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17. Data Report: Downhole Major and Trace Element Chemistry of Volcanic Rocks from Skiff Bank, Kerguelen Plateau (ODP Site 1139)[1]

Peter J. Saccocia,[2] Damon A.H. Teagle,[3] Robert H. Telford,[3] Nicola Eastley,[3] and Timothy S. Brewer[4]

INTRODUCTION

Skiff Bank is a bathymetric and gravimetric high located ~350 km southwest of the Kerguelen Islands in the northern portion of the Kerguelen Igneous Province (KIP). Ocean Drilling Program Site 1139 was drilled at a water depth of 1415 m on Skiff Bank's western edge. Hole 1139A penetrated to a depth of 695 meters below seafloor (mbsf) with sediment recovered from the upper 462 m and igneous basement recovered from the lower 233 m. A total of 19 basement units were identified, including variably welded trachytic to rhyolitic volcanic and volcaniclastic rocks (Units 1–5) and 14 lava flows with intermediate to mafic compositions (Units 6–19) (Shipboard Scientific Party, 2000).

Core observations indicate that the basement units recovered from Hole 1139A display unique alteration patterns, in terms of both the intensity of alteration and secondary mineralogy, when compared to other drill holes from the Kerguelen Plateau. Basement Units 6–17 contain highly altered breccias, commonly corresponding to flow tops, and more massive and somewhat less altered flow interiors. The breccias are highly oxidized and cemented by calcite and clay minerals. Calcite veins and stringers are common throughout, and the groundmass has a bleached appearance due to the replacement of primary igneous minerals by secondary calcite. The lowermost basement Units 18 and 19 are highly to completely altered by intense oxidation to hematite or by nearly complete bleaching to produce a final mineral assemblage that

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[2] Department of Earth Sciences and Geography, Bridgewater State College, Bridgewater MA 02325, USA. psaccocia@bridgew.edu
[3] Southampton Oceanography Centre, School of Ocean and Earth Science, University of Southampton, Southampton SO14-3ZH, UK.
[4] Department of Geology, University of Leicester, Leicester LE1 7RH, UK.

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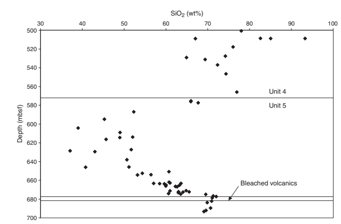
includes quartz, sanidine, and siderite. Veins within the bleached zones contain hematite, quartz, siderite, and calcite.

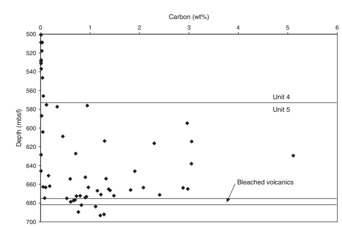
To better assess the mass transfer of major elements associated with these unique alteration patterns, we have conducted a detailed chemical analysis of both major and trace elements in samples from the basement units of Hole 1139A. These data are reported here, along with whole-rock analyses for carbon, sulfur, and ferrous/ferric ratios (Table T1). Downhole trends for SiO_2, C, Fe^{3+}/Fe total, and loss on ignition (LOI) are shown in Figures F1, F2, F3, and F4. The trends serve to quantify the distinct alteration observed in some basement units within Hole 1139A. For example, carbon increases dramatically below 570 mbsf and shows large enrichments in basement Units 5–19 (Fig. F2). The data also show that iron becomes more reducing with depth overall, with Fe^{3+}/Fe total ratios dropping to as low as 0.13 in basement Unit 18 (Fig. F3). The large variations in this ratio with depth probably reflect alteration zones with variable amounts of hematite and siderite. These unique alteration assemblages and whole-rock compositions were likely produced by CO_2-rich hydrothermal fluids interacting with intermediate to felsic volcanic rocks at high water-to-rock ratios. The fluids involved were probably unlike hydrothermal fluids that affected other parts of the KIP.

T1. Major and trace element analyses of whole-rock samples, p. 9.

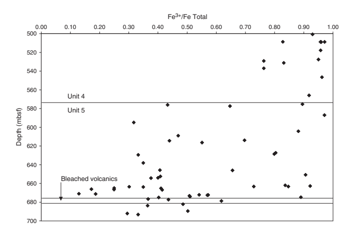
F1. SiO_2 vs. depth, p. 5.



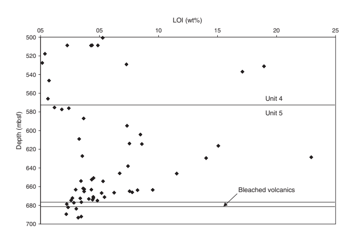
F2. Carbon vs. depth, p. 6.



F3. Fe^{3+}/Fe Total vs. depth, p. 7.



F4. LOI vs. depth, p. 8.



METHODS

Samples were prepared for analysis at the Southampton Oceanography Centre (SOC; UK). All samples were sketched and described before being sectioned and trimmed for powdering. Weathered edges and saw marks were removed by grinding before the samples were washed and scrubbed in deionized water and then oven dried (~110°C). Density was measured on a representative fragment of the sample following Archimedes's principle by weighing it in air and then suspending it in a beaker of water. Following oven drying, samples were reduced to a coarse grit using a fly-press, with the sample wrapped in clean paper to reduce contamination and sample loss. Samples were then reduced to a very fine powder suitable for chemical analyses by grinding in a clean tungsten carbide shatterbox.

Major and trace element analyses of whole-rock samples were conducted at the Ronald B. Gilmore X-Ray Fluorescence Laboratory at the University of Massachusetts—Amherst (USA). Major element analyses (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, and P) were conducted on fused La-bearing lithium borate glass disks using a Siemens MRS-400 multichannel X-ray spectrometer following methods modified from Norrish and Hutton (1969). Trace element analyses (Nb, Zr, Y, Sr, Rb, Th, Pb, Ga, Zn, Ni, Cr, V, Ba, Ce, and La) were obtained from pressed powder pellets on a Philips PW2400 sequential spectrometer. Intensities were corrected for background interferences and variations in mass absorption coefficients following methods modified from Norrish and Chappel (1967). Mass absorption coefficients for elements with shorter and longer wavelengths than the Fe absorption edge were estimated following the techniques of Reynolds (1967) and Walker (1973), respectively. Estimates of the precision and accuracy of these analytical procedures are described in Rhodes and Vollinger (2004).

Carbon and sulfur concentrations were determined on a split of the sample powders (~5 g) at the Department of Geology, University of Leicester (UK) using a Leco C-S analyzer and corrected for instrument blanks. Individual samples were weighed into crucibles, with the addition of iron and tungsten chip accelerants prior to loading into a radiofrequency induction furnace. The system was initially purged with oxygen, which then continued to stream throughout the combustion process. Power is applied until the accelerants are molten; carbon is given off as CO_2 and CO and sulfur is given off as SO_2. A dust filter prevents silicates (a potential infrared wavelength overlap) from entering the infrared cells. The combustion gases are passed through a drying tube of magnesium perchlorate and then passed to the SO_2 infrared cell. Once determined, the gases pass through a platinized silica gel catalyst to convert any CO to CO_2. Any SO_2 is trapped as SO_3. The CO_2 content is then determined in the CO_2 infrared cell, and all gases then vent from the system. The infrared absorption cells use a tungsten filament as the source, heated to ~850°C. The output from the cells is monitored at 4 Hz and converted from an analog signal to a digital signal, and the areas of the peaks are integrated. These values are then corrected for sample weight, blank value, and calibration factors to calculate total carbon and sulfur concentrations. The lower limit of detection for carbon is 10 ppm with a precision of ±5%, and for sulfur the lower limit is 10 ppm with a precision of ±8%.

Ferrous iron concentrations were determined at SOC by titration with a standardized $KMnO_4$ solution following an adapted "Platt" method. Sample powder (0.5 g) was placed in a clean polypropylene bottle to which a mixture of H_2SO_4 and HF was added and then simmered for 20 min to ensure full decomposition. This rock solution was then added to a large volume (~300 mL) of deionized water that had been pre-prepared with 10 mL H_2SO_4 and 10 mL saturated boric acid solution (the latter to render any excess HF inoperative), stirred, and titrated against the standard solution of $KMnO_4$. Most samples were analyzed twice, and duplicate determinations of FeO are generally within ±0.02 wt% (all within 0.05 wt%).

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Walker, D., 1973. Behavior of X-ray mass absorption coefficients near absorption edges: Reynold's method revisited. *Am. Mineral.,* 58:1069–1072.

Figure F1. SiO_2 vs. depth at Site 1139.

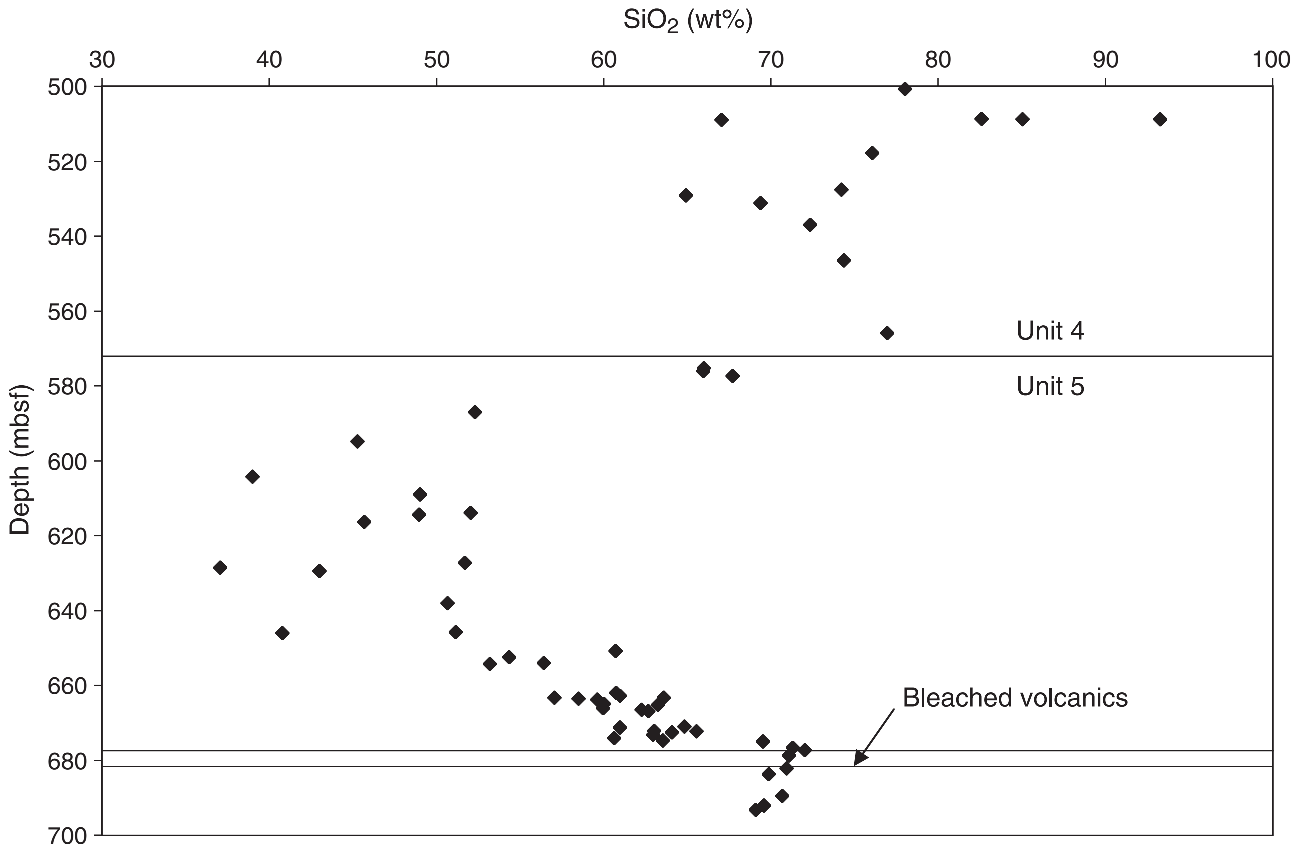

Figure F2. Carbon vs. depth at Site 1139.

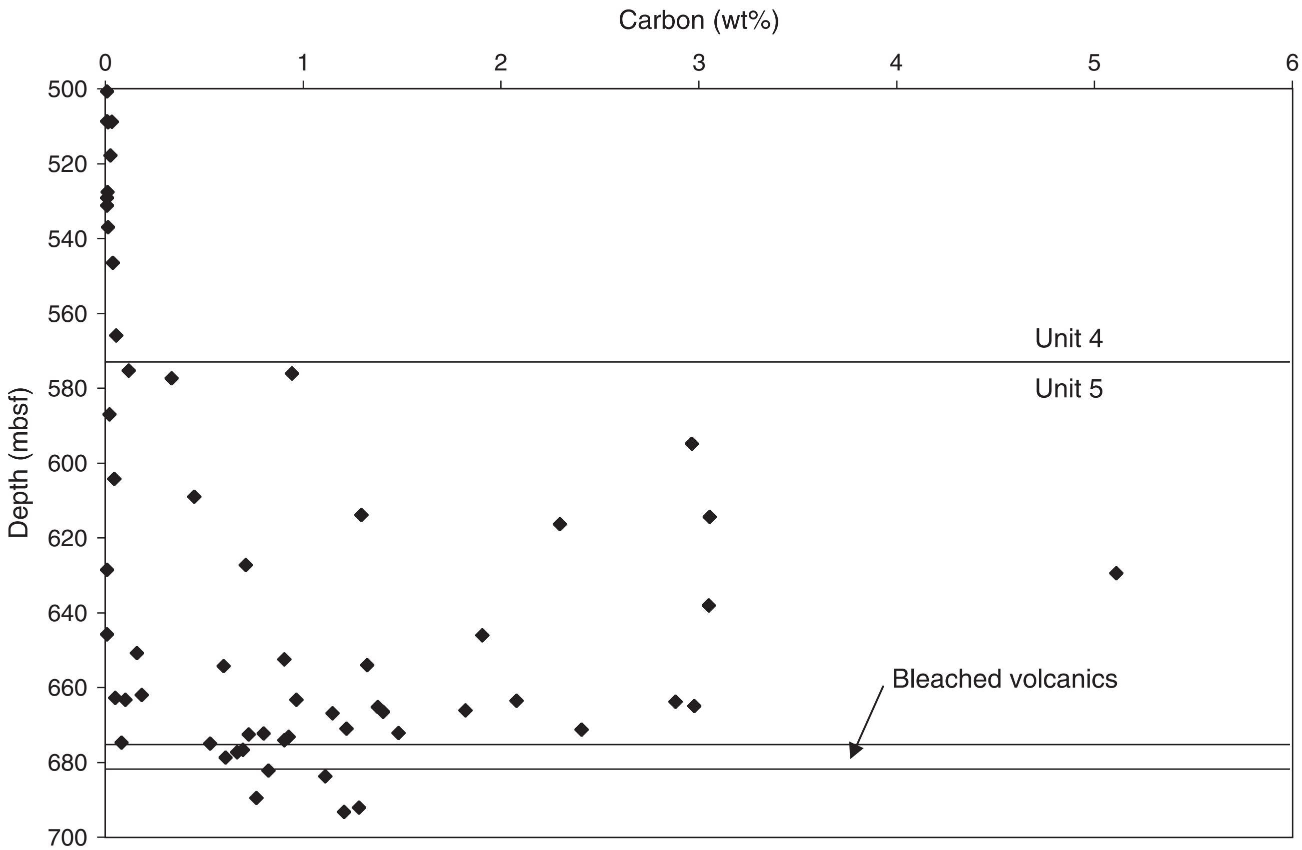

Figure F3. Fe^{3+}/Fe total vs. depth at Site 1139.

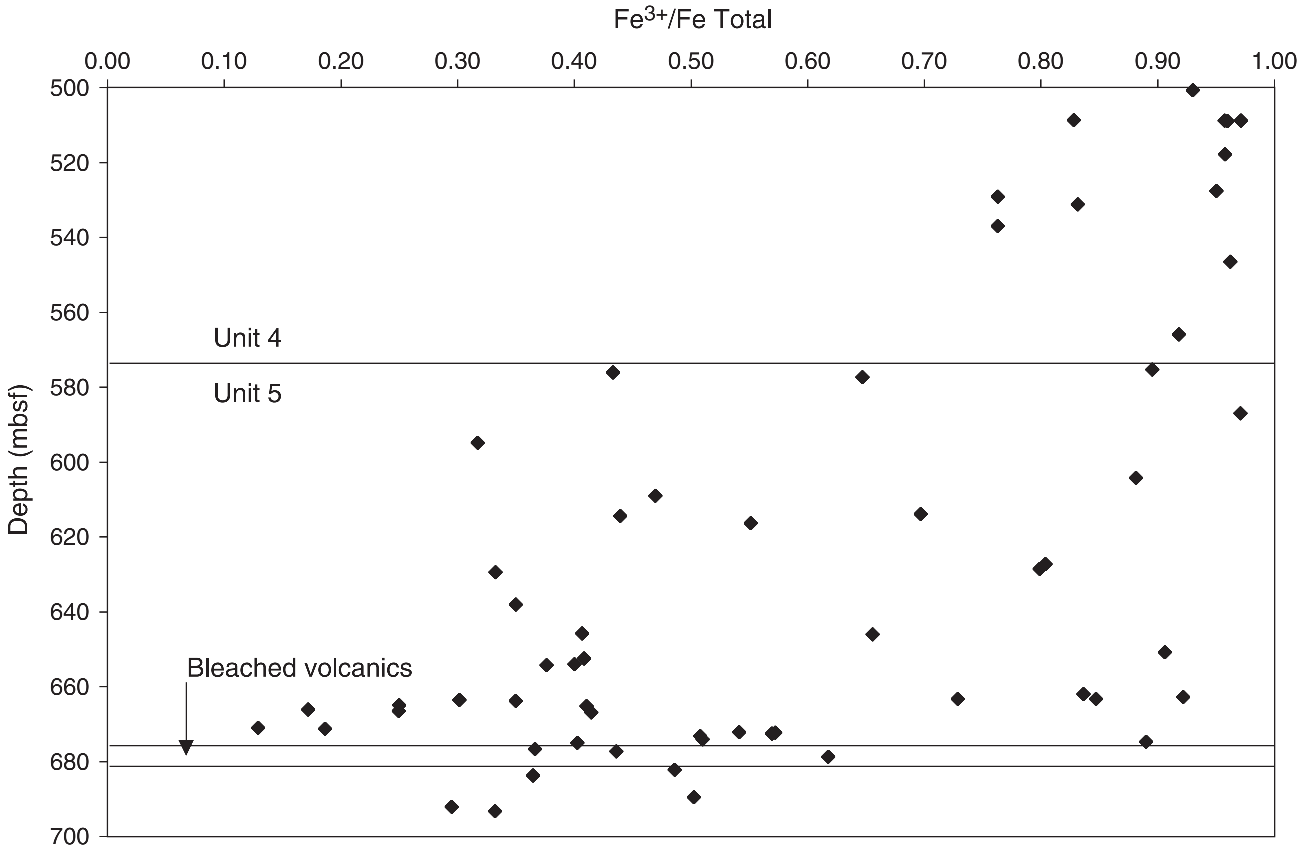

Figure F4. Loss on ignition (LOI) vs. depth at Site 1139.

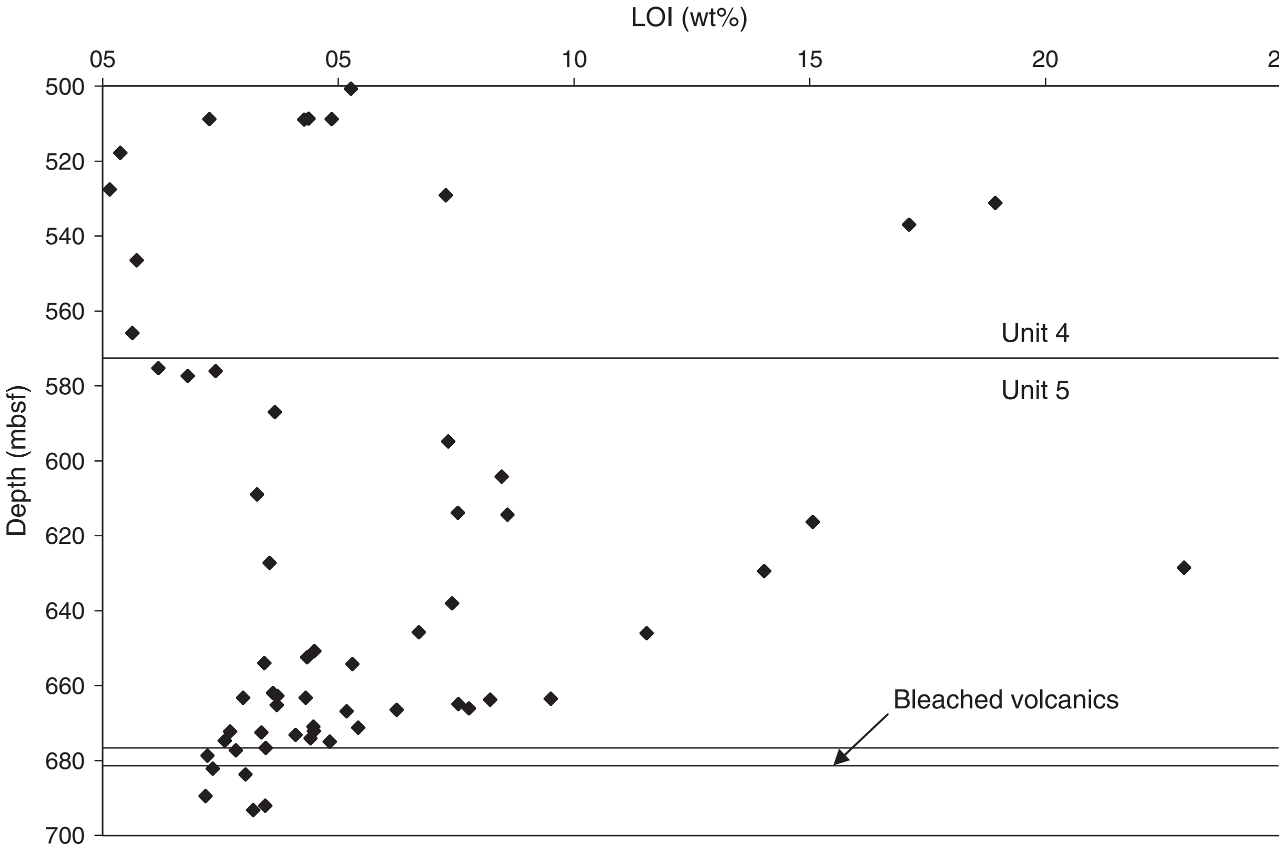

Table T1. Major and trace element analyses of whole-rock samples from Hole 1139A. (Continued on next three pages.)

Core, section, interval (cm)	Depth (mbsf)	Igneous unit	Sample description	Secondary minerals	Density (g/cm^3)
183-1139A-					
53R-1, 47–52	499.27	1D	Brown tuff, altered perlitic glass	Brown clay, FeOx	2.11
53R-2, 52–54	500.79	1D	Hydrothermal breccia	Dark green clay, FeOx	2.06
54R-1, 74–78	508.74	1E	Altered banded rhyolite in felsic welded tuff	Yellow clay	1.73
54R-1, 86–90	508.86	1E	Altered banded rhyolite in felsic tuff	Green clay, SiO_2	2.14
54R-1, 93–96	508.93	1E	Silicified wallrock	Green-yellow clay, SiO_2	2.52
54R-1, 102–106	509.02	1E	Hydrothermally altered tuff	Green clay, FeOx, Cc, zeo	1.84
55R-1, 22–26	517.82	2	Dark red vesicular welded trachyte	Red clay, FeOx, zeo	2.44
56R-1, 32–36	527.62	2	Dark red brown tephra	Red clay, FeOx	2.37
56R-2, 62–67	529.26	3	Dark green crustal vitric tuff	Green clay, SiO_2, zeo	1.59
56R-3, 111–116	531.25	3	Light green crystal vitric tuff	Green clay, SiO_2, zeo	1.56
57R-1, 13–20	537.03	3	Greenish brown crystal vitric tuff	Green clay, SiO_2, zeo	1.87
58R-1, 5–9 (Piece 1)	546.55	4	Red-brown welded vesicular trachyte	Red-brown clay, FeOx	2.38
60R-1, 37–42 (Piece 7)	565.97	4	Fine-grained breccia with red matrix and red-green clasts	Red-brown to green clay, FeOx	2.10
61R-1, 12–19 (Piece 1A)	575.32	5	Breccia with pink-green clasts in red matrix	Red-brown to green clay, FeOx	2.23
61R-1, 98–104 (Piece 1F)	576.18	5	Red-gray lava	Brown to pink clay, FeOx	2.19
61R-2, 84–92 (Piece 6)	577.46	5	Breccia with pale green clasts in red-black matrix	Green clay, FeOx	2.27
62R-3, 8–13	587.01	6	Breccia of brickred vesicular clasts in red-gray matrix	Red clay, FeOx	2.06
63R-1, 33–39 (Piece 7)	594.93	6	Light gray cryptocrystalline lava	Yellow clay, Cc	2.62
64R-2, 12–19 (Piece 2)	604.32	7	Dark brown brecciated lava	Brown clay, Cc	2.16
64R-4, 44–51 (Piece 3B)	609.08	8	Gray basalt	Brown clay, Cc	2.61
65R-1, 0–6 (Piece 1)	613.90	9	Gray vesicular lava	Brown to blue clay, Cc, FeOx	2.31
65R-1, 53–61 (Piece 4A)	614.43	9	Gray vesicular lava	Cc, sid	2.52
65R-2, 118–124 (Piece 3C)	616.38	10	Gray vesicular lava	Green clay, Cc, sid	2.35
66R-3, 85–90 (Piece 1D)	627.33	12	Gray basalt	Brown clay, Cc	2.40
66R-4, 65–70 (Piece 1)	628.57	13	Dark brown volcanic breccia	Brown clay, Cc	2.34
66R-5, 66–71 (Piece 1)	629.58	13	Pink-gray basalt	Brown clay, Cc	2.58
67R-5, 7–13 (Piece 1A)	638.17	14	Light gray basalt	Brown clay, Cc	2.59
68R-3, 37–41 (Piece 1)	645.88	15	Gray basalt with green breccia	Green clay Cc, FeOx	2.33
68R-3, 61–65 (Piece 1)	646.12	15	Green volcanic breccia	Green-brown clay, sid?	2.40
68R-7, 65–70 (Piece 1)	650.88	17	Red-brown breccia with pale matrix	Red-brown clay, FeOx, zeo, Cc	2.24
69R-1, 60–67 (Piece 4A)	652.60	17	Dark gray basalt	Brown clay, sid, Cc, FeOx	2.72
69R-2, 63–68 (Piece 5B)	654.13	17	Light gray basalt	Cc, sid	2.51
69R-2, 84–90 (Piece 5D)	654.34	17	Light gray basalt	Cc, sid, FeOx	2.67
70R-1, 54–60 (Piece 3B)	662.04	18	Dark red welded flowtop breccia	Red clay, FeOx	2.31
70R-2, 14–20 (Piece 1A)	662.86	18	Light gray feldspar-phyric breccia	Green clay	2.13
70R-2, 57–62 (Piece 1C)	663.29	18	Red-brown welded breccia	FeOx	2.22
70R-2, 68–74 (Piece 1E)	663.40	18	Pale green altered lava	Green to red clay, FeOx, Cc, sid	2.37
70R-2, 86–91 (Piece 1F)	663.58	18	Pale yellow-gray altered lava	Green clay, FeOx, sid	2.47
70R-2, 111–117 (Piece 1F)	663.83	18	Bleached, highly altered lava	Yellow clay, Ca, sid	2.31
70R-3, 102–108 (Piece 7)	665.24	18	Red, finely vesicular lava	Red-gray clay, Cc	2.38
70R-4, 54–60 (Piece 4)	665.05	18	Pink altered lava	Brown to pink clay, Cc, sid	2.28
70R-4, 70–76 (Piece 4B)	666.21	18	Bleached altered lava	Yellow clay, Cc	2.42
70R-4, 102–107 (Piece 5B)	666.53	18	Yellow-gray altered lava	Pink, gray, green clay, Cc	2.31
70R-5, 21–27 (Piece 1B)	667.00	18	Red vesicular lava	Pink, gray, green clay, Cc	2.23
71R-1, 20–25 (Piece 2B)	671.10	18	Yellow-gray altered feldspar-phyric lava	Yellow-brown clay	2.63
71R-1, 46–51 (Piece 2C)	671.36	18	Yellow-gray altered feldspar-phyric lava	Yellow-brown clay, FeOx	2.60
71R-2, 41–46 (Piece 1A)	672.26	18	Red-gray basalt with bleached alteration halo	Red-brown clay, FeOx	2.44
71R-2, 54–59 (Piece 1A)	672.39	18	Red-gray lava with pink alteration zone	Brown clay, Cc	2.40
71R-2, 72–77 (Piece 1B)	672.57	18	Red-gray feldspar-phyric lava with gray alteration zone	Brown-red clay, FeOx	2.41
71R-3, 41–48 (Piece 1B)	673.31	18	Red-gray feldspar-phyric lava	Brown clay, FeOx	2.27
71R-4, 1–8 (Piece 1A)	674.21	18	Red-gray feldspar-phyric lava	Brown clay, FeOx, Cc	2.36
71R-4, 54–60 (Piece 1D)	674.74	19	Red-brown welded flow-top breccia	Red-brown clay, FeOx	3.03
71R-4, 80–86 (Piece 1G)	675.00	19	Pale green, highly altered flow-top breccia	Green clay	2.41
71R-5, 100–105 (Piece 1F)	676.66	19	Bleached, intensely altered feldspar-phyric lava	Yellow, green, brown clay	2.42
71R-6, 34–41 (Piece 1B)	677.41	19	Bleached lava with hematite veining	Yellow-brown clay, FeOx	2.52
71R-7, 32–38 (Piece 2)	678.77	19	Red-gray feldspar-phyric lava	Red-brown clay, FeOx	2.44
72R-2, 48–53 (Piece 2B)	682.21	19	Gray feldspar-phyric lava	Gray clay, Cc	2.51
72R-3, 114–120 (Piece 4A)	683.76	19	Gray to pink plagioclase-phyric lava	Gray to pink clay, Cc	2.52
73R-1, 12–18 (Piece 3)	689.62	19	Red-gray feldspar-phyric lava	Red-brown clay, FeOx	2.53
73R-2, 115–120 (Piece 12)	692.15	19	Gray feldspar-phyric lava with hematite vein	Red-brown clay, FeOx, Cc	2.48
73R-3, 77–84 (Piece 5)	693.27	19	Gray feldspar-phyric lava	Green clay, Cc	2.54

Notes: NA = not analyzed, BD = below detection. * = total Fe as ferric oxide. FeO determined by titration. Mg# = $Mg^{2+}/(Mg^{2+} + Fe[tot])$. Total for ignited sample. LOI = loss on ignition. Cc = calcium carbonate, Sid = siderite, FeOx = iron oxyhydroxides, Zeo = zeolite.

Table T1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Major element oxides (wt%)												
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3*	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
183-1139A-														
53R-1, 47–52	499.27	74.84	0.34	10.40	6.26	6.13	0.11	0.13	1.22	0.52	3.20	3.27	0.01	100.19
53R-2, 52–54	500.79	78.04	0.34	10.06	3.21	2.99	0.20	0.02	0.28	0.34	1.94	5.72	0.03	100.00
54R-1, 74–78	508.74	82.61	0.31	8.26	1.00	0.82	0.15	0.01	0.09	0.30	1.69	5.27	0.03	99.56
54R-1, 86–90	508.86	85.05	0.21	6.49	5.49	5.25	0.21	0.03	0.51	0.16	0.58	1.24	0.02	99.78
54R-1, 93–96	508.93	93.30	0.23	3.13	2.11	2.05	0.05	0.08	0.21	0.07	0.25	0.54	0.01	99.93
54R-1, 102–106	509.02	67.06	0.59	14.79	6.98	NA	NA	0.04	0.58	0.16	2.37	7.21	0.07	99.85
55R-1, 22–26	517.82	76.07	0.42	11.50	3.02	2.89	0.11	0.01	0.03	0.05	4.24	4.92	0.03	100.28
56R-1, 32–36	527.62	74.24	0.41	11.80	4.00	3.80	0.18	0.02	0.03	0.04	4.56	5.24	0.03	100.37
56R-2, 62–67	529.26	64.93	0.62	16.67	8.12	6.20	1.73	0.04	1.20	0.27	3.47	4.29	0.04	99.65
56R-3, 111–116	531.25	69.40	0.46	15.16	5.43	4.52	0.82	0.02	3.36	0.40	3.48	2.16	0.02	99.89
57R-1, 13–20	537.03	72.37	0.41	13.60	4.33	3.30	0.92	0.05	2.57	0.52	3.35	2.63	0.01	99.83
58R-1, 5–9 (Piece 1)	546.55	74.37	0.31	10.54	6.42	6.17	0.22	0.02	0.06	0.02	3.55	4.95	0.01	100.25
60R-1, 37–42 (Piece 7)	565.97	76.95	0.31	10.62	3.97	3.64	0.29	0.01	0.04	0.03	3.16	5.10	0.00	100.19
61R-1, 12–19 (Piece 1A)	575.32	65.98	0.59	15.77	6.27	5.62	0.59	0.05	0.12	0.35	4.75	6.33	0.02	100.24
61R-1, 98–104 (Piece 1F)	576.18	65.96	0.50	15.56	6.13	2.66	3.12	0.35	0.10	0.29	5.22	5.91	0.02	100.04
61R-2, 84–92 (Piece 6)	577.46	67.71	0.48	14.99	6.20	4.01	1.97	0.18	0.12	0.26	4.47	5.95	0.02	100.38
62R-3, 8–13	587.01	52.31	2.81	17.17	14.91	14.48	0.39	0.13	1.11	1.87	2.92	5.65	1.21	100.09
63R-1, 33–39 (Piece 7)	594.93	45.29	4.15	15.76	18.15	5.76	11.15	0.90	1.74	5.48	4.29	2.86	1.55	100.17
64R-2, 12–19 (Piece 2)	604.32	39.01	5.68	21.42	20.11	17.73	2.14	0.23	0.78	5.15	1.42	1.92	3.75	99.46
64R-4, 44–51 (Piece 3B)	609.08	49.02	4.50	16.58	13.00	6.11	6.21	0.23	2.38	5.85	4.45	2.70	1.13	99.85
65R-1, 0–6 (Piece 1)	613.90	52.05	4.30	16.08	11.82	8.24	3.22	0.16	1.99	6.08	3.86	2.68	1.28	100.29
65R-1, 53–61 (Piece 4A)	614.43	48.98	4.21	15.91	12.43	5.46	6.27	0.39	1.64	8.14	4.17	2.62	1.23	99.73
65R-2, 118–124 (Piece 3C)	616.38	45.69	4.00	14.28	18.12	9.99	7.31	0.65	3.39	7.68	2.72	2.04	0.95	99.52
66R-3, 85–90 (Piece 1D)	627.33	51.70	4.55	16.60	11.17	8.98	1.97	0.09	1.21	5.75	4.43	2.86	1.72	100.07
66R-4, 65–70 (Piece 1)	628.57	37.08	2.96	11.23	11.08	8.86	2.01	0.79	2.74	30.09	1.58	0.86	1.57	99.99
66R-5, 66–71 (Piece 1)	629.58	43.00	3.85	14.48	16.16	5.37	9.70	0.42	2.30	12.61	3.79	2.50	1.07	100.18
67R-5, 7–13 (Piece 1A)	638.17	50.67	2.83	16.78	11.73	4.11	6.86	0.27	1.36	6.72	4.78	3.88	1.17	100.17
68R-3, 37–41 (Piece 1)	645.88	51.18	4.08	16.81	13.77	5.60	7.35	0.17	3.09	3.92	2.05	3.44	1.19	99.69
68R-3, 61–65 (Piece 1)	646.12	40.78	2.12	9.71	34.86	22.87	10.79	0.97	3.96	5.20	0.80	0.24	0.78	99.41
68R-7, 65–70 (Piece 1)	650.88	60.71	2.51	13.05	13.24	12.00	1.12	0.12	1.91	2.07	2.06	3.25	0.98	99.90
69R-1, 60–67 (Piece 4A)	652.60	54.35	2.95	15.06	12.47	5.10	6.64	0.20	1.50	5.31	4.20	2.96	1.19	100.18
69R-2, 63–68 (Piece 5B)	654.13	56.44	3.07	15.71	9.15	3.66	4.94	0.13	1.25	5.07	4.50	3.25	1.22	99.79
69R-2, 84–90 (Piece 5D)	654.34	53.21	3.12	15.97	11.05	4.16	6.20	0.18	1.78	5.95	4.44	3.24	1.24	100.18
70R-1, 54–60 (Piece 3B)	662.04	60.76	0.85	16.11	12.68	10.61	1.87	0.12	0.86	0.71	3.35	4.67	0.06	100.16
70R-2, 14–20 (Piece 1A)	662.86	60.98	0.86	16.15	13.02	12.00	0.91	0.11	0.84	0.42	3.02	4.10	0.03	99.52
70R-2, 57–62 (Piece 1C)	663.29	57.06	0.83	16.25	15.77	13.36	2.17	0.12	0.69	0.75	3.57	4.67	0.10	99.81
70R-2, 68–74 (Piece 1E)	663.40	63.61	1.10	20.63	2.43	1.77	0.59	0.03	0.61	0.60	4.32	6.83	0.14	100.29
70R-2, 86–91 (Piece 1F)	663.58	58.50	0.81	15.00	14.80	4.47	9.30	0.77	1.18	1.55	3.25	3.95	0.15	99.95
70R-2, 111–117 (Piece 1F)	663.83	59.64	0.86	15.97	10.92	NA	NA	0.54	0.72	2.24	3.71	5.20	0.17	99.97
70R-3, 102–108 (Piece 7)	665.24	63.24	0.85	15.39	8.81	3.62	4.67	0.18	0.32	0.64	4.43	5.87	0.16	99.89
70R-4, 54–60 (Piece 4)	665.05	60.05	0.81	15.48	12.86	3.22	8.67	0.65	0.46	0.76	3.38	5.70	0.17	100.31
70R-4, 70–76 (Piece 4B)	666.21	59.99	0.80	15.35	12.70	2.18	9.46	0.40	0.68	0.77	3.79	5.17	0.16	99.79
70R-4, 102–107 (Piece 5B)	666.53	62.28	0.80	14.79	10.74	2.68	7.25	0.30	0.68	0.64	3.91	5.22	0.15	99.50
70R-5, 21–27 (Piece 1B)	667.00	62.68	0.79	15.11	10.80	4.48	5.69	0.29	0.40	0.62	3.67	5.89	0.17	100.42
71R-1, 20–25 (Piece 2B)	671.10	64.85	0.78	14.44	8.10	1.05	6.35	0.29	0.31	1.15	4.61	5.50	0.14	100.16
71R-1, 46–51 (Piece 2C)	671.36	60.99	0.78	14.95	9.19	1.71	6.73	0.28	0.60	1.93	5.07	5.75	0.14	99.67
71R-2, 41–46 (Piece 1A)	672.26	63.03	0.81	14.96	10.87	5.88	4.49	0.31	0.64	0.65	3.65	5.31	0.15	100.38
71R-2, 54–59 (Piece 1A)	672.39	65.58	0.84	15.71	6.84	3.92	2.63	0.14	0.23	0.67	4.21	5.98	0.18	100.35
71R-2, 72–77 (Piece 1B)	672.57	64.10	0.79	14.94	8.98	5.12	3.48	0.27	0.32	0.75	4.10	5.84	0.16	100.24
71R-3, 41–48 (Piece 1B)	673.31	62.98	0.79	14.71	10.78	5.48	4.77	0.40	0.42	0.70	3.84	5.60	0.15	100.36
71R-4, 1–8 (Piece 1A)	674.21	60.64	0.86	16.26	10.51	5.36	4.63	0.31	0.41	0.87	5.10	4.91	0.27	100.14
71R-4, 54–60 (Piece 1D)	674.74	63.55	0.56	17.11	8.99	8.00	0.89	0.04	0.65	0.26	4.35	4.38	0.05	99.93
71R-4, 80–86 (Piece 1G)	675.00	69.54	0.51	15.50	6.18	2.49	3.32	0.08	0.99	0.63	2.78	3.55	0.07	99.83
71R-5, 100–105 (Piece 1F)	676.66	71.31	0.43	13.23	5.45	2.00	3.11	0.11	0.26	0.64	3.58	4.85	0.04	99.90
71R-6, 34–41 (Piece 1B)	677.41	72.03	0.49	14.66	3.70	1.61	1.88	0.10	0.28	0.57	3.23	5.21	0.03	100.30
71R-7, 32–38 (Piece 2)	678.77	71.08	0.44	13.59	4.71	2.91	1.62	0.09	0.17	0.64	3.84	5.27	0.03	99.86
72R-2, 48–53 (Piece 2B)	682.21	70.95	0.44	13.30	5.63	2.74	2.60	0.14	0.18	0.39	3.99	5.32	0.01	100.35
72R-3, 114–120 (Piece 4A)	683.76	69.87	0.44	13.32	6.46	2.36	3.69	0.16	0.25	0.39	4.09	5.26	0.01	100.24
73R-1, 12–18 (Piece 3)	689.62	70.70	0.44	13.28	5.99	3.01	2.68	0.15	0.10	0.13	4.26	5.22	0.01	100.29
73R-2, 115–120 (Piece 12)	692.15	69.60	0.47	13.78	6.70	1.97	4.25	0.25	0.23	0.16	4.01	5.07	0.02	100.28
73R-3, 77–84 (Piece 5)	693.27	69.12	0.46	13.56	7.01	2.33	4.21	0.24	0.23	0.14	4.09	5.23	0.02	100.10

Table T1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Major element oxides (wt%)					Trace elements (ppm)						
		LOI	C	S	Ferrous iron	Mg#	V	Cr	Ni	Zn	Ga	Rb	Sr
183-1139A-													
53R-1, 47–52	499.27	9.48	0.0089	BD	0.98	0.28	BD	3	1	327	38	68	56
53R-2, 52–54	500.79	5.27	0.0103	0.0020	0.93	0.15	7	3	2	288	35	124	37
54R-1, 74–78	508.74	4.37	NA	NA	0.83	0.15	2	BD	1	39	31	112	38
54R-1, 86–90	508.86	4.86	0.0118	0.0010	0.96	0.16	3	18	1	481	24	64	31
54R-1, 93–96	508.93	2.27	0.0344	0.0030	0.97	0.17	14	70	2	143	10	23	12
54R-1, 102–106	509.02	4.28	0.0141	0.0042	NA	0.14	5	35	3	520	50	190	40
55R-1, 22–26	517.82	0.38	0.0269	BD	0.96	0.02	3	8	BD	70	35	113	6
56R-1, 32–36	527.62	0.15	0.0126	BD	0.95	0.02	BD	4	BD	95	36	127	6
56R-2, 62–67	529.26	7.28	NA	NA	0.76	0.23	NA	NA	NA	NA	NA	NA	NA
56R-3, 111–116	531.25	18.94	NA	NA	0.83	0.55	BD	12	1	384	49	37	75
57R-1, 13–20	537.03	17.11	0.0155	0.0015	0.76	0.54	1	47	1	716	44	43	48
58R-1, 5–9 (Piece 1)	546.55	0.73	0.0388	0.0011	0.96	0.02	BD	3	BD	161	38	144	6
60R-1, 37–42 (Piece 7)	565.97	0.63	0.0555	BD	0.92	0.02	BD	10	1	99	37	124	6
61R-1, 12–19 (Piece 1A)	575.32	1.19	0.1199	BD	0.90	0.04	BD	3	BD	82	32	97	22
61R-1, 98–104 (Piece 1F)	576.18	2.40	0.9459	0.0024	0.43	0.03	BD	6	BD	190	34	88	9
61R-2, 84–92 (Piece 6)	577.46	1.81	0.3366	0.0010	0.65	0.04	BD	1	BD	140	32	108	11
62R-3, 8–13	587.01	3.66	0.0225	0.0012	0.97	0.13	40	8	1	162	25	71	132
63R-1, 33–39 (Piece 7)	594.93	7.34	2.9656	0.0015	0.32	0.16	209	5	BD	130	23	41	419
64R-2, 12–19 (Piece 2)	604.32	8.47	0.0453	0.0036	0.88	0.07	228	2	BD	388	29	22	147
64R-4, 44–51 (Piece 3B)	609.08	3.28	0.4509	BD	0.47	0.27	302	5	6	145	26	43	467
65R-1, 0–6 (Piece 1)	613.90	7.54	1.2956	BD	0.70	0.25	267	BD	4	252	24	42	290
65R-1, 53–61 (Piece 4A)	614.43	8.59	3.0556	BD	0.44	0.21	265	105	5	128	24	39	431
65R-2, 118–124 (Piece 3C)	616.38	15.07	2.2989	BD	0.55	0.27	285	18	16	197	22	31	117
66R-3, 85–90 (Piece 1D)	627.33	3.55	0.7099	0.0016	0.80	0.18	234	224	30	96	26	45	475
66R-4, 65–70 (Piece 1)	628.57	22.95	NA	NA	0.80	0.33	187	3	5	57	14	12	132
66R-5, 66–71 (Piece 1)	629.58	14.04	5.1122	BD	0.33	0.22	229	24	11	97	21	34	378
67R-5, 7–13 (Piece 1A)	638.17	7.42	3.0522	0.0031	0.35	0.19	96	BD	1	87	24	53	453
68R-3, 37–41 (Piece 1)	645.88	6.71	NA	NA	0.41	0.31	215	43	11	132	24	50	123
68R-3, 61–65 (Piece 1)	646.12	11.54	1.9056	BD	0.66	0.18	95	39	BD	207	16	2	54
68R-7, 65–70 (Piece 1)	650.88	4.50	0.1609	0.0022	0.91	0.22	78	18	1	94	20	42	131
69R-1, 60–67 (Piece 4A)	652.60	4.34	0.9049	0.0066	0.41	0.19	128	6	1	134	23	43	394
69R-2, 63–68 (Piece 5B)	654.13	3.43	1.3256	0.0445	0.40	0.21	135	6	1	142	24	51	427
69R-2, 84–90 (Piece 5D)	654.34	5.30	NA	NA	0.38	0.24	136	1	2	140	24	50	431
70R-1, 54–60 (Piece 3B)	662.04	3.62	0.1849	0.0015	0.84	0.12	BD	4	BD	118	34	48	18
70R-2, 14–20 (Piece 1A)	662.86	3.71	0.0517	BD	0.92	0.11	BD	37	BD	95	36	37	50
70R-2, 57–62 (Piece 1C)	663.29	4.31	0.9659	0.0023	0.85	0.08	BD	58	3	316	34	42	33
70R-2, 68–74 (Piece 1E)	663.40	2.98	0.1032	0.0068	0.73	0.33	BD	37	BD	95	36	37	50
70R-2, 86–91 (Piece 1F)	663.58	9.51	2.0789	0.0058	0.30	0.14	BD	129	BD	137	33	31	31
70R-2, 111–117 (Piece 1F)	663.83	8.22	2.8822	0.0045	NA	0.12	1	1	BD	121	33	40	28
70R-3, 102–108 (Piece 7)	665.24	3.70	1.3789	0.0027	0.41	0.07	BD	1	BD	144	33	60	14
70R-4, 54–60 (Piece 4)	665.05	7.55	2.9789	0.0250	0.25	0.07	BD	4	BD	118	34	48	18
70R-4, 70–76 (Piece 4B)	666.21	7.77	1.8222	0.0204	0.17	0.10	BD	25	BD	186	34	42	17
70R-4, 102–107 (Piece 5B)	666.53	6.24	1.4056	0.0163	0.25	0.11	BD	BD	BD	210	33	52	19
70R-5, 21–27 (Piece 1B)	667.00	5.18	1.1489	BD	0.41	0.07	BD	1	BD	97	33	62	18
71R-1, 20–25 (Piece 2B)	671.10	4.47	1.2189	0.0049	0.13	0.07	BD	1	BD	187	31	55	13
71R-1, 46–51 (Piece 2C)	671.36	5.42	2.4089	0.0150	0.19	0.11	BD	BD	BD	175	32	59	15
71R-2, 41–46 (Piece 1A)	672.26	4.48	1.4822	0.2290	0.54	0.10	BD	1	BD	119	33	65	22
71R-2, 54–59 (Piece 1A)	672.39	2.71	0.8009	0.0043	0.57	0.06	BD	BD	BD	81	34	71	18
71R-2, 72–77 (Piece 1B)	672.57	3.37	0.7262	BD	0.57	0.07	BD	1	BD	108	33	72	17
71R-3, 41–48 (Piece 1B)	673.31	4.10	0.9266	BD	0.51	0.07	BD	1	BD	127	33	70	20
71R-4, 1–8 (Piece 1A)	674.21	4.41	0.9059	BD	0.51	0.07	BD	BD	BD	279	33	56	49
71R-4, 54–60 (Piece 1D)	674.74	2.59	0.0822	0.0024	0.89	0.12	BD	66	1	200	51	66	61
71R-4, 80–86 (Piece 1G)	675.00	4.82	0.5316	0.0196	0.40	0.24	BD	BD	1	250	44	60	60
71R-5, 100–105 (Piece 1F)	676.66	3.46	0.6956	0.0528	0.37	0.09	BD	8	BD	102	40	120	15
71R-6, 34–41 (Piece 1B)	677.41	2.83	0.6666	0.0775	0.44	0.13	BD	35	1	86	45	130	17
71R-7, 32–38 (Piece 2)	678.77	2.23	0.6079	BD	0.62	0.06	BD	4	BD	103	40	119	14
72R-2, 48–53 (Piece 2B)	682.21	2.34	0.8262	0.0028	0.49	0.06	BD	3	BD	166	39	123	11
72R-3, 114–120 (Piece 4A)	683.76	3.03	1.1122	0.0037	0.36	0.07	BD	BD	BD	165	40	122	10
73R-1, 12–18 (Piece 3)	689.62	2.19	0.7652	0.0051	0.50	0.03	BD	1	BD	218	40	122	10
73R-2, 115–120 (Piece 12)	692.15	3.45	1.2822	0.0071	0.29	0.06	BD	BD	BD	190	41	110	10
73R-3, 77–84 (Piece 5)	693.27	3.20	1.2089	0.0058	0.33	0.06	BD	2	BD	281	40	112	13

Table T1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Trace elements (ppm)								
		Y	Zr	Nb	Ba	La	Ce	Pb	Th	U
183-1139A-										
53R-1, 47–52	499.27	125	1786	175	11	130	307	29	24	4
53R-2, 52–54	500.79	143	1667	157	4	96	226	18	21	7
54R-1, 74–78	508.74	94	1594	218	BD	105	240	13	19	6
54R-1, 86–90	508.86	126	1159	110	BD	132	282	1	15	4
54R-1, 93–96	508.93	51	500	56	65	36	89	22	6	3
54R-1, 102–106	509.02	169	1434	195	19	224	483	8	17	9
55R-1, 22–26	517.82	69	888	94	20	76	205	16	10	2
56R-1, 32–36	527.62	103	982	103	11	88	195	17	11	3
56R-2, 62–67	529.26	NA	NA	NA	NA	NA	NA	NA	NA	NA
56R-3, 111–116	531.25	84	1551	162	2	146	318	20	20	1
57R-1, 13–20	537.03	53	1384	141	16	64	132	27	18	1
58R-1, 5–9 (Piece 1)	546.55	49	1139	116	BD	63	251	19	13	3
60R-1, 37–42 (Piece 7)	565.97	91	1169	117	11	29	57	12	15	4
61R-1, 12–19 (Piece 1A)	575.32	52	566	65	198	55	126	15	8	4
61R-1, 98–104 (Piece 1F)	576.18	52	613	75	22	66	152	12	8	2
61R-2, 84–92 (Piece 6)	577.46	53	601	73	21	67	152	11	8	3
62R-3, 8–13	587.01	48	316	40	676	42	97	5	3	BD
63R-1, 33–39 (Piece 7)	594.93	43	275	34	931	36	91	3	3	BD
64R-2, 12–19 (Piece 2)	604.32	89	377	46	274	42	136	6	4	2
64R-4, 44–51 (Piece 3B)	609.08	37	312	38	736	32	81	4	3	BD
65R-1, 0–6 (Piece 1)	613.90	37	311	38	527	35	89	4	3	BD
65R-1, 53–61 (Piece 4A)	614.43	40	299	36	703	36	85	4	4	BD
65R-2, 118–124 (Piece 3C)	616.38	33	241	30	362	29	73	4	3	BD
66R-3, 85–90 (Piece 1D)	627.33	43	328	42	864	39	101	4	3	BD
66R-4, 65–70 (Piece 1)	628.57	45	191	21	235	47	105	3	2	BD
66R-5, 66–71 (Piece 1)	629.58	36	245	30	803	33	74	3	2	BD
67R-5, 7–13 (Piece 1A)	638.17	44	345	42	1701	41	96	4	3	BD
68R-3, 37–41 (Piece 1)	645.88	36	318	38	522	35	87	7	3	1
68R-3, 61–65 (Piece 1)	646.12	40	196	24	101	32	77	3	2	1
68R-7, 65–70 (Piece 1)	650.88	39	313	36	822	42	93	5	3	BD
69R-1, 60–67 (Piece 4A)	652.60	43	353	40	864	43	101	6	4	BD
69R-2, 63–68 (Piece 5B)	654.13	41	377	43	922	43	100	6	4	BD
69R-2, 84–90 (Piece 5D)	654.34	47	372	42	901	46	107	6	3	BD
70R-1, 54–60 (Piece 3B)	662.04	55	440	49	201	59	123	6	6	2
70R-2, 14–20 (Piece 1A)	662.86	47	518	54	199	44	129	6	6	BD
70R-2, 57–62 (Piece 1C)	663.29	17	467	53	192	3	14	12	6	BD
70R-2, 68–74 (Piece 1E)	663.40	47	518	54	199	44	129	6	6	BD
70R-2, 86–91 (Piece 1F)	663.58	60	408	48	228	66	123	8	5	1
70R-2, 111–117 (Piece 1F)	663.83	47	441	49	370	50	121	6	5	1
70R-3, 102–108 (Piece 7)	665.24	44	458	54	273	53	111	10	5	1
70R-4, 54–60 (Piece 4)	665.05	55	440	49	201	59	123	6	6	2
70R-4, 70–76 (Piece 4B)	666.21	53	429	50	162	50	121	5	5	1
70R-4, 102–107 (Piece 5B)	666.53	47	420	48	140	47	114	7	5	1
70R-5, 21–27 (Piece 1B)	667.00	56	436	49	172	70	146	6	5	BD
71R-1, 20–25 (Piece 2B)	671.10	43	297	50	142	47	117	7	5	BD
71R-1, 46–51 (Piece 2C)	671.36	49	413	48	195	47	114	6	5	BD
71R-2, 41–46 (Piece 1A)	672.26	39	399	53	321	48	121	10	5	1
71R-2, 54–59 (Piece 1A)	672.39	51	444	54	212	58	130	6	5	BD
71R-2, 72–77 (Piece 1B)	672.57	51	442	51	170	49	118	6	5	1
71R-3, 41–48 (Piece 1B)	673.31	49	432	51	139	45	112	10	5	1
71R-4, 1–8 (Piece 1A)	674.21	99	491	55	162	84	143	7	5	1
71R-4, 54–60 (Piece 1D)	674.74	79	1357	138	106	75	237	25	18	1
71R-4, 80–86 (Piece 1G)	675.00	115	1474	138	112	150	357	10	17	3
71R-5, 100–105 (Piece 1F)	676.66	40	1288	120	84	51	295	12	15	1
71R-6, 34–41 (Piece 1B)	677.41	32	1263	124	130	27	119	9	16	BD
71R-7, 32–38 (Piece 2)	678.77	38	1210	118	82	39	258	13	15	1
72R-2, 48–53 (Piece 2B)	682.21	135	1262	118	60	44	95	17	15	3
72R-3, 114–120 (Piece 4A)	683.76	139	1241	117	45	66	98	13	15	2
73R-1, 12–18 (Piece 3)	689.62	96	1221	116	50	71	124	19	14	1
73R-2, 115–120 (Piece 12)	692.15	173	1131	112	35	153	218	6	14	3
73R-3, 77–84 (Piece 5)	693.27	159	1119	108	48	153	172	14	13	2