

Rates and mechanism of weathering-rind development on andesite gravel in fluvial terrace deposits

著者	Oguchi Chiaki T
著者別名	小口, 千明
内容記述	Thesis (Ph. D. in Science)--University of Tsukuba, (A), no. 1971, 1998.10.31
発行年	1998
その他のタイトル	河成段丘堆積中の安山岩礫に生じた風化皮膜の発達速度と発達機構
URL	http://hdl.handle.net/2241/6868

Tables

Table 1 Classifications of landforms and geology in Nasuno-ga-hara proposed in previous studies.

Era	Sasaki et al. (1958)	Watanabe et al. (1960)	Koike (1961)	Akutsu (1962)	Oguchi (the present study)	Key Tephiras (after Suzuki, 1993)
Holocene	Floodplain Deposits	Recent River Gravel	Recent River Floodplain	Recent River Deposits	Recent River Floodplain	
	Fourth Terrace Gravel	<Fujinita Volcanic Ash Soils Recent Terrace Gravel	Post Volcanic-Ash Soil Terraces	Kamikuroiso Gravel Sabui Gravel Okusawa Gravel	Recent River Gravel Lower Terraces II	Nt-I (12-13 ka) ¹⁾
	< Brown Volcanic Ashes Third Terrace Gravel Second Terrace Gravel First Terrace Gravel	<Nasu Volcanic Ash Soils Nasu Alluvial-fan Gravel	< L _{1,2} Volcanic Ash Soils Nasuno Surface (Lower Terraces I, II, III)	< Tahara and Takaragi Volcanic Ash Soils Nasuno Gravel	Lower Terraces I (Main Alluvial-fan Surfaces) Nasuno Gravel	AT (22-25 ka) ¹⁾ KP (31-32 ka) ²⁾
Pleistocene	Higher Terrace Gravel	<Torinome Volcanic Ash Soils Torinome Gravel	< L _{2,2} Volcanic Ash Soils Middle Terraces < L _{2,2} Volcanic Ash Soils Upper Terraces	< Hoshakuji Volcanic Ash Soils Kanemaruhara Gravel	Middle Terraces Upper Terraces Torinome Gravel	DKP (48 ka) ³⁾ Mas (100 ka) Mzp 9, 10 (135 ka) ⁴⁾ Apm-U (300-350 ka) ⁵⁾ MoP (>300 ka)
	Nasu Formation • Lava of Nasu-Volcano • Kuroiso Pyroclastic Rocks	Nasu Formation Kuroiso Volcanic mud-flow Nabekake Gravel	Nasu Hills	Kuroiso Volcanic Breccia/Nabekake Gravel member	Lower Hills Sakai-bayashi Gravel	Kuroiso Dry Avalanche (\approx 500 ka) Nm-13 (500 ka) ⁵⁾
	Takahara Formation • Ohtawara Pumis Flow • Lava of Takahara-Volcano • Ainosawa Pyroclastic Rocks Yanagi-bayashi Gravel	Takahara Formation • Ohtawara Pumis-Flow • Ainosawa Pyroclastics • Yanagi-bayashi Gravel	Kitsuregawa Hills	Kawasaki Group • Wadayama • Volcanic Breccia • Tatenokawa Tuff • Sakai-bayashi Gravel	Upper Hills Yanagi-bayashi Gravel	YG-HtB (830 ka) ⁶⁾

1) Machida and Arai (1992); 2) Suzuki (1976); 3) Machida and Arai (1979); 4) Suzuki (1992); 5) Suzuki and Hayakawa (1990); 6) Koike et al. (1985)

Table 2 List of rock samples

Samples	Sampling site	The longer diameter of rocks (cm)	Apparent thickness of weathering rind (mm)	Colour of groundmass	Samples	Sampling site	The longer diameter of rocks (cm)	Apparent thickness of weathering rind (mm)	Colour of groundmass
0-A1	Loc. 1	8.3	-	gray	320-A1	Loc. 5	11.0	2.0	gray
0-A2	Loc. 1	5.9	-	brown	320-A2	Loc. 5	11.0	1.2	gray
0-A3	Loc. 1	11.0	-	gray	320-A3	Loc. 5	7.5	1.9	gray
0-A4	Loc. 1	6.4	-	gray	320-A4	Loc. 5	9.2	1.9	gray
0-A5	Loc. 1	7.5	-	gray	320-A5	Loc. 5	9.0	1.5	gray
0-A6	Loc. 1	12.5	-	brown	320-A6	Loc. 5	9.5	1.4	gray
0-A7	Loc. 1	7.6	-	gray	320-B1	Loc. 6	9.5	2.9	brown
0-A8	Loc. 1	6.0	-	gray	320-B2	Loc. 6	7.6	1.6	brown
0-A9	Loc. 1	6.8	-	gray	320-B3	Loc. 6	6.5	0.0	gray
0-A10	Loc. 1	7.6	-	gray	320-B4	Loc. 6	6.5	4.5	gray
0-A11	Loc. 1	4.1	-	gray	320-B5	Loc. 6	7.0	4.0	gray
0-A12	Loc. 1	7.5	-	gray	320-B6	Loc. 6	9.2	3.8	gray
0-A13	Loc. 1	13.4	-	gray	320-B7	Loc. 6	6.7	3.3	brown
0-A14	Loc. 1	6.0	-	gray	320-B8	Loc. 6	7.4	4.2	gray
0-A15	Loc. 1	4.8	-	gray	320-B9	Loc. 6	8.4	2.1	brown
0-A16	Loc. 1	14.0	-	gray	320-B10	Loc. 6	16.0	4.0	gray
0-A17	Loc. 1	8.2	-	gray	320-B11	Loc. 6	12.0	3.4	gray
0-A18	Loc. 1	7.8	-	gray	320-B12	Loc. 6	8.0	2.4	gray
0-A19	Loc. 1	10.8	-	gray	320-B13	Loc. 6	11.5	2.4	gray
0-B1	Loc. 2	7.4	-	gray	320-B14	Loc. 6	9.4	3.8	green
0-B2	Loc. 2	5.6	-	brown	320-B15	Loc. 6	5.3	4.5	gray
0-B3	Loc. 2	6.6	-	gray	320-B16	Loc. 6	6.4	1.8	brown
0-B4	Loc. 2	7.4	-	brown	320-B17	Loc. 6	10.0	0.2	gray
0-B5	Loc. 2	11.4	-	brown	320-B18	Loc. 6	4.4	3.0	gray
0-B6	Loc. 2	6.7	-	brown	320-B19	Loc. 6	8.4	2.6	gray
0-B7	Loc. 2	10.8	-	green	320-B20	Loc. 6	7.3	3.0	gray
0-B8	Loc. 2	6.5	-	gray	320-B21	Loc. 6	7.0	2.1	gray
0-B9	Loc. 2	6.3	-	brown	320-B22	Loc. 6	20.0	2.4	gray
0-B10	Loc. 2	20.2	-	gray					
0-B11	Loc. 2	6.0	-	brown	450-A1	Loc. 7	6.6	4.5	gray
0-B12	Loc. 2	9.0	-	gray	450-A2	Loc. 7	4.0	3.3	gray
0-B13	Loc. 2	7.6	-	brown	450-B1	Loc. 8	5.5	3.3	gray
0-B14	Loc. 2	6.6	-	gray	450-B2	Loc. 8	9.5	2.0	gray
0-B15	Loc. 2	6.6	-	gray	450-B3	Loc. 8	12.0	2.2	gray
0-B16	Loc. 2	6.4	-	green	450-B4	Loc. 8	5.5	5.6	gray
0-B17	Loc. 2	9.1	-	gray	450-B5	Loc. 8	10.0	3.4	gray
0-B18	Loc. 2	5.9	-	gray	450-B6	Loc. 8	9.0	1.9	gray
0-B19	Loc. 2	7.9	-	gray	450-B7	Loc. 8	9.6	2.8	gray
0-B20	Loc. 2	10.5	-	green	450-B8	Loc. 8	0.1	3.2	gray
0-B21	Loc. 2	7.9	-	gray	450-B9	Loc. 8	8.4	2.3	gray
0-B22	Loc. 2	6.0	-	gray	450-B10	Loc. 8	17.2	3.1	gray
0-B23	Loc. 2	7.5	-	brown	450-B11	Loc. 8	11.0	4.4	gray
0-B24	Loc. 2	10.4	-	gray	450-B12	Loc. 8	7.3	4.4	gray
0-B25	Loc. 2	7.6	-	brown	450-B13	Loc. 8	7.3	4.8	gray
0-B26	Loc. 2	6.7	-	brown	450-B14	Loc. 8	9.5	3.9	gray
0-B27	Loc. 2	10.2	-	gray	450-B15	Loc. 8	6.8	3.9	gray
0-B28	Loc. 2	9.3	-	gray	450-B16	Loc. 8	14.0	6.4	gray
0-B29	Loc. 2	6.0	-	gray	450-B17	Loc. 8	5.9	4.5	gray
0-B30	Loc. 2	8.0	-	gray	450-B18	Loc. 8	7.0	11.9	gray
0-B31	Loc. 2	7.6	-	brown	450-B19	Loc. 8	9.0	3.5	gray
0-B32	Loc. 2	5.6	-	gray	450-B20	Loc. 8	16.0	1.1	gray
0-B33	Loc. 2	7.4	-	brown	450-B21	Loc. 8	12.5	3.3	gray
0-B34	Loc. 2	11.2	-	brown	450-B22	Loc. 8	9.8	3.6	gray
0-B35	Loc. 2	8.4	-	gray	450-B23	Loc. 8	5.9	2.8	brown
0-B36	Loc. 2	8.0	-	gray	450-B24	Loc. 8	8.3	5.6	gray
0-B37	Loc. 2	7.5	-	gray	450-B25	Loc. 8	5.4	2.7	gray
20-A1	Loc. 3	9.6	-	gray	450-B26	Loc. 8	5.0	2.6	gray
20-A2	Loc. 3	8.1	-	brown	450-B27	Loc. 8	8.2	4.7	gray
20-A3	Loc. 3	6.0	5.0	gray	450-B28	Loc. 8	7.1	5.5	gray
20-A4	Loc. 3	6.1	-	gray	450-B29	Loc. 8	6.0	2.3	gray
20-A5	Loc. 3	5.0	6.0	gray	450-B30	Loc. 8	13.4	2.2	brown
20-A6	Loc. 3	7.6	-	gray	450-B31	Loc. 8	6.5	3.4	gray
20-A7	Loc. 3	10.0	-	gray	450-B32	Loc. 8	9.5	4.2	gray
20-A8	Loc. 3	8.2	-	green	450-B33	Loc. 8	6.2	4.7	gray
20-A9	Loc. 3	7.2	-	gray	450-B34	Loc. 8	6.7	2.3	gray
20-A10	Loc. 3	4.7	5.0	gray	450-B35	Loc. 8	9.5	5.0	gray
20-A11	Loc. 3	7.0	-	brown	450-B36	Loc. 8	9.0	3.4	gray
20-A12	Loc. 3	7.2	-	gray	450-B37	Loc. 8	12.0	4.1	gray
20-A13	Loc. 3	5.3	1.0	gray	450-B38	Loc. 8	7.5	4.3	gray
20-A14	Loc. 3	8.2	1.0	gray	450-B39	Loc. 8	6.7	3.8	gray
20-A15	Loc. 3	6.7	-	gray	450-B40	Loc. 8	13.0	2.5	gray
20-A16	Loc. 3	8.1	-	gray	450-B41	Loc. 8	6.2	5.4	gray
20-A17	Loc. 3	4.6	-	gray	450-B42	Loc. 8	7.5	3.3	gray
20-A18	Loc. 3	7.0	-	gray	450-B43	Loc. 8	7.3	3.0	gray
20-A19	Loc. 3	4.6	-	gray	450-B44	Loc. 8	6.9	4.1	gray
20-A20	Loc. 3	6.4	6.0	gray	450-B45	Loc. 8	9.0	2.8	gray
20-A21	Loc. 3	9.2	-	gray	450-B46	Loc. 8	6.5	5.0	gray
20-B1	Loc. 4	8.2	-	brown	450-B47	Loc. 8	7.4	4.5	gray
20-B2	Loc. 4	5.4	1.0	gray	450-B48	Loc. 8	10.5	3.9	gray
20-B3	Loc. 4	8.0	-	gray	450-B49	Loc. 8	5.5	6.0	gray
20-B4	Loc. 4	6.2	5.0	gray	450-B50	Loc. 8	7.0	2.7	gray
20-B5	Loc. 4	7.3	-	gray	450-B51	Loc. 8	5.8	4.7	gray
20-B6	Loc. 4	10.8	-	gray	450-B52	Loc. 8	7.2	3.3	gray
20-B7	Loc. 4	10.3	-	gray	450-B53	Loc. 8	6.4	5.4	brown
20-B8	Loc. 4	10.6	4.0	gray	450-B54	Loc. 8	4.0	2.3	gray
20-B9	Loc. 4	8.8	-	brown	450-B55	Loc. 8	4.7	3.6	gray
20-B10	Loc. 4	6.5	-	brown	450-B56	Loc. 8	6.4	2.3	gray
20-B11	Loc. 4	6.0	0.3	gray	450-B57	Loc. 8	4.8	4.5	gray
20-B12	Loc. 4	6.1	0.5	gray	450-B58	Loc. 8	5.1	3.4	gray
20-B13	Loc. 4	8.5	0.5	gray	450-B59	Loc. 8	8.5	3.5	gray
20-B14	Loc. 4	6.0	-	green	450-B60	Loc. 8	6.7	3.3	gray
20-B15	Loc. 4	5.7	-	green	450-B61	Loc. 8	15.0	3.5	gray
20-B16	Loc. 4	5.0	0.5	gray	450-B62	Loc. 8	28.0	3.7	gray
20-B17	Loc. 4	16.0	-	brown	450-B63	Loc. 8	7.3	3.1	gray
20-B18	Loc. 4	9.3	1.0	brown	450-B64	Loc. 8	7.8	4.5	gray
20-B19	Loc. 4	6.5	-	brown	450-B65	Loc. 8	11.5	2.2	gray
20-B20	Loc. 4	7.5	0.5	brown	450-C1	Loc. 9	21.2	2.0	gray
20-B21	Loc. 4	4.5	0.3	gray	838-A1	Loc. 18	12.8	5.8	gray
20-B22	Loc. 4	7.0	-	gray	Average	6-18 rocks	8.1	-	-
20-B23	Loc. 4	7.9	-	gray	Average	20-34 rocks	7.5	2.4	-
20-B24	Loc. 4	8.6	-	gray	Average	320-38 rocks	9.0	2.9	-
20-B25	Loc. 4	9.9	-	brown	Average	450-58 rocks	8.6	3.8	-

Table 3 Results of X-ray diffraction.

Samples	Q	T	Pl	Px	Mgn	Z	K	S	Mgh	H
0-ka rocks										
0-A4, Inner part	△	○	⊙	○	△	-	-	-	-	-
0-A6, Inner part	△	○	⊙	○	△	-	-	-	-	-
0-B1, Inner part	△	○	⊙	○	△	-	-	-	-	-
0-B7, Inner part	○	○	⊙	○	△	-	-	-	-	-
20-ka rocks										
20-A1, Inner part	△	○	⊙	○	△	⊙	-	-	-	-
20-A3, Inner part	△	○	⊙	○	△	-	-	-	-	-
20-A16, Inner part	○	○	⊙	○	△	-	-	-	-	-
20-B2, Inner part	○	○	⊙	○	△	-	-	-	-	-
20-B2, Brown layer (<0.1m)	○	○	△	△	-	-	-	-	-	○
20-B6, Inner part	△	○	⊙	○	△	-	-	-	-	-
320-ka rocks										
320-B5, Inner part	○	○	⊙	○	△	-	△	-	-	-
320-B5, Brown layer	○	△	△	△	△	-	○	△	-	-
320-B10, Inner part	○	○	⊙	○	△	-	-	-	-	-
320-B10, Brown layer	○	△	△	△	△	-	○	△	○	-
320-B20, Inner part	△	○	⊙	○	△	-	-	-	-	-
320-B20, Brown layer	△	△	△	△	△	-	△	-	-	-
320-B22, Inner part	△	○	⊙	○	△	-	-	-	-	-
320-B22, Brown layer	△	△	△	△	△	-	△	△	-	-
450-ka rocks										
450-B1, Inner part	○	○	⊙	○	△	-	-	-	-	-
450-B1, Brown layer	○	△	△	△	△	-	△	-	-	-
450-B10, Inner part	△	△	⊙	○	△	-	-	-	-	-
450-B10, Brown layer	△	△	△	△	△	-	△	△	-	-
450-B38, Inner part	○	○	⊙	○	△	-	△	-	-	-
450-B38, Brown layer	○	△	△	△	△	-	○	-	-	-
450-B39, Inner part	△	△	⊙	○	△	-	△	-	-	-
450-B39, Brown layer	△	△	△	△	△	-	○	-	-	-
450-B64, Inner part	○	○	⊙	○	△	-	△	-	-	-
450-B64 Brown layer	○	△	△	△	△	-	△	△	-	-
830-ka rocks										
830-A1, Inner part	○	○	⊙	○	△	-	-	-	-	-
830-A1, Brown layer	○	△	△	△	△	-	○	△	-	-

Q: Quartz, T: Trydimite, P: Plagioclase, Px: Pyroxene, Mgn: Magnetite, Z: Zeolite,

K: Kaolin minerals, S: Smectite, Mgh: Maghemite, H: Hematite

Table 4 Volume of pores with sub-range of pore diameter from the PSD measurement.

Samples	V_{α} , mm ³ /g	V_{β} , mm ³ /g	V_{γ} , mm ³ /g	V_{δ} , mm ³ /g	V_t , mm ³ /g
0 ka (Inner parts)					
0-A1	2.1229	4.0405	3.8593	7.8794	17.9022
0-A4	1.1909	1.5448	2.7192	3.5060	8.9609
0-B1	1.0028	0.8030	3.0739	6.0431	10.9228
0-B37	1.3441	2.4220	6.7926	5.0267	15.5853
Average	1.4152	2.2026	4.1112	5.6138	13.3428
20 ka (Inner parts)					
20-A1	1.9549	3.2851	1.9432	8.1041	15.2872
20-A3	1.4592	1.3425	1.5807	9.5989	13.9813
20-A16	1.9396	4.5899	4.8062	2.4753	13.8111
20-B2	1.4235	1.2245	14.3528	2.8549	19.8556
20-B6	2.9854	6.6473	10.6682	7.2151	27.5161
Average	2.2044	3.9359	12.5105	5.0350	23.6858
320 ka (Inner parts)					
320-B5	2.9253	9.0869	7.8024	14.6627	34.4772
320-B10	1.0201	1.2343	1.4501	4.1155	7.8201
320-B20	5.9196	4.5359	6.8316	8.9727	26.2597
320-B22	1.3003	2.0807	2.3482	10.8780	16.6073
Average	2.7913	4.2345	4.6081	9.6572	21.2911
320 ka (Brown layers)					
320-B5	24.6117	39.3046	83.4741	18.4807	165.8711
320-B10	33.3253	39.5387	93.9595	39.3556	206.1791
320-B20	84.7236	241.7794	36.8317	0.0000	363.3346
320-B22	12.8463	53.8908	69.7220	47.9633	184.4224
Average	38.8767	93.6284	70.9968	26.4499	229.9518
450 ka (Inner parts)					
450-B1	0.7187	0.5920	0.7230	6.3707	8.4044
450-B10	0.8404	0.6765	0.6213	1.0213	3.1596
450-B12	3.3352	4.4481	3.3062	7.0926	18.1821
450-B37	1.5553	1.5189	1.3552	5.0760	9.5054
450-B38	1.6757	4.6596	3.1865	8.1426	17.6643
450-B39	4.3739	11.1324	9.5261	10.5162	35.5486
450-B64	3.6885	4.2367	4.5382	14.8128	27.2761
450-C1	1.5662	2.2424	2.4206	9.0700	15.2992
Average	2.2192	3.6883	3.2096	7.7628	16.8800
450 ka (White layers)					
450-B64	4.5587	9.7283	14.3134	13.7502	42.3506
450 ka (Brown layers)					
450-B1	12.0556	108.5896	212.7586	26.5769	359.9808
450-B10	63.6768	442.0637	105.6119	27.7545	639.1069
450-B12	24.7445	232.4982	80.3587	46.0986	383.7000
450-B38	32.8754	182.3437	60.1063	33.8372	309.1626
450-B39	35.7825	113.2424	89.9077	61.0800	300.0126
450-B64	17.8091	128.3461	84.1599	20.7235	251.0386
Average	31.1573	201.1806	105.4838	36.0118	373.8336
830 ka (Inner parts)					
830-A1	1.2217	1.5627	2.0727	4.1853	9.0424
830 ka (Brown layers)					
830-A1	40.9261	112.8092	69.1785	36.1935	259.1073

V_{α} : Volume of pores with 33-3 μ m diameter
 V_{β} : Volume of pores with 3-0.3 μ m diameter
 V_{γ} : Volume of pores with 0.3-0.03 μ m diameter
 V_{δ} : Volume of pores with 0.03-0.003 μ m diameter
 V_t : Volume of pores with 33-0.003 μ m diameter

Sampl	Th	U	V	Y	Zr	Ig. Loss (%)	Total (%)
0-ka rc							
0-A4 9	3.924	1.196	64.495	34.958	190.859	4.480	95.520
0-A6 7	2.509	-0.099	142.612	28.258	94.459	-	100.105
0-B1 6	4.360	1.459	283.969	39.086	139.818	0.306	99.694
0-B37 0	4.021	0.564	175.914	25.033	110.289	-	100.162
Average	4.191	1.012	229.942	32.060	125.054	0.306	99.928
20-ka i							
20-A1 6	4.324	0.747	94.067	30.319	160.683	1.378	98.622
20-A3 4	3.702	0.490	188.939	32.869	115.409	1.064	98.936
20-A16 0	2.365	-0.006	215.815	21.764	75.338	-	100.358
20-B2 7	0.713	1.484	36.609	34.648	122.165	0.514	99.486
20-B6 9	3.837	1.170	215.303	23.886	98.117	-	100.800
Average	2.275	1.327	125.956	29.267	110.141	0.514	100.143
320-ka							
320-B13	4.809	1.254	124.406	36.579	136.909	1.177	98.823
320-B15	5.108	1.033	106.284	38.903	152.483	2.036	97.964
320-B14	3.142	1.320	267.868	35.400	137.311	-	101.197
320-B19	5.000	1.188	182.552	29.695	97.047	-	100.825
Average	4.515	1.199	170.278	35.144	130.938	1.606	99.702
320-ka							
320-B15	7.104	1.400	189.116	29.898	190.061	5.522	94.478
320-B12	6.682	0.974	170.961	37.805	200.034	-	102.686
320-B15	6.034	1.422	500.451	42.903	198.247	6.060	93.940
320-B14	4.349	0.499	479.594	32.312	122.312	8.663	91.337
Average	6.042	1.074	335.031	35.730	177.664	6.748	95.610
450-ka							
450-B10	3.639	0.903	216.638	24.074	98.570	1.228	98.772
450-B11	1.844	0.267	230.349	22.657	56.763	-	101.577
450-B15	2.112	1.336	242.444	24.835	75.131	4.174	95.826
450-B16	1.992	0.432	242.726	21.005	49.011	0.988	99.012
450-B11	3.514	1.038	72.715	39.793	151.783	2.741	97.259
Average	2.620	0.795	200.974	26.473	86.252	2.283	98.489
450-ka							
450-B12	3.366	0.393	81.137	33.180	160.235	1.090	98.910
450-ka							
450-B12	8.268	1.861	576.033	26.179	249.482	6.985	93.015
450-B16	1.465	0.745	694.055	29.206	110.738	6.773	93.227
450-B9	2.466	0.532	378.684	23.094	108.726	10.630	89.370
450-B10	1.540	-0.127	233.483	19.962	49.127	11.439	88.561
450-B13	4.550	0.901	116.366	33.031	224.197	3.989	96.011
Average	3.658	0.782	399.724	26.294	148.454	7.963	92.037
830-ka							
830-A2	2.397	1.141	168.660	28.451	98.997	-	102.741
830-ka							
830-A6	4.117	1.120	341.184	17.301	145.625	4.723	95.277

Table 6 Chemical compositions from XRF analysis.

Samples	Major elements (wt %)										Minor elements (ppm)														lg. Loss (%)	Total (%)
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Ba	Cu	Ga	Mo	Nb	Ni	Pb	Rb	Sr	Th	U	V	Y	Zr		
0-ka rocks (Inner parts)																										
0-A4	65.909	0.631	13.732	4.547	0.097	1.095	4.251	3.391	1.602	0.154	474.727	11.895	18.711	2.479	6.032	3.209	10.160	53.718	238.469	3.924	1.196	64.495	34.958	190.859	4.480	95.520
0-A6	60.352	0.942	16.564	8.933	0.181	1.638	7.213	3.295	0.720	0.181	221.257	37.539	20.684	1.070	4.332	3.590	4.537	18.582	276.887	2.509	-0.099	142.612	28.258	94.459	-	100.105
0-B1	60.659	1.200	14.928	10.598	0.151	2.243	5.901	2.437	1.257	0.191	437.818	76.306	18.800	1.319	5.047	16.740	5.973	41.910	217.696	4.360	1.459	283.969	39.086	139.818	0.306	99.694
0-B37	60.614	0.728	16.349	7.987	0.126	3.086	7.116	2.809	1.109	0.139	335.501	23.537	19.233	1.598	4.238	20.351	3.771	32.390	235.300	4.021	0.564	175.914	25.033	110.289	-	100.162
Average	60.637	0.964	15.639	9.293	0.139	2.665	6.509	2.623	1.183	0.165	386.660	49.922	19.017	1.459	4.643	18.546	4.872	37.150	226.498	4.191	1.012	229.942	32.060	125.054	0.306	99.928
20-ka rocks (Inner parts)																										
20-A1	65.817	0.693	15.369	5.539	0.120	1.228	4.712	3.280	1.589	0.170	412.883	24.398	19.210	2.203	5.452	4.256	7.720	51.706	229.756	4.324	0.747	94.067	30.319	160.683	1.378	98.622
20-A3	59.638	0.817	15.994	8.300	0.112	3.358	6.907	2.501	1.046	0.153	403.690	24.412	19.183	1.371	4.483	16.850	6.456	32.670	253.294	3.702	0.490	188.939	32.869	115.409	1.064	98.936
20-A16	54.866	0.744	18.879	9.473	0.153	3.735	8.726	2.721	0.747	0.220	251.078	35.415	19.434	0.353	2.869	27.828	3.357	18.871	263.430	2.365	-0.006	215.815	21.764	75.338	-	100.358
20-B2	71.464	0.764	13.247	4.318	0.111	1.519	1.132	5.778	0.884	0.180	502.344	3.732	16.597	1.337	6.754	10.469	4.489	14.833	129.827	0.713	1.484	36.609	34.648	122.165	0.514	99.486
20-B6	58.243	0.775	17.939	9.340	0.169	3.198	7.390	2.516	0.988	0.138	314.761	29.905	21.140	1.001	4.232	20.373	4.852	26.448	273.199	3.837	1.170	215.303	23.886	98.117	-	100.800
Average	64.854	0.770	15.593	6.829	0.140	2.359	4.261	4.147	0.936	0.159	408.553	16.819	18.869	1.169	5.493	15.421	4.671	20.641	201.513	2.275	1.327	125.956	29.267	110.141	0.514	100.143
320-ka rocks (Inner parts)																										
320-B10	63.764	0.661	15.680	6.300	0.099	2.058	5.581	2.995	1.424	0.154	386.817	38.125	19.111	1.796	4.568	7.995	20.546	46.216	242.963	4.809	1.254	124.406	36.579	136.909	1.177	98.823
320-B5	65.305	0.643	16.479	5.297	0.070	2.080	3.673	2.619	1.539	0.147	494.789	30.704	20.354	1.494	5.986	6.812	11.410	48.338	194.875	5.108	1.033	106.284	38.903	152.483	2.036	97.964
320-B20	62.297	1.144	14.733	9.483	0.148	2.247	6.712	2.875	1.252	0.182	358.460	89.821	19.307	2.164	4.093	35.668	5.658	39.615	239.744	3.142	1.320	267.868	35.400	137.311	-	101.197
320-B22	59.887	0.758	16.478	9.960	0.130	3.432	6.617	2.274	1.063	0.129	301.576	42.405	19.397	1.357	3.667	30.502	4.340	33.488	220.299	5.000	1.188	182.552	29.695	97.047	-	100.825
Average	62.813	0.802	15.843	7.760	0.112	2.454	5.646	2.691	1.320	0.153	385.411	50.264	19.542	1.703	4.579	20.244	10.489	41.914	224.470	4.515	1.199	170.278	35.144	130.938	1.606	99.702
320-ka rocks (Brown layers)																										
320-B10	63.604	0.825	17.043	9.451	0.072	0.620	0.352	0.619	1.681	0.139	-	31.438	23.152	2.482	6.122	35.303	16.279	58.279	126.235	7.104	1.400	189.116	29.898	190.061	5.522	94.478
320-B5	62.837	0.691	17.875	8.493	0.154	2.940	5.864	2.666	0.927	0.107	685.037	26.386	22.772	2.116	6.784	18.525	10.322	58.468	70.982	6.682	0.974	170.961	37.805	200.034	-	102.686
320-B20	54.057	1.592	13.854	21.246	0.066	0.743	0.563	0.447	0.978	0.250	432.841	94.243	27.536	2.181	7.497	47.770	12.920	24.900	38.045	6.034	1.422	500.451	42.903	198.247	6.060	93.940
320-B22	54.096	0.853	16.864	15.497	0.100	0.959	0.628	0.622	1.345	0.188	925.134	65.700	21.119	1.209	5.156	49.208	17.602	45.777	83.984	4.349	0.499	479.594	32.312	122.312	8.663	91.337
Average	58.649	0.990	16.409	13.672	0.098	1.316	1.852	1.089	1.233	0.171	681.004	54.442	23.645	1.997	6.390	37.702	14.281	46.856	79.812	6.042	1.074	335.031	35.730	177.664	6.748	95.610
450-ka rocks (Inner parts)																										
450-B1	56.854	0.762	17.799	9.490	0.151	2.939	7.282	2.313	0.943	0.138	303.422	56.283	19.619	1.089	3.976	15.802	18.825	25.234	225.810	3.639	0.903	216.638	24.074	98.570	1.228	98.772
450-B10	53.857	0.791	17.960	10.791	0.175	5.373	9.766	2.191	0.416	0.156	267.769	57.253	20.305	1.437	3.437	43.271	2.293	13.295	285.061	1.844	0.267	230.349	22.657	56.763	-	101.577
450-B38	55.000	0.791	17.056	10.081	0.169	3.264	6.480	2.171	0.602	0.120	251.961	42.490	18.532	0.754	3.445	21.326	3.978	19.426	207.745	2.112	1.336	242.444	24.835	75.131	4.174	95.826
450-B39	49.899	0.759	22.728	11.044	0.177	4.062	8.124	1.732	0.215	0.172	273.607	60.368	21.004	0.892	2.350	26.136	3.840	4.667	288.286	1.992	0.432	242.726	21.005	49.011	0.988	99.012
450-B64	65.990	0.804	14.657	6.611	0.104	1.000	3.336	3.142	1.341	0.180	388.383	20.073	19.417	2.111	5.078	6.673	5.852	40.324	182.511	3.514	1.038	72.715	39.793	151.783	2.741	97.259
Average	56.320	0.781	18.040	9.603	0.155	3.328	6.998	2.310	0.703	0.153	297.028	47.293	19.775	1.257	3.657	22.642	6.958	20.589	237.883	2.620	0.795	200.974	26.473	86.252	2.283	98.489
450-ka rocks (White layers)																										
450-B64	66.826	0.833	15.376	6.936	0.095	0.973	2.986	3.208	1.400	0.177	463.838	18.821	18.792	1.968	4.451	3.426	5.563	42.275	166.822	3.366	0.393	81.137	33.180	160.235	1.090	98.910
450-ka rocks (Brown layers)																										
450-B1	60.146	1.863	9.198	18.594	0.057	0.444	0.317	0.363	1.635	0.225	571.083	81.568	28.512	3.113	6.090	22.147	16.908	60.647	76.652	8.268	1.861	576.033	26.179	249.482	6.985	93.015
450-B10	52.992	1.120	18.413	15.281	0.200	1.382	2.098	0.706	0.680	0.158	654.928	196.676	32.287	1.437	4.591	187.436	3.432	18.845	33.216	1.465	0.745	694.055	29.206	110.738	6.773	93.227
450-B38	44.477	1.774	13.790	25.864	0.164	1.938	0.492	0.118	0.429	0.171	733.993	86.447	25.603	1.118	4.515	29.619	7.737	23.966	102.479	2.466	0.532	378.684	23.094	108.726	10.630	89.370
450-B39	43.345	1.180	23.346	17.037	0.095	0.982	1.781	0.304	0.167	0.225	277.617	64.806	19.465	0.261	2.801	26.284	5.762	5.404	285.580	1.540	-0.127	233.483	19.962	49.127	11.439	88.561
450-B64	68.682	1.095	11.747	9.635	0.158	0.674	0.704	1.630	1.436	0.141	506.646	32.587	23.046	2.873	6.424	8.858	9.618	47.038	74.113	4.550	0.901	116.366	33.031	224.197	3.989	96.011
Average	53.928	1.406	15.299	17.282	0.135	1.084	1.078	0.624	0.869	0.184	548.853	92.417	25.783	1.760	4.884	54.869	8.691	31.180	114.408	3.658	0.782	399.724	26.294	148.454	7.963	92.037
830-ka rocks (Inner parts)																										
830-A1	62.877	0.692	17.909	8.502	0.153	2.935	5.872	2.671	0.928	0.107	362.523	19.809	19.567	1.806	3.127	28.266	4.365	28.529	184.342	2.397	1.141	168.660	28.451			

Table 7 The absolute weights in unit volume of chemical elements.

Samples	Major elements (g/cm ³)							Minor elements (mg/cm ³)																lg. Loss (g/cm ³)	Total(g/cm ³)	
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Ba	Cu	Ga	Mo	Nb	Ni	Pb	Rb	Sr	Th	U	V	Y			Zr
0-ka rocks (Inner parts)																										
0-A4	1.653	0.016	0.344	0.004	0.114	0.002	0.027	0.107	0.085	0.040	119.076	2.984	4.693	0.622	1.513	0.805	2.548	13.474	59.815	0.984	0.300	16.177	8.769	47.873	0.112	2.673
0-A6	1.537	0.024	0.422	0.005	0.228	0.005	0.042	0.184	0.084	0.018	56.365	9.563	5.269	0.273	1.104	0.915	1.156	4.734	70.536	0.639	-0.025	36.330	7.199	24.063	-	2.766
0-B1	1.601	0.032	0.394	0.005	0.280	0.004	0.059	0.156	0.064	0.033	115.565	20.142	4.962	0.348	1.332	4.419	1.577	11.062	57.462	1.151	0.385	74.956	10.317	36.906	0.008	2.969
0-B37	1.584	0.019	0.427	0.004	0.209	0.003	0.081	0.186	0.073	0.029	87.666	6.150	5.026	0.418	1.107	5.318	0.985	8.464	61.484	1.051	0.147	45.966	6.541	28.819	-	2.874
Average	1.592	0.025	0.411	0.004	0.244	0.004	0.070	0.171	0.069	0.031	101.616	13.146	4.994	0.383	1.220	4.868	1.281	9.763	59.473	1.101	0.266	60.461	8.429	32.862	0.008	2.921
20-ka rocks (Inner parts)																										
20-A1	1.624	0.017	0.379	0.004	0.137	0.003	0.030	0.116	0.081	0.039	101.902	6.022	4.741	0.544	1.346	1.050	1.905	12.761	56.705	1.067	0.184	23.216	7.483	39.657	0.034	2.690
20-A3	1.522	0.021	0.408	0.004	0.212	0.003	0.086	0.176	0.064	0.027	103.014	6.229	4.895	0.350	1.144	4.300	1.647	8.337	64.636	0.945	0.125	48.213	8.388	29.450	-	2.804
20-A16	1.481	0.020	0.509	0.006	0.256	0.004	0.101	0.235	0.073	0.020	67.751	9.556	5.244	0.095	0.774	7.509	0.906	5.092	71.084	0.638	-0.002	58.236	5.873	20.329	-	2.959
20-B2	1.764	0.019	0.327	0.004	0.107	0.003	0.037	0.028	0.143	0.022	123.996	0.921	4.097	0.330	1.667	2.584	1.108	3.661	32.046	0.176	0.366	9.036	8.552	30.155	0.013	2.672
20-B6	1.478	0.020	0.455	0.004	0.237	0.004	0.081	0.188	0.064	0.025	79.867	7.588	5.364	0.254	1.074	5.169	1.231	6.711	69.322	0.974	0.297	54.631	6.061	24.896	-	2.818
Average	1.621	0.019	0.391	0.004	0.172	0.004	0.059	0.108	0.103	0.023	101.932	4.255	4.730	0.292	1.370	3.877	1.170	5.186	50.684	0.575	0.332	31.834	7.307	27.525	0.013	2.745
320-ka rocks (Inner parts)																										
320-B10	1.641	0.017	0.404	0.004	0.162	0.003	0.053	0.144	0.077	0.037	99.572	9.814	4.919	0.462	1.176	2.058	5.289	11.897	62.542	1.238	0.323	32.024	9.416	35.242	0.030	2.817
320-B5	1.532	0.015	0.387	0.003	0.124	0.002	0.049	0.086	0.061	0.036	116.092	7.204	4.776	0.351	1.404	1.598	2.677	11.342	45.724	1.198	0.242	24.937	9.128	35.777	-	2.558
320-B20	1.542	0.028	0.365	0.005	0.235	0.004	0.056	0.166	0.071	0.031	88.730	22.233	4.779	0.536	1.013	8.829	1.401	9.806	59.344	0.778	0.327	66.305	8.763	33.989	-	2.809
320-B22	1.533	0.019	0.422	0.003	0.255	0.003	0.088	0.169	0.058	0.027	77.173	10.851	4.964	0.347	0.938	7.805	1.111	8.570	56.375	1.280	0.304	46.715	7.599	24.834	-	2.826
Average	1.562	0.020	0.394	0.004	0.194	0.003	0.061	0.141	0.067	0.033	95.392	12.526	4.859	0.424	1.133	5.073	2.619	10.403	55.996	1.123	0.299	42.495	8.726	32.461	0.030	2.753
320-ka rocks (Brown layers)																										
320-B10	1.016	0.013	0.272	0.002	0.151	0.001	0.010	0.006	0.010	0.027	-	5.021	3.698	0.396	0.978	5.639	2.600	9.308	20.162	1.135	0.224	30.206	4.775	30.357	0.088	1.622
320-B5	1.088	0.012	0.310	0.002	0.147	0.003	0.051	0.102	0.046	0.016	118.666	4.571	3.945	0.367	1.175	3.209	1.788	10.128	12.296	1.157	0.169	29.615	6.549	34.651	-	2.005
320-B20	0.591	0.017	0.151	0.003	0.232	0.001	0.008	0.006	0.005	0.011	47.320	10.303	3.010	0.238	0.820	5.222	1.412	2.722	4.159	0.660	0.155	54.712	4.690	21.673	-	1.183
320-B22	0.911	0.014	0.284	0.003	0.261	0.002	0.016	0.011	0.010	0.023	155.746	11.061	3.555	0.204	0.868	8.284	2.963	7.707	14.139	0.732	0.084	80.740	5.440	20.591	0.146	1.847
Average	0.902	0.014	0.254	0.002	0.198	0.002	0.021	0.031	0.018	0.019	107.244	7.739	3.552	0.301	0.960	5.589	2.191	7.466	12.689	0.921	0.158	48.818	5.364	26.818	0.117	1.691
450-ka rocks (Inner parts)																										
450-B1	1.506	0.020	0.471	0.004	0.251	0.004	0.078	0.193	0.061	0.025	80.373	14.909	5.197	0.288	1.053	4.186	4.987	6.684	59.815	0.964	0.239	57.385	6.377	26.110	0.033	2.882
450-B10	1.481	0.022	0.494	0.004	0.297	0.005	0.148	0.269	0.060	0.011	73.650	15.747	5.585	0.395	0.945	11.902	0.631	3.657	78.406	0.507	0.073	63.357	6.232	15.613	-	3.068
450-B38	1.431	0.021	0.444	0.003	0.262	0.004	0.085	0.169	0.056	0.016	65.540	11.052	4.821	0.196	0.896	5.547	1.035	5.053	54.039	0.549	0.348	63.065	6.460	19.543	-	2.728
450-B39	1.234	0.019	0.562	0.004	0.273	0.004	0.100	0.201	0.043	0.005	67.675	14.932	5.195	0.221	0.581	6.465	0.950	1.154	71.306	0.493	0.107	60.037	5.195	12.123	-	2.693
450-B64	1.605	0.020	0.356	0.004	0.161	0.003	0.024	0.081	0.076	0.033	94.461	4.882	4.723	0.513	1.235	1.623	1.423	9.807	44.389	0.855	0.252	17.685	9.678	36.916	0.067	2.592
Average	1.451	0.020	0.466	0.004	0.249	0.004	0.087	0.182	0.059	0.018	76.340	12.305	5.104	0.323	0.942	5.944	1.805	5.271	61.591	0.674	0.204	52.306	6.789	22.061	0.050	2.793
450-ka rocks (White layers)																										
450-B64	1.556	0.019	0.358	0.004	0.161	0.002	0.023	0.070	0.075	0.033	107.968	4.381	4.374	0.458	1.036	0.797	1.295	9.840	38.831	0.784	0.091	18.886	7.723	37.298	0.025	2.534
450-ka rocks (Brown layers)																										
450-B1	0.901	0.028	0.138	0.003	0.279	0.001	0.007	0.005	0.005	0.024	85.545	12.218	4.271	0.466	0.912	3.318	2.533	9.085	11.482	1.239	0.279	86.287	3.921	37.371	0.105	1.650
450-B10	0.484	0.010	0.168	0.001	0.140	0.002	0.013	0.019	0.006	0.006	59.877	17.981	2.952	0.131	0.420	17.136	0.314	1.723	3.037	0.134	0.068	63.454	2.670	10.124	-	1.031
450-B38	0.610	0.024	0.189	0.002	0.355	0.002	0.027	0.007	0.002	0.006	100.741	11.865	3.514	0.153	0.620	4.065	1.062	3.289	14.065	0.338	0.073	51.974	3.170	14.923	-	1.434
450-B39	0.607	0.017	0.327	0.003	0.239	0.001	0.014	0.025	0.004	0.002	38.907	9.082	2.728	0.037	0.393	3.684	0.808	0.757	40.023	0.216	-0.018	32.721	2.798	6.885	-	1.379
450-B64	1.002	0.016	0.171	0.002	0.141	0.002	0.010	0.010	0.024	0.021	73.882	4.752	3.361	0.419	0.937	1.292	1.403	6.859	10.808	0.664	0.131	16.969	4.817	32.694	0.058	1.557
Average	0.721	0.019	0.199	0.002	0.230	0.002	0.014	0.013	0.008	0.012	71.790	11.180	3.365	0.241	0.656	5.899	1.224	4.343	15.883	0.518	0.107	50.281	3.475	20.399	0.081	1.410
830-ka rocks (Inner parts)																										
830-A1	1.644	0.018	0.468	0.003	0.222	0.004	0.077	0.154	0.070	0.024	94.798	5.180	5.117	0.472	0.818	7.391	1.141	7.460	48.205	0.627	0.298	44.104	7.440	25.887	-	2.933
830-ka rocks (Brown layers)																										
830-A1	0.917	0.014	0.252	0.002	0.178	0.001	0.006	0.002	0.006	0.014	115.040	6.209	3.151	0.288	0.636	4.294	1.248	4.773	5.389	0.602	0.164	49.929	2.532	21.311	0.069	1.608

Table 8 Chemical changes with depth analyzed by ICP method.

Samples	depth, mm	Major elements (%)									Trace elements (ppm)											
		Al ₂ O ₃	TiO ₂	FeO+Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	As	Ba	Co	Cr	Cu	Li	Ni	Pb	Sr	V	Zr	Zn
20-B2	0~0.1	16.7240	0.0052	9.5086	0.1658	5.3420	9.6573	1.8047	0.3311	0.1479	0.9300	221.6600	51.7130	795.2500	77.7710	3.4614	440.1900	6.4699	2.3512	0.2303	1.2792	8.3799
	0.1~2	11.0550	0.6967	3.4366	0.0796	0.5223	0.4348	4.9213	0.8387	0.0281	0.4382	480.2000	21.2160	415.2700	24.8010	4.4614	450.7100	13.5820	104.6700	25.0750	125.7200	72.4840
	4~6	11.9790	0.6633	4.2414	0.0829	0.4946	0.9118	5.4621	0.7430	0.0458	0.4049	379.7400	33.4810	1495.9000	64.1200	3.8717	911.7800	3.2880	108.0400	24.2060	123.2800	77.3070
	9~11	11.9110	0.6599	3.8831	0.0775	0.4469	0.9381	5.4779	0.6611	0.0844	0.5574	413.7600	27.5410	1125.2000	48.8650	2.9486	844.2000	3.0021	110.9200	18.9010	118.7500	83.5080
	14~16	11.6470	0.7017	5.2228	0.0970	0.4391	0.9678	5.3905	0.7614	0.1135	0.4715	448.9400	55.1380	2862.8000	185.9900	2.8290	1918.5000	6.2903	113.1300	24.3280	118.4800	87.0910
20-B6	0~0.2	9.6740	1.2983	14.6540	0.2464	7.0961	3.2206	0.7353	1.0688	0.2311	0.7105	323.1100	46.8810	283.9800	45.8970	14.6540	137.7500	21.6810	42.4010	390.1600	168.1400	117.7000
	0.2~1	13.7120	0.9538	11.2670	0.1947	5.6628	4.6872	1.4309	0.9164	0.2480	0.7987	328.1000	40.5320	453.9400	42.3920	12.5780	317.6400	25.1670	126.0800	276.5600	131.8500	100.8100
	1~2	16.2630	0.7751	9.6512	0.1702	4.7497	6.7226	1.9730	0.3960	0.1730	0.8110	316.8600	34.5870	829.5200	118.0800	12.6040	333.7700	19.5550	215.1100	221.0300	108.0400	186.2100
	5~7	16.8710	0.7879	9.6356	0.1669	4.5303	7.7853	2.1172	0.8046	0.1875	0.8305	318.2000	31.8530	768.8900	52.3110	17.0160	424.6500	18.6200	259.8600	233.0000	105.2400	84.8260
	9~11	17.4560	0.6969	8.6840	0.1518	4.4064	8.0026	2.0984	0.8388	0.1440	0.7803	295.4400	32.6790	562.6300	50.8100	23.1830	487.1500	23.2960	279.3100	200.7800	98.7420	87.1580
	24~26	16.7170	0.7220	9.2896	0.1656	4.7241	7.1881	1.9912	0.9450	0.1500	0.8787	299.8600	39.9450	514.3200	53.3290	14.4340	402.7300	26.0170	291.1300	217.6600	112.2300	76.3480
34~36	16.3600	0.7844	9.7798	0.1767	5.1594	7.2952	1.9013	0.7678	0.1484	0.8217	307.8900	36.5990	429.5300	37.2980	12.8630	265.3000	21.8290	283.9000	221.9800	103.7100	86.1570	
450-B1	0.2~1	10.7130	1.9787	17.5550	0.0654	0.6304	0.4167	0.3118	1.3330	0.1238	0.5781	623.2600	41.2590	46.1880	64.7450	10.1750	39.0580	15.1780	92.7230	441.5900	280.6300	107.2300
	1~2	14.0680	1.0542	10.4540	0.1353	2.2790	5.9861	2.3384	1.0698	0.1416	0.6478	372.4000	38.9010	629.2400	63.1840	7.9713	645.9500	14.8970	227.0700	250.4800	138.4600	85.1890
	5~7	12.6840	0.9627	8.2145	0.1314	2.0161	5.3916	2.3334	1.0366	0.1521	0.5541	341.7700	35.1230	1509.6000	169.1700	7.5150	489.5200	16.1150	204.4000	209.7000	136.8200	153.9900
	14~16	14.3410	1.0616	9.3422	0.1532	2.4477	6.4895	2.5961	1.1425	0.1122	0.6969	366.0500	69.0780	1535.1000	134.7800	6.9899	2262.7000	8.6194	234.5300	248.6100	139.9900	92.4860
	26~28	14.2410	1.1076	9.7157	0.1549	2.4398	6.7190	2.7550	1.2369	0.0714	0.6705	361.0600	36.4040	747.8500	101.7900	7.6263	413.9500	13.7740	240.1900	267.5900	154.5100	85.2670
450-B10	0~2	8.7981	1.5558	22.0980	0.1411	4.7301	0.8743	0.1437	0.3495	0.1867	0.6378	272.7100	58.3560	241.1600	70.6630	6.8367	155.1200	20.4860	31.0420	523.1300	111.7000	112.1100
	2~4	16.5800	0.7568	11.5800	0.1869	5.9249	9.1714	1.7055	0.3540	0.1643	0.8497	254.4700	48.3240	670.2400	57.3920	4.9175	596.8000	17.1440	269.9100	255.4300	53.6600	80.0170
	8~10	18.0730	0.7123	9.5051	0.1605	5.3360	10.5370	1.8990	0.4239	0.1480	0.8170	167.8000	48.9770	694.7000	71.5720	3.8385	749.3800	19.0850	303.8400	243.0600	53.4730	74.6430
	14~16	17.0880	0.6811	9.3502	0.1571	5.0779	9.5550	1.8092	0.4388	0.1337	0.8159	139.0600	41.2170	1218.6000	75.9610	3.4670	801.0900	13.3700	291.5200	217.0600	47.8960	67.6260
	19~21	18.0030	0.6596	9.8528	0.1808	5.8905	10.4390	1.6263	0.4894	0.1674	0.8978	206.1600	44.8190	1100.8000	83.3970	4.2718	650.0800	15.8500	285.1200	220.4500	49.2590	76.5840
	24~26	8.4015	0.4833	15.9060	0.0460	0.2247	0.3304	3.2614	0.6714	0.0816	0.5144	299.5500	22.2160	73.7260	16.6150	3.9181	181.7600	14.8790	77.6130	79.1130	113.1500	64.9390
450-B12	0~4	13.5850	1.7941	16.4450	0.1512	0.6316	0.3353	0.4742	0.6554	0.0854	0.6458	573.2500	39.6560	31.9440	69.2330	6.7120	23.9100	23.4260	64.2040	399.5800	168.6700	151.5100
	5~6	13.2320	0.8087	7.7299	0.1616	1.4100	3.3936	1.5005	0.4762	0.0598	0.5744	274.8200	24.3080	525.6400	51.4260	6.6270	104.5900	13.9760	148.2800	170.9200	78.3310	78.3380
	9~11	16.0810	0.9499	9.2997	0.1292	0.9289	5.2944	2.4734	0.6764	0.0710	0.7079	276.8000	30.6960	770.5200	75.9530	4.4010	143.6300	20.7640	220.4300	218.5400	92.1300	98.4020
	23~25	15.7900	0.9368	9.3639	0.1284	1.8471	6.1028	2.5995	0.6752	0.0758	0.6261	253.0600	34.4060	1203.6000	73.8030	4.1461	434.9500	22.8940	225.0200	205.2900	92.6780	93.5340
450-B64	0~3	13.0290	1.1585	9.7112	0.3598	0.4212	0.2821	0.8221	0.9654	0.1021	0.5950	473.7400	43.6740	25.2940	44.0060	16.7260	53.8670	10.0070	70.3980	98.2430	241.1000	95.6350
	3~5	13.0010	0.9961	8.1672	0.1707	0.9095	1.8572	2.0728	1.1778	0.0708	0.5445	433.6700	31.2710	220.9000	41.8550	17.6060	176.2700	11.7230	118.6000	87.5440	198.5800	84.1970
	5~9	14.5280	0.9031	7.7714	0.1123	1.1775	2.8419	2.6322	1.1057	0.0462	0.5781	433.4200	22.1640	919.4400	54.0310	15.5810	144.7400	12.9290	155.8600	87.1120	157.5600	74.3170
	9~13	14.4640	0.8001	6.4174	0.0859	0.9506	2.8641	2.7365	1.1166	0.0860	0.5689	436.6300	16.8890	165.7200	28.8030	13.2650	125.3900	6.2771	163.0000	66.0230	154.8800	67.7640
	20~23	14.3340	0.8151	6.6917	0.0915	1.0522	3.5071	3.0000	1.2017	0.0787	0.5804	439.1600	22.2150	372.7000	37.7700	10.6480	284.3700	12.8360	178.5000	74.1050	155.3100	71.6360

Table 9 Agerage VHN values of Zones I to III.

Samples	Zone I Brown layer	Zone II	Zone III Inner part
0-ka rocks			
0-A1	-	-	539
0-A4	-	-	399
0-B1	-	-	602
0-B37	-	-	540
Average	-	-	520
20-ka rocks			
20-A1	-	295	451
20-A3	-	230	467
20-A16	-	523	546
20-B2	-	233	508
20-B6	-	372	546
Average	-	331	504
320-ka rocks			
320-B5	31	361	-
320-B10	86	323	545
320-B22	23	248	517
Average	47	311	531
450-ka rocks			
450-B1	12	287	477
450-B38	17	290	-
450-B64	19	281	-
450-B10	25	227	560
450-B37	34	386	531
450-C1	65	297	442
450-B39	34	255	-
Average	29	289	503
830-ka rock			
830-A1	79	433	485

Table 10 Weathering indices calculated from chemical composition.

Samples	SiO ₂ /Al ₂ O ₃	SiO ₂ /TiO ₂	WPI	PI	CIA
<i>0-ka rocks, Inner part</i>					
0-B1	4.063	50.549	11.633	70.382	60.873
0-B37	3.708	83.261	14.316	71.353	59.705
0-A6	3.644	64.068	13.053	70.300	59.600
0-A4	4.800	104.452	6.081	78.288	59.767
Average	4.054	75.582	11.271	72.581	59.986
<i>20-ka rocks, Inner part</i>					
20-B2	5.395	93.539	8.857	80.270	62.958
20-B6	3.247	75.152	14.845	68.103	62.217
20-A16	2.906	73.745	16.332	65.930	60.757
20-A3	3.729	72.996	12.930	71.055	60.473
20-A1	4.282	94.974	9.562	75.892	61.599
Average	3.912	82.081	12.505	72.250	61.601
<i>320-ka rocks, Inner part</i>					
320-B10	4.067	96.466	11.016	74.366	61.059
320-B5	3.963	101.563	8.004	74.993	67.787
320-B20	4.228	54.455	14.216	72.009	57.614
320-B22	3.634	79.007	14.155	69.374	62.341
Average	3.973	82.873	11.848	72.685	62.200
<i>320-ka rocks, Brown layer</i>					
320-B10	3.732	77.096	-2.487	70.594	86.535
320-B5	3.515	90.936	14.715	70.441	65.400
320-B20	3.902	33.955	-3.780	60.631	87.451
320-B22	3.208	63.419	-5.882	62.570	86.664
Average	3.589	66.352	0.642	66.059	81.512
<i>450-ka rocks, Inner part</i>					
450-B1	3.194	74.612	12.444	67.568	62.812
450-B10	2.999	68.087	19.154	65.196	59.209
450-B38	3.225	69.532	8.717	66.961	64.830
450-B39	2.195	65.743	13.338	59.637	69.295
450-B64	4.502	82.077	6.228	75.626	65.212
Average	3.223	72.010	11.976	66.998	64.271
<i>450-ka rocks, White layer</i>					
450-B64	4.346	80.223	7.550	74.969	66.939
<i>450-ka rocks, Brown layer</i>					
450-B1	6.539	32.284	-4.850	68.396	79.892
450-B10	2.878	47.314	-2.298	61.131	84.089
450-B38	3.225	25.072	-8.961	52.866	92.993
450-B39	1.857	36.733	-9.549	51.769	91.202
450-B64	5.847	62.723	0.366	76.259	75.704
Average	4.069	40.825	-5.059	62.084	84.776
<i>830-ka rocks, Inner part</i>					
830-A1	3.511	90.862	14.801	70.420	65.409
<i>830-ka rocks, Brown layer</i>					
830-A1	3.635	66.724	-3.108	68.059	91.881

Table 11 Thicknesses of Zone A and Zone A+B determined by VHN measurement.

Samples	Porosity, %	Thickness, mm		Diffusion Coefficient, mm ² /1000yrs.	
	<i>n</i>	<i>L_A</i>	<i>L_{A+B}</i>	<i>D_A</i>	<i>D_{A+B}</i>
20-ka Rocks					
20-A1	3.62	<0.10	2.88	0.001	0.413
20-A3	3.25	<0.10	3.03	0.001	0.459
20-A16	3.57	<0.10	1.88	0.001	0.176
20-B2	4.76	<0.10	2.00	0.001	0.200
20-B6	6.73	<0.10	3.00	0.001	0.450
320-ka Rocks					
320-B5	7.95	3.00	>20.00	0.028	1.250
320-B10	1.96	3.30	5.60	0.034	0.098
320-B20	6.15	2.00	>12.00	0.013	0.450
320-B22	4.14	2.00	5.04	0.013	0.079
450-ka Rocks					
450-B1	1.72	2.42	2.79	0.013	0.017
450-B10	0.85	1.87	4.26	0.008	0.040
450-B37	2.48	3.00	6.50	0.020	0.094
450-B38	4.49	3.25	10.20	0.023	0.231
450-B39	8.59	3.03	>21.00	0.020	0.980
450-B64	6.54	3.10	>15.00	0.021	0.500
450-C1	3.91	3.16	8.42	0.022	0.158
830-ka Rock					
830-A1	2.20	4.00	6.00	0.019	0.043