43. GEOCHEMICAL WELL LOGS IN THE IZU-BONIN ARC-TRENCH SYSTEM, SITES 791, 792, AND 793¹

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ABSTRACT

Geochemical well logs were obtained in sediments at Site 791 and in both sediments and basalts at Sites 792 and 793 of Leg 126. Corrections have been applied to the logs from the latter two sites to account for variations in hole size, drilling fluid interference, and drill-pipe attenuation. Oxide and calcium carbonate weight percentages have been calculated from the processed logs and are compared to the available core measurements. Log-derived CaCO₃ measurements correlate well with shipboard CaCO₃ core measurements from Hole 791B. In Holes 792E and 793B the log-derived oxides, with the exception of SiO₂, agree extremely well with the X-ray fluorescence measurements.

INTRODUCTION

Drilling on Legs 125 and 126 was conducted in order to unravel the evolution of the Mariana and Izu-Bonin arc-trench systems. Three of the seven sites of Leg 126 were logged: Site 791, a backarc site logged through sediments, and Sites 792 and 793, forearc sites logged through both sediments and basement. The other sites were not logged because of adverse drilling conditions, such as pipe sticking (Site 787) and caving in of the unstable formation (Sites 787, 788, and 790).

The geochemical tool string, which measures the major elements in a formation at intervals of 0.1524 m, recorded data at each logged site. Thus, an invaluable record of the rock chemistry was obtained in an area where core recovery was very difficult and sporadic. This report describes the hole conditions and logging operations at each site, presents the basic principles of the geochemical tool string, explains the data processing techniques, and compares the final natural gamma-ray and oxide/calcium carbonate fractions estimated from the logs with discrete core measurements.

DATA ACQUISITION

Site 791

Site 791 was drilled 2.4 km to the east of Site 790, after it was discovered that Site 790 was located too far west to penetrate the objective sedimentary structure (Taylor, Fujioka, et al., 1990, pp. 127–220). Hole 791A was cored with the advanced hydraulic piston corer (APC) and the extended core barrel (XCB), until the sinker bars and core barrels broke loose into the pipe. After unsuccessful fishing attempts, the hole was abandoned, and a second hole (791B) was drilled to 416 mbsf, where rotary core barrel (RCB) coring commenced and resulted in very poor recovery. Basement was detected by the driller at 834 mbsf, where an extremely hard interval was encountered. The liberal use of a viscous gel mud stabilized the hole but did not improve core recovery. Drilling penetration became increasingly difficult over the interval from 1100 to 1145 mbsf (2–5 m/hr), where drilling stopped because the scientific objectives

had been attained. As the pipe was being pulled out of the hole, it first stuck temporarily at 884 mbsf and then again at 826 mbsf, at which point it became stuck completely.

The original logging plan called for running a full suite of Schlumberger logs as well as the formation microscanner, vertical seismic profiler, and wireline packer. The shipboard participants decided to run only the geochemical logging string, as this is the only logging suite that can acquire geophysical measurements through the steel pipe. The other tool strings emit or record electrical currents or acoustical sound waves that cannot be measured through steel. Neutrons and gamma rays, however, can pass through and be detected through pipe, allowing geochemical and radioactive logs to be recorded. The signal detected from the formation when the tool is run through pipe or casing is greatly attenuated, and the signal-to-noise ratio decreases. At Hole 791B the base of the BHA was located at 830 mbsf (coinciding with the top of the basement), and logs were recorded through pipe from 811.67 mbsf to the seafloor.

Site 792

The first four holes drilled at Site 792 (Holes 792A through 792D) were unable to reach the target depth, because either the piston rod separated (Hole 792A) or the cutting shoe malfunctioned (Holes 792B–792D). Hole 792E was successfully drilled with the RCB to 885.9 mbsf. Soon after the hole was completed, the formation began sloughing in and trapping the BHA. After some unsuccessful attempts to ream the hole, the bit was released. While pipe was being raised to the previously planned depth of 120 mbsf, it became stuck at 286 mbsf, which necessitated through-pipe logging from this depth up.

The seismic-stratigraphic combination, composed of the dual induction resistivity, long-spaced sonic, natural gamma-ray, and temperature tools, was run first from a depth of 877.1 mbsf to the seafloor. The density tool was omitted from this tool string because of the danger of losing a radioactive source in an unstable hole. The formation microscanner (FMS) was deployed next and provided excellent results in the open-hole section (see Pezard and Lovell, this volume). The geochemical logging string was run through the entire hole, with the upper 287 m through pipe. The hole appeared to be stable at this point and the density tool was run. While entering the hole, the short-spaced detector failed; therefore, only long-spaced density was measured.

Site 793

The target depth of 1700 mbsf was not reached at Hole 793A because the core barrel became stuck and the piston rod sheared during an attempt to pull it out. A reentry cone was set at Hole 793B

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with the casing shoe at 568 mbsf, and subsequent drilling reached a total depth of 1682 mbsf, the deepest basement hole ever to be cored on any ODP/DSDP cruise. After the BHA was changed, logging operations commenced with the seismic-stratigraphic combination. The density tool failed; therefore, only the resistivity, velocity, natural gamma-ray, and temperature measurements were acquired on the first run. Obstructions were encountered at 727.0, 965.0, and 1580 mbsf, which necessitated logging the hole in two separate intervals.

The second logging string included the FMS, natural gamma-ray, and temperature tools. Logs were recorded with these tools from 1539 to 1034 mbsf and from 764.1 to 586.5 mbsf. The geochemical combination was run next, and it logged open hole from 1531 to 1034 mbsf and through pipe from 764.1 to 586.5 mbsf. A vertical seismic profile was conducted after the standard logging operations were completed.

GEOCHEMICAL TOOL STRING

The geochemical logging tool string (GLT) consists of four logging tools: the natural gamma-ray tool (NGT), the compensated neutron tool (CNT), the aluminum activation clay tool (AACT), and the gamma-ray spectrometry tool (GST) (GLT, NGT, CNT, AACT, and GST are trademarks of Schlumberger; Fig. 1). The natural gamma-ray tool is located at the top of the tool string, so that it can measure the naturally occurring radionuclides Th, U, and K before the formation is irradiated by the nuclear sources contained in the other tools. The compensated neutron tool, located below the natural gamma-ray tool, carries low-energy californium-252 (252Cf) to activate the Al atoms in the formation. The aluminum activation clay tool, a modified NGT, is located below the 252Cf source, measuring the activated gamma rays in the formation. By combining the ACT measurement with the previous NGT measurement, the background radiation is subtracted out and a reading of formation AI is obtained (Scott and Smith, 1973). The gamma-ray spectrometry tool, at the base of the string, carries a pulsed neutron generator to bombard the borehole and formation and an NaI(Tl) scintillation detector, which measures the spectrum of gamma rays generated by neutron-capture reactions. On Leg 126 a boron sleeve, designed to absorb neutrons from the GST, was applied for the first time (Fig. 1). Because each of the elements in the formation is characterized by a unique spectral signature, it is possible to derive the contribution (or yield) of each of the major elements silicon (Si), iron (Fe), calcium (Ca), titanium (Ti), sulfur (S), gadolinium (Gd), and potassium (K) to the measured spectrum and, in turn, to estimate its abundance in the formation. The GST also measures hydrogen (H) and chlorine (Cl) in the borehole and formation, but these elements are not used for determining rock geochemistry.

The only major rock-forming elements not measured by the geochemical tool string are magnesium (Mg) and sodium (Na); the neutroncapture cross-sections of these elements are too small relative to their typical abundances for the tool string to detect them. A rough estimate of Mg + Na can be made by using the photoelectric factor (PEF), measured by the lithodensity tool. This measured PEF is compared with a calculated PEF (a summation of the PEF from all of the measured elements). The separation between the measured and calculated PEF is, in theory, attributable to any element left over in the formation (i.e., Mg and Na). Further explanation of this technique is found in Hertzog et al. (1987). This calculation was not performed for any of the three logged sites, because density measurements were not recorded at Sites 791 and 793 and were recorded only in the open-hole section of Hole 792E. Further, it was found that the Mg calculation in the open-hole section of Hole 792E yielded an unreliable MgO curve and induced noise into the results of all of the other elements included in the normalization process.

DATA REDUCTION

The well log data from the Schlumberger tools are transmitted digitally up a wireline and are recorded and processed on the *JOIDES* *Resolution* in the Schlumberger Cyber Service Unit (CSU). The results from the CSU are made available as "field logs" for initial, shipboard interpretation. Subsequent reprocessing is necessary to correct the data for the effects of fluids added to the well, logging speed, and pipe interference. Processing of the spectrometry data is required to transform the relative elemental yields into oxide weight fractions.

The processing is performed with a set of log interpretation programs written by Schlumberger. The steps are summarized below:

1. Reconstruction of Relative Elemental Yields from Recorded Spectral Data

The first processing step uses a weighted, least-squares method to compare the measured spectra from the geochemical spectrometry tool with a series of standard spectra in order to determine the relative contribution (or yield) of each element. Whereas six elemental standards (Si, Fe, Ca, S, Cl, and H) are used to produce the shipboard yields, three additional standards (Ti, Gd, and K) can be included in the shore-based processing to improve the fit of the spectral standards to the measured spectra (Grau and Schweitzer, 1989). Although these additional elements often appear in the formation in very low concentrations, they can make a large contribution to the measured spectra, because they have large neutron-capture cross-sections. For example, the capture cross-section of Gd is 49,000 barns; that of Si is 0.16 barns (Hertzog et al., 1987). Gd is, therefore, included in the calculation of a best fit between the measured and the standard spectra. This best-fit analysis was done for the elements in each of the logged holes to include spectral standards for Si, Ca, Fe, Ti, Gd, H, and Cl. The spectral standards for K and S were not used because these two elements existed in concentrations below the resolu-tion of the tool and including them would significantly increase the noise level of all the other yields. A straight, seven-point smoothing filter was applied to all the yields in both holes to reduce the noise in the data. The Ca yield was divided by 2 to correct for Cl interference, a routine typically done when logging in saline fluids (J. A. Grau, pers. comm., 1988).

Leg 126 was the first ODP leg on which the geochemical logging tool carried a modified boron sleeve around the detector on the gamma-ray spectrometry tool (Fig. 1). Although the boron sleeve is routinely used by Schlumberger when logging oil-field wells, it was not possible to use it before Leg 126 because of the narrow-diameter drill pipe through which the tool must pass on the *JOIDES Resolution*.

Before the boron sleeve was applied, the overall Fe yield had to be shifted to account for Fe detected from the steel within the tool itself. This correction is no longer necessary on open-hole logs, and the Fe reading is much more accurate, because it is now measured from the formation only. The Fe yields throughout Hole 791B and those in the through-pipe section of Holes 792E and 793B were corrected for drill-pipe and BHA Fe by offsetting the yields for each zone by an amount appropriate to the steel thicknesses. The additional effect of the pipe joints was removed from the data at Hole 791B by interpolating between log values above and below each pipe joint.

2. Depth Shifting

The second step in log processing is to depth shift the logging runs to a chosen reference run. A total gamma-ray curve (from the NGT, which is run on each tool string) usually is chosen as a reference curve, based on cable tension (the logging run with the least amount of cable sticking) and cable speed (tools run at faster speeds are less likely to stick). Because no other logging tool strings were run at Site 791, no depth shifting was needed at Hole 791B. The logs were depth referenced to the FMS run at Hole 792E. At Hole 793B the seismic stratigraphic and geochemical logging runs were found to be on depth; thus, only the caliper data from the FMS run were depth shifted to match those of the previous two runs.



Figure 1. Schematic drawing of the geochemical logging string used in the Ocean Drilling Program. A "modified" boron sleeve, which masks out the Fe coming from the tool itself, was innovated for the first time on Leg 126.

3. Calculation of Total Radioactivity and Th, U, and K Concentrations

The third processing routine calculates the total natural gamma radiation in the formation as well as concentrations of Th, U, and K, using the counts in five spectral windows from the natural gamma-ray tool (Lock and Hoyer, 1971). This resembles shipboard processing, except that corrections for hole-size changes are made in the shore-based processing of these curves. A Kalman filter (Ruckebusch, 1983) is applied to minimize the statistical uncertainties in the logs, which would otherwise create erroneous negative readings and anti-correlations (especially between Th and U). At each depth level, calculations and corrections were also performed for K contained in the mud. This K correction is particularly useful where KCl is routinely added to the hole; however, because of dispersion it is difficult to know

exactly how much K is in the borehole. The outputs of this program are: K (wet wt%), U (ppm), and Th (ppm), along with a total gamma-ray curve and a computed gamma-ray curve (total gamma ray minus U contribution).

4. Calculation of Al Concentration

The fourth processing routine calculates an Al curve using four energy windows, while concurrently correcting for natural activity, borehole fluid neutron-capture cross-section, formation neutron-capture cross-section, formation slowing-down length, and borehole size. Porosity and density logs are needed in this routine to convert the wet weight percent K and Al curves to dry weight percent. Because no density or porosity tools were run in Hole 791B, the porosity and density curves used were derived from interpolated core measurements. At Hole 792E the density curve from the lithodensity tool was used in the open-hole portion, and in the through-pipe section interpolated core measurements were used. A porosity curve was calculated using matrix density from cores. In Hole 793B a porosity curve was calculated from the velocity logs and used to calculate a pseudodensity curve.

A correction is also made for Si interference with Al; the ²⁵²Cf source activates the Si, producing the aluminum isotope, Al²⁸ (Hertzog et al., 1987). The program uses the Si yield from the gamma-ray spectrometry tool to determine the Si background correction. The program outputs dry weight percentages of Al and K, which are used in the calculation and normalization of the remaining elements.

5. Normalization of Elemental Yields from the GST to Calculate the Elemental Weight Fractions

This routine combines the dry weight percentages of Al and K with the reconstructed yields to obtain dry weight percentages of the GST elements using the relationship

$$Wt_i = FY_i/S_i,$$
(1)

in which Wt_i = absolute elemental concentration, F = normalization factor, Y_i = relative elemental yield, and S_i = tool spectral sensitivity.

The normalization factor, F_i is a calibration factor determined at each depth from a closure argument to account for the number of neutrons captured by a specific concentration of rock elements. Because the sum of oxides in a rock is 100%, F is given by

$$F(\Sigma_{i}X_{i}Y_{i}/S_{i}) + X_{K}Wt_{K} + X_{AI}Wt_{AI} = 100,$$
(2)

where $X_i = dry wt\%$ of oxide or carbonate $\div dry wt\%$ of element *i*, Y_i = fraction of spectra attributed to element *i*, S_i = sensitivity factor, X_K = dry wt\% of oxide of element K $\div dry wt\%$ of K, Wt_K = dry wt% K, X_{AI} = dry wt% of oxide of element Al $\div dry wt\%$ of Al, and Wt_{AI} = dry wt% Al.

The sensitivity factor, S_i , is a tool constant measured in the laboratory, which depends on the capture cross-section, gamma-ray production, and detection probabilities of each element measured by the GST (Hertzog et al., 1987).

The value X_i accounts for the C and O associated with each element. Table 1 lists the oxide factors used in this calculation. All of the measured elements associate with C and O in a constant ratio, except for Ca, which associates with C and O in two ways: CaCO₃ or CaO. To convert the measured yields to elements/oxides, the dominant form of Ca must be assumed. The assumption is based on the lithology described in the cores. The CaO fraction was estimated in the upper 249 m of Hole 791B, whereas the CaCO₃ fraction was computed from 249 mbsf to the bottom of this logged interval. Throughout Holes 792E and 793B CaO was estimated.

6. Calculation of Oxide Percentages

The sixth and final routine simply multiplies the percentage of each element by its associated oxide factor using the same oxide factors as were used in the previous step (Table 1).

COMPARISON OF GEOCHEMICAL LOGS TO CORE

Site 791

The processed natural gamma-ray curves from the geochemical logging string at Hole 791B are shown in Figure 2. Although the logs were recorded through pipe, the results have been corrected for pipe attenuation and erroneous spikes caused by pipe joints. The attenu-

Table 1. Oxide factors used in normalizing elements to 100% and converting elements to oxides.

Element	Oxide/carbonate	Conversion factor
Si	SiO ₂	2,139
Ca	CaO	1.399
	CaCO ₃	2.497
Fe	FeO* (total Fe)	1.358
K	K ₂ O	1.205
Ti	TiO ₂	1.668
Al	Al ₂ O ₃	1.899

ation caused by the steel pipe was accounted for by using a Schlumberger casing correction algorithm. However, without any open-hole logs or core measurements for comparison, it was difficult to determine whether the reprocessed logs that displayed higher values than the field logs were fully corrected for pipe attenuation.

The natural gamma-ray logs are the most useful lithologic markers in this hole. In most cases the positive spikes in the total gamma-ray curve correlate with increased Th values, indicating rock of volcanic origin (Serra, 1984). The radioactive highs correlate with clay beds associated with black sand/silt (Taylor, Fujioka, et al., 1990, pp. 127–220). This association allows the total gamma-ray and Th curves to be used to distinguish between the thick pumiceous sands and gravels and the thin black clay sands in lithologic Unit I. At least five volcanic events, each containing a thick pumiceous layer at the bottom and a thin black clay interval at the top, can be distinguished on the logs at the following depths: 0–166, 166–273, 273–327, 327–428, and 367–428 mbsf. The frequency of total gamma-ray highs increases downhole into Unit II.

Figure 3 displays the oxide weight fractions estimated from the logs at Hole 791B. Core measurements of $CaCO_3$ are displayed for comparison with the log-derived $CaCO_3$ measurements in the interval between 428 and 800 mbsf, in which the dominant lithology is a nannofossil-rich clay. The logs have a low signal-to-noise ratio because of the high porosity of the formation and the through-pipe conditions. The CaO values generally increase downhole, as do the core measurements. As expected, the SiO₂ log mirrors this CaO profile.

The increase in the FeO* (total Fe₂O₃ and FeO) between 605–625 and 650–668 mbsf correlates with high magnetic susceptibility measurements resulting from increased concentrations of ferromagnetic or paramagnetic minerals (e.g., magnetite, ilmenite, pyrrhotite, and hematite; Taylor, Fujioka, et al., 1990, pp. 127–220). The accuracy of the oxide percentages can be tested at 472 mbsf, where X-ray fluorescence (XRF) measurements were made on a core sample. These measurements yielded percentages of 13.6 for Al₂O₃, 73.08 for SiO₂, 2.98 for CaO, 3.55 for Fe₂O₃, 0.91 for K₂O, and 0.4 for TiO₂ (Taylor, Fujioka, et al., 1990, pp. 127–220). Each of the measured XRF values agrees well with the log values, except for those of Al₂O₃, which indicates that pipe attenuation was not completely accounted for. We estimate that the Al concentrations are about 200% too low throughout the well, despite the attenuation correction.

Site 792

The processed natural gamma-ray logs from Hole 792E are displayed in Figure 4. The data come from the geochemical tool string, which was logged through pipe from 0 to 286 mbsf and in open hole from 286 mbsf to the bottom of the hole. The through-pipe logs are corrected for pipe and BHA attenuation but not for the presence of pipe joints, which corresponds to most of the spikes seen between 35 and 205 mbsf.

The natural gamma-ray logs are, in most cases, useful for defining lithologic units. Unit I, however, is indistinguishable from Unit II in these records from Hole 792E. Considering that the boundary roughly

coincides with the junction between the pipe and BHA, one cannot interpret any character of the logs in this interval as reflecting a change in lithology.

The natural gamma-ray logs in Unit II were recorded through pipe and in open holes, with the base of the BHA located at 286 mbsf. The character of the logs indicates an homogeneous unit with low clay content.

The upper boundary of Unit III is marked by an increase in total gamma-ray content, which continues to increase downhole within this unit. Variations in K content closely mimic the total gamma-ray curve, suggesting that K is the dominant radioactive component. An increase in Th content, which indicates volcanic influx, occurs between 385 and 400 mbsf.

The upper part of Unit IV consists of alternating vitric sandstones and muddy intervals. Conglomerate beds, which contain clasts of volcanic material and claystone, are found in the middle and lower portions of this unit. Variations in K concentration between the sandstone and mud intervals result in the fluctuating gamma-ray values recorded over this interval.

A fault is marked at the boundary between Units IV and V by a dramatic decrease in the K concentration and total gamma-ray values. The top of Unit IV, the basement, is marked on the logs by an increase in Th content.

The oxide weight fractions for Hole 792E are shown in Figure 5. The through-pipe logs are not displayed because logging conditions in this section were extremely poor, with porosities at roughly 65%, and with the thick steel in the BHA causing the signal to be dominated by the Cl in the fluids and the Fe in the steel. The lower portion of Unit II is characterized by moderate CaO and high Al_2O_3 and FeO* contents. The extreme low SiO₂ values in Units II and III are not a lithologic phenomenon but rather an artifact of processing. These low values occur wherever the spectral count rates from the formation are so low that the calculation becomes unstable. The FeO* content generally decreases downhole through Unit III. The CaO content increases in the middle of Unit III, the result of a nannofossil-rich interval.

A fault separates the carbonate-rich interval from a zone rich in vitric and pumiceous sand. The TiO_2 content increases in Unit IV, then decreases again in Unit V. XRF measurements agree well with the geochemical logs, except for that of SiO_2 . The discrepancy in SiO_2 content may be the result of MgO not having been calculated with the logs, which resulted in log values greater than expected. This effect is primarily seen on the SiO_2 log because it makes up the greatest percentage of the rock's oxide content. The slight discrepancy between the log- and core-measured K₂O values may be the result either of selectively sampling unaltered rocks in the core or of miscalibration of the NGT measurement.

Site 793

The processed natural gamma-ray logs from the geochemical tool string recorded at Hole 793B are displayed in Figure 6. The upper portion of the log is recorded through pipe and the lower portion in open hole. Logs could not be recorded above 568 mbsf because the combination of casing and pipe would mask out any signal from the formation. Attenuation corrections were applied to the upper log section.

Units I, II, and III are not readily distinguished by the natural gamma-ray logs. The natural gamma-ray logs are highly variable and increase in magnitude in the claystones of Unit IV, reflecting the variable nannofossil content described in cores (low gamma-ray values reflect high nannofossil content). The upper, through-pipe log in Unit V is characterized by decreasing natural gamma-ray, K, and Th values. An increase in total natural gamma-ray content, largely attributable to increased K content, marks the top of Unit VI in this

unit. The gamma-ray content decreases in the breccia and pillow lavas of Unit VII.

The oxide-weight fractions along with XRF measurements from discrete core samples for Hole 793B are shown in Figure 7. The two data sets agree well except for the SiO_2 values. The discrepancy between the SiO_2 logs and core measurements is related to the fact that MgO and Na₂O contents could not be calculated from the logs, because a density log was not available.

The olivine-clinopyroxene diabase sill of Unit II is marked by an increase in TiO_2 . The Al_2O_3 and K_2O contents increase downhole in Unit III, reflecting an increase in clay content downsection. This variable carbonate content described in the core of Unit IV is not readily seen on the CaO log; however, the variable lithology is reflected in the increased character on the Al_2O_3 , SiO_2 , FeO*, and K_2O logs.

Unit V consists of graded beds of vitric sandstone to siltstone. The excellent agreement between log measurements and core descriptions in this interval provides the basis for more detailed work on resolving the turbidite and debris flow intervals described in the recovered core.

Unit VI consists of volcanic breccia with clasts similar to those found in the basement section. The high K content in this zone indicates more alteration minerals are present than in the surrounding units. The logs in the basement section of the hole have higher signal-to-noise ratios as a result of the low porosity in the interval. The log response in this basement interval is the most reliable of the entire well.

CONCLUSION

The reprocessing of natural gamma-ray logs improves the measurements obtained in the field by incorporating hole size corrections and better calibrations of Th, U, and K. Geochemical logs, converted to elemental and oxide measurements, compare well with core data. When core data are missing or sparse, the reprocessed logs represent an invaluable data set from which to interpret lithology. The general trends of Al_2O_3 and K_2O were found to be particularly useful in portraying relative increases or decreases in clay content. The Th log is useful in distinguishing volcanic influxes, particularly in Hole 791B, where it helped distinguish pumice from black clay and defined at least five volcanic events. The addition of the boron sleeve, which masks out the Fe from the steel within the tool, has greatly improved our FeO* measurement. The FeO* curve correlates well with magnetic susceptibility measurements and depicts the zones of ferromagnetic- and paramagnetic-rich intervals.

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Figure 2. Processed natural gamma-ray data, Hole 791B.



Hole 791B: legend of lithologic units

Unit I. Pumiceous sand, gravel, silt, and clay Unit II. Nannofossil-rich claystone and sandy mudstone

Figure 2 (continued).



Figure 3. Estimates of calcium carbonate and major-oxide weight fractions from geochemical logs, Hole 791B. Solid squares represent carbonate values from core measurements (Taylor, Fujioka, et al., 1990, pp. 127–220).



Figure 3 (continued).

E. L. PRATSON ET AL.



Figure 4. Processed natural gamma-ray data, Hole 792E.



Figure 4 (continued).

665



Hole 792E: legend of lithologic units

Unit I. Alternations of nannofossil-rich vitric silty clay, silt, and sand

Unit II. Nannofossil-rich mudstone to sandstone

Unit III. Nannofossil-rich claystone and chalk

Unit IV. Nannofossil-rich vitric sandstone, volcanic conglomerate, and claystone Unit V. Altered volcanic sandstone

Unit VI. Andesite

Figure 4 (continued).

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Figure 5. Calcium carbonate and major-oxide weight fractions from geochemical logs in Hole 792E compared to XRF measurements (solid squares) in the basement section of the hole (Taylor, Fujioka, et al., 1990, pp. 221–314).



Figure 5 (continued).



Figure 6. Processed natural gamma-ray data, Hole 793B.



Figure 6 (continued).



Hole 793B: legend of lithologic units

Unit II. Olivine-clinopyroxene diabase sill

Unit III. Nannofossil-rich claystone, vitric sandstone, and clayey siltstone

Unit IV. Claystone with varying carbonate content

Unit V. Vitric and pumiceous sandstone and siltstone

Unit VI. Volcanic breccia with andesite clasts

Unit VII. Breccia and massive to pillow lava of andesitic composition

Figure 6 (continued).

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Figure 7. Estimates of the major-oxide weight fractions from geochemical logs in Hole 793B compared to XRF measurements (solid squares) from core (Taylor, Fujioka, et al., 1990, pp. 314–403).



Figure 7 (continued).



Figure 7 (continued).