-décollement zone in Hole 1048A was compared to that in Hole 1044A. The top of the proto-décollement zone, as defined by log Unit 3 in Hole 1048A, is ~20 m deeper than that in Hole 1044A. The density, resistivity, and lithologic indicator logs show similar profiles through the proto-décollement zone in both boreholes, suggesting similar effective stress conditions at the two sites. This indicates that, compared with Site 1044, there has been no significant consolidation of the proto-décollement zone sediments at Site 1048. The implication is that because Site 1044 is buried deeper than Site 1048, greater excess pore pressure exists along the proto-décollement zone at Site 1048 than at Site 1044. The low densities along the proto-décollement zone may lead to higher permeabilities along this zone compared with the surrounding sediments. Thus, the continued underconsolidation of the proto-décollement zone at Site 1048 suggests that the proto-décollement zone may be a continuous zone of high permeabilities that channels flow seaward from beneath the prism. That slightly greater densities are observed directly below the proto-décollement zone in Hole 1048A than in Hole 1044A may be a reflection of differences either in consolidation history or lithology.

LOGS AND SEISMIC DATA

We constructed a synthetic seismogram (Fig. 11) from the LWD density data using the same assumed linear velocity gradient that was

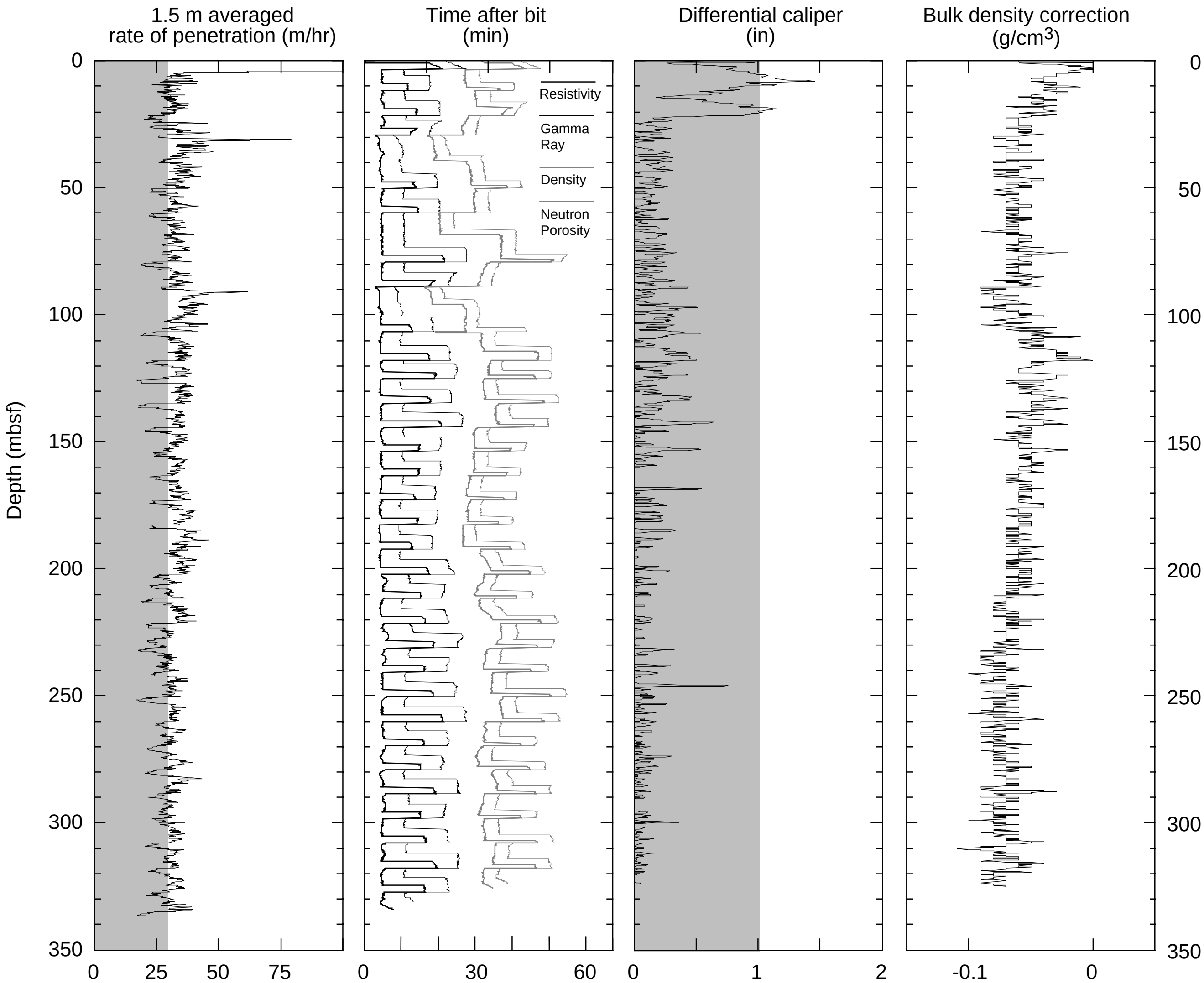

Figure 6. Summary of the quality-control logs. The shaded area in the ROP shows the reliable zone for NGT measurements according to industry experience. The shaded area in the differential caliper indicates good borehole conditions.

used in constructing the synthetic seismogram for Sites 1044 through 1047 (see “Explanatory Notes” chapter, this volume).

The LWD density data produce a synthetic seismogram that resembles the data reasonably well along most of the trace. The proto-décollement zone (shaded in Fig. 11) is part of a series of closely spaced reflections in the data. Although the data and synthetic trace show some differences in the upper part of this series at ~5200 mbsl, the LWD data indicate that the proto-décollement zone is a 25- to 30-m-thick, low-density interval centered at ~190 mbsf within the lower part of this reflection series. This low-density (1.4–1.45 g/cm^3) interval produces reflections that correlate reasonably well in amplitude, waveform, and traveltime, and the LWD density log appears to be a good indicator of the physical properties that produce the reflection at Site 1048. This proto-décollement zone reflection is slightly higher in the upper reflective sequence (seismic Unit 1; Fig. 3) than that at Site 1044.

REFERENCES

Shipboard Scientific Party, 1984. Site 543: oceanic reference site east of the Barbados Ridge complex. *In* Biju-Duval, B., and Moore, J.C., et al., *Init. Repts. DSDP,* 78A: Washington (U.S. Govt. Printing Office), 227–298.

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————, 1988b. Site 676. *In* Mascle, A., Moore, J.C., et al., *Proc. ODP, Init. Repts.,* 110: College Station, TX (Ocean Drilling Program), 509–573.

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NOTE: For all sites drilled, shore-based log processing data are available on CD-ROM. See Table of Contents for material contained on CD-ROM.

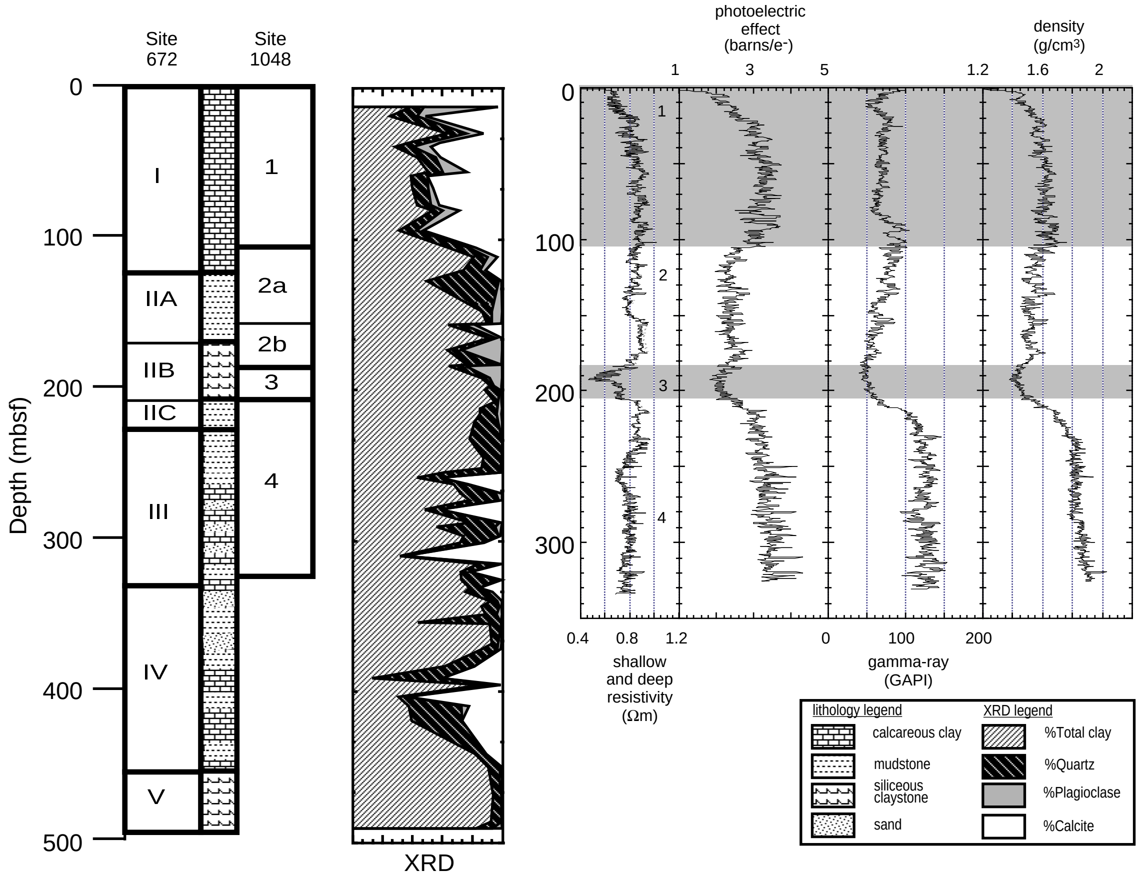

Figure 7. Summary of Site 1048 log units and Site 672 lithologic data, including XRD mineralogy. The lithology column summarizes the major lithologic units described for Site 672 (Shipboard Scientific Party, 1988a). Shaded areas in the log plot represent the extent of the major log units. The dark curve in the resistivity column is the shallow resistivity; the light curve is the deep resistivity.

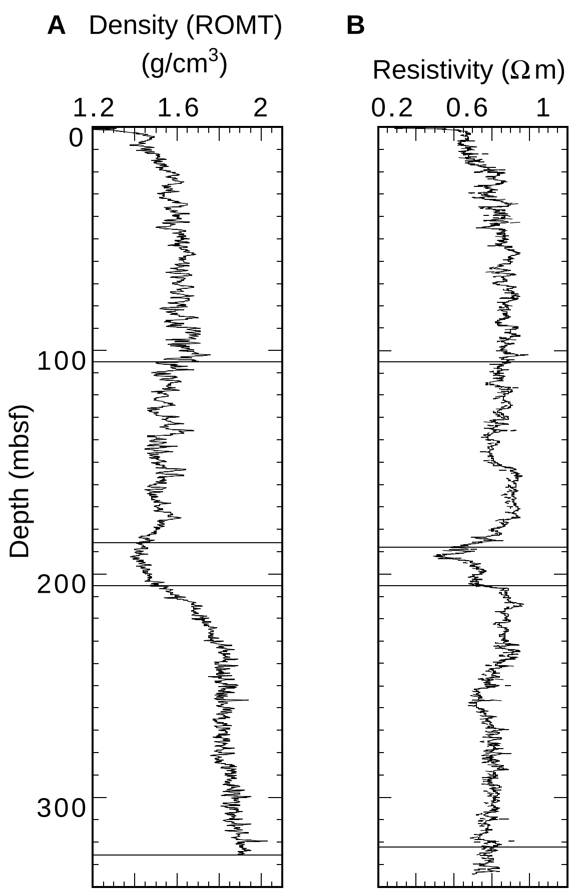

Figure 8. (**A**) Density and (**B**) resistivity vs. depth in Hole 1048A. Lines represent intervals discussed in the text (log unit boundaries). Dashed line = shallow resistivity.

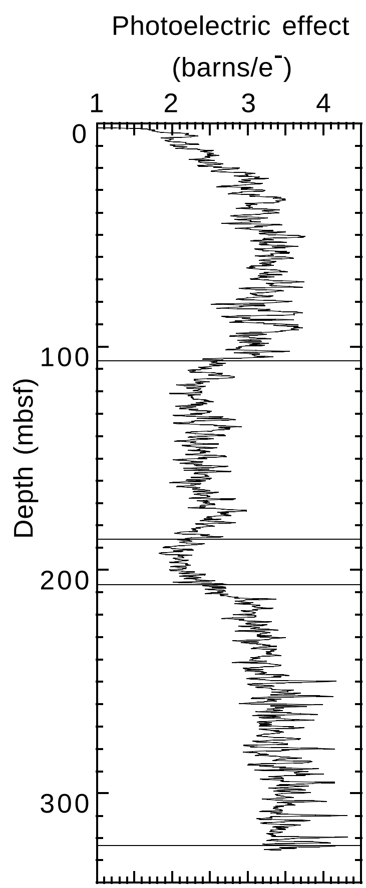

Figure 9. Photoelectric effect vs. depth in Hole 1048A. Lines represent intervals discussed in the text (log unit boundaries).

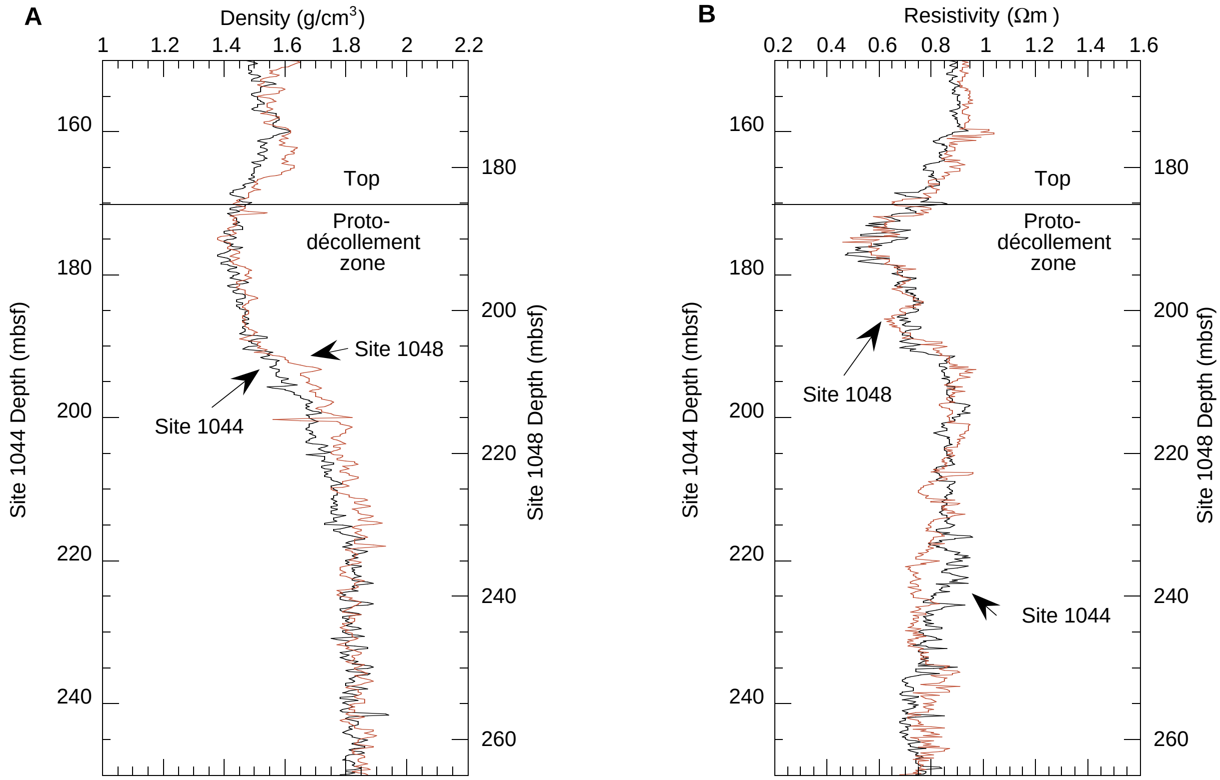

Figure 10. Comparison of (**A**) density and (**B**) resistivity across the décollement zone at Sites 1044 and 1048.

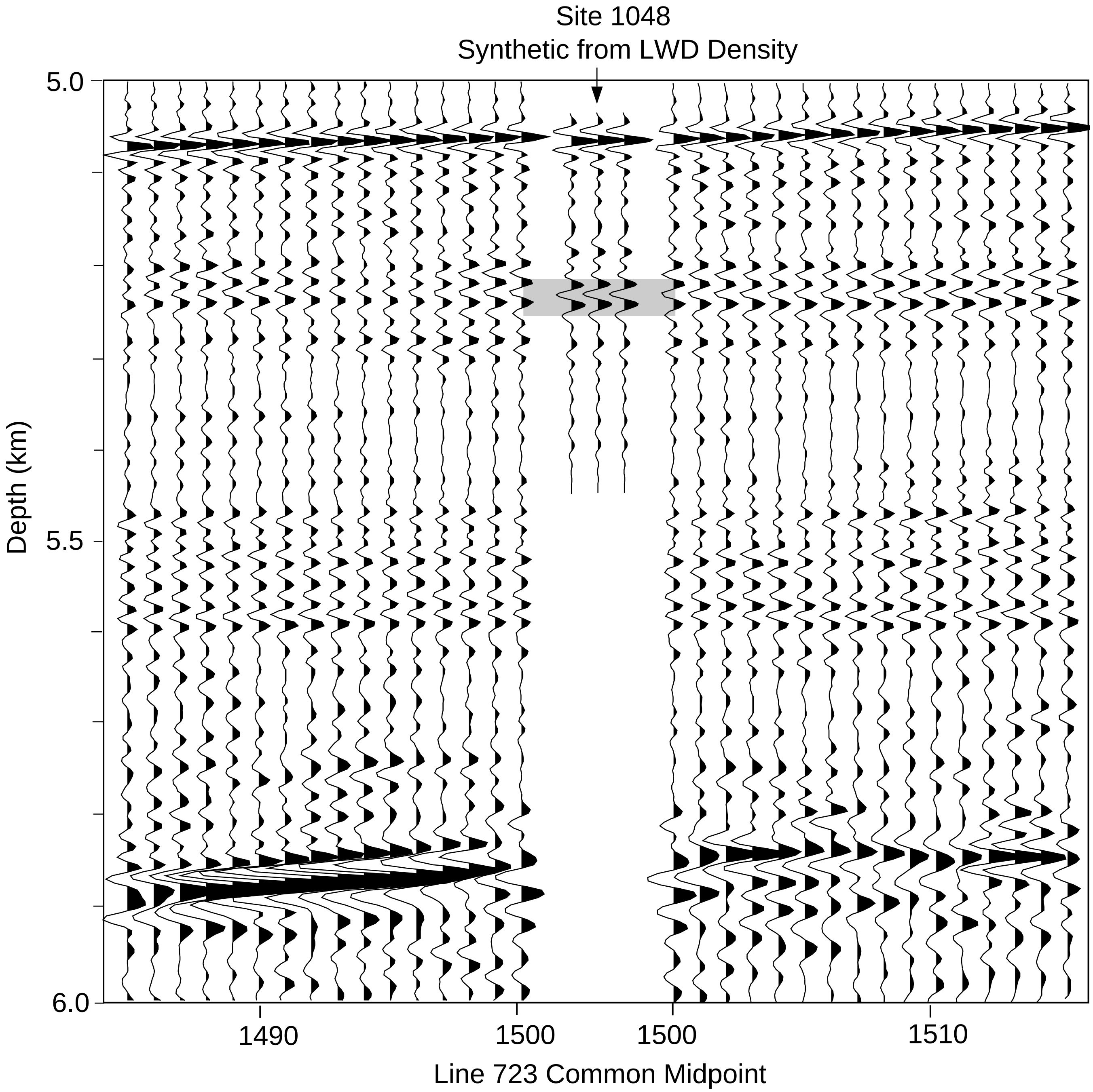

Figure 11. Three identical synthetic traces are shown at Site 1048 on Line 723. The shaded area shows the location of the décollement zone, as indicated by the density log. See “Explanatory Notes” chapter (this volume) for description of the synthetic seismogram construction. Trace spacing is 15 m; horizontal exaggeration is 2×.

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