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Report

Geochemical mapping of remote islands around Kyushu, Japan

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Atsuyuki Ohta (2018) Geochemical mapping of remote islands around Kyushu, Japan. *Bull. Geol. Surv. Japan*, vol. 69 (5), p. 233–263, 11 figs, 6 tables.

Abstract: This paper describes high-density geochemical mapping of isolated islands in southwest Japan. A total of 193 stream sediments and three volcanic ash deposits collected from isolated islands around Kyushu were analyzed to determine the content of 53 elements to supplement land and sea geochemical mapping of the Kyushu area and regional Sr isotope mapping. The relationship between the spatial distribution of elements in stream sediments and volcanic ash deposits and the geology was closely examined using geographical information system (GIS) software. Stream sediments derived from mafic volcanic and pyroclastic rocks and volcanic ash deposits were enriched with MgO, CaO, Sc, TiO_2, V, T-Fe_2O_3, Co, and Sr. The presence of alkaline mafic volcanic rock increased the concentration of Cr, Ni, Nb, La, Ce, Pr, Nd, and Ta in stream sediments. Stream sediments originating from granitic rock were abundant in Be, Na_2O, K_2O, CaO, Sr, Y, Sn, Ln, Th, and U. Accretionary and non-accretionary sedimentary rocks caused an increase in Nb and Ta concentrations in stream sediments, and a reduction in Na_2O, MgO, CaO, and Sr concentrations. These geochemical features could be explained by the relative abundance of major rock forming minerals (such as quartz, plagioclase, K-feldspar, and mafic minerals) and accessary minerals (such as apatite and monazite) derived from the host rocks. Also, Zn-Pb deposits increased Zn, Cd, and Pb concentrations in stream sediments on Tsushima Island, and Sb deposits enhanced the Sb concentration in stream sediments on Amakusa-Shimoshima Island.

Keywords: stream sediment; geochemical map; isolated island; Kyushu; multi-element analysis

1. Introduction

Geochemical maps showing the regional distribution of element concentration at the Earth's surface, provide fundamental information about elements in nature and are used for mineral exploration and environmental assessment (Darnley *et al.*, 1995; Webb *et al.*, 1978). The Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), has created nationwide geochemical maps of Japan and the surrounding sea mainly for environmental assessment (Imai *et al.*, 2010; Imai *et al.*, 2004). As a next step, high-density geochemical mapping was conducted in the Kanto and Tokai areas, which have high population densities and are important industrial zones (Imai *et al.*, 2015). In addition, higher-density geochemical mapping of remote islands has been ongoing in order to supplement previously published land and sea geochemical maps of Japan (Ohta, 2018). In the present study, stream sediments and volcanic ash deposits were collected from 23 remote islands around Kyushu and the concentration of 53 elements was analyzed (Fig. 1). Geochemical maps of remote islands around Kyushu are very important for evaluating the influence of terrigenous clastics on marine sediments in the Tsushima Strait and the East China Sea, which were collected far from mainland Kyushu, and for assessing the influence of specific rocks narrowly or sporadically distributed on the main islands of Japan on stream sediments. This study focuses on the geochemical features of stream sediments derived from Neogene-Quaternary alkaline volcanic rocks, Neogene granitic rocks, Paleogene sediments hosting coal deposits, and Cretaceous sedimentary rocks on remote islands. The results obtained in this study will contribute to future research on land and marine geochemical mapping and Sr isotope map in the Kyushu region.

2. Study area and samples

2. 1 Geology

Figure 2 shows a geological map of the isolated islands in the Kyushu region, which has been simplified from a seamless digital geological map of Japan at a 1:200,000 scale (Geological Survey of Japan, AIST (ed.), 2015). Figure 2a shows that Paleogene-Neogene sediment is distributed mainly in the northern and southern parts of Tsushima Island. Neogene granitic rock and non-alkaline

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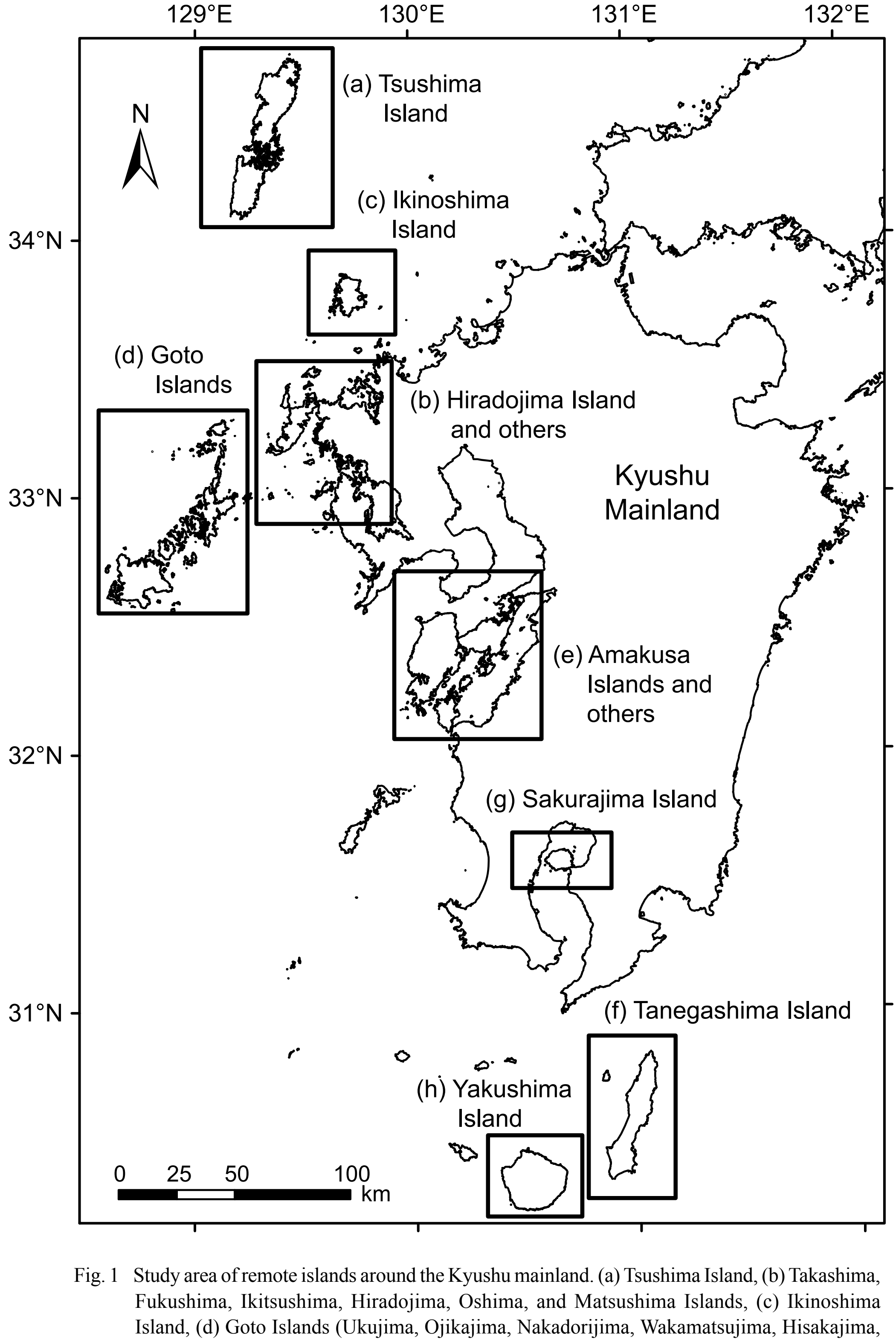

Fig. 1 Study area of remote islands around the Kyushu mainland. (a) Tsushima Island, (b) Takashima, Fukushima, Ikitsushima, Hiradojima, Oshima, and Matsushima Islands, (c) Ikinoshima Island, (d) Goto Islands (Ukujima, Ojikajima, Nakadorijima, Wakamatsujima, Hisakajima, and Fukuejima Islands), (e) Uto Peninsula, and Amakusa Islands (Oyanojima, Amakusa-kamishima, Amakusa-shimoshima, Goshorajima, Shishijima, and Nagashima Islands), (f) Tanegashima Island, (g) Sakurajima Island, (h) Yakushima Island.

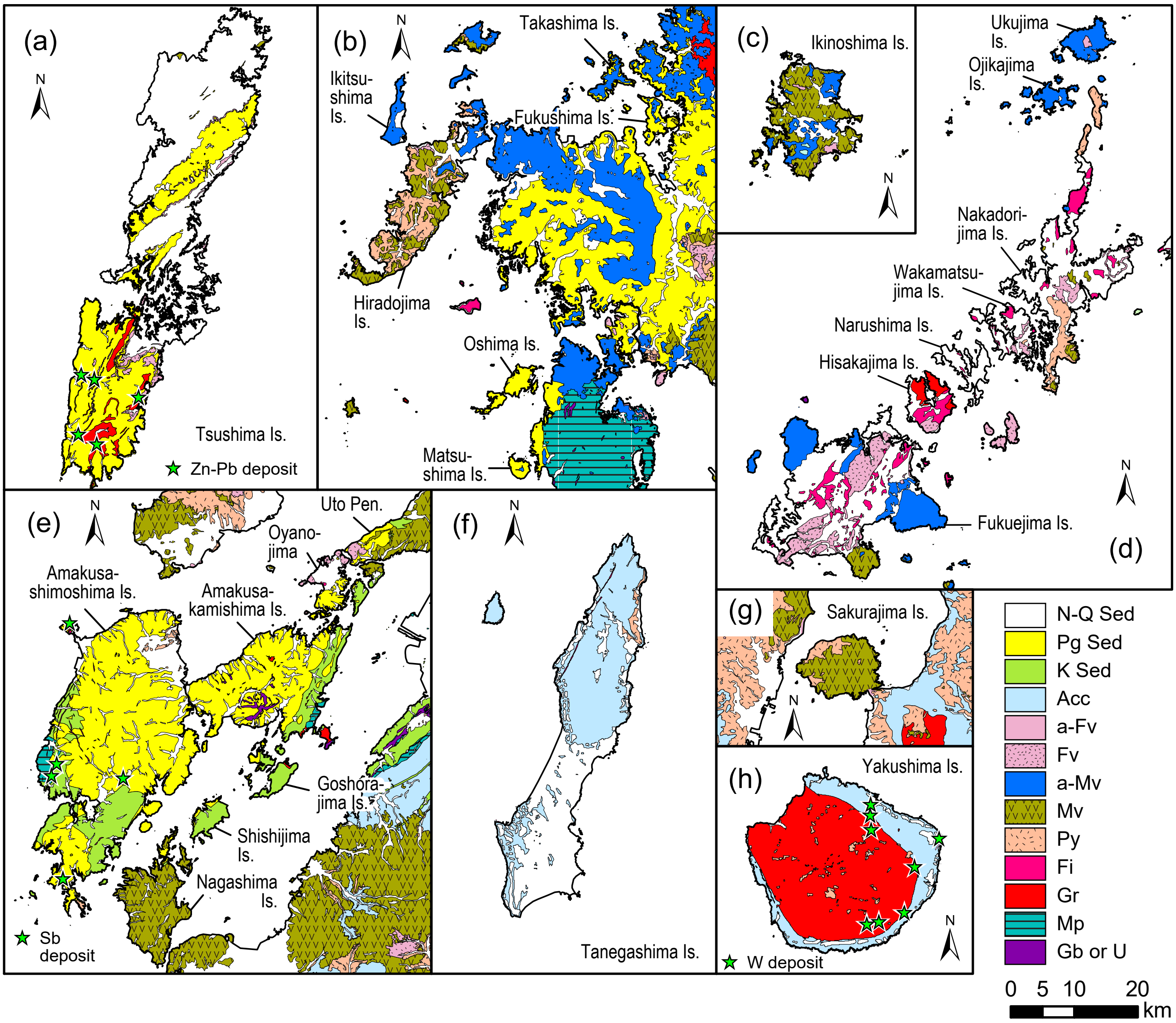

Fig. 2 Geological map for remote islands around the Kyushu mainland at a scale of 1:200,000 (Geological Survey of Japan, AIST (ed.), 2015). (a)-(h) same as Fig. 1. Star symbols indicate metalliferous deposits. N-Q Sed: Neogene and Quaternary sediment, Pg Sed: Paleogene sediment, K Sed: Cretaceous sedimentary rock, Acc: Paleogene Accretionary complex, a-Fv: Neogene alkaline felsic volcanic rock, Fv: Neogene non-alkaline felsic volcanic rock, a-Mv: Neogene and Quaternary alkaline mafic volcanic rock, Mv: Neogene and Quaternary non-alkaline mafic volcanic rock, Py: Neogene and Quaternary non-alkaline pyroclastic rock, Fi: Neogene non-alkaline felsic intrusive rock, Gr: Cretaceous and Neogene granitic rock, Mp: Cretaceous high-pressure metamorphic rock, Gb or U: Neogene gabbroic rock or ultramafic rock.

felsic volcanic rocks also are found in the southern part of Tsushima Island. Some metalliferous deposits, especially near the Taishu mine, yielding Cu, Zn, Pb, and Bi, are located around a granitic rock intrusion (Karakida *et al.*, 1992).

Figure 2b shows the geology in the northwest part of Kyushu Island. Neogene alkaline mafic volcanic rock and Paleogene-Neogene sediment are found on Takashima, Fukushima, and Ikitushima Islands. The northeast part of Hiradojima Island is covered by Neogene alkaline mafic volcanic rock. The rest of the region is underlain with Neogene non-alkaline mafic volcanic rock and pyroclastic rock. Paleogene-Neogene sediment is distributed on Oshima and Matsushima Islands. Ikinoshima Island is composed mainly of Neogene non-alkaline volcanic rocks and Quaternary alkaline volcanic rock (Fig. 2c).

The geology of the Goto Islands is shown in Fig. 2d. Ukujima Island and Ojikajima Island are underlain by Neogene alkaline volcanic rock and Quaternary alkaline volcanic rock (dominantly mafic rock), respectively. Nakadorijima and Wakamatsujima Islands are composed of Neogene sediments, Neogene non-alkaline felsic volcanic rock, Neogene non-alkaline pyroclastic rock, and Neogene non-alkaline felsic intrusive rocks. Hisakajima Island and Fukuejima Island contain Neogene-Quaternary unconsolidated sediments, Neogene non-alkaline felsic volcanic and intrusive rock, and Neogene granitic rock. Furthermore, Quaternary alkaline mafic volcanic rock erupted in the northwest and southeast parts of Fukuejima Island.

Amakusa-kamishima, Amakusa-shimoshima, Goshorajima, and Shishijima Islands are dominantly covered by Paleogene sedimentary rock associated with coal-field and Cretaceous sedimentary rock (Karakida *et al.*, 1992) (Fig. 2e). Cretaceous high-pressure metamorphic rock (Nagasaki metamorphic rock) and Neogene gabbroic rock are found in the western portion of Amakusa-shimoshima Island and the south-central part of Amakusa-kamishima Island; however their exposed area is small. The star symbols on Amakusa-shimoshima Island are small Sb deposits (Karakida *et al.*, 1992). By contrast, Nagashima Island is composed of Neogene non-alkaline mafic volcanic rock. Paleogene and Neogene sediments are widely distributed on Oyanojima Island. Uto Peninsula is composed mainly of Quaternary non-alkaline mafic volcanic rock.

The dominant deposits on Sakurajima Island consist of Quaternary non-alkaline mafic volcanic rock and pyroclastic rock (Fig. 2g). The Paleogene accretionary complex, composed mainly of sedimentary rock, is distributed mainly in the northern part of Tanegashima Island, and Neogene and Quaternary unconsolidated sediment outcrops are found mainly in the southern part of Tanegashima Island (Fig. 2f). The central part of Yakushima Island is intruded by Neogene granitic rock while the outer areas are composed mainly of a Paleogene accretionary complex (Fig. 2h). The star symbols in Fig. 2h indicate tungsten (W) deposits (Karakida *et al.*, 1992).

2. 2 Samples

From 2013 to 2014, 191 stream sediment samples were collected from 23 islands, two stream sediments were collected from Uto Peninsula, and three volcanic ash deposits were collected from Sakurajima Island (Fig. 3). The sampling locations are summarized in Table 1. The sampling density was one sample per 6–31 km^2, with a mean of 15 km^2, which is approximately one-seventh of that used for nationwide geochemical mapping (100–120 km^2). All rivers on the remote islands, except for Yakushima Island, are maintained with revetment walls on both banks. Stream sediments were collected from the river bed, air-dried at room temperature over 2 to 3 weeks, and sieved through an 83 mesh (180 μm) screen. In addition, magnetic minerals were removed from the air-dried samples using a hand magnet to minimize the effect of magnetic mineral accumulation (Imai *et al.*, 2004). Table 1 also shows the relative weight ratio of grains with sizes of less than 180 μm to stream sediments with grain sizes of less than 2 mm. The ratio is about 3–6% in the most cases, but is extremely low for samples from Yakushima Island (generally less than 2%), and high for samples from Fukushima Island (9–15%), Matsushima Island (20%), Sakurajima Island (22–60%), and Tanegashima Island (3–60%).

In addition, samples SK03, Tn02, Tn09, Tn26, Yk01, and Yk17 were further sieved using seven types of screens: 2 mm, 1 mm, 500 μm, 250 μm, 125 μm, 63 μm, and 32 μm. Coarser grains larger than 2 mm (gravel fraction) were not used in the present study. The sieved samples were ground with an agate mortar and pestle. The relative weight ratio for the different grain sizes to stream sediments less than 2 mm is shown in Table 2. About 60–94% of stream sediments smaller than 2 mm was composed of medium to very coarse-grained sand (larger than 250 μm), but the proportion for Sk03 was just 26%. The modal center was very coarse sand (1–2 mm) for Tn09, coarse sand (0.5–1 mm) for Yk17, medium sand (250–500 μm) for Sk03, Tn26, and Yk01, and fine sand (125–250 μm) for Tn02. The fine and very fine sand fractions (63–250 μm) were 20–37% of stream sediments less than 2 mm for Sk03, Tn02, Tn26, and Yk01, and only 4–10% for Tn09 and Yk17.

2. 3 Watershed analyses

Stream sediments consist of the products of weathering and erosion of soil and rocks in the watershed area upstream of the sampling site (Howarth and Thornton, 1983). Therefore, the geochemistry of stream sediments is determined by the dominant lithology distributed in their water catchment area (Ohta *et al.*, 2004). The watershed area for each sampling location was obtained using a digital elevation model (50 m mesh data) obtained from the Geospatial Information Authority of Japan (GSI). Geographic information system software (ArcGIS 10.5; Environmental Systems Research Institute) was used for the calculation.

The representative lithology for each sample was defined as the rock type exposed most widely in a drainage basin. The detailed process of Ohta *et al.* (2004) was followed carefully. In this study, a total of 196 samples were classified into 13 subgroups on the basis of the dominant geology: Neogene–Quaternary sediment (N–Q Sed), Paleogene sediment (Pg Sed), Cretaceous sedimentary rock (K Sed), Paleogene accretionary complex composed mainly of sedimentary rocks (Acc), Neogene and Quaternary alkaline felsic and mafic volcanic rocks (a-Fv and a-Mv, respectively), Neogene and Quaternary non-alkaline felsic and mafic volcanic rocks (Fv and Mv, respectively), Neogene and Quaternary non-alkaline pyroclastic rock (Py), Neogene non-alkaline felsic intrusive rock (Fi), Neogene granitic rocks (Gr), Neogene gabbroic rock (Gb), and Cretaceous metamorphic rock composed mainly of high-pressure metamorphic rock (Mp). If no representative rock was present in the watershed, the sample was classified as other (Oth). Tables 3 and 4 summarize the relative exposed areas of these lithologies in each drainage basin for the northern and southern regions, respectively.

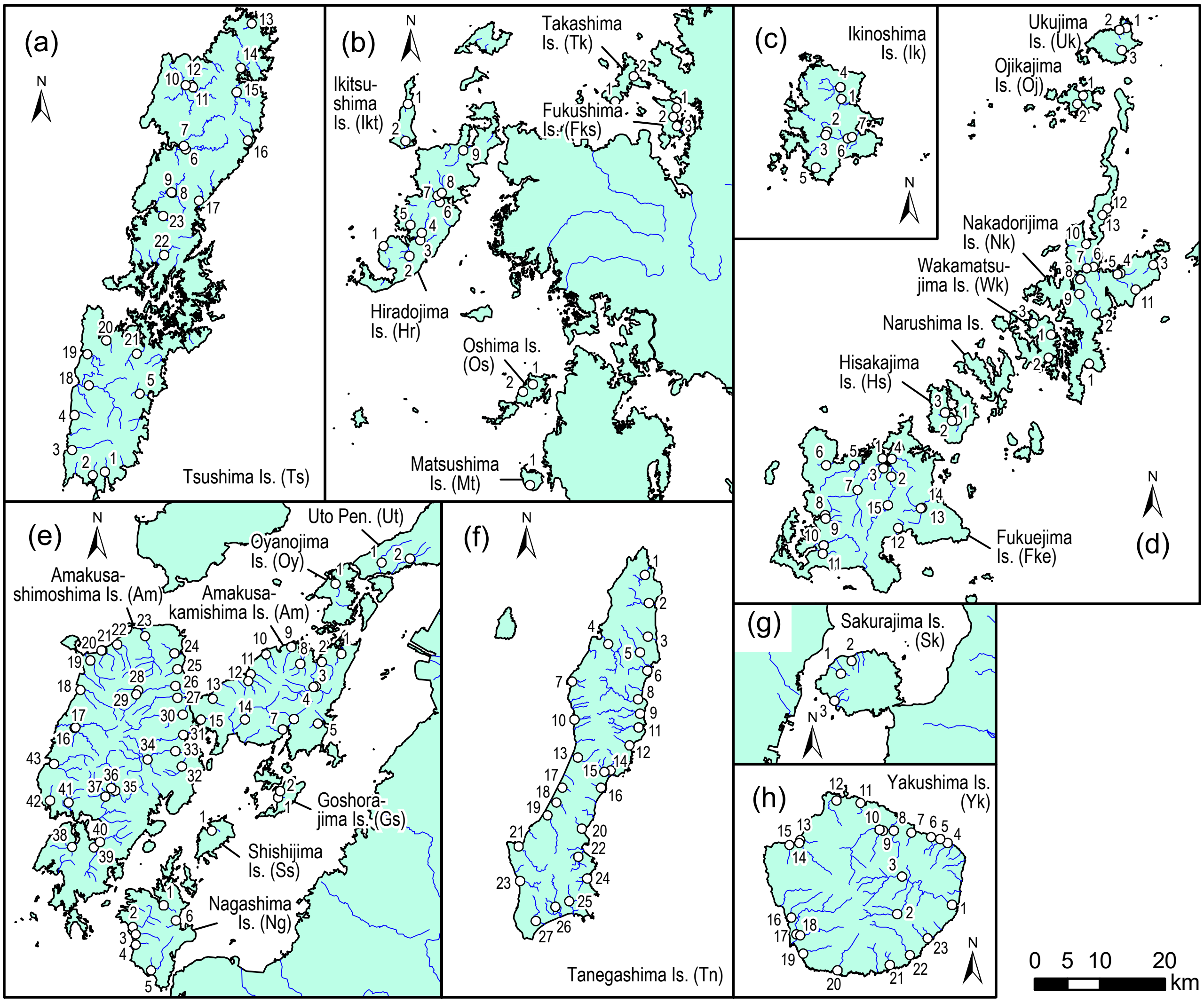

Fig. 3 Stream sediment sampling locations on remote islands around Kyushu mainland. (a)-(h) are the same as Fig. 1.

3. Analytical methods

The analytical methods of Ohta (2018) were followed for 53 elements in stream sediment samples. The amount of moisture (H_2O^-) was determined with 0.1 g of stream sediment sample after drying at 110°C for 2 h. A thermally-dried sample (0.1 g) was digested using an HF, HNO_3, and $HClO_4$ mixed solution at 125°C for 2 h and 145°C for 1 h. The digested product was evaporated to dryness at 190°C. The residue was dissolved in HNO_3 and diluted to 100 mL with double-deionized water. A solution of digested geochemical reference material JB-1a was used as a standard (Imai, 1990). In addition to the standard solution, a high concentration standard solution also was prepared from 1,000 mg/L solutions (Kanto Chemical Co. Inc.) for elemental analyses of samples having Li, Be, Cu, Zn, Cd, Mo, Sn, Sb, Cs, Tl, Pb, and Bi concentrations greater than ten times those of JB-1a (Ohta, 2018).

For As determination, 0.1 g of not thermally-dried (undried) samples were digested using an HF, HNO_3, and $HClO_4$ mixed solution with $KMnO_4$ at 120°C for 20 min, a procedure modified from that reported by Terashima (1976, 1984). The degraded product was evaporated at 190°C until the solution was ca. 1 mL. HCl was added to the residual solution, which was then heated at 135°C for 30 min, and finally diluted to 100 mL with double-deionized water. A standard solution was prepared from a 1,000 mg/L arsenic atomic absorption standard solution (Kanto Chemical Co. Inc.).

Inductively coupled plasma atomic emission spectrometry (ICP-AES) (Thermo Fisher Scientific Inc., iCap 6300) was used to determine the Na, Mg, Al, P, K, Ca, Ti, Mn, Fe, Li, Be, V, Sr, and Ba concentrations. The major elements, Na, Mg, Al, P, K, Ca, Ti, Mn, and Fe, in stream sediments are expressed as oxides. The analytical wavelengths (nm) chosen were: Li (670.7), Be (313.1), Al (237.3), P (213.6), V (292.4), Ti (323.4), Mn (257.6), Sr (407.7), and Ba (455.4) using axial plasma viewing;

Table 1 Samples, places (islands), and rivers, along with locations and descriptions of samples and rivers.

Sample	Island		River		Longitude (JGD2000)	Latitude (JGD2000)	Sampling data	Width of river (m)	Depth of river (cm)	Flow rate of river	Ratio of <180 μm[a]
Ts01	Tsushima	対馬島	Nain	内院川	129°13'51.4"E	34°7'12.8"N	2013/10/9	4	20	1 m / 2 s	6.0%
Ts02	Tsushima	対馬島	Asamo	浅藻川	129°12'44.9"E	34°6'56.5"N	2013/10/9	8	20	1 m / 6 s	3.7%
Ts03	Tsushima	対馬島	Segawa	瀬川	129°10'52.8"E	34°8'53.5"N	2013/10/9	20	n.d.	very slow	7.2%
Ts04	Tsushima	対馬島	Kotsuki	上槻川	129°11'4.8"E	34°11'31.9"N	2013/10/9	6	20	1 m / 2 s	9.9%
Ts05	Tsushima	対馬島	Asu	阿須川	129°17'4.1"E	34°13'8.5"N	2013/10/9	7	30	1 m / 4 s	10%
Ts06	Tsushima	対馬島	Kaidokoro	飼所川	129°21'20.7"E	34°31'43.5"N	2013/10/10	8	>50	1 m / 4 s	2.4%
Ts07	Tsushima	対馬島	Nita	仁田川	129°21'10.5"E	34°31'59"N	2013/10/10	7	n.d.	1 m / 5 s	13%
Ts08	Tsushima	対馬島	Sagauchi	佐賀内川	129°20'3.2"E	34°28'24.2"N	2013/10/10	8	20	1 m / 6 s	2.7%
Ts09	Tsushima	対馬島	Mine	三根川	129°19'59.6"E	34°28'28.1"N	2013/10/10	6	100	1 m / 8 s	1.4%
Ts10	Tsushima	対馬島	Sago	佐護川	129°21'54.4"E	34°36'36.5"N	2013/10/10	5	35	1 m / 10 s	3.7%
Ts11	Tsushima	対馬島	Sago	佐護川	129°22'1.8"E	34°36'26.9"N	2013/10/10	8	30	1 m / 4 s	7.3%
Ts12	Tsushima	対馬島	Nakayama	中山川	129°21'20.9"E	34°36'36.6"N	2013/10/10	7	20	1 m / 2 s	1.8%
Ts13	Tsushima	対馬島	Toyokawa	豊川	129°27'27.5"E	34°41'16.8"N	2013/10/10	5	20	very slow	3.9%
Ts14	Tsushima	対馬島	Kusu	玖須川	129°26'24.9"E	34°37'54.2"N	2013/10/10	20	40	1 m / 14 s	8.8%
Ts15	Tsushima	対馬島	Syushi	舟志川	129°26'3.1"E	34°36'4"N	2013/10/10	12	40	1 m / 3 s	9.4%
Ts16	Tsushima	対馬島	Ashimi	芦見川	129°27'3"E	34°32'22.4"N	2013/10/11	8	20	1 m / 8 s	1.2%
Ts17	Tsushima	対馬島	Saga	佐賀川	129°22'33.9"E	34°27'47.8"N	2013/10/11	4	30	1 m / 7 s	4.5%
Ts18	Tsushima	対馬島	Sasu	佐須川	129°12'23.9"E	34°13'46.5"N	2013/10/11	20	>70	very slow	3.2%
Ts19	Tsushima	対馬島	Aren	阿連川	129°12'17.4"E	34°16'9.4"N	2013/10/11	8	20	1 m / 3 s	2.4%
Ts20	Tsushima	対馬島	Kashi	加志川	129°13'58.7"E	34°17'11.2"N	2013/10/11	3	30	1 m / 3 s	1.3%
Ts21	Tsushima	対馬島	Sumo	洲藻川	129°16'47.8"E	34°16'10.9"N	2013/10/11	12	30	1 m / 4 s	6.2%
Ts22	Tsushima	対馬島	Ni-i	仁位川	129°19'18"E	34°23'40.7"N	2013/10/11	6	30	very slow	3.9%
Ts23	Tsushima	対馬島	Yoshida	吉田川	129°19'15.1"E	34°26'39.3"N	2013/10/11	5	40	1 m / 6 s	2.5%
Tk01	Takashima	鷹島	Tokonami	床浪川	129°44'19.5"E	33°24'31.8"N	2014/10/10	2.5	20	1 m / 6 s	4.9%
Tk02	Takashima	鷹島	-	−	129°46'0.9"E	33°26'25.3"N	2014/10/10	0.7	3	1 m / 3 s	8.8%
Fks01	Fukushima	福島	-	−	129°49'52.3"E	33°23'59.7"N	2014/10/11	0.7	10	1 m / 3 s	13%
Fks02	Fukushima	福島	-	−	129°49'38.1"E	33°23'20.2"N	2014/10/11	2	10	1 m / 4 s	15%
Fks03	Fukushima	福島	-	−	129°49'56.5"E	33°22'36.6"N	2014/10/11	2.5	40	very slow	9.3%
Ikt01	Ikitsushima	生月島	-	−	129°25'33.2"E	33°24'25.6"N	2014/10/9	4.5	<1	1 m / 4 s	7.0%
Ikt02	Ikitsushima	生月島	Kaminogawa	神ノ川	129°25'16.9"E	33°21'36.8"N	2014/10/9	2	10	1 / 210 s	9.3%
Hr01	Hiradojima	平戸島	-	−	129°23'18.6"E	33°13'35.7"N	2014/10/9	2	10	1 m / 15 s	10%
Hr02	Hiradojima	平戸島	Kota	古田川	129°25'37.1"E	33°12'50.5"N	2014/10/9	2.5	20	1 m / 9 s	2.2%
Hr03	Hiradojima	平戸島	Shikisa	敷佐川	129°26'35.7"E	33°14'3.4"N	2014/10/9	2.5	15	1 m / 30 s	2.8%
Hr04	Hiradojima	平戸島	Nakatsura	中津良川	129°26'43.8"E	33°14'36.3"N	2014/10/9	3	40	1 m / 10 s	4.9%
Hr05	Hiradojima	平戸島	-	−	129°25'41.9"E	33°15'12.8"N	2014/10/9	5	35	1 m / 10 s	3.2%
Hr06	Hiradojima	平戸島	Magome	馬込川	129°28'25.6"E	33°16'56.6"N	2014/10/9	5	20	1 m / 11 s	3.0%
Hr07	Hiradojima	平戸島	Nakagawa	中川	129°28'9.8"E	33°17'24.9"N	2014/10/9	5	35	1 m / 15 s	2.0%
Hr08	Hiradojima	平戸島	Yasuman	安満川	129°28'34.3"E	33°17'40.2"N	2014/10/9	8	70	1 m / 14 s	2.9%
Hr09	Hiradojima	平戸島	Kozone	神曽根川	129°30'31.7"E	33°20'52"N	2014/10/9	14	20	1 m / 10 s	3.0%
Os01	Oshima	大島	-	−	129°36'42.4"E	33°3'3.6"N	2014/10/8	1.5	3	1 m / 4 s	6.4%
Os02	Oshima	大島	-	−	129°35'48.2"E	33°2'28.9"N	2014/10/8	3	12	1 m / 16 s	7.5%
Mt01	Matsushima	松島	-	−	129°36'23.8"E	32°55'22.2"N	2014/10/8	0.7	6	1 m / 32 s	20%
Iki01	Ikinoshima	壱岐島	Tanie	谷江川	129°44'12.9"E	33°48'46.4"N	2013/10/7	40	n.d.	n.d.	11%
Iki02	Ikinoshima	壱岐島	Hatahoko	幡鉾川	129°42'52.6"E	33°46'18.2"N	2013/10/8	5	10	1 m / 6 s	1.9%
Iki03	Ikinoshima	壱岐島	Hatahoko	幡鉾川	129°42'44.1"E	33°46'0.7"N	2013/10/8	3	25	1 m / 16 s	0.8%
Iki04	Ikinoshima	壱岐島	Tsunogawa	角川	129°44'6.9"E	33°49'40.5"N	2013/10/8	4	10	1 m / 6 s	6.7%
Iki05	Ikinoshima	壱岐島	-	−	129°41'50.3"E	33°43'33.2"N	2014/10/7	V.C.	n.d.	n.d.	8.4%
Iki06	Ikinoshima	壱岐島	Ikeda	池田川	129°44'45.9"E	33°45'46.1"N	2014/10/7	4	35	very slow	2.9%
Iki07	Ikinoshima	壱岐島	Hatahoko	幡鉾川	129°45'9.2"E	33°45'51.9"N	2014/10/7	10	10	1 m / 7 s	4.2%
Uk01	Ukujima	宇久島	-	−	129°7'57.6"E	33°17'24.7"N	2013/11/14	1	10	1 m / 3-4 s	4.7%
Uk02	Ukujima	宇久島	-	−	129°7'20.4"E	33°17'16.4"N	2013/11/14	3	10	1 m / 8 s	1.4%
Uk03	Ukujima	宇久島	Ebata	江端川	129°7'33.4"E	33°15'43.1"N	2013/11/14	3	10	1 m / 8 s	1.4%
Oj01	Ojikajima	小値賀島	-	−	129°4'4.6"E	33°12'17.1"N	2013/11/14	3.5	35	>1 m / 30 s	7.1%
Oj02	Ojikajima	小値賀島	-	−	129°3'31.7"E	33°11'38.5"N	2013/11/14	1.4	10	1 m / 4 s	3.1%
Nk01	Nakadorijima	中通島	-	福見川	129°4'35.6"E	32°51'53.3"N	2013/11/13	2	15	1 m / 10 s	5.3%
Nk02	Nakadorijima	中通島	-	−	129°5'13.2"E	32°55'40.7"N	2013/11/13	4	15	1 m / 11 s	2.7%
Nk03	Nakadorijima	中通島	-	−	129°10'22.7"E	32°59'23.4"N	2013/11/13	4	15	1 m / 7 s	5.8%
Nk04	Nakadorijima	中通島	Okawa	大川	129°7'24.7"E	32°58'45.5"N	2013/11/13	6	30	1 m / 8 s	5.4%
Nk05	Nakadorijima	中通島	Kiba	木場川	129°7'7.9"E	32°58'40"N	2013/11/13	4	40	1 m / 13 s	3.2%
Nk06	Nakadorijima	中通島	Miyanogawa	宮ノ川	129°5'0.6"E	32°59'13.8"N	2013/11/13	5	5	1 m / 4 s	2.9%
Nk07	Nakadorijima	中通島	Tsurido	釣道川	129°4'21.6"E	32°59'6.8"N	2013/11/13	3	70	1 m / 15 s	6.4%
Nk08	Nakadorijima	中通島	Aiko	相河川	129°3'48.4"E	32°58'18.8"N	2013/11/13	8–10	40	very slow	21%
Nk09	Nakadorijima	中通島	Sanohara	佐野原川	129°3'43.1"E	32°57'11"N	2013/11/13	8	40–80	1 m / 25 s	1.9%
Nk10	Nakadorijima	中通島	-	−	129°4'20.4"E	33°0'58.2"N	2013/11/13	5	10	1 m / 7 s	5.3%
Nk11	Nakadorijima	中通島	-	−	129°8'46.6"E	32°57'30"N	2013/11/15	2	10	1 m / 5 s	6.3%
Nk12	Nakadorijima	中通島	-	−	129°6'15.7"E	33°3'39.5"N	2013/11/15	0.6	10	1 m / 6-8 s	5.3%
Nk13	Nakadorijima	中通島	-	−	129°5'48.3"E	33°3'10.1"N	2013/11/15	3	6	1 m / 6 s	4.0%
Wk01	Wakamatsujima	若松島	Suzuki	鈴木川	129°1'9.2"E	32°54'4.7"N	2013/11/15	2	15–20	1 m / 13 s	1.8%
Wk02	Wakamatsujima	若松島	-	−	129°0'55.1"E	32°52'18.6"N	2013/11/15	1.7	10	1 m / 1 s	5.3%
Wk03	Wakamatsujima	若松島	-	−	128°59'34.6"E	32°54'56.9"N	2013/11/15	2	15	1 m / 8 s	5.8%
Hs01	Hisakajima	久賀島	-	−	128°52'40.5"E	32°47'34.3"N	2013/11/12	6	50	very slow	5.8%
Hs02	Hisakajima	久賀島	Ichikogi	市小木川	128°52'13.5"E	32°47'31.4"N	2013/11/12	10	10	1 m / 4 s	5.1%
Hs03	Hisakajima	久賀島	Inoki	猪ノ木川	128°51'36.9"E	32°48'9.7"N	2013/11/12	4	20	1 m / 8 s	6.2%
Fke01	Fukuejima	福江島	-	−	128°46'47.7"E	32°44'36.1"N	2013/11/11	7	20	1 m / 1 s	1.2%
Fke02	Fukuejima	福江島	Ichinokawa	一ノ河川	128°46'45.3"E	32°43'15.6"N	2013/11/11	15	35	1 m / 4 s	0.8%
Fke03	Fukuejima	福江島	Uranogawa	浦ノ川	128°46'1.6"E	32°43'53"N	2013/11/11	8	45	1 m / 8 s	2.4%
Fke04	Fukuejima	福江島	Wanigawa	鰐川	128°45'56.1"E	32°44'39.1"N	2013/11/11	V.C.	n.d.	n.d.	25%

Table 1　continued.

Sample	Island		River		Longitude (JGD2000)	Latitude (JGD2000)	Sampling data	Width of river (m)	Depth of river (cm)	Flow rate of river	Ratio of <180 μm[a]
Fke05	Fukuejima	福江島	Okawabaru	大川原川	128°43'24"E	32°44'8.1"N	2013/11/11	5	25	1 m / 3 s	5.4%
Fke06	Fukuejima	福江島	-	−	128°40'54"E	32°44'6.4"N	2013/11/11	3	30	1 m / 8 s	12%
Fke07	Fukuejima	福江島	Wanigawa	鰐川	128°43'45.3"E	32°42'14.1"N	2013/11/11	7	40	1 m / 13 s	1.5%
Fke08	Fukuejima	福江島	Nanan-take	七岳川	128°40'47.4"E	32°40'19.2"N	2013/11/11	8	40	1 m / 8 s	5.4%
Fke09	Fukuejima	福江島	Arakawa	荒川川	128°40'51.6"E	32°40'2.4"N	2013/11/11	8	20	1 m / 15 s	0.8%
Fke10	Fukuejima	福江島	Nakasu	中須川	128°40'41.6"E	32°38'2.2"N	2013/11/11	10	50	1 m / 6 s	1.4%
Fke11	Fukuejima	福江島	Ogawa	小川川	128°40'35.2"E	32°37'24.3"N	2013/11/11	6	65	1 m / 6 s	1.9%
Fke12	Fukuejima	福江島	Masuda	増田川	128°47'23.3"E	32°39'22.2"N	2013/11/11	6	25	1 m / 6 s	4.7%
Fke13	Fukuejima	福江島	Muta	牟田川	128°49'34.4"E	32°40'53.2"N	2013/11/12	2	15	1 m / 4 s	6.5%
Fke14	Fukuejima	福江島	Fukue	福江川	128°49'26.6"E	32°40'52.1"N	2013/11/12	16	50	1 m / 8 s	2.7%
Fke15	Fukuejima	福江島	Ichinokawa	一ノ河川	128°46'25.7"E	32°41'5.6"N	2013/11/12	15	20	1 m / 4 s	1.5%
Ut01	Uto Peninsula	宇土半島	Hatagawa	波多川	130°29'41.4"E	32°37'32.7"N	2013/12/9	4	15	1 m / 3 s	3.0%
Ut02	Uto Peninsula	宇土半島	Kouno-ura	郡浦川	130°32'13.1"E	32°37'48.2"N	2013/12/9	1.5	5	1 m / 4 s	7.1%
Oy01	Oyanojima	大矢野島	-	−	130°25'30"E	32°35'58.6"N	2013/12/9	6	5	1 m / 6 s	0.9%
Am01	Amakusa-kamishima	天草上島	Aitsu	合津川	130°25'56.1"E	32°30'38.1"N	2013/12/9	3	10	1 m / 6 s	5.2%
Am02	Amakusa-kamishima	天草上島	Imaizumi	今泉川	130°24'10.4"E	32°30'3.3"N	2013/12/9	16	30	very slow	60%
Am03	Amakusa-kamishima	天草上島	Yokomichi	横道川	130°23'37"E	32°28'9.8"N	2013/12/9	1.5	35	1 m / 7 s	1.7%
Am04	Amakusa-kamishima	天草上島	Kyoragi	教良木川	130°23'25.1"E	32°28'8.8"N	2013/12/9	8	20	1 m / 16 s	3.1%
Am05	Amakusa-kamishima	天草上島	Nishi-kawachi	西河内川	130°23'47.2"E	32°25'21.1"N	2013/12/9	10	15	very slow	3.6%
Am06	Amakusa-kamishima	天草上島	Urakawa	浦川	130°21'34.9"E	32°25'43.2"N	2013/12/9	12	35	1 m / 8 s	4.3%
Am07	Amakusa-kamishima	天草上島	Tanasoko	棚底川	130°20'34.5"E	32°24'56.7"N	2013/12/9	2	40	1 m / 40 s	6.1%
Am08	Amakusa-kamishima	天草上島	Kusubo	楠甫川	130°22'15.6"E	32°29'55.4"N	2013/12/10	12	15	1 m / 5 s	11%
Am09	Amakusa-kamishima	天草上島	Ohura	大浦川	130°21'28"E	32°31'12.8"N	2013/12/10	3	30	1 m / 16 s	5.1%
Am10	Amakusa-kamishima	天草上島	Nishioi	西追川	130°19'10.3"E	32°30'39.6"N	2013/12/10	3	40	1 m / 12 s	3.5%
Am11	Amakusa-kamishima	天草上島	Kotsu-ura	上津浦川	130°17'47.2"E	32°29'10.8"N	2013/12/10	4	25	1 m / 8 s	6.4%
Am12	Amakusa-kamishima	天草上島	Shimotsu-ura	下津浦川	130°17'34.5"E	32°28'40.3"N	2013/12/10	12	18	very slow	5.1%
Am13	Amakusa-kamishima	天草上島	Egawa	江川	130°14'21.5"E	32°27'19.3"N	2013/12/10	5	15	1 m / 6 s	11%
Am14	Amakusa-kamishima	天草上島	Kawachi	河内川	130°17'14.1"E	32°25'44.6"N	2013/12/10	8	40	1 m / 4 s	4.2%
Am15	Amakusa-kamishima	天草上島	Kote	小手川	130°13'15"E	32°25'45.4"N	2013/12/10	3	15	1 m / 10 s	22%
Am16	Amakusa-shimoshima	天草下島	Shimoyama	下山川	130°1'56.7"E	32°25'13.8"N	2013/12/13	15	30	1 m / 16 s	4.1%
Am17	Amakusa-shimoshima	天草下島	Shimotsu-fukae	下津深江川	130°2'1.1"E	32°25'16.9"N	2013/12/13	12	3	1 m / 3 s	3.4%
Am18	Amakusa-shimoshima	天草下島	Tororo	都呂々川	130°2'28.5"E	32°28'8.1"N	2013/12/13	8	10–15	1 m / 9 s	3.1%
Am19	Amakusa-shimoshima	天草下島	Shiki	志岐川	130°3'23.4"E	32°30'21.2"N	2013/12/13	3	30	1 m / 16 s	14%
Am20	Amakusa-shimoshima	天草下島	Kotsu-fukae	上津深江川	130°4'28.6"E	32°31'6.4"N	2013/12/13	4	10–20	1 m / 5 s	3.9%
Am21	Amakusa-shimoshima	天草下島	Kotsu-fukae	上津深江川	130°4'24.2"E	32°31'6.2"N	2013/12/13	2	10–15	1 m / 7 s	5.1%
Am22	Amakusa-shimoshima	天草下島	Matsubara	松原川	130°5'47.8"E	32°31'33.8"N	2013/12/13	5	10	1 m / 4 s	1.8%
Am23	Amakusa-shimoshima	天草下島	Uchino	内野川	130°8'19.8"E	32°32'9.5"N	2013/12/13	20	15	1 m / 10 s	12%
Am24	Amakusa-shimoshima	天草下島	Nakasu	中洲川	130°10'55.7"E	32°30'49.7"N	2013/12/13	12	30	1 m / 20 s	4.7%
Am25	Amakusa-shimoshima	天草下島	Sumida	隅田川	130°11'10.9"E	32°29'38.1"N	2013/12/13	14	5	1 m / 7 s	2.2%
Am26	Amakusa-shimoshima	天草下島	Hirose	広瀬川	130°10'59.1"E	32°28'20.3"N	2013/12/13	16	40	1 m / 8 s	2.5%
Am27	Amakusa-shimoshima	天草下島	Machiyamaguchi	町山口川	130°11'9.2"E	32°27'26.8"N	2013/12/13	16	>40	1 m / 9 s	3.7%
Am28	Amakusa-shimoshima	天草下島	Hiratoko	平床川	130°7'40.1"E	32°28'3"N	2013/12/13	3	20	1 m / 5 s	4.4%
Am29	Amakusa-shimoshima	天草下島	Hirose	広瀬川	130°7'30.5"E	32°27'45"N	2013/12/13	16	60	1 m / 16 s	2.2%
Am30	Amakusa-shimoshima	天草下島	Kamegawa	亀川	130°11'38.1"E	32°26'8.9"N	2013/12/11	8	25	1 m / 4 s	4.4%
Am31	Amakusa-shimoshima	天草下島	Hobaru	方原川	130°11'39.4"E	32°24'37.6"N	2013/12/11	5	15	1 m / 4 s	9.5%
Am32	Amakusa-shimoshima	天草下島	Nagare-ai	流合川	130°11'28.8"E	32°22'12.2"N	2013/12/11	4	15	1 m / 8 s	11%
Am33	Amakusa-shimoshima	天草下島	Omiyaji	大宮地川	130°10'57.4"E	32°23'23.6"N	2013/12/11	15	20	1 m / 5 s	6.3%
Am34	Amakusa-shimoshima	天草下島	Omiyaji	大宮地川	130°8'27.8"E	32°22'46.8"N	2013/12/11	10	40	1 m / 2 s	4.0%
Am35	Amakusa-shimoshima	天草下島	Itchoda	一町田川	130°5'29.2"E	32°20'26.8"N	2013/12/11	10	25	1 m / 3 s	6.6%
Am36	Amakusa-shimoshima	天草下島	Imada	今田川	130°5'9.1"E	32°20'36.2"N	2013/12/11	8	30	1 m / 5 s	2.9%
Am37	Amakusa-shimoshima	天草下島	Katsuragochi	葛河内川	130°4'37.1"E	32°19'59.8"N	2013/12/11	26	30	1 m / 20 s	6.1%
Am38	Amakusa-shimoshima	天草下島	Kameura	亀浦川	130°1'35.2"E	32°16'10.9"N	2013/12/11	10	30	1 m / 14 s	4.2%
Am39	Amakusa-shimoshima	天草下島	Haya-ura	早浦川	130°3'32.3"E	32°16'6.5"N	2013/12/11	10	35–45	1 m / 11 s	5.5%
Am40	Amakusa-shimoshima	天草下島	Rogi	路木川	130°4'4.4"E	32°16'32.9"N	2013/12/11	5	15	1 m / 4 s	1.1%
Am41	Amakusa-shimoshima	天草下島	Imatomi	今富川	130°1'19.8"E	32°19'34"N	2013/12/11	6	80	1 m / 8 s	2.3%
Am42	Amakusa-shimoshima	天草下島	Oe	大江川	129°59'38.5"E	32°19'42.5"N	2013/12/11	7	5	1 m / 5 s	3.6%
Am43	Amakusa-shimoshima	天草下島	Takahama	高浜川	130°0'1.7"E	32°22'29.7"N	2013/12/11	10–15	20	1 m / 4 s	2.7%
Gs01	Goshorajima	御所浦島	Furuyashiki	古屋敷川	130°20'6"E	32°19'46.3"N	2013/12/10	1	5	N.D.	8.5%
Gs02	Goshorajima	御所浦島	Karakizaki	唐木崎川	130°20'15.8"E	32°20'14.3"N	2013/12/10	3	1	1 m / 5 s	5.4%
Ss01	Shishijima	獅子島	-	−	130°14'7.3"E	32°17'17.6"N	2013/12/12	2.5	5	1 m / 4 s	8.9%
Ng01	Nagashima	長島	Urasoko	浦底川	130°9'43.6"E	32°11'40.6"N	2013/12/12	3	15	1 m / 6 s	4.9%
Ng02	Nagashima	長島	Kohama	小浜川	130°6'56.8"E	32°10'3"N	2013/12/12	8	60	1 m / 11 s	2.2%
Ng03	Nagashima	長島	Sashie	指江川	130°7'14.4"E	32°9'29.2"N	2013/12/12	3	20	1 m / 7 s	4.9%
Ng04	Nagashima	長島	Jokawa-uchi	城川内川	130°7'12.3"E	32°8'42.5"N	2013/12/12	1.5	10	1 m / 10 s	15%
Ng05	Nagashima	長島	Shiomi	汐見川	130°8'34.5"E	32°6'43.3"N	2013/12/12	4	30	1 m / 5 s	3.9%
Ng06	Nagashima	長島	Akasaki	赤崎川	130°10'49.9"E	32°10'30.3"N	2013/12/12	4	40	1 m / 8 s	6.6%
Tn01	Tanegashima	種子島	Minato	湊川	131°3'30.1"E	30°48'11.9"N	2014/12/5	6	30	1 m / 9 s	26%
Tn02	Tanegashima	種子島	Saikyo	西京川	131°3'49"E	30°46'2.9"N	2014/12/5	15	>60	1 m / 40 s	22%
Tn03	Tanegashima	種子島	An-no	安納川	131°3'40.7"E	30°43'30.3"N	2014/12/5	3	15	1 m / 4 s	6.8%
Tn04	Tanegashima	種子島	Koume	甲女川	131°0'11.4"E	30°42'58.4"N	2014/12/5	20	>70	very slow	22%
Tn05	Tanegashima	種子島	Minatogawa	湊川	131°2'57.4"E	30°42'18.3"N	2014/12/5	10	45	1 m / 5 s	12%
Tn06	Tanegashima	種子島	Azako	浅川川	131°3'34.2"E	30°40'54.6"N	2014/12/5	4	30	1 m / 7 s	15%
Tn07	Tanegashima	種子島	-	−	130°56'55.4"E	30°40'10.5"N	2014/12/4	4	30	1 m / 9 s	7.5%
Tn08	Tanegashima	種子島	Kawa-waki	川脇川	131°2'41.8"E	30°38'45.4"N	2014/12/4	8	25	1 m / 11 s	3.5%
Tn09	Tanegashima	種子島	Okawada	大川田川	131°2'50.7"E	30°37'39.4"N	2014/12/4	10	40	1 m / 7 s	7.2%
Tn10	Tanegashima	種子島	-	−	130°57'2.8"E	30°37'18"N	2014/12/4	5	20–30	1 m / 4 s	7.9%
Tn11	Tanegashima	種子島	Waseda	早稲田川	131°2'40.9"E	30°36'35.8"N	2014/12/4	6	60	1 m / 3–4 s	7.3%

Table 1 continued.

Sample	Island		River		Longitude (JGD2000)	Latitude (JGD2000)	Sampling data	Width of river (m)	Depth of river (cm)	Flow rate of river	Ratio of <180 µm[a]
Tn12	Tanegashima	種子島	-	−	131°1'52.1"E	30°35'16.1"N	2014/12/4	4	15	1 m / 3 s	6.8%
Tn13	Tanegashima	種子島	Owatase	大渡瀬川	130°57'17.3"E	30°34'22.4"N	2014/12/3	4	25	1 m / 4 s	7.3%
Tn14	Tanegashima	種子島	Mukai	向井川	131°0'12.9"E	30°33'21.3"N	2014/12/4	8	40–60	1 m / 5 s	5.0%
Tn15	Tanegashima	種子島	Tagiri	沸川	130°59'37.2"E	30°33'16.7"N	2014/12/4	8	35	1 m / 3 s	13%
Tn16	Tanegashima	種子島	-	−	130°59'18.2"E	30°32'2.8"N	2014/12/4	4	45	1 m / 5 s	11%
Tn17	Tanegashima	種子島	-	−	130°55'53.7"E	30°32'7.7"N	2014/12/3	4	20	1 m / 3 s	5.2%
Tn18	Tanegashima	種子島	Adakaiso	阿高磯川	130°55'21.9"E	30°30'59.8"N	2014/12/3	5	40–70	1 m / 15 s	9.8%
Tn19	Tanegashima	種子島	Kuhama	苦浜川	130°54'34.8"E	30°30'1"N	2014/12/3	15	60	very slow	18%
Tn20	Tanegashima	種子島	Imakumano	今熊野川	130°57'33.7"E	30°28'57.6"N	2014/12/4	5	15	1 m / 3 s	13%
Tn21	Tanegashima	種子島	Shimama	島間川	130°51'57.2"E	30°27'41.1"N	2014/12/3	5	35	1 m / 4 s	3.3%
Tn22	Tanegashima	種子島	Oura	大浦川	130°57'11.4"E	30°26'50.2"N	2014/12/4	20	N.D.	1 m / 4–5 s	60%
Tn23	Tanegashima	種子島	Okawa	大川	130°52'2.5"E	30°25'3.5"N	2014/12/3	6	35	1 m / 3 s	6.1%
Tn24	Tanegashima	種子島	Abusuki	阿武鋤川	130°57'55.6"E	30°25'10.8"N	2014/12/4	20	>60	very slow	31%
Tn25	Tanegashima	種子島	Miyase	宮瀬川	130°56'21.4"E	30°23'28.5"N	2014/12/3	6	60	1 m / 8 s	16%
Tn26	Tanegashima	種子島	Korigawa	郡川	130°55'7"E	30°23'4"N	2014/12/3	8	25	1 m / 3 s	11%
Tn27	Tanegashima	種子島	Shikanaki	鹿鳴川	130°53'21.6"E	30°22'1.3"N	2014/12/3	4	60	1 m / 9 s	11%
Sk01	Sakurajima	桜島	-	−	130°37'44.7"E	31°35'56.3"N	2014/11/10	V.C.	n.d.	n.d.	38%
Sk02	Sakurajima	桜島	-	−	130°38'43.3"E	31°36'52.9"N	2014/11/10	V.C.	n.d.	n.d.	22%
Sk03	Sakurajima	桜島	-	−	130°37'9.4"E	31°33'52.8"N	2014/11/10	V.C.	n.d.	n.d.	59%
Yk01	Yakushima	屋久島	Anbo	安房川	130°39'4.1"E	30°18'57.1"N	2014/11/13	60–100	>100	n.d.	1.2%
Yk02	Yakushima	屋久島	Arakawa	荒川	130°34'16.1"E	30°18'16.9"N	2014/11/13	12	10–80	1 m / 3–5 s	0.4%
Yk03	Yakushima	屋久島	Anbo	安房川	130°34'43.2"E	30°21'8.3"N	2014/11/13	15	50	1 m / 5 s	0.7%
Yk04	Yakushima	屋久島	Menko	女川	130°38'46"E	30°23'38.4"N	2014/11/11	>16	>70	1 m / 4 s	13%
Yk05	Yakushima	屋久島	Ogako	男川	130°38'7.5"E	30°23'56.5"N	2014/11/15	3	25	1 m / 4 s	0.7%
Yk06	Yakushima	屋久島	Tabu	椨川	130°37'20.3"E	30°24'6.2"N	2014/11/11	>20	60	1 m / 5 s	0.4%
Yk07	Yakushima	屋久島	Jonogawa	城之川	130°35'38.2"E	30°24'27.7"N	2014/11/11	>3	40–50	1 m / 2–4 s	0.5%
Yk08	Yakushima	屋久島	Shiratani	白谷川	130°34'2.9"E	30°24'38"N	2014/11/14	8	50–70	1 m / 5 s	1.7%
Yk09	Yakushima	屋久島	Miyano-ura	宮之浦川	130°33'6.6"E	30°24'39.5"N	2014/11/11	>20	40	1 m / 5 s	2.7%
Yk10	Yakushima	屋久島	Miyano-ura	宮之浦川	130°32'46.9"E	30°24'45"N	2014/11/11	>30	60	1 m / 5 s	1.4%
Yk11	Yakushima	屋久島	Shidoko	志戸子川	130°31'11.6"E	30°26'47"N	2014/11/15	8	45	1 m / 9 s	0.5%
Yk12	Yakushima	屋久島	Isso	一湊川	130°29'4.7"E	30°26'59.1"N	2014/11/14	50	20	1 m / 22 s	1.2%
Yk13	Yakushima	屋久島	Domen	土面川	130°25'51"E	30°24'0.8"N	2014/11/15	20	15	1 m / 5 s	2.4%
Yk14	Yakushima	屋久島	Nagata	永田川	130°25'44.4"E	30°23'47.8"N	2014/11/14	50	70	1 m / 12 s	1.5%
Yk15	Yakushima	屋久島	Takeno	嶽之川	130°24'54.3"E	30°23'39.4"N	2014/11/14	6–8	40–100	1 m / 4–5 s	1.3%
Yk16	Yakushima	屋久島	Okogawa	大川	130°24'59.1"E	30°18'6.9"N	2014/11/15	12	40–70	1 m / 3–6 s	7.0%
Yk17	Yakushima	屋久島	Koyoji	小揚子川	130°25'23.1"E	30°16'51.3"N	2014/11/12	>50	60	1 m / 11 s	3.2%
Yk18	Yakushima	屋久島	Kurio	栗生川	130°25'43.3"E	30°16'46.7"N	2014/11/12	30	70	1 m / 5 s	0.9%
Yk19	Yakushima	屋久島	Nakama	中間川	130°25'58.4"E	30°15'21.9"N	2014/11/12	16	25	1 m / 4 s	0.3%
Yk20	Yakushima	屋久島	Yukawa	湯川	130°28'57"E	30°14'3.2"N	2014/11/12	>20	50	1 m / 11 s	0.7%
Yk21	Yakushima	屋久島	Futamata	二又川	130°33'33.9"E	30°14'24.7"N	2014/11/15	4	45	1 m / 6 s	0.8%
Yk22	Yakushima	屋久島	Tainogawa	鯛ノ川	130°35'20.5"E	30°15'9.2"N	2014/11/12	>40	40	1 m / 3–4 s	0.4%
Yk23	Yakushima	屋久島	Kodakumi	小田汲川	130°36'54.4"E	30°16'23.6"N	2014/11/15	4	90	1 m / 4–5 s	2.2%

V.C.: Vacant channel, n.d.: not determined

[a] Relative ratio by weight of the <180 µm fraction to sediments less than 2 mm

Table 2 Relative weight ratio of grain size to stream sediments less than 2 mm.

Grain size	Sk03	Tn02	Tn09	Tn26	Yk01	Yk17
<180 µm	59%	22%	7.2%	11%	1.2%	3.2%
Very coarse sand (1–2 mm)	0.3%	20%	39%	12%	5.5%	31%
Coarse sand (0.5–1 mm)	5.7%	19%	28%	14%	15%	44%
Medium sand (250–500 µm)	20%	23%	20%	43%	38%	19%
Fine sand (125–250 µm)	12%	26%	7.9%	28%	33%	4%
Very fine sand (63–125 µm)	8.1%	6.7%	2.4%	2.1%	4.1%	0.4%
Coarse silt (32–63 µm)	3.4%	2.3%	1.2%	0.6%	0.4%	0.2%[a]
Fine silt and clay (<32 µm)	3.1%	1.9%	0.8%	0.4%	0.2%	

[a] Grain size less than 63 µm

Table 3 Watershed area and estimated ratios of exposed lithology areas in each watershed for samples collected from the northern region of the study area.

Sample	Watershed area (km^2)	Sed	a-Fv	Fv	a-Mv	Mv	Py	Fi	Gr	Dominant lithology	Sample	Watershed area (km^2)	Sed	a-Fv	Fv	a-Mv	Mv	Py	Fi	Gr	Dominant lithology
Ts01	5.0	74%	-	-	-	-	-	-	26%	Sed	Iki03	3.7	42%	-	-	37%	20%	1%	-	-	Mv+a-Mv
Ts02	4.9	74%	-	-	-	-	-	-	26%	Sed	Iki04	3.0	2%	2%	-	60%	36%	-	-	-	a-Mv
Ts03	16.4	48%	-	-	-	-	-	-	52%	Gr	Iki05	1.7	-	-	-	-	100%	-	-	-	Mv
Ts04	6.4	89%	-	6%	-	2%	-	-	3%	Sed	Iki06	2.7	22%	10%	-	-	68%	-	-	-	Mv
Ts05	5.7	100%	-	-	-	-	-	-	-	Sed	Iki07	22.0	39%	2%	-	27%	30%	2%	-	-	Mv+a-Mv
Ts06	25.9	98%	-	2%	-	<1%	-	-	-	Sed	Uk01	1.2	-	-	-	100%	-	-	-	-	a-Mv
Ts07	24.7	96%	-	4%	-	<1%	-	-	-	Sed	Uk02	1.7	-	1%	-	99%	-	-	-	-	a-Mv
Ts08	8.9	92%	-	7%	-	1.0%	-	-	-	Sed	Uk03	1.8	<1%	52%	-	48%	-	-	-	-	a-Fv
Ts09	8.9	97%	-	3%	-	-	-	-	-	Sed	Oj01	0.15	-	-	-	100%	-	-	-	-	a-Mv
Ts10	4.8	100%	-	-	-	-	-	-	-	Sed	Oj02	0.5	-	-	-	100%	-	-	-	-	a-Mv
Ts11	15.1	98%	-	-	-	2%	-	-	-	Sed	Nk01	0.8	-	-	-	-	25%	75%	-	-	Py
Ts12	21.9	100%	-	-	-	<1%	-	-	-	Sed	Nk02	0.8	71%	-	29%	-	-	-	-	-	Sed
Ts13	2.5	100%	-	-	-	-	-	-	-	Sed	Nk03	2.8	68%	-	16%	-	6%	-	10%	-	Sed
Ts14	5.5	100%	-	-	-	-	-	-	-	Sed	Nk04	3.9	70%	-	9%	-	-	-	21%	-	Sed
Ts15	10.6	96%	-	4%	-	-	-	-	-	Sed	Nk05	4.0	74%	-	-	-	13%	-	13%	-	Sed
Ts16	3.2	100%	-	-	-	<1%	-	-	-	Sed	Nk06	1.2	85%	-	-	-	-	-	15%	-	Sed
Ts17	4.4	85%	-	15%	-	-	-	-	-	Sed	Nk07	4.2	99%	-	-	-	1%	-	-	-	Sed
Ts18	33.7	83%	-	7%	-	<1%	-	-	10%	Sed	Nk08	6.9	50%	-	48%	-	3%	-	-	-	Sed
Ts19	10.6	94%	-	5%	-	-	-	-	<1%	Sed	Nk09	6.2	25%	-	37%	-	-	37%	1%	-	Fv+Py
Ts20	5.6	94%	-	3%	-	<1%	-	-	2%	Sed	Nk10	1.7	98%	-	-	-	2%	-	<1%	-	Sed
Ts21	9.8	56%	-	27%	-	-	-	-	17%	Sed	Nk11	1.5	80%	-	13%	-	-	-	7%	-	Sed
Ts22	7.4	100%	-	-	-	-	-	-	-	Sed	Nk12	0.9	-	-	-	-	-	-	100%	-	Fi
Ts23	4.9	93%	-	7%	-	-	-	-	-	Sed	Nk13	0.8	13%	-	-	-	-	-	87%	-	Fi
Tk01	0.6	41%	-	-	59%	-	-	-	-	a-Mv	Wk01	1.9	68%	-	32%	-	-	-	-	-	Sed
Tk02	0.5	26%	-	-	74%	-	-	-	-	a-Mv	Wk02	0.5	23%	-	77%	-	-	-	-	-	Fv
Fks01	0.4	28%	-	-	72%	-	-	-	-	a-Mv	Wk03	0.8	60%	-	-	-	-	-	40%	-	Sed
Fks02	1.0	50%	-	-	50%	-	-	-	-	Sed	Hs01	3.9	14%	-	25%	-	-	-	60%	<1%	Fi
Fks03	0.8	71%	-	-	19%	-	-	-	-	Sed	Hs02	3.5	15%	-	15%	-	-	-	70%	-	Fi
Ikt01	0.7	-	-	-	100%	-	-	-	-	a-Mv	Hs03	3.5	55%	-	-	-	-	-	21%	24%	Sed
Ikt02	1.1	-	-	-	100%	-	-	-	-	a-Mv	Fke01	6.3	43%	-	49%	-	-	-	8%	-	Oth
Hr01	1.6	-	-	-	-	44%	56%	-	-	Py	Fke02	26.5	62%	-	27%	-	-	-	12%	-	Sed
Hr02	3.8	17%	-	-	-	32%	51%	-	-	Py	Fke03	5.0	52%	-	-	-	-	-	48%	-	Sed
Hr03	4.3	5%	-	-	-	19%	76%	-	-	Py	Fke04	32.0	36%	-	19%	24%	-	-	21%	-	Oth
Hr04	7.3	16%	-	-	-	22%	62%	-	-	Py	Fke05	11.1	100%	-	-	-	-	-	-	-	Sed
Hr05	3.2	14%	-	-	-	15%	71%	-	-	Py	Fke06	4.1	21%	-	-	79%	-	-	-	-	a-Mv
Hr06	4.5	9%	-	-	-	22%	68%	-	-	Py	Fke07	23.8	53%	-	12%	-	-	-	35%	-	Sed
Hr07	3.8	23%	-	-	-	63%	14%	-	-	Mv	Fke08	6.3	-	-	100%	-	-	-	-	-	Fv
Hr08	6.0	20%	-	-	3%	34%	42%	-	-	Mv+Py	Fke09	5.2	72%	-	4%	-	-	-	23%	-	Sed
Hr09	7.1	42%	-	-	12%	33%	13%	-	-	Mv+Py	Fke10	14.5	46%	-	52%	-	-	-	2%	-	Fv
Os01	0.8	100%	-	-	-	-	-	-	-	Sed	Fke11	5.1	39%	-	61%	-	-	-	<1%	-	Fv
Os02	0.8	100%	-	-	-	-	-	-	-	Sed	Fke12	2.4	96%	-	-	3%	-	-	<1%	-	Sed
Mt01	0.3	100%	-	-	<1%	-	-	-	-	Sed	Fke13	2.1	14%	-	-	86%	-	-	-	-	a-Mv
Iki01	21.6	5%	3%	-	33%	59%	-	-	-	Mv	Fke14	12.1	69%	-	1%	21%	-	-	9%	-	Sed
Iki02	4.4	56%	-	-	27%	16%	2%	-	-	Sed	Fke15	16.0	79%	-	11%	-	-	-	10%	-	Sed

Sed: Paleogene-Neogene-Quaternary sediment, a-Fv: Neogene alkaline felsic volcanic rock, Fv: Neogene non-alkaline felsic volcanic rock, a-Mv: Neogene-Quaternary alkaline mafic volcanic rock, Mv: Neogene non-alkaline mafic volcanic rock, Py: Neogene-Quaternary pyroclastic rock, debris, and tephra, Fi: Neogene felsic intrusive rock, Gr: Neogene granitic rocks, Oth: other rocks.

Table 4 Watershed area and estimated ratio of exposed area of lithology to watershed area for samples collected from the southern region of the study area.

Sample	Watershed area (km^2)	Sed	K Sed	Acc	Mv	Py	Fi	Gr	Gb	Mp	Dominant lithology
Ut01	8.1	39%	11%	-	50%	-	-	-	-	-	Mv
Ut02	3.9	11%	-	-	89%	-	-	-	-	-	Mv
Oy01	2.5	100%	-	-	-	-	-	-	-	-	Sed
Am01	3.2	36%	64%	-	-	-	-	-	-	-	K Sed
Am02	6.0	55%	45%	-	-	-	-	-	-	-	Sed
Am03	6.1	49%	51%	-	-	-	-	-	-	-	K Sed
Am04	17.4	100%	-	-	-	-	-	-	<1%	-	Sed
Am05	3.0	18%	81%	-	-	-	-	1%	-	-	K Sed
Am06	8.7	96%	-	-	-	-	-	-	4%	-	Sed
Am07	3.2	63%	-	-	-	-	-	-	37%	-	Sed
Am08	5.4	100%	-	-	-	-	-	-	<1%	-	Sed
Am09	3.2	100%	-	-	-	-	-	-	<1%	-	Sed
Am10	3.0	90%	-	-	-	-	-	9%	1%	-	Sed
Am11	5.9	99%	-	-	-	-	-	-	1%	-	Sed
Am12	9.1	100%	-	-	-	-	-	-	<1%	-	Sed
Am13	3.3	98%	-	-	-	-	-	-	2%	-	Sed
Am14	18.6	89%	-	-	-	-	-	-	11%	-	Sed
Am15	3.9	100%	-	-	-	-	-	-	-	-	Sed
Am16	11.8	63%	35%	-	-	-	2%	-	-	-	Sed
Am17	19.0	99%	<1%	-	-	-	-	-	-	-	Sed
Am18	14.0	100%	-	-	-	-	<1%	-	-	-	Sed
Am19	8.7	100%	-	-	-	-	<1%	-	-	-	Sed
Am20	5.0	100%	-	-	-	-	-	-	<1%	-	Sed
Am21	2.8	100%	-	-	-	-	-	-	-	-	Sed
Am22	6.4	100%	-	-	<1%	-	-	-	<1%	-	Sed
Am23	27.8	97%	-	-	-	3%	-	-	<1%	-	Sed
Am24	4.4	89%	-	-	-	11%	-	-	-	-	Sed
Am25	3.9	100%	-	-	-	-	-	-	-	-	Sed
Am26	25.8	100%	-	-	-	<1%	-	-	<1%	-	Sed
Am27	12.3	100%	-	-	-	-	-	-	-	-	Sed
Am28	8.5	100%	-	-	-	-	-	-	<1%	-	Sed
Am29	8.1	100%	-	-	-	-	-	-	-	-	Sed
Am30	22.5	100%	-	-	-	-	-	-	-	-	Sed
Am31	9.9	100%	-	-	-	-	-	-	-	-	Sed
Am32	11.1	100%	-	-	<1%	-	-	-	-	-	Sed
Am33	31.1	100%	-	-	-	-	-	-	-	-	Sed
Am34	19.2	100%	-	-	-	-	-	-	-	-	Sed
Am35	17.8	94%	6%	-	<1%	-	-	-	-	-	Sed
Am36	17.7	100%	-	-	-	-	<1%	-	-	-	Sed
Am37	12.1	99%	-	-	<1%	-	1%	-	-	-	Sed
Am38	5.7	49%	51%	-	<1%	-	-	-	-	-	K Sed
Am39	12.1	42%	58%	-	-	-	<1%	-	-	-	K Sed
Am40	10.0	3%	97%	-	-	-	-	-	-	-	K Sed
Am41	8.8	69%	31%	-	-	-	-	-	-	-	Sed
Am42	4.9	2%	28%	-	-	-	-	-	-	69%	Mp
Am43	18.3	77%	19%	-	<1%	-	3%	-	-	1%	Sed
Gs01	0.9	-	100%	-	-	-	-	-	-	-	K Sed
Gs02	0.8	-	100%	-	-	-	-	-	-	-	K Sed
Ss01	0.8	1%	99%	-	-	-	-	-	-	-	K Sed
Ng01	3.4	8%	-	-	92%	-	-	-	-	-	Mv
Ng02	11.3	11%	-	-	89%	-	-	-	-	-	Mv
Ng03	4.2	7%	-	-	93%	-	-	-	-	-	Mv
Ng04	3.7	5%	-	-	95%	-	-	-	-	-	Mv
Ng05	12.2	12%	-	-	88%	-	-	-	-	-	Mv
Ng06	3.0	7%	-	-	93%	-	-	-	-	-	Mv

Sample	Watershed area (km^2)	Sed	K Sed	Acc	Mv	Py	Fi	Gr	Gb	Mp	Dominant lithology
Tn01	5.7	3%	-	97%	-	-	<1%	-	-	-	Acc
Tn02	16.7	2%	-	97%	-	<1%	2%	-	-	-	Acc
Tn03	3.8	<1%	-	89%	-	11%	-	-	-	-	Acc
Tn04	18.8	24%	-	77%	-	-	-	-	-	-	Acc
Tn05	12.9	27%	-	69%	-	4%	-	-	-	-	Acc
Tn06	4.9	12%	-	89%	-	-	-	-	-	-	Acc
Tn07	3.5	3%	-	95%	-	-	2%	-	-	-	Acc
Tn08	17.4	8%	-	92%	-	-	-	-	-	-	Acc
Tn09	12.7	2%	-	98%	-	-	-	-	-	-	Acc
Tn10	3.2	6%	-	94%	-	-	-	-	-	-	Acc
Tn11	9.5	1%	-	99%	-	-	-	-	-	-	Acc
Tn12	4.7	3%	-	97%	-	-	-	-	-	-	Acc
Tn13	3.9	34%	-	66%	-	-	-	-	-	-	Acc
Tn14	8.5	30%	-	70%	-	-	-	-	-	-	Acc
Tn15	6.4	42%	-	58%	-	-	-	-	-	-	Acc
Tn16	4.2	95%	-	5%	-	-	-	-	-	-	Sed
Tn17	2.6	86%	-	14%	-	-	-	-	-	-	Sed
Tn18	7.6	84%	-	16%	-	-	-	-	-	-	Sed
Tn19	10.3	79%	-	21%	-	-	-	-	-	-	Sed
Tn20	3.7	93%	-	7%	-	-	-	-	-	-	Sed
Tn21	10.7	62%	-	38%	-	-	-	-	-	-	Sed
Tn22	8.5	97%	-	3%	-	-	-	-	-	-	Sed
Tn23	7.0	80%	-	20%	-	-	-	-	-	-	Sed
Tn24	4.5	100%	-	-	-	-	-	-	-	-	Sed
Tn25	5.7	94%	-	6%	-	-	-	-	-	-	Sed
Tn26	12.6	99%	-	2%	-	-	-	-	-	-	Sed
Sk01	N.D.	-	-	-	-	100%	-	-	-	-	Py
Sk02	N.D.	-	-	-	-	100%	-	-	-	-	Py
Sk03	N.D.	-	-	-	-	100%	-	-	-	-	Py
Tn27	6.4	92%	-	8%	-	-	-	-	-	-	Sed
Yk01	84.1	<1%	-	2%	-	4%	-	93%	-	-	Gr
Yk02	13.2	-	-	-	-	4%	-	96%	-	-	Gr
Yk03	29.5	1%	-	-	-	7%	-	93%	-	-	Gr
Yk04	7.9	4%	-	87%	-	3%	-	6%	-	-	Acc
Yk05	1.9	8%	-	92%	-	-	-	-	-	-	Acc
Yk06	5.7	2%	-	87%	-	<1%	-	10%	-	-	Acc
Yk07	3.8	1%	-	72%	-	-	-	27%	-	-	Acc
Yk08	12.7	<1%	-	10%	-	3%	-	87%	-	-	Gr
Yk09	8.3	-	-	<1%	-	4%	-	96%	-	-	Gr
Yk10	37.3	<1%	-	5%	-	2%	-	92%	-	-	Gr
Yk11	6.6	2%	-	64%	-	1%	-	33%	-	-	Acc
Yk12	12.6	2%	-	20%	-	5%	-	74%	-	-	Gr
Yk13	4.5	-	-	-	-	1%	-	99%	-	-	Gr
Yk14	30.5	1%	-	-	-	2%	-	96%	-	-	Gr
Yk15	7.3	3%	-	-	-	<1%	-	97%	-	-	Gr
Yk16	11.3	-	-	3%	-	3%	-	95%	-	-	Gr
Yk17	28.1	-	-	4%	-	6%	-	90%	-	-	Gr
Yk18	20.7	-	-	2%	-	6%	-	93%	-	-	Gr
Yk19	11.8	<1%	-	16%	-	<1%	-	84%	-	-	Gr
Yk20	10.5	4%	-	7%	-	<1%	-	89%	-	-	Gr
Yk21	2.7	<1%	-	6%	-	<1%	-	93%	-	-	Gr
Yk22	17.2	-	-	2%	-	4%	-	94%	-	-	Gr
Yk23	5.9	-	-	5%	-	2%	-	93%	-	-	Gr

Sed: Paleogene-Neogene-Quaternary sediment, K Sed: Cretaceous sedimentary rock, Mv: Neogene non-alkaline mafic volcanic rock, Py: Neogene-Quaternary pyroclastic rock, debris, and tephra, Fi: Miocene felsic intrusive rock, Gr: Neogene granitic rocks, Gb: Neogene gabbroic rocks, Mp: Cretaceous high-pressure type metamorphic rock.

and Na (589.5), Mg (202.5), K (766.4), Ca (315.8), and Fe (259.9) using radial plasma viewing. An ICP mass spectrometer (ICP-MS) (Agilent Technologies Inc., 7500ce) equipped with a He collision cell was used to determine the concentration of 38 elements. The elements and isotopes chosen for analysis were: Sc (45), Cr (53), Co (59), Ni (60), Cu (63), Zn (66), Ga (71), As (75), Rb (85), Y (89), Zr (90), Nb (93), Mo (95), Cd (111), Sn (120), Sb (121), Cs (133), La (139), Ce (140), Pr (141), Nd (146), Sm (147), Eu (151), Gd (157), Tb (159), Dy (163), Ho (165), Er (167), Tm (169), Yb (173), Lu (175), Hf (178), Ta (181), Tl (205), Pb (208), Bi (209), Th (232), and U (238). Although Pb isotope ratios in stream sediments change depending on the source rock, the quantitative values of Pb concentration obtained by ICP-MS were consistent with those determined by ICP-AES (Ohta, 2018).

The mercury concentration in undried samples was determined using an atomic absorption spectrometer that measured the quantity of Hg vapor generated from direct thermal decomposition of samples (Nihon Instruments Corp.; MA-2000). A standard solution prepared from a 1,000 mg/L mercury standard solution (Kanto Chemical Co. Inc.) was used to obtain the calibration curve. A wavenumber of 253.7 nm was used for determining the Hg concentration.

Quality control for the ICP-AES and ICP-MS analyses involved two geochemical reference samples, JB-1a and JB-3 (Imai *et al.*, 1995), which were inserted at the rate of 1 for every 5 and 10 samples, respectively. The geochemical reference sample JSl-1 (Imai *et al.*, 1996) was used for quality control of As and Hg determination and inserted at a rate of 1 for every 10 samples. Table 5 summarizes the analytical results for 53 elements in fine stream sediments (<180 μm) collected from remote islands around Kyushu. Element concentrations for SK03, Tn02, Tn09, Tn26, Yk01, and Yk17 samples, grouped into 7 grain sizes, are shown in Table 6. The As and Hg concentrations were re-calculated as concentration per 1 kg of the thermally dried samples. The Zr and Hf concentrations were used only as a guide because the heavy mineral fraction, especially zircon, was not digested by the HF-HNO_3-$HClO_4$ solution.

The relative standard deviation (RSD) of the element concentration obtained from repeated measurements (n = 3) for Ts02, Fke07, Hr04, Am23, Tn02, and Yk01 samples was within ±2% for major elements, within ±5% for many minor elements, within ±10% for H_2O^-, Li, Be, V, Cu, Zn, As, Nb, Ta, and Bi, and within ±15–20% for Sc, Cr, Mo, Cd, and Sb. The largest RSDs for Sn and Hg were within ±100% and ±40%, respectively, perhaps due to heterogeneity of the Sn minerals (such as cassiterite) and Hg minerals (such as native Hg and cinnabar).

4. Results and discussion

4. 1 Dependence of element concentration in stream sediments on grain size

Figure 4 shows the grain size dependence of the Al_2O_3, K_2O, CaO, TiO_2, T-Fe_2O_3, Cr, Cu, Y, Cd, Cs, La, and Pb concentration for Sk03, Tn02, Tn09, Tn26, Yk01, and Yb17. The Sk03 sample originated from Quaternary mafic pyroclastic rock, Tn02 and Tn09 originated from a Paleogene accretionary complex, Tn26 originated from Neogene sediment, and Yk01 and Yk17 originated from Neogene granitic rock. The concentration of most elements in Sk03 was similar regardless of grain size, which suggests that sand-sized particles formed the agglutinate of silty-sized volcanic ash fall in Sk03.

The chemical composition variations for Tn02, Tn09, and Tn26 were similar across grain size. Concentrations of many elements in Tn02, Tn09, and Tn26 decreased with decreasing grain size from the very coarse sand fraction (1–2 mm) to the fine sand fraction (125–250 μm), and then increased with a further decrease in grain size. This is called a V-shaped pattern. The CaO and Sr concentrations were largest in the coarse sand fractions (500–1000 μm), and then sharply decreased in the fine fractions (<250 μm). Their systematic variation across grain size was controlled dominantly by the abundance of plagioclase in clastics. The coarse and medium sand fractions (250–1000 μm) in Tn09 and the very fine fraction (63–125 μm) in Tn26 had the greatest concentrations of MgO, Sc, TiO_2, V, MnO, T-Fe_2O_3, and Co. These concentrations were influenced by the abundance of mafic minerals (olivine, pyroxene, amphibole, and biotite) and opaque minerals (magnetite and ilmenite). Enrichment of many elements in the finer stream sediments has been reported by Imai (1987) and Terashima *et al.* (2008), and was caused mainly by an increase in layer silicates (mainly clay minerals) containing Al_2O_3 and alkali metal elements, an increase in organic compounds bonding with heavy metals, and a less effective dilution effect with quartz that was less abundant in the finer fraction.

In contrast, the Be, Na_2O, Al_2O_3, CaO, and Sr concentrations in Yk01 and Yk17 samples increased gradually with decreasing grain size. These element concentrations, except for Al_2O_3, reached a maximum for the very fine sand fraction (63–125 μm) or the coarse silt fraction (32–63 μm). Systematic variations in CaO and Sr in these samples were opposite to those in Tn02, Tn09, and Tn26. Plagioclase appeared to be abundant in the fine sand fraction originating from granitic rock in Yakushima Island. The variations in the Li, K_2O, Rb, and Cs concentrations with grain size show a V-shaped pattern: the fine sand fraction (125–250 μm) or the very fine fractions (63–125 μm) had the lowest concentration. The steep decreases in K_2O and Rb concentrations with decreasing grain size can be explained by resistance of K-feldspar to weathering because the physical disruption of quartz and K-feldspar produced little fine-grained material in the silty size fraction and was likely preserved in the coarser fractions (Minami *et al.*, 2017). The concentrations of heavy metals, such as Cu, Zn, Cd, Sn, and Pb, increased dramatically in fractions smaller than

Table 5 Elemental analysis for fine stream sediments (<180 µm) collected from remote islands in the Kyushu region.

Element	Unit	Ts01	Ts02	Ts03	Ts04	Ts05	Ts06	Ts07	Ts08	Ts09	Ts10	Ts11	Ts12[a]	Ts13	Ts14	Ts15	Ts16	Ts17	Ts18	Ts19	Ts20	Ts21	Ts22	Ts23	Tk01	Tk02	Fks01	Fks02	Fks03	Ikt01	Ikt02	Hr01	Hr02	Hr03
Na_2O	wt%	1.24	1.60	1.32	0.563	0.689	0.936	0.916	0.941	0.914	0.898	0.893	1.04	0.806	1.00	0.850	0.957	0.912	0.712	0.966	0.945	0.715	0.932	0.907	0.864	0.575	1.38	1.19	1.29	0.893	0.928	0.697	0.919	0.645
MgO	wt%	1.07	0.81	1.06	1.33	1.48	1.08	0.996	1.10	0.845	1.00	1.12	1.18	0.970	1.40	0.876	1.05	1.09	1.40	1.39	1.22	1.13	0.966	1.04	1.76	0.995	0.975	1.00	0.826	2.04	2.06	5.18	2.11	3.61
Al_2O_3	wt%	10.60	9.05	10.63	13.03	13.95	13.80	11.76	13.00	12.07	13.03	13.96	14.01	12.52	13.72	11.84	12.82	13.14	12.83	14.28	13.62	12.32	11.02	12.90	16.33	16.44	10.80	11.14	10.14	17.87	18.71	15.45	16.89	15.05
P_2O_5	wt%	0.093	0.084	0.087	0.143	0.121	0.111	0.110	0.130	0.102	0.120	0.115	0.122	0.106	0.108	0.105	0.107	0.141	0.149	0.106	0.153	0.159	0.119	0.117	0.252	0.219	0.130	0.149	0.093	0.377	0.317	0.115	0.207	0.135
K_2O	wt%	2.29	1.58	2.35	2.00	2.21	2.27	1.96	2.10	2.01	2.13	2.33	2.31	2.02	2.22	1.91	2.16	2.09	2.04	2.45	2.24	2.02	1.81	2.04	1.12	1.18	2.24	2.31	2.34	1.23	0.965	0.617	0.872	1.02
CaO	wt%	0.974	1.23	1.20	0.497	0.565	0.199	0.217	0.497	0.253	0.313	0.272	0.299	0.280	0.197	0.218	0.322	0.515	0.644	0.204	0.395	0.571	0.397	0.305	0.766	0.543	0.919	0.861	0.748	1.59	1.58	3.32	3.25	2.74
TiO_2	wt%	1.08	2.52	1.83	0.846	0.850	0.823	0.730	0.791	0.761	0.800	0.805	0.848	0.768	0.796	0.747	0.801	0.808	0.853	0.779	0.743	0.679	0.635	0.736	1.77	2.07	0.821	0.772	0.686	2.13	2.03	1.34	0.99	4.61
MnO	wt%	0.092	0.121	0.116	0.106	0.107	0.080	0.083	0.097	0.057	0.083	0.080	0.073	0.109	0.110	0.085	0.073	0.111	0.157	0.131	0.082	0.073	0.088	0.069	0.295	0.182	0.069	0.102	0.088	0.538	0.399	0.249	0.338	0.287
$T\text{-}Fe_2O_3$	wt%	5.09	4.65	5.06	5.18	5.42	5.37	4.68	5.22	4.63	5.11	5.58	5.73	4.56	5.69	4.67	4.92	5.10	5.62	5.67	5.45	4.78	4.13	4.92	11.8	11.9	4.63	4.56	3.34	11.9	12.1	12.3	9.77	14.4
H_2O^-	wt%	1.45	0.72	8.96	3.89	2.42	1.06	1.25	2.86	1.64	1.65	2.37	1.42	3.09	2.52	1.61	1.91	3.17	2.99	1.03	1.79	4.09	1.72	2.17	6.83	4.02	2.81	6.78	8.74	6.33	4.54	10.1	8.26	8.13
Li	mg/kg	26.9	22.5	26.3	42.2	42.6	43.8	49.4	48.0	39.3	54.5	53.0	57.7	40.4	55.5	37.6	40.0	41.6	41.7	56.0	44.6	41.4	37.0	40.6	26.0	21.2	18.9	22.4	19.2	22.2	22.7	16.3	15.7	19.5
Be	mg/kg	1.54	1.41	1.56	2.24	2.54	2.10	1.79	2.01	1.82	2.03	2.19	2.34	1.88	2.20	1.88	2.02	2.08	2.17	2.26	2.16	2.34	1.75	1.96	1.93	1.87	1.42	1.63	1.38	2.04	1.83	0.953	1.01	1.25
Sc	mg/kg	11.0	11.8	13.7	11.4	12.4	11.3	9.79	10.9	9.41	10.1	11.3	11.2	10.0	11.1	9.20	10.8	11.1	11.1	11.2	11.1	10.6	8.03	10.6	18.1	19.8	7.73	8.34	7.14	22.7	23.0	40.9	26.0	39.1
V	mg/kg	84.7	83.3	90.6	98.5	99.0	104	94.9	105	91.7	102	110	102	96.6	108	91.4	99.6	102	98.9	107	105	85.2	83.5	98.8	184	191	78.2	78.1	56.7	199	207	242	207	364
Cr	mg/kg	29.4	24.4	23.7	79.6	79.5	85.4	74.8	84.5	72.1	79.9	91.4	88.8	79.2	88.7	69.3	82.9	77.0	74.0	84.4	81.3	66.7	64.7	78.4	234	317	52.5	73.8	53.3	181	241	109	65.1	45.8
Co	mg/kg	9.64	5.80	8.30	15.9	14.8	13.2	12.3	14.5	11.3	14.3	15.3	14.8	15.1	16.4	12.9	13.6	14.9	17.3	15.2	14.1	17.5	14.3	13.9	44.1	36.0	12.7	14.3	10.7	46.1	48.7	50.3	30.2	35.2
Ni	mg/kg	12.0	10.4	11.1	37.9	38.5	37.4	34.2	39.0	31.7	35.3	39.6	39.9	35.4	42.0	32.1	36.2	36.6	36.5	41.4	38.6	34.0	32.0	35.5	92.8	105	21.3	29.2	22.1	71.2	74.1	21.6	20.6	13.3
Cu	mg/kg	15.9	7.45	12.0	29.3	38.2	27.0	23.5	29.2	21.6	26.0	26.5	29.2	23.4	27.0	23.3	26.2	31.5	49.2	25.8	39.4	33.0	43.4	28.1	28.9	36.0	12.0	15.1	12.9	46.1	31.6	43.4	40.9	26.5
Zn	mg/kg	91.3	52.8	72.0	134	144	99.0	103	132	89.7	92.3	108	172	90.5	109	87.5	111	124	1855	156	130	190	113	107	129	124	74.0	68.5	78.3	217	149	176	354	163
Ga	mg/kg	14.4	12.7	14.2	17.7	18.7	17.7	15.2	16.6	15.0	16.5	17.9	18.1	16.1	17.3	15.6	17.2	17.6	18.0	19.1	17.6	17.0	13.9	16.8	20.4	21.2	13.3	13.1	12.1	24.0	21.8	16.6	17.9	16.8
As	mg/kg	9.62	3.81	5.60	12.3	29.0	9.97	9.55	9.58	8.31	11.9	10.1	10.5	9.92	11.5	8.92	9.88	9.71	25.0	11.2	11.2	12.3	6.31	9.19	6.64	5.90	3.94	4.53	4.40	7.04	7.27	12.0	6.34	5.58
Rb	mg/kg	96.6	63.4	91.6	111	124	117	97.4	108	99.3	108	120	117	107	117	98.0	112	112	109	125	120	113	90.1	109	48.0	51.8	79.0	81.6	79.5	48.4	44.5	28.6	35.1	44.6
Sr	mg/kg	86.3	97.5	89.0	62.5	59.5	70.3	71.4	77.4	68.7	75.3	72.6	75.4	67.6	71.1	62.8	67.7	75.0	64.8	63.3	66.6	62.4	63.6	67.9	86.8	71.8	146	143	143	183	175	138	156	137
Y	mg/kg	19.8	20.7	24.4	13.1	17.1	12.1	9.43	10.1	8.78	10.1	9.70	10.7	8.00	8.35	9.37	9.72	12.8	15.0	11.3	11.0	16.2	6.61	8.25	20.2	18.1	13.9	13.5	14.1	20.8	22.2	17.0	16.0	13.8
Zr	mg/kg	7.7	6.3	8.4	32	18	40	41	43	41	44	41	47	36	36	45	45	51	28	48	45	42	25	35	154	164	90	91	82	249	223	101	77	112
Nb	mg/kg	15.3	35.8	26.6	15.3	15.5	15.0	13.3	14.1	13.8	14.5	15.1	15.9	14.4	14.6	14.4	14.9	15.0	14.8	15.2	14.2	13.6	11.5	13.9	27.5	32.5	16.3	14.0	10.1	28.5	29.5	8.84	6.98	14.7
Mo	mg/kg	0.468	0.230	0.336	0.620	0.586	0.711	0.971	0.777	0.576	0.635	0.687	0.736	0.676	0.750	0.581	0.652	0.899	0.773	1.102	0.939	0.900	0.455	0.659	1.49	1.14	0.577	0.523	0.416	1.31	1.21	0.761	1.03	0.949
Cd	mg/kg	0.422	0.130	0.157	0.827	0.702	0.154	0.108	0.336	0.163	0.189	0.211	0.354	0.168	0.101	0.194	0.218	0.335	16.6	0.294	0.336	0.429	0.227	0.246	0.130	0.201	0.101	0.136	0.133	0.599	0.375	0.295	0.392	0.268
Sn	mg/kg	5.25	4.59	4.22	3.13	4.61	3.00	2.33	2.88	2.61	2.63	2.84	2.95	2.64	2.76	2.36	2.83	3.09	9.22	2.88	3.15	3.78	2.41	2.68	1.95	2.08	1.25	1.51	1.84	3.35	2.56	1.74	2.49	2.18
Sb	mg/kg	0.436	0.333	0.425	1.04	0.917	0.841	0.789	1.00	0.755	0.943	0.950	1.31	0.736	0.759	0.711	0.970	0.942	3.96	0.945	1.15	1.17	0.714	0.854	0.513	0.491	0.355	0.437	1.98	0.654	0.544	0.731	0.993	0.519
Cs	mg/kg	5.16	2.43	4.17	7.59	8.07	7.49	6.35	7.54	6.47	7.78	8.58	7.85	7.07	7.93	6.57	7.68	8.22	7.14	7.84	8.41	7.58	6.78	7.08	3.69	3.28	2.87	3.47	3.28	2.57	2.71	3.36	3.14	3.79
Ba	mg/kg	534	405	526	418	446	411	328	403	387	384	414	420	361	353	363	409	411	414	439	415	433	363	391	256	358	612	620	624	585	472	348	360	459
La	mg/kg	40.4	52.1	38.7	35.7	40.3	38.3	31.1	23.3	26.4	29.0	26.4	28.8	24.2	24.5	29.3	25.0	29.3	35.8	33.6	24.9	34.9	16.9	22.0	32.9	28.5	26.3	25.2	35.1	45.3	30.5	12.5	11.8	11.5
Ce	mg/kg	82.6	103	80.2	76.2	83.4	77.2	62.7	49.6	54.6	60.4	54.5	58.2	49.5	50.6	61.8	52.7	61.6	72.2	72.1	53.2	70.9	35.0	45.3	68.1	62.9	51.8	49.0	70.5	94.8	67.1	25.9	27.3	23.4
Pr	mg/kg	9.57	11.4	9.64	8.26	9.27	8.94	7.17	5.74	6.11	6.61	6.04	6.62	5.58	5.76	6.76	5.97	7.03	8.43	8.27	6.29	8.28	4.14	5.17	7.30	6.43	5.89	5.53	8.07	10.2	6.91	3.12	2.91	2.80
Nd	mg/kg	35.3	39.5	36.2	30.5	33.8	32.5	25.8	21.4	22.5	24.1	22.5	24.3	20.4	21.1	24.7	22.4	26.4	31.4	30.3	23.8	31.3	15.7	19.3	27.6	24.0	21.4	19.9	29.2	36.8	25.1	12.2	11.6	10.7
Sm	mg/kg	6.32	6.80	6.99	5.62	6.33	5.96	4.57	4.12	4.22	4.42	4.17	4.52	3.77	4.13	4.54	4.14	5.07	5.77	5.52	4.67	5.87	3.27	3.76	5.43	4.88	4.03	3.66	5.32	6.44	4.71	2.69	2.69	2.44
Eu	mg/kg	0.928	0.849	0.920	0.951	0.980	0.874	0.840	0.812	0.748	0.827	0.767	0.847	0.700	0.758	0.810	0.810	0.993	1.10	0.925	0.859	1.04	0.589	0.728	1.22	1.21	0.846	0.837	0.756	1.51	1.26	0.674	0.749	0.625
Gd	mg/kg	4.86	4.94	5.74	4.23	4.84	4.24	2.94	3.03	2.71	3.14	2.97	3.09	2.56	2.77	3.01	2.94	3.71	4.49	3.57	3.39	4.78	2.46	2.69	4.54	4.11	3.16	2.83	3.92	5.06	4.00	2.59	2.54	2.29
Tb	mg/kg	0.648	0.658	0.796	0.547	0.640	0.512	0.347	0.382	0.324	0.390	0.358	0.383	0.311	0.354	0.369	0.360	0.464	0.581	0.430	0.412	0.591	0.302	0.313	0.642	0.568	0.447	0.396	0.488	0.671	0.591	0.410	0.394	0.356
Dy	mg/kg	3.69	3.66	4.60	2.70	3.37	2.63	1.81	1.97	1.68	2.06	1.91	2.08	1.63	1.71	1.87	1.91	2.41	2.97	2.18	2.23	3.08	1.43	1.70	3.64	3.26	2.38	2.32	2.57	3.78	3.69	2.68	2.46	2.23
Ho	mg/kg	0.680	0.694	0.844	0.460	0.614	0.432	0.325	0.370	0.326	0.371	0.326	0.371	0.304	0.324	0.341	0.367	0.440	0.528	0.417	0.391	0.553	0.241	0.292	0.696	0.637	0.463	0.450	0.489	0.730	0.775	0.565	0.535	0.480
Er	mg/kg	1.89	1.95	2.34	1.19	1.53	1.10	0.929	1.01	0.911	0.999	0.930	1.06	0.816	0.871	0.929	0.996	1.23	1.39	1.17	1.10	1.48	0.668	0.863	1.93	1.79	1.27	1.23	1.31	2.05	2.36	1.71	1.61	1.44
Tm	mg/kg	0.264	0.268	0.328	0.167	0.206	0.159	0.136	0.139	0.130	0.138	0.143	0.155	0.122	0.117	0.140	0.133	0.168	0.184	0.161	0.158	0.186	0.090	0.129	0.274	0.256	0.199	0.203	0.195	0.284	0.334	0.260	0.230	0.215
Yb	mg/kg	1.66	1.74	2.18	1.04	1.28	1.03	0.933	0.985	0.912	1.00	0.956	1.06	0.830	0.777	0.958	1.02	1.11	1.15	1.07	1.05	1.27	0.557	0.751	1.78	1.66	1.25	1.31	1.29	1.84	2.26	1.83	1.57	1.54
Lu	mg/kg	0.238	0.250	0.315	0.144	0.169	0.144	0.130	0.141	0.125	0.141	0.140	0.152	0.117	0.122	0.131	0.139	0.168	0.159	0.162	0.161	0.178	0.087	0.115	0.260	0.244	0.184	0.192	0.183	0.287	0.322	0.278	0.232	0.232
Hf	mg/kg	0.25	0.26	0.33	0.82	0.49	1.1	1.1	1.2	1.1	1.2	1.1	1.2	0.95	0.90	1.1	1.2	1.4	0.78	1.2	1.3	1.1	0.63	0.94	3.5	3.6	2.1	2.3	2.1	5.4	4.6	2.6	2.0	3.0
Ta	mg/kg	1.31	2.29	1.68	1.32	1.35	1.28	1.09	1.16	1.17	1.24	1.26	1.33	1.19	1.18	1.16	1.21	1.23	1.28	1.28	1.26	1.17	0.95	1.17	1.80	2.11	1.14	1.01	0.785	1.83	2.03	0.607	0.525	0.676
Hg	mg/kg	0.029	0.021	0.024	0.077	0.035	0.041	0.063	0.084	0.047	0.094	0.088	0.079	0.076	0.067	0.056	0.057	0.092	0.103	0.041	0.063	0.097	0.091	0.057	0.077	0.055	0.037	0.040	0.048	0.063	0.078	0.661	0.151	0.056
Tl	mg/kg	0.496	0.344	0.472	0.631	0.764	0.621	0.506	0.608	0.532	0.586	0.637	0.625	0.549	0.593	0.531	0.602	0.636	0.629	0.655	0.649	0.647	0.503	0.589	0.269	0.337	0.410	0.436	0.456	0.362	0.331	0.290	0.274	0.288
Pb	mg/kg	32.0	16.5	16.7	55.5	41.8	25.7	24.2	30.6	21.8	26.1	29.3	50.9	26.5	27.1	23.1	26.1	30.5	1452	76.1	58.6	36.4	26.9	27.0	14.4	14.2	14.7	15.9	95.8	27.2	19.1	21.6	39.7	21.3
Bi	mg/kg	0.314	0.197	0.204	0.642	0.794	0.335	0.282	0.398	0.290	0.359	0.399	0.375	0.398	0.411	0.317	0.378	0.405	0.650	0.316	0.431	0.494	0.294	0.369	0.187	0.187	0.134	0.142	0.128	0.320	0.232	0.218	0.280	0.188
Th	mg/kg	9.08	8.38	15.4	11.1	11.9	15.4	9.53	9.60	9.54	10.7	10.0	10.4	9.15	9.85	10.4	9.92	10.2	10.7	11.4	10.3	11.2	7.94	8.84	10.0	8.07	6.48	7.18	12.4	11.7	7.70	4.58	4.33	4.98
U	mg/kg	1.08	1.02	1.69	1.45	1.36	2.28	2.40	1.56	1.43	1.64	1.49	1.60	1.39	1.67	1.54	1.65	1.69	1.44	2.26	1.75	1.68	1.24	1.42	2.25	1.59	1.29	1.41	1.76	1.84	1.70	1.25	1.09	1.33

[a] The mean values of repeated analyses (n=3).

Table 5 continued.

Element	Unit	Hr04[a]	Hr05	Hr06	Hr07	Hr08	Hr09	Os01	Os02	Mt01	Iki01	Iki02	Iki03	Iki04	Iki05	Iki06	Iki07	Uk01	Uk02	Uk03	Oj01	Oj02	Nk01	Nk02	Nk03	Nk04	Nk05	Nk06	Nk07	Nk08	Nk09	Nk10	Nk11	Nk12
Na_2O	wt%	0.632	0.515	0.506	0.465	0.641	1.05	1.34	1.35	1.80	1.88	1.38	1.49	0.77	0.59	1.77	1.80	0.459	0.951	1.62	0.442	0.560	1.71	1.96	0.557	1.01	1.16	1.70	0.785	0.899	1.03	1.23	0.824	1.94
MgO	wt%	2.14	2.33	1.91	1.65	3.02	1.89	1.42	1.18	0.94	1.94	1.83	2.09	1.55	1.40	1.47	2.23	1.05	1.21	1.17	1.28	1.26	0.947	0.930	0.669	1.26	0.771	1.32	0.759	0.931	0.681	0.805	0.966	1.83
Al_2O_3	wt%	17.45	17.26	16.65	13.85	16.95	13.27	11.08	12.39	10.84	17.74	15.33	14.06	20.01	19.86	17.45	16.00	18.29	14.58	17.47	20.21	20.11	12.61	12.25	7.54	10.66	10.10	10.96	7.85	11.70	9.87	9.05	8.22	11.59
P_2O_5	wt%	0.138	0.126	0.125	0.180	0.107	0.105	0.108	0.093	0.078	0.289	0.322	0.261	0.423	0.310	0.318	0.292	0.713	0.380	0.290	0.399	0.304	0.102	0.083	0.054	0.088	0.068	0.128	0.060	0.080	0.060	0.106	0.148	0.175
K_2O	wt%	1.02	0.968	0.967	1.20	0.759	1.60	2.12	2.34	1.36	1.42	1.63	1.60	1.24	0.75	1.78	1.64	0.856	0.982	1.24	0.715	0.829	1.71	1.90	1.59	1.57	1.71	1.87	1.44	1.90	1.90	1.59	1.53	1.67
CaO	wt%	2.48	2.20	1.65	1.29	2.75	1.77	1.36	0.866	0.636	2.33	1.69	1.99	1.45	1.18	1.72	2.98	1.08	1.44	1.90	1.41	1.23	0.815	0.712	0.344	1.19	0.635	1.79	1.02	0.937	0.638	1.14	0.970	3.41
TiO_2	wt%	1.28	1.22	1.08	1.14	1.23	1.18	0.581	0.527	1.08	2.08	3.82	3.34	2.46	2.66	3.35	3.31	2.14	2.22	2.24	2.49	2.47	0.597	0.580	0.522	0.637	0.701	0.571	1.08	0.636	0.593	0.606	0.479	0.930
MnO	wt%	0.301	0.217	0.223	0.269	0.234	0.174	0.267	0.068	0.107	0.131	0.292	0.325	0.332	0.300	0.209	0.179	0.216	0.220	0.196	0.432	0.338	0.076	0.095	0.068	0.089	0.059	0.084	0.127	0.100	0.092	0.088	0.067	0.204
$T\text{-}Fe_2O_3$	wt%	10.2	10.7	9.74	9.42	12.1	8.44	3.96	3.46	5.67	10.6	13.0	11.5	13.7	16.2	12.2	12.0	15.9	16.6	13.5	17.6	16.6	3.72	3.33	2.71	3.89	3.12	3.76	3.79	3.79	3.32	3.29	3.09	5.49
H_2O^-	wt%	8.62	10.7	7.46	6.13	8.45	6.36	3.88	15.48	2.56	5.99	4.33	3.73	10.6	10.9	6.34	4.29	8.44	4.75	4.91	7.30	5.94	4.04	3.10	1.63	2.64	1.91	1.49	0.79	3.49	1.37	3.20	1.85	1.74
Li	mg/kg	19.9	18.8	17.8	24.1	19.4	18.1	24.1	33.5	24.5	63.8	24.8	25.2	24.0	19.8	24.2	32.1	27.2	29.3	24.9	32.6	23.8	22.6	34.6	20.4	21.7	22.4	23.7	19.9	35.1	25.0	21.2	18.6	16.5
Be	mg/kg	1.32	1.02	1.07	1.18	1.11	1.38	1.42	1.58	1.01	2.11	2.75	2.55	2.90	1.70	2.93	2.28	2.56	2.46	1.99	1.35	1.86	1.38	1.53	0.91	1.33	1.36	1.25	1.02	1.52	1.38	1.20	1.09	1.13
Sc	mg/kg	27.0	28.9	26.4	23.2	33.6	20.9	8.70	8.31	11.2	20.4	20.0	18.2	25.7	26.4	18.2	19.7	21.8	16.6	16.5	29.2	26.0	10.8	9.56	6.11	11.0	8.33	11.3	10.5	11.0	8.08	8.07	7.58	16.19
V	mg/kg	253	274	231	195	289	191	63.0	57.9	109	160	190	172	199	244	193	193	75.4	111	117	196	194	62.0	44.1	53.6	70.7	56.6	57.3	50.7	62.9	48.1	41.8	53.8	60.7
Cr	mg/kg	44.2	65.9	21.2	35.7	31.1	41.3	58.9	42.8	239	162	142	145	235	261	140	151	40.0	33.8	62.6	131	138	30.9	24.7	26.8	69.1	31.6	52.7	26.4	36.7	26.0	35.6	44.8	50.8
Co	mg/kg	28.8	30.7	20.6	23.9	27.2	16.3	12.1	8.20	20.2	31.7	40.2	38.7	48.0	62.4	34.1	33.4	26.8	26.4	28.4	46.0	50.0	7.89	6.16	6.99	11.1	7.09	8.58	7.36	8.70	6.64	6.42	8.01	9.46
Ni	mg/kg	14.5	21.4	7.83	13.5	9.8	12.4	20.8	15.6	48.3	68.0	57.6	62.5	124	112	59.3	66.4	19.5	15.9	38.9	68.1	66.4	9.96	11.0	10.6	21.1	12.9	17.9	11.2	15.3	12.3	14.7	14.7	21.3
Cu	mg/kg	48.9	57.3	23.4	25.2	40.6	13.2	16.1	17.0	18.4	35.7	25.9	21.7	42.9	53.3	18.2	19.5	41.6	27.6	44.6	58.6	48.2	18.5	14.0	10.5	19.6	20.5	17.0	9.57	17.1	18.5	33.7	26.4	13.0
Zn	mg/kg	139	154	166	180	132	115	139	118	80.0	183	186	196	316	168	167	188	363	227	280	390	201	132	86.4	57.1	119	81.6	183	84.3	106	116	135	160	253
Ga	mg/kg	18.1	19.0	18.4	17.1	19.0	16.5	12.4	13.1	12.6	23.0	22.9	22.4	26.7	25.4	25.2	22.1	31.7	25.2	24.9	25.3	25.8	12.6	12.5	8.34	11.9	11.2	12.1	9.61	13.5	12.4	10.9	9.81	13.2
As	mg/kg	7.56	5.59	7.19	42.9	9.12	7.13	5.85	7.43	4.43	14.9	9.69	13.1	5.74	6.85	6.76	6.68	9.52	13.4	5.12	23.8	10.9	16.2	13.2	4.94	21.3	12.37	7.30	9.03	27.7	19.5	7.15	18.9	5.40
Rb	mg/kg	46.2	39.6	44.0	53.1	34.0	66.8	73.0	87.5	52.4	61.3	73.0	68.9	47.6	33.8	71.0	55.2	49.0	39.1	40.5	36.9	42.8	75.8	78.5	59.0	66.0	69.8	64.1	54.1	86.6	84.3	56.7	58.0	54.0
Sr	mg/kg	129	121	91.1	80.5	115	137	129	103	81.1	161	161	156	142	106	183	235	119	125	171	98	98	100	125	57.6	93.8	89.5	160	77.8	75.2	74.1	111	86.8	189
Y	mg/kg	16.0	12.3	18.6	15.3	17.9	19.8	16.3	15.8	13.4	22.9	23.4	22.6	29.8	18.7	25.1	22.6	50.4	35.6	24.6	13.8	18.3	13.5	17.3	6.8	13.3	11.6	13.9	9.8	13.8	12.6	11.1	10.1	23.6
Zr	mg/kg	102	94	99	81	94	102	78	90	80	222	249	194	287	204	253	209	312	241	158	178	186	75	80	44	45	40	35	26	53	39	29	36	43
Nb	mg/kg	6.50	6.45	6.25	8.18	6.31	9.22	7.76	7.67	10.6	44.0	69.3	82.1	54.9	33.2	75.7	58.1	69.9	52.1	47.0	31.2	36.0	6.58	7.18	6.59	8.24	9.31	7.28	8.94	7.71	8.13	7.92	6.44	8.08
Mo	mg/kg	0.867	0.856	0.806	1.19	0.884	0.686	0.624	0.785	0.530	2.229	2.29	1.80	2.65	1.50	2.14	1.75	3.10	2.63	2.66	1.37	2.10	0.763	0.682	0.363	0.965	0.426	0.730	0.368	0.626	0.941	0.827	0.572	0.549
Cd	mg/kg	0.275	0.313	0.230	0.291	0.217	0.191	0.259	0.177	0.191	0.221	0.332	0.306	0.474	0.414	0.208	0.211	0.448	0.168	0.274	0.640	0.283	0.228	0.205	0.172	0.396	0.176	0.138	0.102	0.494	0.581	0.146	0.447	0.374
Sn	mg/kg	4.63	1.86	1.94	2.59	2.30	2.15	2.14	2.30	1.67	3.47	3.70	4.00	3.40	2.95	3.44	2.65	5.31	5.52	14.1	3.01	3.04	2.23	2.06	1.40	2.30	1.81	2.08	1.45	1.93	1.94	2.82	2.58	2.17
Sb	mg/kg	0.806	0.626	1.05	4.08	0.691	0.543	0.654	0.772	0.501	0.764	0.915	0.915	0.693	0.558	0.665	0.487	0.726	0.425	0.496	0.631	0.752	1.54	1.22	0.459	1.03	1.04	0.756	1.09	1.76	1.34	0.840	0.984	0.681
Cs	mg/kg	4.10	2.94	4.16	9.42	6.02	4.67	3.69	5.38	3.04	4.46	4.10	3.59	3.23	2.21	3.41	2.07	3.67	1.61	1.51	3.41	3.52	7.09	8.56	2.63	5.62	6.84	3.76	4.37	9.26	7.64	3.64	4.34	3.50
Ba	mg/kg	419	399	310	401	289	480	572	343	265	272	538	569	592	450	574	428	421	310	393	313	445	476	391	401	389	418	400	349	418	416	360	378	376
La	mg/kg	13.5	10.8	12.4	12.4	13.4	20.5	19.5	18.2	12.8	36.3	56.1	103	41.7	21.1	58.7	52.2	43.2	29.9	26.6	20.1	22.3	19.4	17.6	9.71	17.8	22.7	15.7	10.3	17.0	20.5	13.9	15.0	16.0
Ce	mg/kg	28.6	23.6	28.2	26.7	29.8	40.0	38.4	35.1	28.4	74.2	101	164	83.1	51.2	101	89.8	93.9	82.3	53.9	47.9	61.4	37.0	34.8	20.2	34.2	45.8	30.1	21.4	34.0	39.3	27.5	27.4	34.1
Pr	mg/kg	3.20	2.57	3.11	3.11	3.17	4.90	4.58	3.89	3.07	8.01	10.2	15.1	8.98	5.05	10.8	9.32	11.2	7.15	5.96	4.41	5.08	4.34	4.08	2.13	4.05	5.08	3.55	2.53	3.85	4.52	3.27	3.34	4.22
Nd	mg/kg	12.5	9.8	12.3	12.3	12.3	18.7	16.9	13.8	11.4	29.5	34.8	46.4	33.8	20.1	37.8	32.7	47.2	29.8	24.2	16.5	19.5	15.6	15.4	7.63	15.3	18.3	13.4	9.79	14.7	16.5	11.8	12.2	16.8
Sm	mg/kg	2.77	2.21	2.89	2.78	2.83	3.92	3.40	2.65	2.28	5.90	6.27	6.94	6.72	4.31	7.00	5.88	11.4	6.99	5.52	3.57	4.10	3.11	3.19	1.51	3.16	3.31	2.72	2.17	2.96	3.18	2.54	2.33	4.06
Eu	mg/kg	0.700	0.591	0.755	0.657	0.741	0.937	0.671	0.569	0.560	1.60	1.68	1.42	1.95	1.28	1.87	1.65	3.30	2.073	1.78	0.958	1.16	0.680	0.738	0.347	0.690	0.598	0.694	0.480	0.650	0.559	0.566	0.532	1.03
Gd	mg/kg	2.62	2.05	2.90	2.67	2.76	3.61	2.76	2.15	2.15	5.09	5.41	5.50	6.13	4.00	5.93	5.26	12.2	7.13	5.28	3.02	3.79	2.50	2.89	1.23	2.58	2.52	2.46	1.85	2.53	2.65	2.17	2.08	4.05
Tb	mg/kg	0.413	0.320	0.460	0.413	0.437	0.543	0.395	0.334	0.339	0.720	0.756	0.752	0.874	0.617	0.868	0.745	1.78	1.12	0.800	0.466	0.572	0.376	0.441	0.180	0.371	0.343	0.371	0.273	0.385	0.388	0.306	0.278	0.618
Dy	mg/kg	2.59	2.00	2.94	2.54	2.80	3.29	2.58	2.28	2.13	4.17	4.41	4.22	5.18	3.58	4.88	4.37	10.4	6.48	4.45	2.68	3.44	2.18	2.65	1.11	2.26	1.99	2.35	1.75	2.32	2.20	1.90	1.69	3.84
Ho	mg/kg	0.543	0.421	0.642	0.548	0.606	0.693	0.537	0.494	0.458	0.797	0.823	0.803	0.967	0.698	0.895	0.789	1.85	1.262	0.859	0.500	0.638	0.458	0.562	0.229	0.453	0.404	0.470	0.354	0.471	0.439	0.380	0.334	0.806
Er	mg/kg	1.62	1.27	1.95	1.60	1.84	2.00	1.58	1.63	1.36	2.19	2.28	2.16	2.67	1.96	2.50	2.22	5.01	3.40	2.33	1.51	1.93	1.34	1.65	0.686	1.25	1.12	1.36	0.98	1.44	1.15	1.10	0.94	2.19
Tm	mg/kg	0.242	0.195	0.287	0.236	0.261	0.298	0.254	0.259	0.205	0.304	0.317	0.305	0.382	0.280	0.360	0.308	0.646	0.458	0.300	0.210	0.269	0.201	0.248	0.108	0.181	0.160	0.188	0.139	0.198	0.167	0.150	0.134	0.308
Yb	mg/kg	1.62	1.27	1.95	1.55	1.74	1.93	1.75	1.77	1.40	1.94	2.13	2.01	2.42	1.82	2.30	1.97	4.13	3.01	1.97	1.49	1.86	1.45	1.73	0.684	1.25	1.10	1.23	0.921	1.32	1.10	1.02	0.904	2.05
Lu	mg/kg	0.243	0.190	0.288	0.226	0.263	0.297	0.264	0.266	0.208	0.298	0.312	0.295	0.355	0.277	0.344	0.292	0.551	0.421	0.279	0.210	0.249	0.225	0.263	0.109	0.181	0.159	0.180	0.137	0.192	0.166	0.145	0.137	0.288
Hf	mg/kg	2.73	2.5	2.7	2.2	2.5	2.6	2.1	2.4	2.0	5.1	5.4	4.5	6.4	4.6	5.6	4.6	7.5	5.8	3.9	4.1	4.3	2.0	2.2	1.1	1.2	1.1	1.0	0.76	1.5	1.1	0.81	0.96	1.3
Ta	mg/kg	0.538	0.522	0.503	0.687	0.510	0.672	0.724	0.698	0.812	3.24	3.46	6.29	3.87	2.21	4.79	3.40	4.63	3.24	3.15	2.09	2.40	0.569	0.589	0.505	0.686	0.776	0.614	0.634	0.675	0.702	0.632	0.552	0.725
Hg	mg/kg	0.252	0.069	0.236	0.139	0.798	0.070	0.046	0.058	0.058	0.075	0.043	0.231	0.066	0.075	0.054	0.065	0.085	0.102	0.075	0.099	0.090	0.055	0.043	0.040	0.042	0.034	0.041	0.019	0.063	0.051	0.025	0.030	0.028
Tl	mg/kg	0.314	0.293	0.304	0.530	0.328	0.489	0.514	0.558	0.337	0.354	0.382	0.352	0.292	0.256	0.292	0.235	0.278	0.144	0.168	0.327	0.301	0.505	0.481	0.333	0.555	0.484	0.413	0.390	0.842	0.756	0.397	0.443	0.477
Pb	mg/kg	24.6	24.8	20.5	22.9	21.3	20.4	17.9	21.4	14.7	25.0	31.2	25.9	21.7	18.9	20.6	14.3	42.3	23.4	95.2	21.2	20.3	27.4	22.7	14.4	38.5	22.8	21.4	15.4	39.2	86.7	22.3	27.9	21.2
Bi	mg/kg	0.226	0.228	0.237	0.836	0.211	0.229	0.216	0.262	0.205	0.304	0.208	0.226	0.246	0.223	0.163	0.107	0.395	0.103	0.196	0.297	0.248	0.238	0.246	0.142	0.646	0.273	0.264	0.218	0.441	0.429	0.283	0.325	0.343
Th	mg/kg	5.64	4.68	4.72	5.35	4.89	6.49	7.27	6.93	4.87	10.5	15.0	21.8	10.9	6.11	14.1	9.53	10.3	6.05	5.85	6.94	7.83	7.35	6.71	3.97	5.62	8.44	5.42	3.77	5.90	8.70	4.61	4.66	3.86
U	mg/kg	1.52	1.23	1.19	1.27	1.20	1.43	1.62	2.16	1.55	2.49	2.10	2.24	2.48	1.64	2.30	1.86	2.46	2.12	1.66	1.57	1.76	1.50	2.18	0.864	1.06	1.12	1.43	0.745	1.23	1.66	1.20	1.01	0.767

[a] The mean values of repeated analyses (n=3).

Table 5 continued.

Element	Unit	Nk13	Wk01	Wk02	Wk03	Hs01	Hs02	Hs03	Fke01	Fke02	Fke03	Fke04	Fke05	Fke06	Fke07[a]	Fke08	Fke09	Fke10	Fke11	Fke12	Fke13	Fke14	Fke15	Ut01	Ut02	Oy01	Am01	Am02	Am03	Am04	Am05	Am06	Am07	Am08
Na_2O	wt%	1.05	0.873	0.728	1.02	1.30	1.73	0.925	0.862	0.573	0.994	1.17	0.282	0.285	0.977	0.564	1.29	0.873	0.738	0.415	0.631	0.555	0.336	1.42	1.16	2.28	1.45	1.82	1.51	1.41	1.32	1.50	1.24	1.29
MgO	wt%	1.13	0.833	0.614	0.710	0.700	0.860	0.792	0.732	0.563	0.865	1.40	0.570	0.615	0.943	0.653	0.728	0.887	0.904	0.975	1.70	1.27	0.617	1.90	2.91	3.82	1.70	1.55	1.36	0.96	1.84	1.27	1.08	0.916
Al_2O_3	wt%	7.93	10.69	9.46	10.04	12.00	13.09	9.99	11.11	9.31	11.70	10.68	7.90	7.00	14.95	10.30	10.59	9.51	10.50	11.46	20.58	10.93	8.47	12.26	20.16	14.48	12.53	12.45	11.12	10.93	13.52	11.58	13.06	12.06
P_2O_5	wt%	0.067	0.056	0.111	0.057	0.080	0.084	0.085	0.085	0.068	0.080	0.141	0.087	0.119	0.150	0.074	0.063	0.100	0.106	0.152	0.385	0.187	0.070	0.112	0.140	0.229	0.111	0.120	0.091	0.091	0.134	0.170	0.136	0.108
K_2O	wt%	1.25	1.70	1.77	1.82	1.82	2.26	1.83	1.99	1.32	1.63	2.02	1.52	0.949	2.46	2.54	2.13	1.45	1.49	1.48	0.95	1.16	1.14	1.28	0.653	0.832	1.77	1.92	1.93	1.96	2.20	2.17	2.32	1.85
CaO	wt%	1.50	0.980	0.649	0.699	1.28	2.32	1.13	0.829	0.593	1.51	1.23	0.274	0.536	0.746	0.324	0.665	1.19	0.997	0.814	1.53	1.16	0.369	1.61	3.30	5.18	1.61	0.533	1.14	0.540	0.984	0.548	0.632	0.420
TiO_2	wt%	1.97	0.530	0.461	0.495	0.540	0.589	0.573	0.570	0.520	0.908	0.872	0.560	0.561	0.611	0.509	0.563	0.630	0.634	0.866	1.74	0.847	0.477	1.56	1.18	1.90	0.908	0.635	0.640	0.545	0.691	0.579	0.553	0.625
MnO	wt%	0.248	0.091	0.122	0.095	0.098	0.114	0.073	0.111	0.170	0.240	0.079	0.064	0.209	0.122	0.033	0.052	0.093	0.091	0.110	0.232	0.118	0.101	0.174	0.231	0.209	0.106	0.024	0.122	0.046	0.095	0.081	0.064	0.072
T-Fe_2O_3	wt%	5.15	3.61	3.03	3.19	4.05	4.17	3.29	3.78	2.79	4.79	4.41	2.86	3.41	5.61	2.51	3.05	4.20	4.56	5.89	13.4	5.96	2.59	11.4	10.6	10.1	5.92	4.59	4.36	3.79	5.03	3.95	3.68	4.16
H_2O^-	wt%	8.74	1.26	3.64	2.59	2.22	1.82	1.48	1.95	1.49	2.06	1.63	1.15	3.20	2.58	1.46	1.37	1.80	2.20	2.46	7.97	2.81	1.28	2.10	3.11	1.86	1.95	2.90	1.59	1.88	2.64	2.62	2.09	1.86
Li	mg/kg	14.8	24.5	25.0	27.3	25.8	32.4	33.4	29.2	23.3	24.9	27.2	21.5	18.7	26.6	28.3	24.3	21.1	26.8	21.8	25.7	20.8	20.6	25.4	24.6	20.3	32.8	46.2	33.7	43.3	50.7	41.3	44.3	47.1
Be	mg/kg	0.97	1.29	1.60	1.57	1.30	1.35	1.12	1.82	1.87	1.52	1.16	1.05	0.78	1.74	1.51	1.34	1.20	1.35	1.33	1.84	1.00	1.27	1.15	1.34	1.23	1.47	1.47	1.10	1.57	1.61	1.70	2.10	1.87
Sc	mg/kg	13.3	8.88	7.43	8.08	12.5	13.3	8.80	9.82	9.10	15.0	10.4	6.49	5.77	13.3	6.56	10.0	12.6	14.1	11.0	23.3	12.1	7.84	14.1	23.0	21.7	15.8	10.7	10.3	7.01	12.5	7.94	8.36	8.06
V	mg/kg	59.2	59.7	37.4	49.7	60.9	67.6	57.3	49.8	40.8	64.8	59.8	49.8	45.6	67.5	39.9	41.5	65.4	65.6	84.5	169	85.4	44.3	235	202	262	93.5	71.8	75.0	62.6	101	72.0	61.6	75.2
Cr	mg/kg	31.0	36.7	24.4	30.0	30.1	35.2	35.2	31.5	23.2	27.5	31.1	33.6	50.2	34.6	23.4	21.5	32.8	52.1	64.8	182	95.4	28.9	63.3	29.9	97.7	161	107	140	61.8	80.5	69.6	62.2	53.9
Co	mg/kg	7.51	7.97	5.66	7.26	8.23	8.14	7.13	7.72	53.5	9.15	12.0	8.07	12.5	8.84	4.76	6.06	8.59	10.5	16.1	39.9	16.8	36.1	18.8	21.5	21.8	15.4	12.5	12.7	8.58	12.6	9.84	10.6	10.8
Ni	mg/kg	11.2	15.3	10.7	14.7	9.91	10.3	13.6	14.2	40.5	11.6	24.5	14.9	19.3	13.1	9.54	9.14	11.1	14.5	36.5	100	47.8	20.3	17.1	9.77	28.3	72.3	53.7	68.9	24.6	41.3	26.3	23.0	23.4
Cu	mg/kg	7.25	17.0	19.0	16.3	15.8	13.3	24.8	16.1	24.6	11.8	11.0	14.0	10.1	14.2	10.7	13.7	13.5	29.6	20.9	46.8	25.2	26.6	15.9	14.1	21.5	26.7	31.7	20.0	13.8	27.2	35.9	21.0	16.2
Zn	mg/kg	116	71.6	116	80.1	128	118	116	93.0	127	93.5	64.3	78.8	53.6	88.7	69.9	56.4	79.7	82.9	140	266	127	69.9	157	154	202	154	252	106	92	132	114	91	114
Ga	mg/kg	9.51	12.2	11.4	11.8	14.7	15.8	11.5	13.4	10.5	14.8	11.2	9.33	9.28	16.2	11.2	12.0	11.2	13.4	13.8	22.7	12.4	9.38	17.4	22.3	18.0	15.4	14.8	11.7	12.6	15.8	14.4	16.8	15.0
As	mg/kg	3.39	12.7	21.8	6.96	7.67	11.8	6.07	8.69	13.4	6.16	9.31	12.1	5.52	26.7	23.9	7.98	15.8	14.8	35.6	10.1	10.5	15.4	3.55	2.95	2.86	6.09	5.61	8.06	6.26	7.12	6.07	5.92	5.02
Rb	mg/kg	43.0	71.2	82.4	71.4	77.5	92.1	72.8	79.8	49.2	65.1	81.4	62.4	40.8	120	124	83.6	54.2	60.0	66.6	50.9	46.8	42.9	51.5	28.3	34.1	81.2	90.9	63.3	76.1	99.0	87.7	108	86.6
Sr	mg/kg	88.5	73.9	65.2	90.0	83.6	116	93.7	84.4	55.5	101	133	41.8	46.3	80.2	49.9	77.7	88.1	78.9	75.1	151	86.7	48.0	145	264	315	149	98	122	91.4	103	95.6	103	84.1
Y	mg/kg	14.9	10.4	13.4	13.7	17.7	21.3	11.7	15.1	43.9	21.3	13.4	7.22	6.35	19.9	8.79	10.3	14.0	15.6	10.9	23.2	10.9	25.3	15.0	22.5	25.6	19.2	19.2	12.1	10.0	19.4	11.7	12.1	10.9
Zr	mg/kg	33	40	44	42	31	19	13	39	18	38	48	29	43	29.7	10	9.4	23	31	60	167	63	12	75	124	55	73	79	41	50	79	57	51	56
Nb	mg/kg	14.5	7.01	6.38	8.20	6.53	7.13	7.57	9.63	7.59	10.8	15.7	9.43	9.66	9.24	7.81	8.54	7.48	8.06	15.5	31.6	12.6	6.88	12.9	9.94	14.0	11.6	10.6	7.87	9.56	10.2	10.0	10.8	11.0
Mo	mg/kg	0.561	0.642	1.12	0.615	0.609	0.799	0.496	1.09	2.41	0.723	1.04	0.400	0.453	1.28	2.26	1.05	0.568	0.808	1.47	1.40	0.983	3.57	0.884	0.835	0.531	0.671	1.05	0.654	0.633	0.907	0.965	0.488	0.552
Cd	mg/kg	0.150	0.112	0.407	0.474	0.264	0.205	0.317	0.334	0.653	0.346	0.100	0.137	0.169	0.197	0.133	0.137	0.176	0.178	0.367	0.293	0.216	0.193	0.294	0.223	0.212	0.234	0.426	0.218	0.182	0.244	0.136	0.185	0.248
Sn	mg/kg	3.89	1.88	3.87	1.76	2.62	2.68	3.49	2.58	2.50	2.23	1.77	1.73	1.27	2.55	1.75	2.40	2.61	4.91	2.40	3.05	2.11	2.68	1.89	1.35	2.11	3.27	2.57	1.70	1.58	2.73	2.13	2.48	2.12
Sb	mg/kg	0.860	1.13	1.94	0.890	1.68	2.38	1.35	1.15	0.970	0.991	0.947	0.754	0.654	1.69	1.94	1.46	2.25	1.71	1.38	0.868	0.882	0.924	0.447	0.239	0.448	1.05	0.879	0.885	0.849	0.936	0.720	0.597	0.606
Cs	mg/kg	2.37	6.23	7.53	5.49	8.12	4.67	6.26	6.48	4.29	3.38	4.54	5.05	2.84	10.0	9.14	7.23	5.50	7.41	6.92	4.23	3.12	4.70	3.29	2.57	4.46	5.89	7.22	4.81	4.41	9.18	5.54	7.80	5.19
Ba	mg/kg	333	352	380	465	410	433	408	496	359	484	451	363	279	581	468	450	422	410	405	537	389	291	301	444	260	318	249	398	410	277	346	450	363
La	mg/kg	13.3	12.1	13.6	16.2	14.0	18.5	12.8	15.9	33.5	18.6	26.2	16.3	25.0	22.1	28.1	22.5	14.2	14.2	16.6	25.6	13.0	21.4	41.6	19.4	15.9	25.3	24.9	16.8	21.7	20.9	24.2	29.8	25.8
Ce	mg/kg	28.4	21.1	25.7	30.6	28.4	36.9	24.7	30.6	55.0	42.7	50.9	36.7	57.2	45.7	54.8	44.5	28.2	29.1	38.7	64.9	28.9	45.4	82.7	44.3	38.7	49.6	49.7	31.7	43.7	41.7	47.0	57.1	51.1
Pr	mg/kg	3.29	2.73	3.06	3.58	3.46	4.25	3.04	3.76	7.77	4.44	5.56	3.82	6.44	5.18	5.95	5.17	3.45	3.49	3.82	5.97	3.05	5.73	9.33	4.91	4.61	5.76	5.87	3.73	4.95	5.03	5.44	6.71	5.80
Nd	mg/kg	12.7	10.1	11.7	13.3	13.5	16.1	11.4	14.0	30.4	17.2	20.1	14.0	24.6	19.8	21.1	19.5	13.5	13.9	14.4	23.7	11.4	22.6	33.6	20.1	19.5	21.8	22.4	14.1	18.3	19.1	19.7	24.3	21.1
Sm	mg/kg	2.99	1.99	2.53	2.68	2.96	3.51	2.35	2.88	6.29	3.79	3.69	2.46	4.58	4.28	3.88	3.86	3.02	3.13	2.91	5.25	2.52	5.18	5.83	4.24	4.49	3.93	4.37	2.72	3.27	3.77	3.61	4.38	3.79
Eu	mg/kg	0.614	0.477	0.548	0.595	0.708	0.852	0.588	0.715	1.72	1.08	0.777	0.480	0.696	1.01	0.542	0.695	0.765	0.788	0.674	1.40	0.594	1.27	0.804	1.34	1.28	0.880	0.875	0.638	0.647	0.821	0.718	0.880	0.710
Gd	mg/kg	2.81	1.81	2.25	2.38	2.91	3.28	2.06	2.72	7.05	3.60	3.13	1.83	2.75	3.84	2.85	2.91	2.71	2.83	2.30	4.69	2.13	5.06	4.16	4.15	4.28	3.33	3.76	2.38	2.48	3.38	2.67	3.28	2.91
Tb	mg/kg	0.400	0.273	0.342	0.353	0.452	0.518	0.315	0.424	1.08	0.574	0.433	0.248	0.307	0.563	0.348	0.385	0.420	0.436	0.323	0.689	0.320	0.766	0.489	0.579	0.660	0.503	0.550	0.340	0.328	0.508	0.355	0.409	0.362
Dy	mg/kg	2.52	1.70	2.13	2.18	2.85	3.33	1.89	2.62	6.39	3.61	2.40	1.34	1.41	3.44	1.70	2.10	2.58	2.71	2.01	4.20	1.99	4.55	2.64	3.62	4.10	3.05	3.17	2.02	1.81	3.08	2.02	2.22	2.00
Ho	mg/kg	0.519	0.352	0.449	0.446	0.585	0.669	0.378	0.501	1.278	0.709	0.470	0.269	0.241	0.675	0.318	0.386	0.502	0.542	0.387	0.819	0.388	0.856	0.505	0.749	0.871	0.635	0.621	0.405	0.344	0.615	0.389	0.405	0.376
Er	mg/kg	1.48	1.03	1.30	1.30	1.65	1.89	1.11	1.46	3.35	1.98	1.29	0.751	0.620	1.85	0.807	1.06	1.32	1.53	1.06	2.33	1.14	2.30	1.47	2.29	2.40	1.79	1.76	1.14	0.916	1.81	1.15	1.10	1.05
Tm	mg/kg	0.216	0.144	0.180	0.182	0.231	0.280	0.147	0.204	0.436	0.272	0.186	0.106	0.091	0.263	0.129	0.149	0.203	0.209	0.160	0.341	0.162	0.299	0.205	0.331	0.356	0.261	0.247	0.163	0.145	0.272	0.166	0.158	0.155
Yb	mg/kg	1.43	0.988	1.18	1.21	1.42	1.88	1.00	1.27	2.51	1.67	1.21	0.688	0.611	1.69	0.75	0.956	1.18	1.29	0.977	2.18	1.07	1.78	1.37	2.30	2.34	1.69	1.61	1.08	0.935	1.78	1.10	1.02	0.960
Lu	mg/kg	0.193	0.150	0.179	0.180	0.197	0.250	0.140	0.181	0.355	0.225	0.170	0.104	0.087	0.244	0.125	0.134	0.158	0.171	0.140	0.308	0.147	0.228	0.212	0.363	0.343	0.259	0.244	0.158	0.141	0.269	0.163	0.157	0.150
Hf	mg/kg	1.1	1.1	1.2	1.2	0.89	0.62	0.38	1.2	0.52	1.1	1.1	0.77	1.1	0.837	0.30	0.27	0.67	0.93	1.4	3.8	1.5	0.3	2.0	3.1	1.8	2.0	2.2	1.2	1.3	2.2	1.5	1.4	1.5
Ta	mg/kg	0.589	0.583	0.589	0.682	0.545	0.603	0.627	0.798	0.618	0.770	1.15	0.744	0.704	0.835	0.793	0.719	0.597	0.641	1.05	2.12	0.902	0.650	0.871	0.709	0.811	0.928	0.931	0.746	0.824	0.884	0.828	0.906	0.919
Hg	mg/kg	0.017	0.015	0.073	0.039	0.032	0.032	0.029	0.045	0.019	0.026	0.014	0.015	0.023	0.028	0.028	0.018	0.027	0.025	0.045	0.075	0.041	0.022	0.043	0.031	0.031	0.065	0.162	0.079	0.058	0.136	0.088	0.066	0.055
Tl	mg/kg	0.362	0.460	0.752	0.581	0.751	0.858	0.715	0.722	0.582	0.559	0.662	0.378	0.266	1.10	1.26	0.815	0.540	0.551	0.588	0.402	0.438	0.521	0.287	0.225	0.195	0.427	0.543	0.348	0.414	0.519	0.471	0.625	0.482
Pb	mg/kg	74.2	20.8	26.7	29.6	36.7	34.9	22.1	30.4	25.9	26.2	12.7	16.6	12.5	26.0	21.9	20.7	17.8	19.6	25.0	23.9	15.4	14.1	15.0	15.3	13.9	23.4	24.7	18.0	19.5	38.9	25.7	25.7	20.9
Bi	mg/kg	0.503	0.250	0.468	0.261	0.495	0.592	0.517	0.434	0.914	0.457	0.221	0.175	0.154	0.549	0.277	0.329	0.634	1.41	0.687	0.337	0.298	0.936	0.176	0.157	0.124	0.292	0.357	0.198	0.201	0.458	0.277	0.366	0.255
Th	mg/kg	3.35	5.17	5.40	5.29	4.51	6.41	4.51	5.63	4.60	4.41	6.94	6.78	7.60	8.44	7.56	6.26	4.56	4.66	5.66	7.81	4.71	4.63	11.6	4.72	5.99	9.99	8.43	5.79	8.11	8.05	7.69	9.06	8.78
U	mg/kg	0.671	1.55	1.25	1.05	0.912	2.29	0.894	1.13	0.972	1.06	1.16	0.882	1.08	1.48	2.16	1.41	0.771	0.856	1.07	1.77	1.10	0.793	1.73	1.00	0.844	1.93	2.32	1.22	1.41	2.55	2.15	1.69	1.61

[a] The mean values of repeated analyses (n=3).

Table 5 continued.

Element	Unit	Am09	Am10	Am11	Am12	Am13	Am14	Am15	Am16	Am17	Am18	Am19	Am20	Am21	Am22	Am23[a]	Am24	Am25	Am26	Am27	Am28	Am29	Am30	Am31	Am32	Am33	Am34	Am35	Am36	Am37	Am38	Am39	Am40	Am41
Na_2O	wt%	1.13	1.31	1.35	1.32	1.30	1.36	1.18	1.23	1.48	1.69	1.44	1.38	1.29	1.40	1.70	1.82	1.68	1.47	1.68	1.44	1.42	1.53	1.36	1.43	1.48	1.46	1.60	1.34	1.32	1.26	1.41	1.58	1.54
MgO	wt%	0.972	1.51	0.978	1.06	1.07	1.29	1.03	0.660	1.05	1.12	1.02	1.05	1.02	1.05	1.40	1.71	1.70	1.14	1.43	1.06	0.936	1.17	0.831	1.83	1.00	0.988	2.45	1.00	0.981	0.883	0.947	1.09	0.882
Al_2O_3	wt%	12.24	12.69	11.31	13.85	12.34	13.46	12.29	12.51	14.15	11.64	12.53	12.27	13.81	12.27	10.74	13.90	14.25	11.69	11.39	11.76	11.62	13.71	10.39	13.23	11.36	11.51	12.68	11.12	11.80	10.53	12.52	15.08	13.17
P_2O_5	wt%	0.136	0.119	0.147	0.116	0.098	0.111	0.090	0.064	0.084	0.201	0.133	0.129	0.107	0.101	0.085	0.160	0.262	0.116	0.118	0.156	0.082	0.154	0.100	0.163	0.115	0.095	0.117	0.095	0.103	0.078	0.094	0.065	0.089
K_2O	wt%	1.82	2.06	1.65	2.09	1.94	2.17	1.84	2.00	2.04	1.66	2.00	2.06	2.47	2.03	1.53	1.69	1.28	1.92	1.75	2.09	1.93	2.36	1.92	2.21	2.12	1.92	1.84	1.90	1.99	1.90	1.95	2.32	2.18
CaO	wt%	0.612	1.01	0.419	0.311	0.416	0.502	0.401	0.573	0.647	1.06	0.871	0.643	0.421	0.559	0.891	1.20	1.72	0.640	0.835	0.905	0.424	0.525	0.395	0.743	0.261	0.427	1.71	0.558	0.558	0.305	0.538	0.790	0.537
TiO_2	wt%	0.612	0.689	0.591	0.715	0.712	0.679	0.628	0.544	0.693	0.651	0.629	0.677	0.695	0.594	0.642	0.766	0.773	0.764	0.723	0.619	0.637	0.655	0.515	0.731	0.608	0.600	1.34	0.582	0.567	0.779	0.657	0.707	0.652
MnO	wt%	0.066	0.080	0.092	0.063	0.050	0.051	0.043	0.092	0.048	0.063	0.085	0.065	0.057	0.050	0.065	0.086	0.216	0.057	0.062	0.056	0.046	0.058	0.084	0.102	0.041	0.055	0.079	0.052	0.059	0.045	0.055	0.080	0.067
T-Fe_2O_3	wt%	4.28	4.61	4.03	4.82	4.40	4.96	4.19	3.59	4.72	3.83	4.15	4.10	4.77	4.04	4.12	5.30	6.82	4.30	4.25	4.03	3.67	4.67	3.03	5.26	3.69	4.12	6.32	3.77	3.80	3.75	4.10	4.67	4.10
H_2O^-	wt%	2.13	1.99	1.57	1.99	1.78	1.70	2.05	2.12	2.18	2.38	2.01	2.07	1.89	2.02	1.48	2.91	3.80	1.76	1.63	1.73	1.84	1.84	1.65	1.99	1.55	1.73	1.63	1.44	1.60	2.12	1.96	2.58	1.93
Li	mg/kg	43.3	45.2	43.2	48.1	41.6	47.6	44.7	69.2	46.0	32.0	39.3	36.3	40.5	39.8	35.9	43.0	32.9	39.1	38.7	36.7	38.4	45.4	31.2	42.1	42.5	39.7	39.3	37.9	41.7	36.1	32.0	29.9	34.4
Be	mg/kg	1.84	2.03	1.77	2.16	1.91	2.13	1.67	1.78	1.82	1.46	1.89	1.81	2.21	1.71	1.41	1.66	1.52	1.60	1.48	1.76	1.53	2.11	1.40	2.08	1.71	1.61	1.78	1.79	2.16	1.48	1.56	1.68	1.78
Sc	mg/kg	8.54	10.1	8.03	9.14	8.40	9.20	8.54	9.00	10.6	8.86	8.97	8.86	8.98	8.74	9.32	12.9	14.9	9.36	10.0	8.40	7.87	8.94	6.26	10.8	7.05	7.29	14.2	6.83	7.02	6.90	7.78	10.0	8.03
V	mg/kg	73.5	78.4	65.0	78.5	73.9	77.7	77.7	50.3	78.9	64.1	67.6	73.4	72.3	69.7	67.4	95.0	98.8	78.5	80.6	70.1	64.4	78.0	56.5	93.4	62.6	66.1	126	57.6	62.6	58.3	62.2	78.9	67.5
Cr	mg/kg	65.9	75.5	54.3	60.8	61.3	72.4	54.3	29.4	55.1	59.6	57.4	57.5	63.5	63.5	55.1	64.8	76.1	59.0	66.2	61.4	47.0	66.7	38.5	150	60.6	51.2	156	49.8	58.0	35.8	40.6	32.4	45.9
Co	mg/kg	9.32	12.4	9.66	11.4	11.5	12.0	9.57	9.22	10.2	9.47	11.4	9.27	11.8	9.33	11.0	12.8	18.6	8.83	9.16	9.26	7.60	10.4	7.55	16.5	8.27	8.36	17.2	9.50	14.9	8.37	8.50	9.92	9.27
Ni	mg/kg	24.0	31.4	22.3	26.6	23.2	28.1	23.8	12.3	21.3	21.1	24.3	22.5	26.3	23.4	24.9	26.7	28.1	22.2	24.2	22.4	19.7	26.9	17.7	41.7	21.8	22.4	44.6	24.7	33.0	14.5	17.4	11.8	16.8
Cu	mg/kg	18.9	24.6	20.0	21.5	16.4	22.2	20.1	11.6	21.2	27.7	22.4	21.4	23.0	19.5	12.7	27.4	278	27.5	21.2	33.4	17.1	21.0	14.2	22.4	15.6	16.8	15.3	13.3	18.0	11.4	13.9	14.8	16.2
Zn	mg/kg	100	106	121	102	87.7	100	116	71.3	85.9	136	139	116	102	109	80.2	123	436	111	120	201	88.5	118	199	126	99.7	104	93.3	95.7	129	70.8	91.3	85.7	83.4
Ga	mg/kg	15.0	16.2	13.6	17.1	15.8	17.0	15.2	14.9	16.5	13.3	15.5	15.1	17.8	14.8	12.8	17.0	16.1	15.0	14.1	14.7	14.2	17.1	12.3	17.6	14.6	14.4	15.9	13.9	15.1	13.3	14.6	16.6	15.5
As	mg/kg	9.99	19.3	6.17	7.13	6.17	7.75	6.07	19.0	8.99	6.91	6.44	5.83	6.83	4.69	4.38	5.98	34.1	3.52	4.46	5.20	4.31	7.05	3.12	6.66	5.36	4.73	6.44	4.65	5.23	6.17	6.34	9.06	8.72
Rb	mg/kg	87.1	92.5	75.7	101	90.2	104	83.4	87.8	92.5	68.3	87.1	86.1	108	85.7	64.8	78.7	56.5	81.0	69.9	85.9	78.1	105	71.0	103	88.7	76.3	84.5	79.7	86.8	81.2	80.9	93.5	93.9
Sr	mg/kg	88.7	99.7	82.1	88.6	82.9	91.1	75.2	100	121	144	118	94.0	97.0	89.9	118	137	177	94.2	110	118	79.8	109	80.0	105	88.2	82.6	125	100	106	82.4	114	152	117
Y	mg/kg	12.2	13.5	12.4	12.6	11.6	11.0	12.7	15.0	15.0	14.2	14.4	13.3	12.9	14.9	12.7	19.1	20.1	14.2	14.3	12.2	13.1	12.8	11.3	13.7	10.7	12.3	13.0	11.1	13.1	11.3	12.6	17.0	15.3
Zr	mg/kg	55	54	63	59	64	53	81	77	75	65	68	75	72	84	68.2	114	110	78	79	77	82	68	70	81	68	81	81	64	58	76	74	107	85
Nb	mg/kg	11.3	11.1	10.2	13.3	13.0	12.5	10.7	9.03	11.4	10.1	11.2	10.9	13.4	9.64	9.34	11.6	9.56	11.2	10.2	11.0	10.0	12.9	9.6	14.3	11.4	10.4	15.4	10.4	10.8	10.9	10.1	9.59	14.1
Mo	mg/kg	0.622	0.686	0.717	0.657	0.625	0.668	1.039	0.569	0.603	0.708	0.807	0.747	0.710	0.648	0.49	0.891	51.4	0.540	1.06	1.16	0.616	0.663	0.556	1.00	0.645	0.542	0.516	0.503	0.479	0.693	0.392	0.623	0.455
Cd	mg/kg	0.249	0.317	0.215	0.181	0.149	0.174	0.179	0.140	0.119	0.374	0.199	0.242	0.167	0.228	0.09	0.167	1.01	0.177	0.088	0.283	0.159	0.158	0.323	0.171	0.076	0.168	0.122	0.151	0.210	0.074	0.149	0.147	0.120
Sn	mg/kg	2.04	2.37	2.10	2.36	2.10	2.24	2.25	2.43	13.0	2.62	2.54	2.35	2.33	2.25	1.99	2.48	22.7	3.05	2.41	2.29	2.02	2.25	1.83	2.31	1.97	1.94	1.98	1.81	1.85	1.62	1.87	1.78	2.17
Sb	mg/kg	1.22	1.55	0.925	0.674	0.585	0.674	0.628	4.18	1.13	1.29	0.803	0.770	0.724	0.655	0.57	0.643	7.19	0.576	0.656	0.866	0.546	0.616	0.502	0.577	0.478	0.534	0.605	0.581	0.645	0.636	0.810	0.707	0.960
Cs	mg/kg	5.95	6.98	4.83	6.45	5.66	6.89	5.10	9.00	7.36	5.07	5.95	5.72	6.50	5.80	3.89	5.79	4.15	4.77	3.97	4.67	4.45	5.87	3.45	6.09	4.51	4.11	5.06	4.25	5.23	4.94	5.62	6.96	6.29
Ba	mg/kg	373	425	315	402	394	429	404	389	441	407	464	429	492	482	280	278	313	517	349	487	477	475	504	498	394	466	360	431	431	340	464	587	488
La	mg/kg	27.8	25.0	21.9	30.4	27.5	25.9	21.6	22.7	26.8	22.8	27.8	22.7	33.7	19.6	25.6	24.6	21.6	26.7	20.3	27.3	20.7	30.5	21.3	30.2	24.4	23.1	27.5	31.2	33.2	26.7	29.1	20.8	27.8
Ce	mg/kg	54.5	49.3	43.7	60.0	56.6	52.8	45.5	42.6	51.1	41.8	54.6	44.4	67.3	38.4	45.9	48.9	43.8	53.2	41.6	53.6	42.7	61.7	43.0	62.2	49.5	46.5	53.2	62.4	64.8	49.7	53.8	32.5	51.0
Pr	mg/kg	6.19	5.83	4.90	6.78	6.17	5.86	4.86	4.99	5.94	5.10	6.45	5.20	7.33	4.65	5.24	6.05	5.35	6.20	4.74	6.36	4.84	6.92	4.82	7.08	5.56	5.34	6.15	7.09	7.48	5.49	6.10	4.55	6.01
Nd	mg/kg	22.4	21.5	17.7	24.2	22.4	21.4	17.6	18.1	21.7	18.9	23.8	19.1	26.6	17.1	18.3	22.6	20.7	22.3	17.4	23.3	17.5	25.1	17.4	25.7	20.3	19.3	22.7	25.3	27.0	19.2	21.7	16.4	22.2
Sm	mg/kg	3.94	4.06	3.24	4.31	4.04	4.02	3.13	3.46	3.99	3.50	4.42	3.53	4.78	3.25	3.19	4.65	4.25	3.97	3.19	4.18	3.12	4.53	3.00	4.91	3.71	3.46	4.21	4.33	4.99	2.98	3.60	3.08	3.97
Eu	mg/kg	0.759	0.835	0.660	0.882	0.765	0.808	0.633	0.764	0.876	0.791	0.843	0.704	0.856	0.686	0.670	0.985	0.981	0.702	0.661	0.795	0.619	0.895	0.607	0.955	0.720	0.665	0.902	0.760	0.846	0.543	0.691	0.778	0.785
Gd	mg/kg	2.99	3.22	2.53	3.24	2.97	2.99	2.49	2.93	3.07	2.92	3.36	2.79	3.42	2.63	2.47	3.87	3.81	3.04	2.63	3.17	2.50	3.49	2.37	3.76	2.66	2.75	3.42	3.20	3.92	2.48	2.82	2.84	3.09
Tb	mg/kg	0.381	0.410	0.349	0.419	0.383	0.382	0.349	0.429	0.428	0.414	0.447	0.400	0.447	0.397	0.345	0.564	0.570	0.418	0.390	0.414	0.356	0.432	0.332	0.480	0.354	0.384	0.442	0.404	0.502	0.348	0.383	0.417	0.428
Dy	mg/kg	2.13	2.34	2.01	2.25	2.14	2.10	2.09	2.51	2.56	2.40	2.50	2.25	2.35	2.42	2.06	3.23	3.29	2.31	2.37	2.21	2.11	2.38	1.80	2.55	1.95	2.12	2.42	2.06	2.49	2.06	2.15	2.70	2.52
Ho	mg/kg	0.403	0.454	0.393	0.420	0.414	0.392	0.427	0.498	0.506	0.466	0.487	0.439	0.456	0.500	0.417	0.656	0.677	0.482	0.485	0.427	0.454	0.457	0.379	0.501	0.373	0.442	0.476	0.396	0.456	0.398	0.433	0.570	0.497
Er	mg/kg	1.17	1.27	1.09	1.14	1.17	1.06	1.25	1.43	1.49	1.34	1.34	1.32	1.31	1.49	1.26	1.89	1.94	1.39	1.43	1.19	1.32	1.31	1.07	1.39	1.05	1.20	1.27	1.10	1.19	1.16	1.23	1.69	1.44
Tm	mg/kg	0.167	0.175	0.164	0.168	0.173	0.155	0.187	0.235	0.218	0.203	0.202	0.203	0.192	0.217	0.188	0.280	0.282	0.207	0.211	0.170	0.197	0.184	0.163	0.196	0.141	0.180	0.191	0.164	0.168	0.183	0.183	0.253	0.215
Yb	mg/kg	1.11	1.18	1.08	1.09	1.13	1.00	1.28	1.47	1.49	1.31	1.33	1.27	1.22	1.44	1.27	1.85	1.92	1.36	1.37	1.15	1.28	1.22	1.09	1.33	1.05	1.21	1.28	1.08	1.10	1.17	1.23	1.71	1.48
Lu	mg/kg	0.163	0.170	0.165	0.169	0.163	0.145	0.194	0.220	0.224	0.205	0.202	0.191	0.183	0.220	0.192	0.287	0.291	0.208	0.213	0.167	0.194	0.185	0.156	0.208	0.162	0.183	0.200	0.167	0.160	0.181	0.194	0.262	0.217
Hf	mg/kg	1.5	1.5	1.6	1.6	1.7	1.4	2.1	2.1	2.0	1.7	1.7	1.9	1.8	2.1	1.77	2.9	2.9	2.0	2.1	1.9	2.2	1.8	1.8	2.1	1.7	2.0	2.1	1.6	1.5	2.0	2.0	2.8	2.2
Ta	mg/kg	0.969	0.973	0.882	1.12	1.07	1.03	0.901	0.876	0.964	0.879	0.924	0.918	1.14	0.797	0.737	0.988	1.07	0.887	0.820	0.923	0.824	1.11	0.792	1.11	0.929	0.917	1.05	0.891	0.914	0.889	0.854	0.813	1.14
Hg	mg/kg	0.059	0.054	0.130	0.058	0.047	0.054	0.059	0.252	0.070	0.126	0.068	0.074	0.060	0.076	0.031	0.070	0.125	0.062	0.056	0.052	0.043	0.065	0.039	0.061	0.044	0.048	0.048	0.047	0.077	0.065	0.074	0.073	0.078
Tl	mg/kg	0.488	0.525	0.406	0.559	0.517	0.595	0.442	0.514	0.504	0.391	0.487	0.482	0.595	0.465	0.356	0.467	0.416	0.418	0.351	0.485	0.416	0.573	0.408	0.591	0.476	0.429	0.468	0.442	0.481	0.440	0.459	0.526	0.522
Pb	mg/kg	23.5	23.6	20.4	25.3	23.0	26.2	21.3	21.6	23.7	28.6	24.9	21.7	25.3	19.1	15.6	24.4	222	19.8	19.9	25.7	18.7	24.3	19.6	22.2	18.2	19.5	18.6	19.8	21.5	17.2	20.5	21.1	20.4
Bi	mg/kg	0.271	0.284	0.298	0.635	0.274	0.304	0.254	0.345	0.281	0.284	0.277	0.249	0.306	0.295	0.169	0.289	0.675	0.230	0.226	0.255	0.235	0.285	0.249	0.273	0.190	0.204	0.203	0.258	0.241	0.172	0.179	0.181	0.263
Th	mg/kg	9.19	8.05	7.56	9.83	10.2	8.77	7.87	6.92	8.69	7.38	9.49	8.37	10.9	7.06	6.50	8.95	8.28	9.50	6.92	8.97	7.43	9.99	7.08	10.1	8.27	8.06	8.19	10.3	9.93	8.91	9.05	7.70	8.92
U	mg/kg	1.58	1.53	1.73	1.66	1.58	1.47	2.47	1.96	1.62	1.63	1.61	1.65	1.73	1.60	1.41	2.01	1.97	1.82	2.39	1.49	1.54	1.62	1.26	1.65	1.92	1.61	1.30	1.40	1.54	2.19	1.70	1.83	1.76

[a] The mean values of repeated analyses (n=3).

Table 5 continued.

Element	Unit	Am42	Am43	Gs01	Gs02	Ss01	Ng01	Ng02	Ng03	Ng04	Ng05	Ng06	Tn01	Tn02[a]	Tn03	Tn04	Tn05	Tn06	Tn07	Tn08	Tn09	Tn10	Tn11	Tn12	Tn13	Tn14	Tn15	Tn16	Tn17	Tn18	Tn19	Tn20	Tn21	Tn22
Na_2O	wt%	2.92	1.58	1.55	1.29	1.19	1.37	0.581	0.970	1.05	0.814	1.11	0.955	1.10	1.17	0.886	1.13	1.01	1.02	1.16	1.22	1.12	0.98	1.16	1.30	1.28	1.04	1.57	1.20	1.20	1.31	1.59	1.14	1.38
MgO	wt%	1.59	1.02	1.88	1.84	1.22	2.90	1.73	1.94	2.13	2.04	2.73	0.780	0.959	1.21	1.03	0.823	0.984	0.952	1.00	1.08	0.899	0.817	0.812	1.79	1.00	0.847	1.20	1.76	1.70	2.36	1.63	1.09	0.510
Al_2O_3	wt%	13.39	12.24	12.11	11.14	8.80	21.14	23.05	22.78	22.28	21.74	19.68	9.25	10.46	13.83	6.98	10.11	9.27	10.23	10.78	10.51	10.43	8.80	9.32	10.20	9.87	11.22	10.28	9.70	11.19	9.35	9.41	10.02	6.93
P_2O_5	wt%	0.198	0.145	0.139	0.133	0.093	0.239	0.311	0.196	0.172	0.262	0.202	0.084	0.077	0.219	0.048	0.181	0.073	0.080	0.066	0.073	0.059	0.058	0.056	0.078	0.077	0.123	0.062	0.073	0.114	0.069	0.037	0.075	0.051
K_2O	wt%	1.60	1.93	2.06	1.59	1.45	0.589	0.542	0.757	0.621	0.708	0.731	1.69	1.88	1.71	1.36	1.69	1.70	1.75	2.30	2.13	2.07	1.96	2.31	1.84	1.85	1.63	1.49	1.54	1.44	1.39	1.32	1.80	1.68
CaO	wt%	1.62	0.914	1.08	0.674	0.844	3.91	1.57	2.29	2.58	1.98	2.86	0.650	0.558	1.17	0.610	0.703	0.573	0.594	0.382	0.457	0.418	0.446	0.283	1.04	0.689	0.757	1.34	1.09	1.15	1.50	1.42	0.689	0.180
TiO_2	wt%	0.746	0.586	0.657	0.670	0.656	1.17	1.50	1.41	1.45	1.47	1.69	0.544	0.645	0.892	0.575	0.645	0.862	0.821	0.581	0.748	0.720	0.591	0.577	1.12	0.872	0.669	0.875	1.03	0.933	1.18	1.49	1.01	0.360
MnO	wt%	0.138	0.132	0.070	0.070	0.048	0.246	0.246	0.241	0.238	0.209	0.173	0.056	0.078	0.113	0.055	0.083	0.068	0.071	0.068	0.060	0.068	0.053	0.043	0.108	0.077	0.075	0.079	0.118	0.114	0.129	0.109	0.082	0.014
$T\text{-}Fe_2O_3$	wt%	4.56	4.25	4.70	4.08	3.24	9.25	10.8	10.0	10.8	10.1	10.4	3.05	3.87	5.47	2.93	3.64	4.47	4.38	3.46	4.20	3.94	3.30	3.05	5.04	4.25	4.04	4.11	4.89	5.09	5.72	5.31	4.62	2.08
H_2O^-	wt%	1.16	1.77	8.83	9.57	1.54	4.82	4.57	4.03	5.15	4.48	3.57	1.80	2.57	4.96	0.796	2.23	2.05	1.86	1.73	2.01	2.14	1.84	1.09	1.38	1.51	2.94	1.58	1.91	2.46	1.46	0.890	1.53	0.602
Li	mg/kg	26.8	59.1	38.9	36.1	30.9	22.7	26.1	26.5	26.6	23.5	26.7	26.1	30.6	31.3	24.1	26.4	25.1	29.3	29.7	30.5	33.1	27.3	27.9	33.3	27.2	31.1	29.4	30.1	31.9	30.1	25.6	31.1	27.9
Be	mg/kg	1.34	1.63	1.34	1.25	0.94	1.16	1.61	1.66	1.54	1.43	1.47	1.10	1.39	1.48	0.82	1.10	1.15	1.31	1.53	1.43	1.41	1.17	1.37	1.34	1.15	1.18	1.08	1.09	1.13	1.06	1.03	1.26	0.945
Sc	mg/kg	10.6	8.62	11.3	9.37	8.38	31.2	28.6	24.6	26.9	26.5	28.6	7.08	8.26	13.7	7.09	7.71	8.58	7.85	6.74	7.37	6.89	5.45	4.84	13.8	8.36	9.28	10.6	13.0	14.7	17.1	12.6	10.2	1.80
V	mg/kg	84.2	62.7	86.7	77.0	58.8	168	215	201	236	208	226	50.4	62.1	94.9	42.5	60.4	88.4	86.1	63.9	80.3	74.0	64.4	64.2	85.0	77.7	62.3	62.7	77.2	77.2	88.4	86.9	83.3	31.4
Cr	mg/kg	79.5	52.5	103	125	85.4	73.0	54.1	38.2	48.9	54.3	111	29.6	35.8	40.7	21.9	27.2	31.5	35.4	43.4	54.1	37.8	32.0	38.1	39.1	30.8	28.8	23.2	27.6	31.0	30.5	21.6	34.7	21.2
Co	mg/kg	11.7	9.49	17.5	14.3	9.97	27.3	25.5	23.4	26.6	24.2	27.1	7.16	8.87	11.7	6.74	7.35	8.57	8.99	8.85	8.62	8.15	6.90	7.12	11.2	8.58	8.29	8.22	10.7	11.6	12.9	9.46	9.32	4.40
Ni	mg/kg	29.8	19.3	53.1	72.0	48.3	18.6	16.6	12.5	12.7	15.4	25.9	12.1	15.4	16.9	9.42	11.3	12.1	14.1	18.0	19.5	15.6	13.0	15.1	15.7	11.8	12.4	8.82	12.0	13.5	11.7	7.39	13.7	8.47
Cu	mg/kg	32.8	17.5	31.0	47.3	27.3	25.7	23.9	19.9	16.1	30.2	28.9	10.3	13.4	22.0	7.07	11.8	10.4	12.2	14.1	12.4	13.6	13.4	11.2	13.1	9.99	12.2	6.14	10.9	12.0	7.73	3.87	11.9	5.54
Zn	mg/kg	129	93.4	377	144	125	166	170	155	140	212	225	48.0	59.2	108	39.7	62.7	56.2	57.5	56.5	61.5	60.5	47.2	45.7	87.6	59.9	67.3	61.3	70.7	79.3	75.3	64.6	81.0	33.7
Ga	mg/kg	13.4	14.1	12.6	11.6	9.4	23.2	26.2	24.6	25.3	24.2	23.3	10.6	12.5	15.7	7.58	10.5	10.5	11.4	12.7	12.5	11.9	10.3	10.7	12.2	10.8	12.1	11.0	10.4	11.7	10.7	9.43	12.1	6.55
As	mg/kg	5.74	18.8	6.53	6.68	4.23	3.07	4.46	4.83	3.71	4.06	4.02	4.57	5.30	7.79	3.28	4.49	4.33	6.03	5.51	5.03	5.77	4.58	5.03	7.46	4.62	6.26	4.57	5.55	8.06	8.98	3.34	5.38	4.89
Rb	mg/kg	65.6	83.8	73.1	64.1	52.2	25.1	29.5	34.9	27.4	32.5	32.5	64.5	75.5	72.9	48.7	63.9	64.5	69.8	90.7	83.4	82.7	73.2	87.6	76.3	71.9	64.8	57.4	59.1	58.1	53.0	51.0	72.7	56.7
Sr	mg/kg	146	119	120	94.3	92.9	229	112	160	178	136	168	82.9	82.7	110	71.1	91.1	82.2	84.4	80.9	84.7	79.1	77.5	80.7	96.8	93.6	93.4	129	94.3	97.0	104	122	82.2	80.5
Y	mg/kg	14.0	15.4	14.4	12.7	9.7	27.2	29.7	25.2	25.8	26.7	27.4	11.5	13.1	20.6	8.42	12.5	11.8	11.7	11.2	12.1	10.6	9.77	10.3	13.3	10.2	14.5	11.5	12.2	14.6	14.6	10.4	12.2	7.01
Zr	mg/kg	34	84	35	60	53	134	191	164	165	155	158	67	73	106	43	69	67	76	59	72	67	62	62	66	56	76	50	57	71	61	45	60	44
Nb	mg/kg	9.16	9.75	7.52	8.67	8.18	10.2	13.5	11.7	11.4	13.0	16.1	8.53	10.3	10.9	7.92	8.85	9.02	11.5	10.8	10.5	10.9	9.24	10.4	13.4	10.7	9.18	10.3	10.8	10.3	12.6	13.5	11.5	6.77
Mo	mg/kg	0.370	0.667	0.722	0.795	0.394	0.874	1.18	1.31	1.05	1.21	1.24	0.363	0.426	0.747	0.191	0.259	0.341	0.403	0.220	0.298	0.295	0.255	0.262	0.352	0.246	0.398	0.185	0.246	0.489	0.264	0.159	0.396	0.329
Cd	mg/kg	0.164	0.124	0.313	0.165	0.188	0.325	0.302	0.241	0.257	0.291	0.374	0.064	0.097	0.162	0.034	0.061	0.044	0.050	0.067	0.067	0.062	0.057	0.070	0.062	0.044	0.076	0.044	0.040	0.074	0.060	0.028	0.047	0.009
Sn	mg/kg	27.2	2.26	3.10	5.07	1.46	2.02	2.69	2.31	2.09	2.96	3.07	1.27	1.61	2.81	0.87	1.39	1.34	1.55	1.72	2.37	1.48	1.33	1.48	1.74	1.47	1.55	1.25	1.31	1.55	1.36	1.29	1.75	0.92
Sb	mg/kg	1.41	6.32	1.43	1.20	1.17	0.503	0.498	0.624	0.417	0.667	0.592	0.435	0.516	0.742	0.356	0.436	0.423	0.714	0.578	0.507	0.572	0.563	0.538	0.581	0.435	0.522	0.388	0.433	0.615	0.453	0.284	0.505	0.370
Cs	mg/kg	4.91	7.85	5.29	3.94	3.11	2.85	3.76	3.39	2.70	3.09	3.81	3.04	3.79	4.55	2.16	3.03	2.98	3.74	4.68	3.99	4.33	3.26	3.94	4.58	3.50	3.49	2.66	4.59	3.42	2.57	2.40	3.84	2.15
Ba	mg/kg	381	341	369	254	290	278	379	392	386	324	379	351	388	463	350	409	431	402	493	489	479	471	530	437	445	446	359	330	364	324	312	460	350
La	mg/kg	16.8	22.3	15.3	15.4	10.0	22.6	23.9	20.2	19.6	22.1	22.2	20.2	21.8	24.2	17.2	19.8	20.0	20.8	24.2	23.0	21.8	20.9	22.4	19.6	17.2	18.2	16.1	18.2	16.1	20.8	13.4	29.1	16.1
Ce	mg/kg	33.0	42.6	25.6	24.3	17.4	46.7	55.3	45.6	44.9	48.6	49.2	39.5	44.5	49.7	34.2	39.5	39.4	41.2	49.8	46.0	43.2	39.4	44.5	39.8	35.5	37.1	32.0	37.9	33.5	41.5	26.5	61.7	32.4
Pr	mg/kg	3.89	5.09	3.83	3.18	2.23	5.41	5.84	5.04	4.91	5.41	5.44	4.52	5.11	5.88	3.94	4.55	4.49	4.65	5.62	5.25	4.74	4.37	5.00	4.56	4.01	4.32	3.78	4.38	3.93	5.03	3.19	7.25	3.59
Nd	mg/kg	14.4	18.8	14.6	11.7	8.4	21.3	22.8	19.4	19.2	20.8	20.9	16.4	18.6	22.3	14.0	16.3	16.1	16.8	20.3	18.7	16.6	14.9	17.7	16.7	14.7	16.1	14.1	16.0	15.0	18.7	11.9	27.1	12.8
Sm	mg/kg	2.88	3.47	3.16	2.32	1.68	4.67	4.93	4.43	4.22	4.59	4.61	3.05	3.40	4.43	2.51	2.95	2.98	2.95	3.69	3.27	2.78	2.56	3.09	3.12	2.80	3.15	2.64	3.16	3.20	3.62	2.28	5.12	2.27
Eu	mg/kg	0.671	0.735	0.760	0.561	0.416	1.35	1.40	1.24	1.26	1.31	1.27	0.624	0.690	0.986	0.441	0.642	0.604	0.622	0.712	0.667	0.563	0.529	0.576	0.664	0.573	0.710	0.658	0.694	0.733	0.674	0.601	0.873	0.419
Gd	mg/kg	2.44	2.92	2.77	2.13	1.55	4.57	4.87	4.10	4.18	4.32	4.45	2.33	2.66	3.91	1.91	2.49	2.42	2.38	2.68	2.54	2.11	1.95	2.34	2.61	2.17	2.67	2.26	2.49	2.72	3.01	2.02	3.63	1.68
Tb	mg/kg	0.355	0.403	0.405	0.297	0.250	0.694	0.753	0.638	0.663	0.664	0.711	0.314	0.370	0.552	0.246	0.349	0.337	0.335	0.369	0.347	0.301	0.270	0.311	0.381	0.318	0.392	0.331	0.348	0.384	0.415	0.285	0.431	0.214
Dy	mg/kg	2.19	2.53	2.44	1.95	1.51	4.28	4.71	4.14	4.11	4.28	4.38	1.99	2.20	3.41	1.42	2.12	1.95	2.00	1.97	2.01	1.85	1.65	1.84	2.25	1.80	2.45	1.99	2.16	2.47	2.56	1.76	2.34	1.19
Ho	mg/kg	0.445	0.503	0.481	0.400	0.341	0.890	1.01	0.853	0.867	0.888	0.907	0.384	0.439	0.674	0.281	0.416	0.398	0.388	0.404	0.396	0.373	0.341	0.357	0.462	0.346	0.489	0.398	0.422	0.497	0.525	0.355	0.440	0.246
Er	mg/kg	1.31	1.52	1.37	1.15	0.958	2.63	2.96	2.53	2.57	2.61	2.68	1.15	1.30	2.05	0.852	1.29	1.12	1.20	1.12	1.18	1.14	1.05	1.11	1.39	1.04	1.52	1.12	1.30	1.52	1.50	1.10	1.28	0.738
Tm	mg/kg	0.196	0.223	0.184	0.173	0.149	0.385	0.438	0.366	0.383	0.382	0.403	0.164	0.193	0.289	0.120	0.179	0.174	0.171	0.160	0.182	0.166	0.154	0.161	0.205	0.149	0.219	0.178	0.188	0.230	0.220	0.164	0.180	0.099
Yb	mg/kg	1.29	1.43	1.23	1.15	0.971	2.52	2.92	2.55	2.55	2.62	2.67	1.12	1.30	1.96	0.812	1.25	1.12	1.18	1.04	1.17	1.14	1.02	1.01	1.30	1.05	1.48	1.16	1.25	1.47	1.53	1.12	1.24	0.706
Lu	mg/kg	0.190	0.222	0.175	0.166	0.151	0.392	0.448	0.384	0.403	0.407	0.416	0.175	0.198	0.313	0.128	0.184	0.174	0.183	0.159	0.182	0.180	0.159	0.158	0.213	0.153	0.227	0.173	0.195	0.230	0.226	0.170	0.193	0.108
Hf	mg/kg	0.98	2.3	1.0	1.6	1.3	3.4	4.7	4.0	4.0	3.9	4.1	1.8	1.9	2.8	1.2	1.9	1.7	1.9	1.5	1.8	1.7	1.6	1.6	1.7	1.5	2.0	1.4	1.6	1.9	1.6	1.3	1.6	1.2
Ta	mg/kg	0.746	0.877	0.633	0.728	0.627	0.764	1.05	0.920	0.867	0.978	1.20	0.745	0.87	0.952	0.638	0.785	0.768	1.02	0.954	0.927	0.922	0.769	0.928	1.04	0.832	0.786	0.745	0.680	0.798	0.598	0.479	0.933	0.588
Hg	mg/kg	0.061	0.173	0.124	0.093	0.075	0.071	0.083	0.050	0.060	0.077	0.062	0.054	0.065	0.087	0.028	0.055	0.046	0.058	0.037	0.052	0.035	0.045	0.043	0.041	0.044	0.058	0.024	0.030	0.056	0.031	0.015	0.040	0.031
Tl	mg/kg	0.366	0.463	0.419	0.343	0.270	0.273	0.378	0.332	0.338	0.302	0.353	0.375	0.431	0.488	0.279	0.380	0.362	0.384	0.478	0.455	0.449	0.413	0.477	0.405	0.411	0.399	0.335	0.333	0.358	0.314	0.282	0.404	0.299
Pb	mg/kg	19.1	18.3	279	21.3	17.1	16.9	22.7	20.7	16.9	44.7	22.5	15.0	16.4	23.0	10.4	14.4	14.3	15.0	15.9	16.9	15.2	15.6	15.2	14.7	14.4	15.8	11.5	12.1	13.7	11.1	9.68	15.0	10.3
Bi	mg/kg	0.179	0.229	0.249	0.263	0.163	0.220	0.271	0.213	0.235	0.268	0.269	0.165	0.182	0.383	0.123	0.171	0.151	0.201	0.260	0.201	0.189	0.164	0.148	0.251	0.175	0.193	0.106	0.144	0.256	0.151	0.080	0.163	0.122
Th	mg/kg	6.37	8.08	4.80	5.70	4.27	5.35	7.42	6.26	5.88	6.01	6.99	5.92	7.08	8.47	6.16	6.41	6.45	6.45	12.4	7.17	6.93	5.94	7.00	6.63	6.60	6.35	5.23	5.07	5.69	6.84	4.69	9.62	4.86
U	mg/kg	1.31	1.96	1.53	2.36	1.28	1.23	1.68	1.35	1.27	1.45	1.55	1.32	1.43	1.83	1.04	1.23	1.24	1.31	1.44	1.34	1.39	1.21	1.32	1.26	1.23	1.31	1.02	1.10	1.23	1.14	0.840	1.32	1.07

[a] The mean values of repeated analyses (n=3).

Table 5 continued.

Element	Unit	Tn23	Tn24	Tn25	Tn26	Tn27	Sk01	Sk02	Sk03	Yk01[a]	Yk02	Yk03	Yk04	Yk05	Yk06	Yk07	Yk08	Yk09	Yk10	Yk11	Yk12	Yk13	Yk14	Yk15	Yk16	Yk17	Yk18	Yk19	Yk20	Yk21	Yk22	Yk23
Na_2O	wt%	1.23	1.53	1.23	1.03	1.02	3.04	2.78	2.95	3.43	3.90	4.06	0.934	0.757	1.06	1.78	2.80	3.56	3.36	2.23	3.00	2.68	4.34	3.93	3.43	3.27	3.67	4.09	3.63	3.54	3.05	3.20
MgO	wt%	1.28	0.577	0.612	0.527	0.880	3.28	4.76	3.57	1.00	1.09	0.864	1.42	1.53	1.39	1.25	0.958	0.834	0.882	1.34	1.68	0.897	0.801	0.929	0.933	1.34	0.866	0.809	0.765	0.728	0.967	1.08
Al_2O_3	wt%	12.38	7.58	6.84	6.70	10.29	16.93	15.51	16.88	14.95	17.20	18.96	13.75	11.99	12.19	14.37	16.03	16.67	15.53	15.36	17.91	14.35	18.49	17.51	16.95	14.99	17.39	17.44	17.56	16.95	15.63	16.05
P_2O_5	wt%	0.114	0.034	0.050	0.036	0.128	0.153	0.139	0.150	0.108	0.132	0.150	0.101	0.102	0.110	0.128	0.142	0.182	0.179	0.159	0.185	0.195	0.191	0.161	0.154	0.247	0.181	0.216	0.147	0.145	0.136	0.155
K_2O	wt%	2.09	1.77	1.62	1.54	1.47	1.36	1.21	1.30	3.09	3.24	3.36	1.98	1.91	2.30	2.67	3.42	3.45	3.23	2.90	3.57	3.25	3.15	3.27	3.41	3.05	3.10	2.78	3.05	2.85	3.42	3.18
CaO	wt%	0.634	0.273	0.237	0.222	0.658	7.30	7.46	7.33	2.55	2.87	2.68	0.757	0.743	0.904	1.32	1.99	2.39	2.34	1.92	2.13	1.71	2.92	2.73	2.40	2.57	2.66	3.04	2.43	2.53	2.16	2.37
TiO_2	wt%	0.885	0.387	0.484	0.851	0.581	0.776	0.981	0.820	0.452	0.582	0.532	0.741	0.838	0.757	0.629	0.564	0.492	0.499	0.781	1.06	0.481	0.478	0.472	0.490	1.05	0.548	0.453	0.498	0.462	0.551	0.633
MnO	wt%	0.139	0.027	0.035	0.035	0.070	0.150	0.196	0.158	0.058	0.074	0.078	0.081	0.104	0.082	0.090	0.072	0.065	0.066	0.088	0.114	0.069	0.070	0.068	0.070	0.102	0.070	0.056	0.061	0.062	0.069	0.075
$T\text{-}Fe_2O_3$	wt%	5.34	2.01	2.47	2.99	3.74	7.68	10.3	8.25	2.58	3.16	3.43	5.24	5.27	4.49	4.66	3.39	3.03	2.75	4.94	5.00	2.75	2.93	2.99	2.96	3.76	3.04	2.44	3.04	2.90	3.13	3.26
H_2O^-	wt%	2.03	0.852	0.653	0.755	2.84	0.398	0.986	0.200	0.65	0.607	0.934	2.42	1.95	1.93	2.12	0.798	0.695	0.462	2.38	1.20	0.715	0.684	0.800	0.779	0.559	0.469	0.458	0.607	1.25	0.655	0.580
Li	mg/kg	37.9	30.8	24.8	24.9	28.0	17.3	16.1	17.0	37.1	43.2	62.8	42.7	41.4	46.0	49.1	55.3	62.8	49.3	43.3	79.2	49.5	61.6	51.2	45.6	35.2	46.9	40.6	48.4	41.7	43.3	39.4
Be	mg/kg	1.69	0.897	0.95	0.93	1.09	1.15	1.03	1.05	3.93	4.94	5.57	1.90	2.31	2.54	3.47	4.56	5.24	4.30	3.39	4.97	2.94	6.00	5.37	4.67	4.42	4.93	5.12	5.13	4.86	4.33	4.30
Sc	mg/kg	11.6	4.15	4.87	5.35	9.13	27.3	34.9	29.1	6.89	7.58	5.98	11.3	9.95	8.69	8.05	6.63	5.59	4.93	11.6	12.6	4.80	4.83	5.67	6.20	9.78	6.83	6.10	6.18	6.04	7.02	8.14
V	mg/kg	105	39.1	42.4	51.8	67.4	181	285	201	28.3	32.9	33.9	84.0	78.1	73.3	66.9	42.3	27.5	30.8	79.8	49.9	30.9	30.9	32.1	34.4	43.6	35.9	24.4	30.7	36.7	36.5	32.0
Cr	mg/kg	52.2	19.9	21.4	24.4	30.0	12.2	19.9	13.6	7.98	16.8	14.3	58.1	51.0	42.1	35.9	18.4	13.1	11.3	27.0	18.6	9.8	13.0	11.1	13.3	10.1	11.0	10.6	15.7	13.6	16.2	12.2
Co	mg/kg	12.7	4.03	6.20	5.73	7.97	17.5	24.2	19.4	4.64	5.81	6.07	12.1	12.1	9.2	9.41	6.75	6.00	5.37	9.46	9.30	5.22	5.16	5.64	5.96	7.21	5.79	4.70	5.61	6.03	5.98	5.94
Ni	mg/kg	22.2	7.96	9.40	9.66	14.1	4.98	6.65	5.44	3.90	7.82	7.28	25.1	24.3	19.8	17.4	8.71	6.86	5.20	13.3	9.11	5.42	6.49	5.86	6.48	4.96	5.53	5.15	7.46	6.74	7.39	6.20
Cu	mg/kg	29.3	4.73	5.91	6.71	17.1	16.8	14.3	19.2	5.73	7.22	10.1	25.6	26.8	19.4	18.3	12.0	9.55	7.09	18.5	12.0	7.21	8.97	8.46	9.39	7.47	9.38	7.79	9.64	9.25	9.86	8.15
Zn	mg/kg	138	41.4	50.8	43.7	70.3	94.2	102	88.0	40.3	59.1	86.8	131	126	90.7	89.5	67.8	66.6	62.3	97.1	82.6	50.0	83.6	55.9	56.8	56.9	48.8	41.2	57.3	47.0	58.1	55.6
Ga	mg/kg	14.9	7.33	6.60	6.95	11.1	17.6	17.0	17.7	19.3	25.9	24.5	17.0	15.3	17.1	19.2	24.3	26.1	25.8	20.9	31.7	25.0	25.1	25.2	23.6	40.4	29.4	31.0	28.3	26.2	25.9	28.9
As	mg/kg	6.64	4.83	5.03	5.03	6.48	4.18	3.33	4.54	9.41	5.17	13.8	24.9	31.6	41.7	18.8	15.1	17.8	14.9	16.7	16.5	23.2	11.9	6.41	15.1	13.3	9.42	4.54	8.09	20.9	17.2	15.9
Rb	mg/kg	89.9	59.2	54.4	55.2	58.2	48.7	42.2	47.2	116	137	163	88.7	82.8	100	123	153	159	136	120	182	134	158	152	152	121	136	123	138	125	146	131
Sr	mg/kg	76.1	101	81.7	71.3	76.9	278	262	279	152	168	174	72.6	72.1	76.2	100	133	152	152	126	137	137	191	171	158	146	162	181	156	163	144	140
Y	mg/kg	14.3	7.56	8.21	7.90	14.9	24.7	23.8	24.7	18.3	29.8	24.0	12.3	11.6	13.2	13.1	24.0	29.7	32.3	19.4	41.3	36.0	28.4	27.4	25.0	70.8	34.9	39.5	26.9	25.0	28.0	36.6
Zr	mg/kg	72	44	45	52	73	106	96	105	9.0	9.3	7.9	53	29	22	25	9.9	5.8	7.0	42	14	7.3	7.2	9.6	8.2	14	8.6	6.9	11	15	8.6	18
Nb	mg/kg	11.8	6.74	8.23	10.8	8.67	4.98	4.62	4.83	7.45	10.5	14.6	11.9	11.0	12.1	11.2	12.9	14.2	10.6	11.1	21.2	11.9	14.7	12.3	12.3	13.5	12.4	11.6	13.0	11.9	11.5	11.5
Mo	mg/kg	0.634	0.202	0.260	0.291	0.610	0.676	0.624	0.735	0.502	0.170	0.304	1.38	0.821	0.563	0.683	0.346	0.292	0.086	0.841	0.292	0.084	0.269	0.065	0.190	0.174	0.220	0.046	0.233	0.512	0.430	0.319
Cd	mg/kg	0.154	0.038	0.058	0.056	0.124	0.134	0.141	0.134	0.055	0.087	0.104	0.212	0.511	0.236	0.359	0.118	0.096	0.094	0.250	0.076	0.152	0.124	0.150	0.119	0.078	0.081	0.072	0.079	0.139	0.075	0.106
Sn	mg/kg	2.27	1.03	1.05	1.07	1.57	1.36	1.25	1.37	3.85	5.76	8.20	3.72	4.81	5.24	4.92	5.17	6.33	4.85	2.87	6.19	4.99	8.23	5.00	4.17	4.35	4.59	6.19	4.16	4.51	5.38	4.60
Sb	mg/kg	0.658	0.335	0.463	0.408	0.594	0.359	0.312	0.266	0.403	0.312	0.586	0.926	0.806	0.608	0.608	0.363	0.298	0.227	0.563	0.385	0.367	0.210	0.195	0.157	0.156	0.275	0.281	0.319	0.310	0.327	0.465
Cs	mg/kg	6.00	2.20	2.14	2.19	3.06	2.87	2.50	2.84	8.52	12.0	17.3	9.43	10.2	10.4	13.0	15.3	17.1	11.1	8.85	18.8	9.66	15.0	12.7	11.1	8.48	12.7	11.2	13.3	12.0	12.1	10.5
Ba	mg/kg	486	362	363	458	407	244	215	236	251	259	316	419	421	393	336	332	317	307	383	313	349	271	280	316	267	270	233	277	258	332	274
La	mg/kg	21.7	17.3	17.0	15.8	18.3	13.9	12.2	13.6	66.8	124	68.0	21.7	26.7	56.4	33.7	97.4	111	164	61.0	188	180	77.7	106	86.6	685	153	167	119	102	126	174
Ce	mg/kg	45.9	34.6	33.6	31.7	37.4	30.4	26.8	29.7	142	424	146	53.7	55.0	121	74.3	210	238	566	131	662	619	165	227	184	1430	326	356	255	218	267	255
Pr	mg/kg	5.24	3.79	3.72	3.50	4.28	3.72	3.36	3.62	15.6	28.6	15.9	5.16	6.19	13.3	8.11	23.4	26.4	38.1	14.4	44.6	41.5	18.3	25.3	20.2	97.2	35.7	39.1	28.2	23.8	29.4	40.7
Nd	mg/kg	18.9	13.8	13.1	12.4	16.4	15.4	14.0	15.1	57.1	104	57.6	19.0	22.8	48.7	29.9	84.8	96.7	138	52.6	162	150	66.5	92.6	74.2	355	130	144	103	87.1	106	148
Sm	mg/kg	3.68	2.33	2.42	2.22	3.18	3.82	3.55	3.74	10.4	18.6	10.9	3.94	4.20	9.00	5.75	15.1	17.5	23.6	9.49	28.3	26.1	12.5	16.5	13.4	60.0	23.3	25.8	18.5	15.8	18.9	25.8
Eu	mg/kg	0.757	0.467	0.415	0.433	0.717	1.04	0.978	1.02	0.918	1.12	1.07	0.789	0.800	0.957	0.812	0.993	1.04	1.02	0.936	1.06	0.950	1.08	1.05	1.03	1.30	1.11	1.22	1.12	1.11	0.988	1.08
Gd	mg/kg	2.94	1.83	1.76	1.70	2.76	3.82	3.54	3.73	7.30	12.3	7.69	3.03	3.29	6.21	4.42	10.5	12.4	16.1	6.92	19.1	17.7	8.90	11.4	9.47	40.3	16.4	18.3	12.9	11.1	13.2	18.0
Tb	mg/kg	0.405	0.239	0.235	0.242	0.401	0.608	0.584	0.609	0.825	1.38	0.943	0.409	0.448	0.707	0.541	1.20	1.41	1.76	0.810	2.05	1.90	1.11	1.27	1.09	4.12	1.79	2.01	1.40	1.24	1.43	1.93
Dy	mg/kg	2.42	1.27	1.39	1.33	2.45	3.97	3.83	3.92	3.97	6.46	4.81	2.36	2.34	3.27	2.73	5.57	6.72	7.89	4.09	9.37	8.56	5.70	6.16	5.38	17.91	8.03	8.90	6.27	5.78	6.39	8.66
Ho	mg/kg	0.475	0.254	0.282	0.271	0.522	0.836	0.795	0.832	0.642	1.02	0.801	0.443	0.409	0.484	0.459	0.870	1.06	1.17	0.715	1.47	1.28	0.988	0.956	0.851	2.51	1.23	1.39	0.956	0.853	0.960	1.28
Er	mg/kg	1.36	0.783	0.819	0.800	1.49	2.47	2.40	2.49	1.55	2.37	2.01	1.20	1.06	1.11	1.11	1.88	2.39	2.49	1.68	3.24	2.71	2.34	2.17	2.03	5.23	2.61	3.00	2.12	2.02	2.15	2.84
Tm	mg/kg	0.198	0.113	0.129	0.118	0.223	0.351	0.346	0.353	0.194	0.290	0.259	0.172	0.140	0.141	0.149	0.220	0.288	0.277	0.226	0.376	0.310	0.308	0.265	0.254	0.552	0.301	0.347	0.239	0.239	0.256	0.340
Yb	mg/kg	1.41	0.778	0.855	0.769	1.42	2.42	2.32	2.47	1.15	1.58	1.61	1.14	0.840	0.839	0.958	1.31	1.76	1.58	1.35	2.13	1.61	1.81	1.50	1.50	2.90	1.70	1.83	1.37	1.36	1.37	1.86
Lu	mg/kg	0.203	0.119	0.122	0.115	0.217	0.362	0.358	0.371	0.156	0.226	0.218	0.154	0.119	0.112	0.123	0.169	0.220	0.203	0.193	0.289	0.207	0.244	0.210	0.203	0.371	0.242	0.251	0.176	0.180	0.185	0.247
Hf	mg/kg	1.7	1.2	1.2	1.3	1.9	2.7	2.4	2.7	0.28	0.34	0.27	1.4	0.79	0.61	0.67	0.33	0.24	0.23	1.1	0.54	0.25	0.28	0.32	0.30	0.45	0.29	0.25	0.33	0.49	0.29	0.54
Ta	mg/kg	0.947	0.550	0.713	0.775	0.734	0.428	0.371	0.419	1.05	1.50	2.04	1.09	0.99	1.67	1.36	1.73	2.05	1.59	1.33	3.10	1.89	2.12	1.78	1.72	1.93	1.83	1.66	1.84	1.67	1.68	1.69
Hg	mg/kg	0.120	0.036	0.038	0.031	0.062	0.002	0.000	0.000	0.012	0.021	0.018	0.054	0.051	0.043	0.051	0.024	0.018	0.011	0.032	0.011	0.014	0.015	0.015	0.011	0.011	0.016	0.011	0.017	0.058	0.021	0.025
Tl	mg/kg	0.497	0.303	0.277	0.286	0.369	0.328	0.263	0.315	0.56	0.700	0.855	0.587	0.602	0.584	0.742	0.803	0.816	0.698	0.656	0.917	0.676	0.793	0.768	0.746	0.578	0.687	0.601	0.678	0.659	0.723	0.675
Pb	mg/kg	17.8	11.3	10.5	11.5	16.6	10.5	10.2	10.4	36.7	33.5	36.2	27.0	21.4	23.9	33.4	31.5	31.1	30.4	28.3	30.0	28.0	36.1	32.9	30.8	29.8	29.6	29.7	30.4	31.5	41.1	30.9
Bi	mg/kg	0.351	0.107	0.104	0.107	0.215	0.202	0.134	0.249	0.314	0.271	0.595	0.564	0.688	0.701	0.727	0.907	2.27	1.55	11.4	0.849	0.994	0.588	0.591	0.576	0.378	0.783	0.355	0.462	0.626	1.03	0.793
Th	mg/kg	7.74	5.38	5.24	5.06	6.12	4.45	3.86	4.31	27.1	49.0	26.5	8.77	8.65	18.2	13.1	41.2	47.2	67.9	24.6	81.0	74.8	29.6	44.9	34.8	297	63.6	69.6	50.7	41.5	51.4	73.8
U	mg/kg	1.41	1.06	1.03	0.992	1.37	1.01	0.872	0.979	2.47	3.30	3.88	1.53	1.10	1.90	1.94	3.31	4.32	4.80	2.19	5.89	4.40	3.31	3.28	3.23	7.41	4.62	3.65	3.47	3.51	4.09	4.17

[a] The mean values of repeated analyses (n=3).

Table 6 Element concentrations in stream sediments grouped into 7 grain size categories.

		Sk03						Tn02							Tn09							Tn26						
Element	Unit	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G
Na_2O	wt%	3.19	3.01	2.93	3.03	3.07	3.08	1.43	2.22	1.54	0.913	1.13	1.37	1.28	1.30	1.56	1.09	0.773	1.23	1.67	1.44	1.34	1.31	1.06	0.866	1.08	1.72	1.94
MgO	wt%	3.06	3.89	4.22	3.60	3.07	2.46	1.32	1.11	1.47	0.988	0.894	1.11	1.32	1.23	1.63	3.49	1.51	0.992	1.08	1.45	0.753	0.758	0.683	0.487	0.583	0.655	0.871
Al_2O_3	wt%	16.35	15.97	15.97	16.98	17.46	16.83	14.36	17.67	11.93	7.80	10.68	14.64	17.30	12.89	13.78	8.98	7.09	9.77	12.72	16.60	9.69	10.19	7.98	6.00	7.28	9.86	12.68
P_2O_5	wt%	0.171	0.158	0.150	0.152	0.154	0.169	0.112	0.098	0.066	0.048	0.075	0.125	0.159	0.099	0.086	0.062	0.047	0.066	0.093	0.136	0.116	0.099	0.046	0.028	0.043	0.063	0.082
K_2O	wt%	1.54	1.41	1.32	1.34	1.34	1.36	2.54	1.93	1.38	1.47	1.89	2.23	2.50	2.51	2.10	1.31	1.48	2.08	2.38	2.79	1.65	1.76	1.55	1.35	1.57	1.97	2.18
CaO	wt%	6.73	6.97	7.24	7.50	7.53	7.13	1.09	3.57	2.60	0.848	0.524	0.547	0.489	0.351	1.89	2.20	0.662	0.396	0.401	0.414	0.302	0.573	0.534	0.306	0.186	0.222	0.263
TiO_2	wt%	0.808	0.824	0.848	0.823	0.780	0.778	0.576	0.469	0.451	0.579	0.757	0.762	0.804	0.630	0.507	1.06	1.24	0.733	0.640	0.803	0.426	0.399	0.309	0.443	2.05	0.526	0.667
MnO	wt%	0.149	0.170	0.178	0.159	0.142	0.124	0.072	0.068	0.094	0.070	0.079	0.109	0.140	0.067	0.076	0.173	0.100	0.056	0.065	0.092	0.029	0.034	0.031	0.024	0.078	0.029	0.046
T-Fe_2O_3	wt%	7.59	8.46	9.05	8.31	7.69	7.43	6.07	4.83	4.12	3.72	4.59	5.16	5.99	5.89	5.39	9.71	8.19	4.12	4.08	5.43	7.06	6.34	3.40	2.51	7.85	3.43	4.45
H_2O^-	wt%	0.099	0.098	0.294	0.199	0.200	0.589	2.27	1.80	1.24	0.865	1.65	3.82	4.53	1.65	1.36	0.727	0.679	1.16	2.14	3.09	1.32	1.22	0.873	0.671	0.637	1.08	1.49
Li	mg/kg	17.6	17.0	16.6	16.9	17.1	17.5	43.1	33.9	25.7	23.3	31.0	39.3	46.1	44.5	39.2	24.4	22.6	29.0	35.8	45.3	43.6	41.5	30.4	22.7	24.9	33.2	40.8
Be	mg/kg	1.14	1.12	1.04	1.08	1.10	1.10	2.10	1.84	1.18	0.98	1.37	1.85	2.25	2.02	1.79	1.10	1.02	1.30	1.74	2.30	1.66	1.60	1.07	0.787	1.11	1.46	1.81
Sc	mg/kg	26.6	29.7	31.4	28.5	26.5	23.5	9.95	9.43	10.92	7.22	8.21	11.0	13.8	8.96	11.0	21.0	10.5	7.05	8.01	12.8	5.57	6.08	4.86	3.66	8.47	5.19	7.90
V	mg/kg	173	197	224	201	188	177	80.4	64.8	56.8	65.9	90.5	90.5	101	87.3	73.3	192	204	92.7	72.9	93.2	54.1	54.5	40.2	37.9	185	51.0	61.1
Cr	mg/kg	10.3	13.0	14.6	14.0	12.8	12.4	56.8	42.8	26.6	23.2	35.2	48.0	64.7	58.2	49.4	37.4	34.7	41.9	52.7	73.9	41.0	36.7	22.8	17.3	37.5	34.7	50.5
Co	mg/kg	17.1	19.3	21.1	18.9	17.1	15.6	9.89	8.78	8.95	7.47	9.45	11.8	14.9	9.04	9.58	18.2	14.0	8.45	8.94	12.0	10.0	9.87	6.35	4.77	11.0	7.67	11.6
Ni	mg/kg	4.66	5.22	5.76	5.36	4.86	5.56	24.3	18.4	12.9	10.3	15.4	20.9	27.7	25.1	21.1	14.2	14.1	18.7	23.0	31.7	22.3	20.3	11.9	8.02	11.7	15.3	22.5
Cu	mg/kg	17.3	17.6	16.9	17.4	19.2	28.6	24.0	18.2	11.3	8.3	12.8	19.5	26.4	21.2	17.1	10.6	9.8	12.2	16.8	24.8	16.2	14.7	8.49	5.20	8.36	11.4	15.5
Zn	mg/kg	85.5	89.2	92.0	85.4	81.1	79.0	80.3	66.7	58.2	48.9	64.5	80.0	96.1	71.3	70.4	110	94.5	62.6	74.1	97.3	77.0	76.9	48.7	36.1	93.8	60.7	74.2
Ga	mg/kg	17.4	16.6	16.6	17.4	18.3	18.2	17.4	18.7	12.7	9.2	12.5	17.2	20.4	15.6	15.6	11.8	10.8	12.6	15.4	20.2	11.6	11.9	9.1	6.8	11.2	12.2	14.9
As	mg/kg	3.86	3.54	3.88	4.24	4.92	7.96	10.2	7.66	5.85	3.95	5.41	8.16	10.2	14.8	8.84	4.69	3.84	4.90	6.47	9.81	15.9	15.3	7.57	4.10	5.58	7.89	10.5
Rb	mg/kg	55.3	50.3	46.9	47.2	47.8	46.2	113	84.0	54.7	53.8	73.9	94.0	116	106	88.7	50.5	54.4	79.0	96.7	128	70.7	72.1	58.9	47.1	55.9	75.5	92.4
Sr	mg/kg	263	259	262	280	289	284	117	236	164	81.2	84.0	95.0	94.8	86.4	143	107	65.3	84.1	97.4	98.8	82.7	92.0	82.0	66.9	75.5	96.3	111
Y	mg/kg	27.3	26.2	25.0	24.8	24.6	23.5	15.1	12.7	9.69	7.60	12.2	21.3	25.1	13.6	11.8	10.1	7.66	10.5	13.9	21.2	11.92	11.5	7.47	5.59	9.77	12.0	15.6
Zr	mg/kg	121	111	103	103	104	106	77	60	42	37	65	117	132	89	58	36	39	60	84	107	45	43	32	25	72	69	79
Nb	mg/kg	5.59	5.13	4.73	4.83	4.82	5.14	11.0	8.63	5.74	6.57	9.72	12.5	14.4	11.2	9.07	6.13	7.40	9.95	11.6	14.9	8.42	7.59	5.38	6.03	19.6	10.3	13.4
Mo	mg/kg	0.790	0.656	0.647	0.702	0.700	0.993	0.710	0.631	0.459	0.298	0.479	0.732	1.04	0.814	0.610	0.400	0.372	0.448	0.555	0.956	0.793	0.866	0.488	0.233	0.669	0.470	0.767
Cd	mg/kg	0.127	0.116	0.121	0.123	0.119	0.129	0.099	0.102	0.081	0.058	0.094	0.146	0.177	0.113	0.105	0.101	0.078	0.100	0.138	0.179	0.069	0.073	0.049	0.037	0.058	0.069	0.096
Sn	mg/kg	1.41	1.36	1.30	1.37	1.33	1.73	2.08	1.65	1.14	0.993	1.62	2.19	3.23	2.09	1.64	1.17	1.25	1.45	1.93	3.41	1.39	1.30	0.980	0.735	1.85	1.73	2.36
Sb	mg/kg	0.360	0.275	0.254	0.245	0.254	0.364	0.840	0.751	0.469	0.430	0.527	0.672	0.918	0.870	0.708	0.421	0.389	0.596	0.618	0.793	0.832	0.779	0.611	0.379	0.539	0.624	0.739
Cs	mg/kg	3.28	3.01	2.87	2.86	2.93	2.72	6.97	5.27	3.08	2.34	3.69	5.52	7.54	5.90	5.04	2.64	2.43	3.51	4.98	8.04	3.69	3.78	2.71	1.84	2.37	3.46	5.12
Ba	mg/kg	270	248	229	235	238	251	422	329	287	320	405	434	452	480	410	278	355	497	537	562	355	356	342	356	498	535	600
La	mg/kg	15.2	14.1	13.4	13.6	13.6	13.8	27.0	20.7	14.0	13.9	19.5	36.0	36.2	28.9	21.6	12.3	14.2	24.6	28.8	38.1	19.9	18.5	13.3	11.7	26.5	31.4	30.3
Ce	mg/kg	33.7	31.1	29.3	29.7	30.1	29.5	52.6	40.4	28.0	27.0	39.0	73.5	75.7	57.1	42.3	24.3	27.8	52.4	59.9	75.9	40.6	37.6	26.3	22.7	52.9	65.6	63.2
Pr	mg/kg	4.18	3.85	3.64	3.66	3.68	3.70	6.26	4.66	3.23	3.17	4.52	8.35	8.51	6.46	4.79	2.89	3.30	6.22	6.81	8.81	4.68	4.33	3.03	2.57	6.08	7.43	7.04
Nd	mg/kg	17.1	16.0	15.0	15.2	15.1	15.3	22.4	17.0	11.8	11.3	16.6	30.5	31.2	22.9	17.4	10.9	12.1	23.0	24.9	32.1	17.5	16.4	11.0	9.56	21.5	26.9	25.6
Sm	mg/kg	4.01	3.86	3.66	3.63	3.67	3.55	4.10	2.98	2.27	2.05	3.07	5.68	5.85	3.86	3.06	2.17	2.12	4.06	4.36	5.74	3.28	3.13	2.11	1.71	3.88	4.93	4.82
Eu	mg/kg	1.07	1.01	1.01	1.02	1.05	1.02	0.844	0.939	0.692	0.473	0.659	0.981	1.19	0.755	0.798	0.570	0.471	0.804	0.778	1.13	0.721	0.716	0.477	0.390	0.595	0.734	0.895
Gd	mg/kg	4.09	3.93	3.85	3.80	3.71	3.76	3.07	2.48	1.91	1.61	2.46	4.46	4.88	2.84	2.41	1.90	1.64	2.73	3.30	4.50	2.82	2.60	1.62	1.32	2.66	3.31	3.67
Tb	mg/kg	0.67	0.64	0.61	0.60	0.59	0.60	0.428	0.367	0.277	0.229	0.350	0.627	0.692	0.420	0.351	0.284	0.237	0.346	0.432	0.611	0.365	0.361	0.218	0.172	0.326	0.426	0.484
Dy	mg/kg	4.30	4.07	3.95	3.86	3.78	3.81	2.55	2.13	1.68	1.36	2.11	3.62	4.11	2.36	2.10	1.71	1.37	1.88	2.41	3.53	2.09	2.01	1.31	0.977	1.78	2.25	2.77
Ho	mg/kg	0.91	0.88	0.84	0.83	0.80	0.80	0.526	0.433	0.337	0.264	0.416	0.714	0.838	0.477	0.412	0.373	0.272	0.377	0.495	0.721	0.409	0.396	0.254	0.194	0.343	0.419	0.523
Er	mg/kg	2.65	2.55	2.47	2.49	2.42	2.39	1.52	1.26	0.98	0.75	1.21	2.10	2.45	1.38	1.20	1.06	0.80	1.03	1.40	2.04	1.10	1.07	0.714	0.536	0.968	1.17	1.52
Tm	mg/kg	0.38	0.37	0.36	0.36	0.34	0.35	0.226	0.185	0.148	0.114	0.184	0.308	0.361	0.205	0.176	0.158	0.123	0.152	0.218	0.302	0.156	0.156	0.102	0.077	0.138	0.170	0.220
Yb	mg/kg	2.55	2.44	2.35	2.34	2.27	2.36	1.48	1.19	0.98	0.74	1.20	2.05	2.40	1.43	1.22	1.11	0.79	1.06	1.42	2.07	1.03	1.02	0.752	0.553	0.980	1.14	1.50
Lu	mg/kg	0.42	0.41	0.37	0.36	0.36	0.35	0.229	0.187	0.151	0.117	0.187	0.314	0.369	0.218	0.183	0.173	0.123	0.158	0.212	0.304	0.155	0.152	0.108	0.085	0.150	0.161	0.218
Hf	mg/kg	3.0	2.8	2.6	2.6	2.6	2.8	2.0	1.6	1.1	0.98	1.7	3.1	3.4	2.3	1.6	1.0	1.1	1.6	2.2	2.8	1.2	1.2	0.9	0.7	1.9	1.8	2.1
Ta	mg/kg	0.476	0.446	0.419	0.416	0.420	0.436	0.966	0.729	0.501	0.538	0.815	1.20	1.23	0.953	0.770	0.418	0.402	0.807	1.01	1.26	0.714	0.637	0.470	0.424	1.01	0.867	1.14
Hg	mg/kg	n.d.	n.d.	n.d.	n.d.	n.d.	0.005	0.084	0.061	0.049	0.038	0.063	0.095	0.118	0.062	0.051	0.034	0.028	0.042	0.060	0.081	0.042	0.053	0.034	0.021	0.034	0.052	0.073
Tl	mg/kg	0.286	0.273	0.278	0.302	0.329	0.407	0.597	0.449	0.318	0.299	0.426	0.556	0.682	0.566	0.453	0.276	0.298	0.429	0.533	0.692	0.347	0.360	0.293	0.234	0.286	0.394	0.470
Pb	mg/kg	10.6	9.87	9.65	10.2	10.8	12.8	20.4	17.2	12.8	11.6	16.5	26.3	28.6	22.1	17.2	11.9	13.4	15.4	19.3	26.5	18.5	18.8	13.1	9.59	14.8	20.5	25.9
Bi	mg/kg	0.144	0.125	0.150	0.194	0.260	0.544	0.269	0.246	0.148	0.108	0.168	0.270	0.391	0.257	0.215	0.125	0.120	0.183	0.236	0.355	0.163	0.185	0.139	0.102	0.120	0.151	0.224
Th	mg/kg	4.97	4.52	4.29	4.29	4.28	4.46	9.18	6.79	4.71	4.25	6.53	12.4	12.7	9.70	7.21	4.02	4.51	6.50	10.6	12.8	6.68	6.39	4.59	3.53	8.52	11.9	10.4
U	mg/kg	1.13	1.03	0.972	0.974	0.967	1.00	1.67	1.23	0.849	0.836	1.32	2.26	2.56	1.76	1.28	0.74	0.841	1.27	1.83	2.39	1.32	1.25	0.858	0.659	1.32	1.76	2.04

A: 2-1 mm, B: 1-0.5 mm, C: 500-250 μm, D: 250-125 μm, E: 125-63 μm, F: 63-32 μm, G: <32 μm

Table 6 continued.

		Yk01							Yk17					
Element	Unit	A	B	C	D	E	F	G	A	B	C	D	E	F+G
Na_2O	wt%	1.13	1.54	2.44	3.14	3.48	3.41	2.80	1.20	1.49	1.97	2.35	3.27	3.33
MgO	wt%	0.987	1.15	1.10	1.04	0.965	1.01	1.25	0.896	1.05	2.49	2.58	1.10	0.816
Al_2O_3	wt%	9.67	11.73	13.82	14.08	14.91	16.77	18.49	9.38	10.54	10.93	11.27	14.82	18.11
P_2O_5	wt%	0.053	0.048	0.045	0.057	0.142	0.271	0.196	0.056	0.049	0.054	0.106	0.282	0.214
K_2O	wt%	4.14	4.48	4.06	3.28	2.83	2.63	2.50	4.05	3.83	3.06	2.42	2.86	3.09
CaO	wt%	0.49	1.04	1.87	2.36	2.54	2.29	1.50	0.545	1.14	2.23	2.30	2.45	2.17
TiO_2	wt%	0.577	0.601	0.478	0.503	0.761	0.922	0.902	0.507	0.469	1.00	2.63	1.67	0.94
MnO	wt%	0.063	0.069	0.064	0.060	0.070	0.084	0.075	0.058	0.064	0.141	0.204	0.119	0.091
T-Fe_2O_3	wt%	3.90	4.13	3.49	3.41	4.18	5.00	5.27	3.33	3.34	8.05	17.2	8.34	4.42
H_2O^-	wt%	0.502	0.535	0.741	0.513	0.656	1.64	3.87	0.381	0.487	0.365	0.324	0.546	1.36
Li	mg/kg	95.4	97.4	67.5	40.7	34.9	53.2	73.2	79.2	70.8	47.9	30.0	34.1	48.0
Be	mg/kg	2.09	2.18	2.67	3.41	4.02	4.81	4.50	2.13	2.12	2.25	2.84	4.45	5.77
Sc	mg/kg	7.98	8.83	8.17	7.25	8.00	8.80	11.8	5.39	7.30	16.5	20.0	9.65	7.98
V	mg/kg	33.7	33.8	38.8	50.5	77.8	78.6	69.6	33.2	31.2	153	416	190	76.0
Cr	mg/kg	18.8	18.0	12.2	8.6	10.4	20.0	43.5	14.4	12.7	13.4	17.4	13.6	22.8
Co	mg/kg	5.86	6.42	5.64	5.65	6.90	7.64	8.98	5.20	5.65	13.6	24.7	11.8	8.21
Ni	mg/kg	6.93	7.17	5.18	3.94	4.89	8.95	18.2	5.80	5.93	5.76	6.30	5.57	10.4
Cu	mg/kg	6.62	6.49	5.04	4.42	6.39	13.9	24.5	4.98	5.32	5.49	7.68	6.94	15.0
Zn	mg/kg	67.8	73.0	57.7	46.5	61.2	83.1	107	59.8	58.1	94.8	176	101	101
Ga	mg/kg	13.9	16.1	16.3	16.1	23.4	41.5	29.7	13.0	13.1	14.7	24.4	50.4	31.4
As	mg/kg	7.86	6.49	6.42	6.63	9.09	20.5	32.8	6.59	8.63	5.71	7.37	13.8	22.4
Rb	mg/kg	195	211	176	128	113	120	134	185	176	130	93.5	113	151
Sr	mg/kg	70.4	94.7	132	145	148	145	122	71.0	90.4	110	115	148	156
Y	mg/kg	9.07	8.82	7.38	7.86	25.3	65.0	33.8	9.14	9.23	10.6	25.1	84.3	42.8
Zr	mg/kg	3.8	3.9	6.0	6.4	12	34	37	2.1	2.7	6.7	16	20	17
Nb	mg/kg	15.3	16.8	11.8	7.11	8.26	15.4	20.0	13.2	12.1	9.18	9.30	13.5	16.5
Mo	mg/kg	0.255	0.176	0.134	0.151	0.307	0.852	1.81	0.000	0.030	0.057	0.244	0.257	0.618
Cd	mg/kg	0.021	0.038	0.042	0.053	0.075	0.084	0.090	0.032	0.036	0.062	0.078	0.090	0.137
Sn	mg/kg	6.00	6.71	5.30	3.61	4.42	6.74	12.1	5.08	4.70	3.79	3.49	4.35	8.40
Sb	mg/kg	5.43	0.397	0.465	0.299	0.475	1.20	1.98	0.116	0.158	0.131	0.119	0.155	0.361
Cs	mg/kg	14.8	16.3	13.1	8.87	8.39	11.8	16.0	12.1	11.6	8.33	6.02	8.04	12.9
Ba	mg/kg	470	381	303	253	246	273	315	422	315	235	194	264	358
La	mg/kg	22.1	19.6	14.8	16.4	102	323	92.8	21.5	17.5	18.0	108	513	164
Ce	mg/kg	45.4	40.3	30.1	33.5	217	691	204	45.0	36.0	37.4	230	1086	351
Pr	mg/kg	5.17	4.62	3.36	3.70	23.6	75.8	22.1	5.15	4.12	4.28	25.1	119	38.8
Nd	mg/kg	19.2	17.1	12.4	13.7	87.1	278	82.2	18.9	15.2	15.8	92.9	438	142
Sm	mg/kg	3.74	3.36	2.39	2.68	15.5	49.8	15.8	3.63	3.08	3.08	16.1	74.5	25.5
Eu	mg/kg	0.487	0.573	0.752	0.840	0.997	1.34	1.24	0.484	0.517	0.627	0.768	1.43	1.28
Gd	mg/kg	2.76	2.53	1.93	2.17	11.1	34.1	11.3	2.81	2.36	2.58	11.1	49.7	17.6
Tb	mg/kg	0.350	0.319	0.259	0.274	1.19	3.56	1.43	0.354	0.316	0.329	1.22	5.17	2.06
Dy	mg/kg	1.81	1.73	1.36	1.49	5.73	16.2	7.64	1.85	1.71	1.96	5.69	21.8	9.62
Ho	mg/kg	0.302	0.301	0.251	0.277	0.910	2.35	1.24	0.310	0.307	0.363	0.893	3.07	1.50
Er	mg/kg	0.768	0.769	0.658	0.721	2.01	4.98	3.13	0.773	0.751	0.997	2.04	6.07	3.44
Tm	mg/kg	0.098	0.104	0.093	0.097	0.251	0.574	0.415	0.109	0.109	0.146	0.251	0.662	0.429
Yb	mg/kg	0.606	0.657	0.590	0.633	1.42	2.99	2.56	0.656	0.674	0.863	1.50	3.25	2.40
Lu	mg/kg	0.084	0.089	0.085	0.089	0.194	0.389	0.351	0.085	0.090	0.139	0.219	0.451	0.342
Hf	mg/kg	0.13	0.13	0.14	0.19	0.33	1.1	1.1	0.08	0.11	0.22	0.49	0.69	0.57
Ta	mg/kg	1.46	1.74	1.41	0.91	1.09	2.07	2.52	1.19	1.14	0.97	1.08	1.75	2.19
Hg	mg/kg	0.004	0.004	0.003	0.005	0.010	0.044	0.121	0.002	0.002	0.003	0.005	0.009	0.028
Tl	mg/kg	0.987	1.09	0.881	0.616	0.544	0.635	0.795	0.895	0.853	0.626	0.451	0.552	0.782
Pb	mg/kg	42.9	34.3	34.8	35.0	43.4	69.5	115	22.5	22.5	24.9	31.3	34.4	50.7
Bi	mg/kg	0.337	0.287	0.265	0.282	0.363	0.794	1.30	0.268	0.370	0.337	0.359	0.887	0.945
Th	mg/kg	8.97	7.64	5.17	5.87	41.8	141	37.7	8.95	6.75	6.01	44.2	215	67.7
U	mg/kg	1.74	1.72	1.48	1.44	3.25	9.77	9.74	1.52	1.39	1.37	3.05	14.7	7.71

A: 2-1 mm, B: 1-0.5 mm, C: 500-250 μm, D: 250-125 μm, E: 125-63 μm, F: 63-32 μm, G: <32 μm

the coarse silt fraction (32–63 μm), as with the Tn02, Tn09, and Tn26 samples. The concentrations of P_2O_5, Y, lanthanide (Ln: La–Lu), Th, and U were significantly high for Yk01 and Yk17 in the fine sand fractions of 63–250 μm. The steep slope of the riverbed in Yakushima Island (3/100–1/50) (Shimazu and Nishi, 2004) and the high river discharge due to heavy rainfall (about 3,250–4,480 mm/year) (Meteorological Agency, http://www.jma.go.jp/jma/menu/menureport.html, accessed 2018-9-4) caused the accumulation of accessary minerals with a greater specific gravity than quartz, plagioclase, and K-feldspar in the fine sand fraction. Mafic elements, such as MgO, TiO_2, and Fe_2O_3 in Yk17, were very abundant in the fine sand fraction (125–250 μm). Their systematic variations reflect the relative abundance of magnetic minerals in clastics. Actually, the relative weight ratio of magnetic minerals removed using a hand magnet to the total <180 μm fraction is extremely high in Yk12 (26%) and Yk17 (31%), but low for other samples (< 6%). The concentrations of mafic elements in the <180 μm fraction were comparable to those for the coarse sand fraction (A, B, and C) and those for silty size fractions (F and G) (Tables 5 and 6). Thus, the procedure to remove excessive magnetic minerals from the fine sand fraction using a magnet was validated (Imai *et al.*, 2004).

Minami *et al.* (2017) reported that stream sediments derived from granitic rocks have variation patterns similar to that shown in Fig. 4: A V-shaped pattern and the

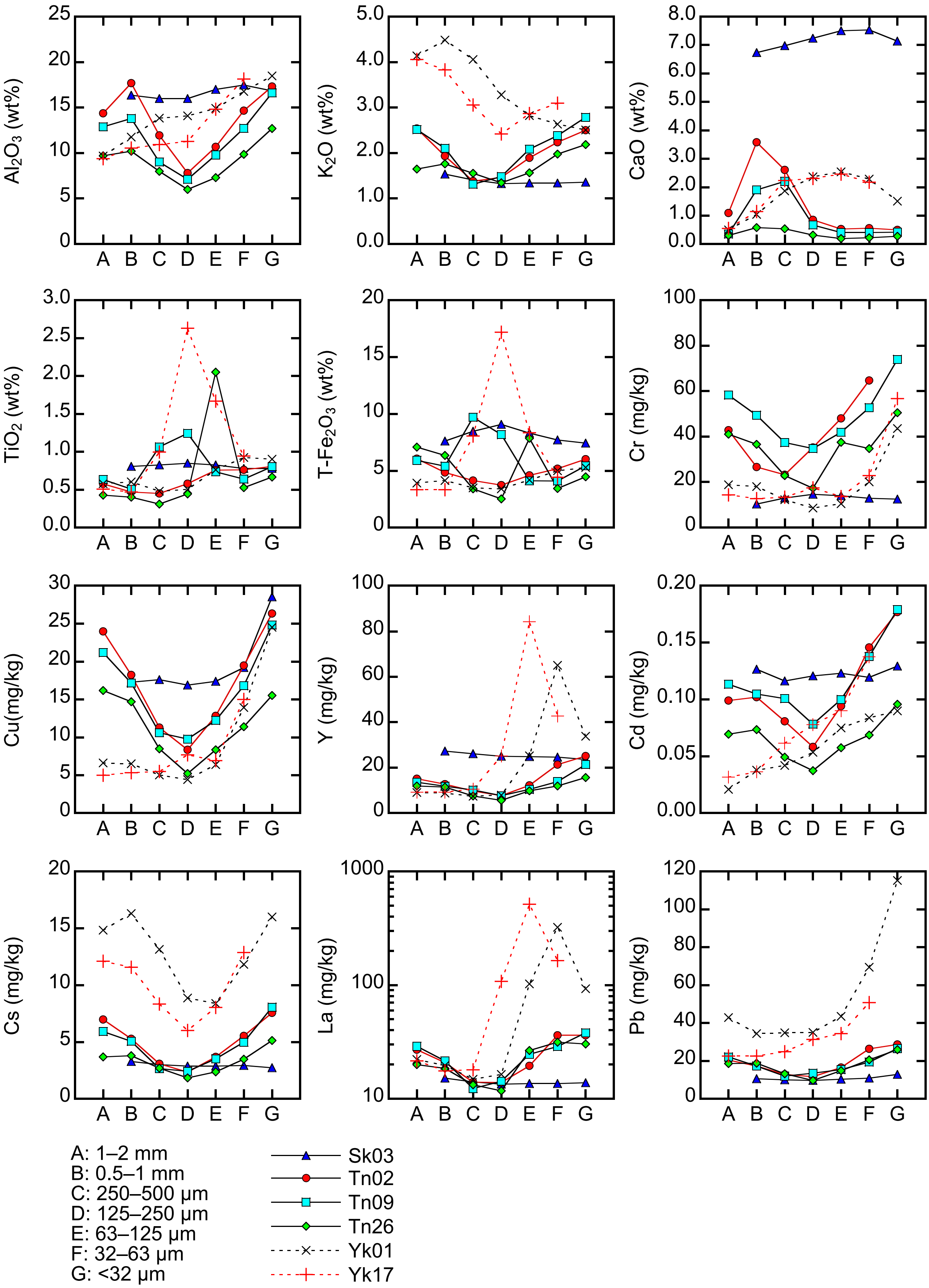

Fig. 4 Element concentrations in stream sediments by grain size category.

systematic decrease or increase in SiO_2, K_2O, CaO, Rb, Sr, and Ba concentrations. The element concentrations in the fine sand fraction (300–75 μm) of stream sediments were comparable to those of the host rocks. This is because quartz, K-feldspar, and plagioclase in stream sediments are more abundantly preserved in the coarse sand fraction (>300 μm) and finer grained accessary minerals have higher concentrations in the silty size fraction (<75 μm) than in the host rocks. Therefore, the fine sand fraction of <180 μm was less likely accumulate rock-forming minerals and was suitable for use in geochemical mapping.

4. 2 Element concentrations in fine stream sediments collected from remote islands around Kyushu

Figures 5–9 show geochemical maps for Al_2O_3, K_2O, CaO, T-Fe_2O_3, Cr, Zn, Nb, Cd, La, and Yb on remote islands around the Kyushu mainland. The maps were prepared using the ArcGIS 10.5 software. The geochemical maps were created following the method of Ohta *et al.* (2004). Element concentration intervals in the color image maps were categorized into 8 classes according to the percentile range: $0 \leq x \leq 5$, $5 < x \leq 10$, $10 < x \leq 25$, $25 < x \leq 50$, $50 < x \leq 75$, $75 < x \leq 90$, $90 < x \leq 95$, and $95 < x \leq 100\%$, where x represents the element concentration, according to Reimann (2005).

Enrichment with Li, Be, Na_2O, K_2O, CaO, Rb, Y, Nb, Sn, Cs, Ln, Ta, Tl, Pb, Th, and U was found in stream sediments collected from Yakushima Island, which is underlain mainly by Neogene granitic rock (Figs. 5–8). Stream sediments derived from Paleogene-Neogene sediment on Tsushima Island and stream sediments from Paleogene and Cretaceous sedimentary rocks on Amakusa Islands had abundant Li, Be, K_2O, Rb, Cs, La, Ce, Pr, Nd, Tl, and Th (Figs. 5 and 8). Stream sediments from Tanegashima Island had average chemical compositions for all samples but were poor in MgO, CaO, Sc, TiO_2, V, T-Fe_2O_3, Co, and Sr (Fig. 6). Islands with mafic volcanic and pyroclastic rocks outcrops, such as Ikinoshima, Hiradojima, Nagashima, and Sakurajima Islands, contained high amounts of Al_2O_3, MgO, CaO, P_2O_5, Sc, TiO_2, V, MnO, T-Fe_2O_3, Co, Cu, Zn, and Sr (Figs. 5 and 6). Their spatial distributions were influenced by the abundance of mafic minerals (olivine, pyroxene, and hornblende) in stream sediments. Stream sediments derived from alkaline mafic volcanic rocks on Ikinoshima, Ikitsushima, Takashima, Ukujima, and Ojikajima Islands were also highly enriched with Cr, Ni, Zn, Nb, Ln, and Ta. These elements are relatively uncommon in stream sediments derived from non-alkaline mafic volcanic and pyroclastic rocks distributed on Hiradojima, Nagashima, and Sakurajima Islands (Figs. 7 and 8). However, the reason for the lack of abundance of Na_2O and K_2O in stream sediments derived from alkaline mafic volcanic rocks is unclear because the host rock is enriched with Na_2O and K_2O.

The Cu, Zn, As, Mo, Cd, Sn, Sb, Hg, Pb, and Bi in stream sediments were influenced strongly by mineral deposits. They were abundant in stream sediments from the south part of Tsushima Island, Ikinoshima Island, Ikitsushima Island, Takashima Island, Ukujima Island, and Ojikajima Island (Fig. 9). The Ts18 sample, in particular, had extremely high concentrations of Zn (1,855 mg/kg), Cd (16.6 mg/kg), and Pb (1,452 mg/kg) due to the Taishu Mine containing Zn and Pb in its drainage basin. The Am25 sample also had very high concentrations of Mo (51.4 mg/kg) and Sn (22.7 mg/kg) and rather high amounts of Cu (278 mg/kg), Zn (436 mg/kg), and Pb (222 mg/kg). However, no metalliferous mines or contaminant sources were found in the sampling location. In contrast, the Am42 and Am43 samples had the highest concentrations of Sb (1.41 mg/kg and 6.32 mg/kg, respectively) because of the Takahama Mine containing Sb located in the drainage basin of Am42 and near the sampling location of Am43. The W mines in the Yakushima Islands did not elevate concentrations of heavy metals in stream sediments. The high concentrations of Sn and Pb on Yakushima Island appear to be caused not by a W mine, but by the parent lithology (granitic rock).

4. 3 Abundance patterns for elements in stream sediments normalized to Japanese stream sediments

Figures 10 and 11 display median element concentrations for stream sediments normalized to the median concentrations of Japanese stream sediments (Imai *et al.*, 2004). Stream sediment samples were classified based on the dominant lithology in the watershed (Tables 2 and 3). Ikinoshima Island is mostly covered by both alkaline and non-alkaline mafic volcanic rock (Fig. 2c). The chemical compositions of sediments samples derived from alkaline mafic volcanic rock (a-Mv) and non-alkaline rock (Mv) were mutually consistent. Thus, Ikinoshima samples were classified as a mixture type of a-Mv and Mv (a-Mv+Mv). Similarly, stream sediment samples collected from Hiradojima Island were classified as a mixture of non-alkaline pyroclastic (Py) and mafic volcanic (Mv) rocks (Py+Mv) because these rock types are distributed together in the drainage basins (Table 3).

Geochemical abundance patterns for stream sediments derived from alkaline mafic volcanic rock (a-Mv) were similar among samples collected from the northern islands (Fig. 10a). Stream sediments were enriched with P_2O_5, TiO_2, Cr, MnO, T-Fe_2O_3, Co, Ni, Nb, La, Ce, Pr, Nd, Sm, and Ta, but were poor in Na_2O and CaO compared to Japanese stream sediments. In contrast, some differences were found in the geochemical abundance patterns for stream sediments from Hiradojima, Nagashima, and Sakurajima Islands, where non-alkaline mafic volcanic (Mv) and pyroclastic (Py) rock outcrops were present (Fig. 10b). In contrast with stream sediments derived from alkaline mafic volcanic rock (a-Mv), the abundance ratios relative to Japanese stream sediments were nearly constant among mafic elements (Sc, TiO_2, V, MnO, T-Fe_2O_3, and Co) and among Y and Ln. Volcanic ash deposits on Sakurajima Island were extremely poor in

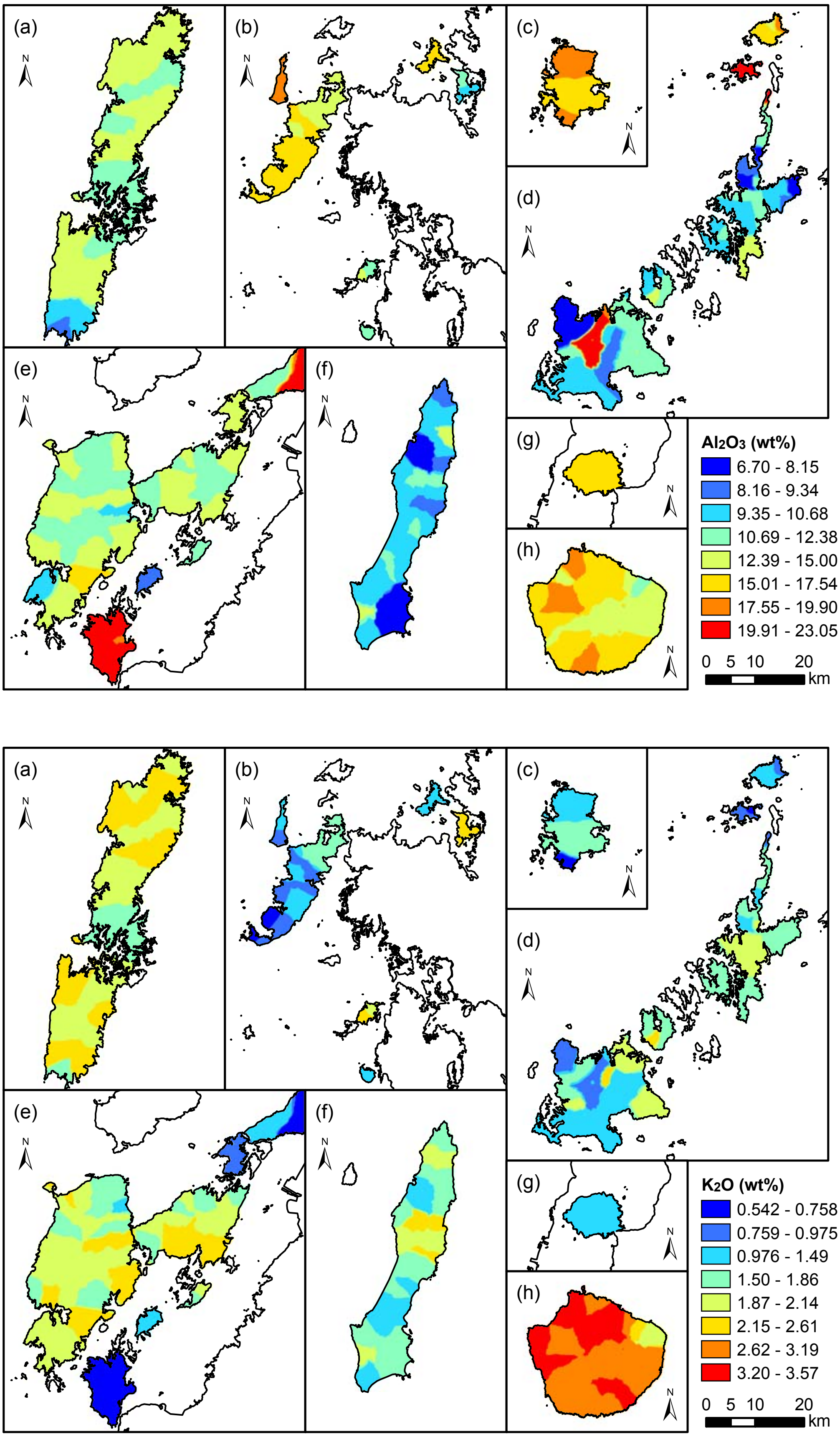

Fig. 5 Spatial distribution of Al_2O_3 and K_2O concentrations on remote islands. (a)-(h) are the same as Fig. 1.

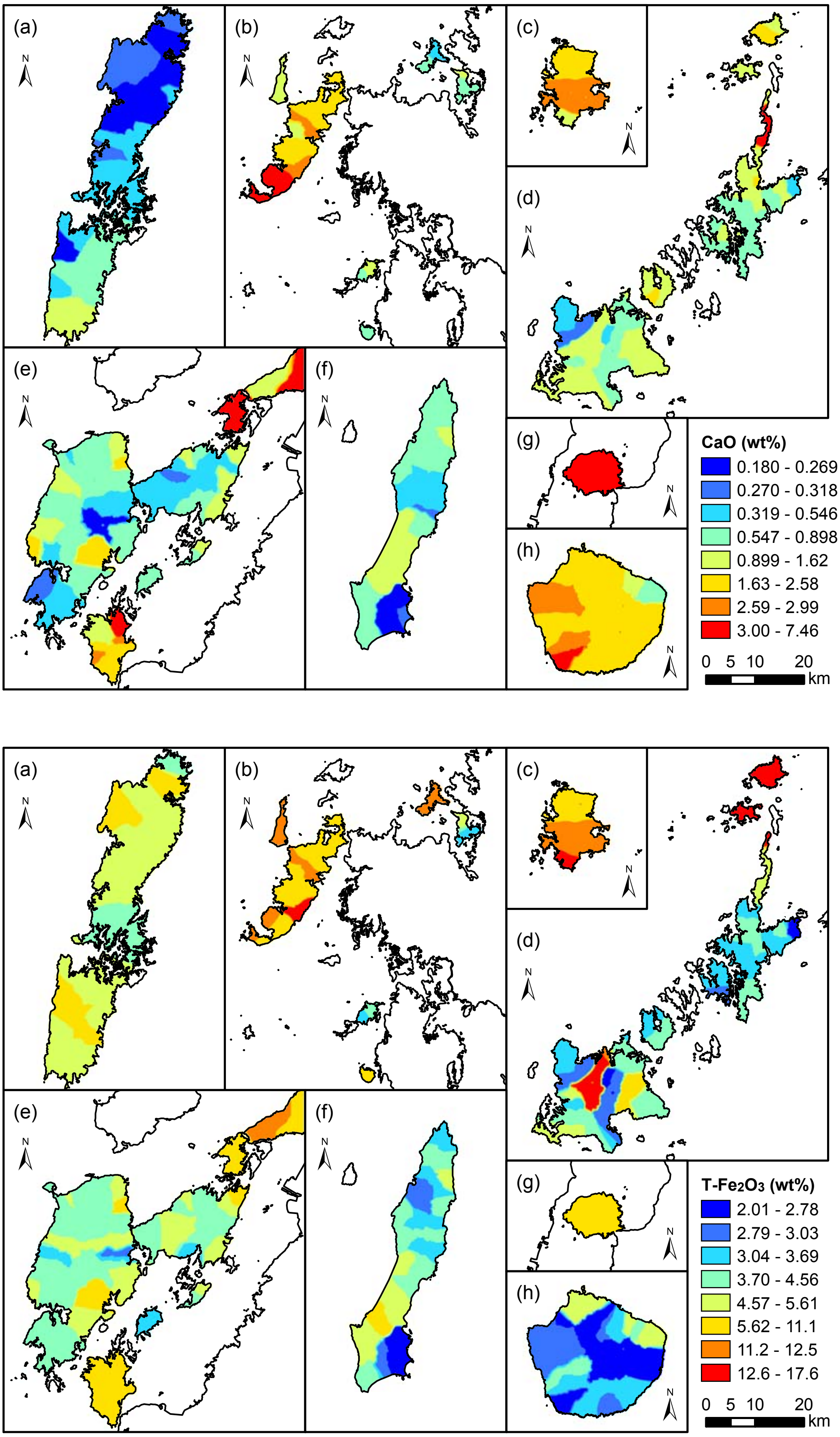

Fig. 6 Spatial distributions of CaO and T-Fe_2O_3 concentrations on remote islands. (a)-(h) are the same as Fig. 1.

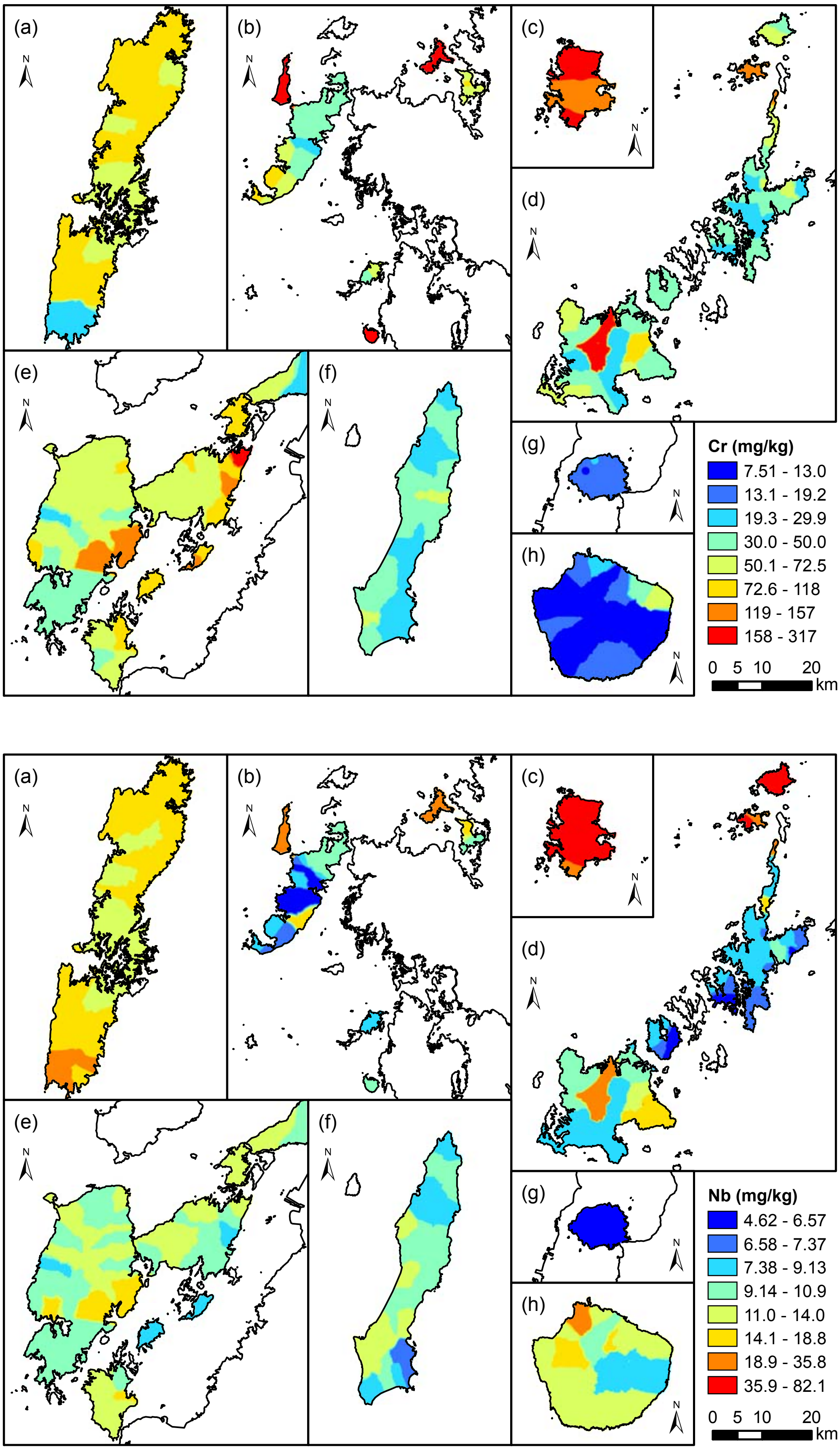

Fig. 7 Spatial distributions of Cr and Nb concentrations on remote islands. (a)-(h) are the same as Fig. 1.

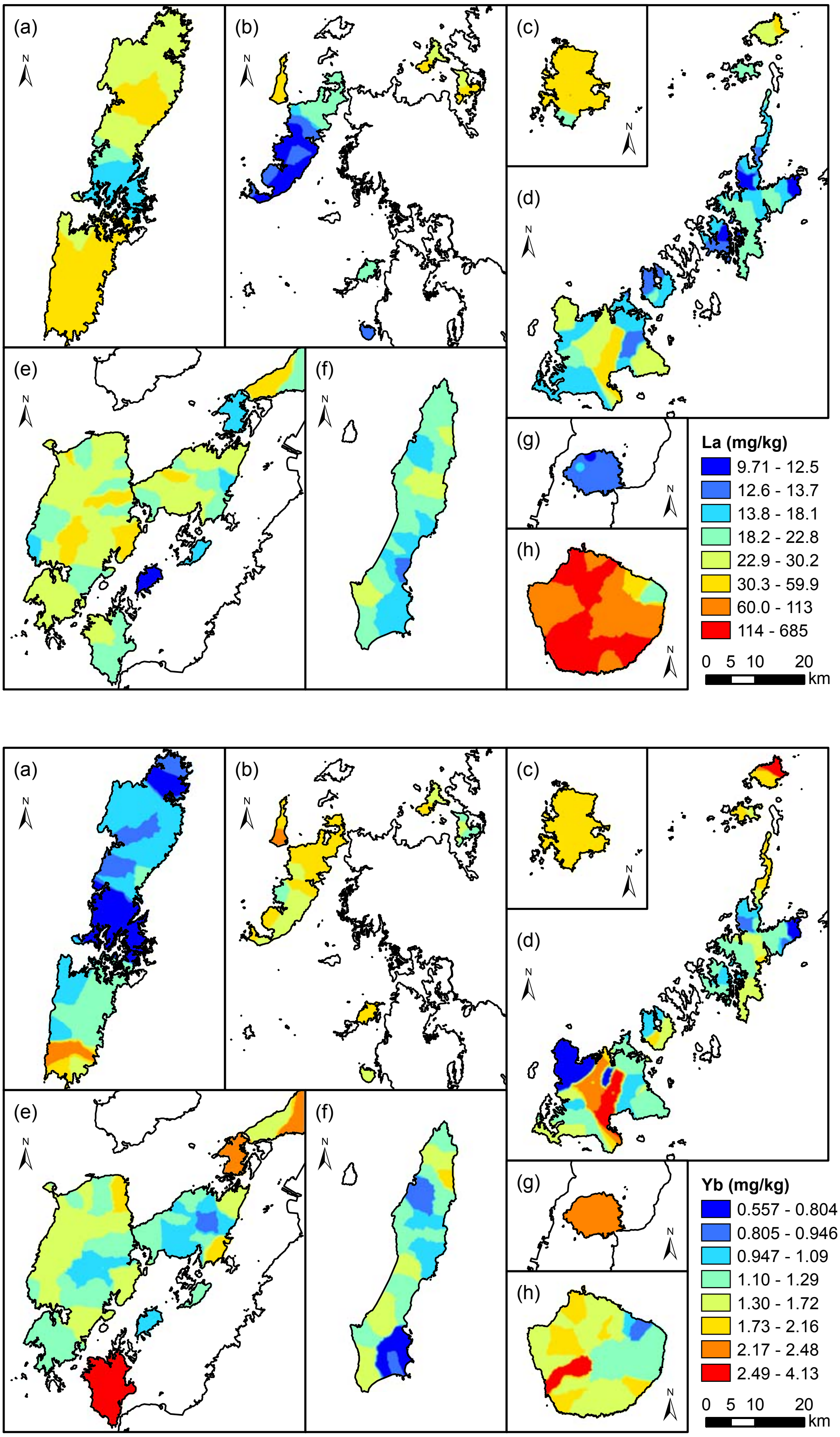

Fig. 8 Spatial distributions of La and Yb concentrations on remote islands. (a)-(h) are the same as Fig. 1.

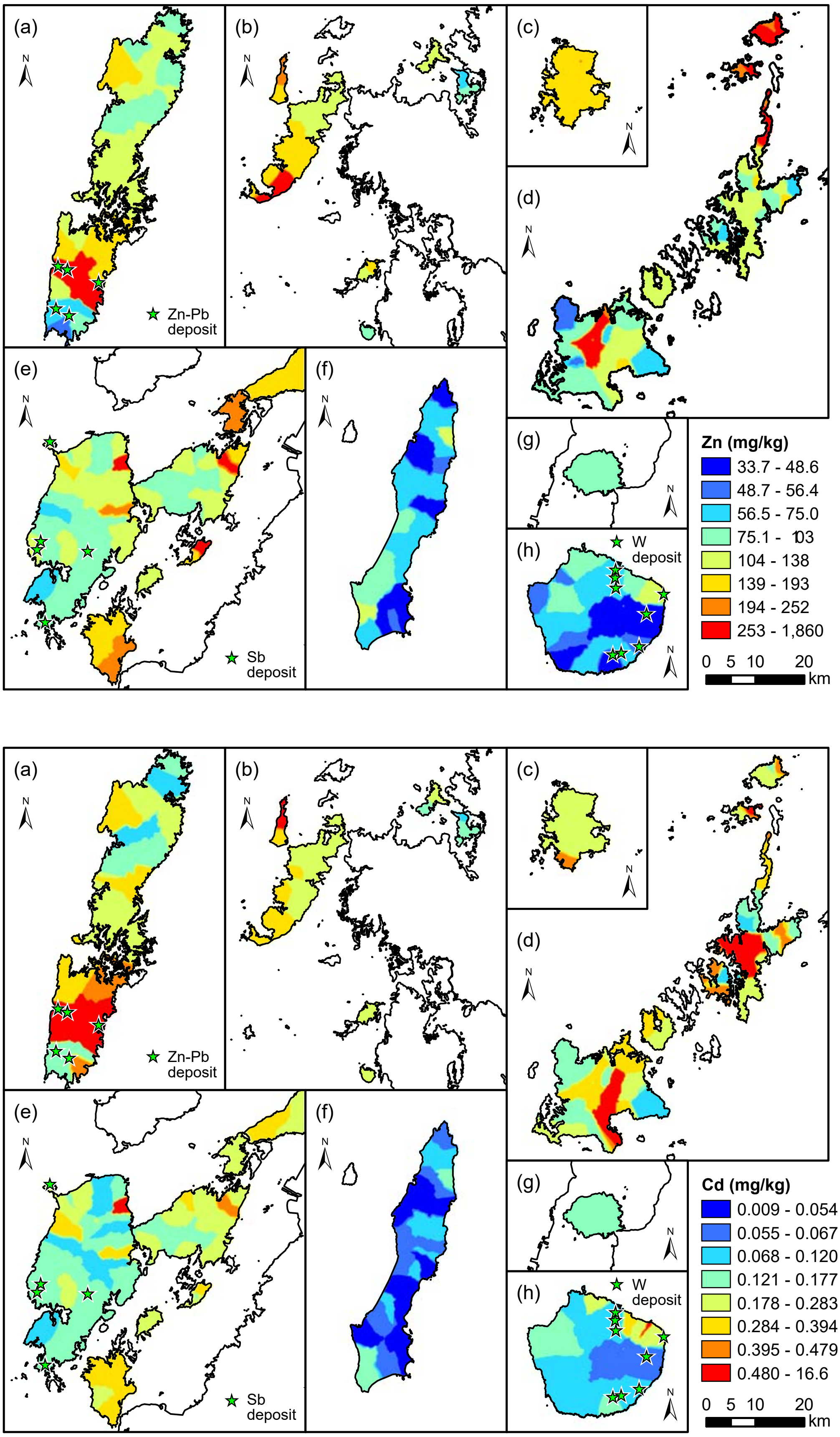

Fig. 9 Spatial distributions of Zn and Cd concentrations on remote islands. Star symbols indicate metalliferous deposits. (a)-(h) are the same as Fig. 1.

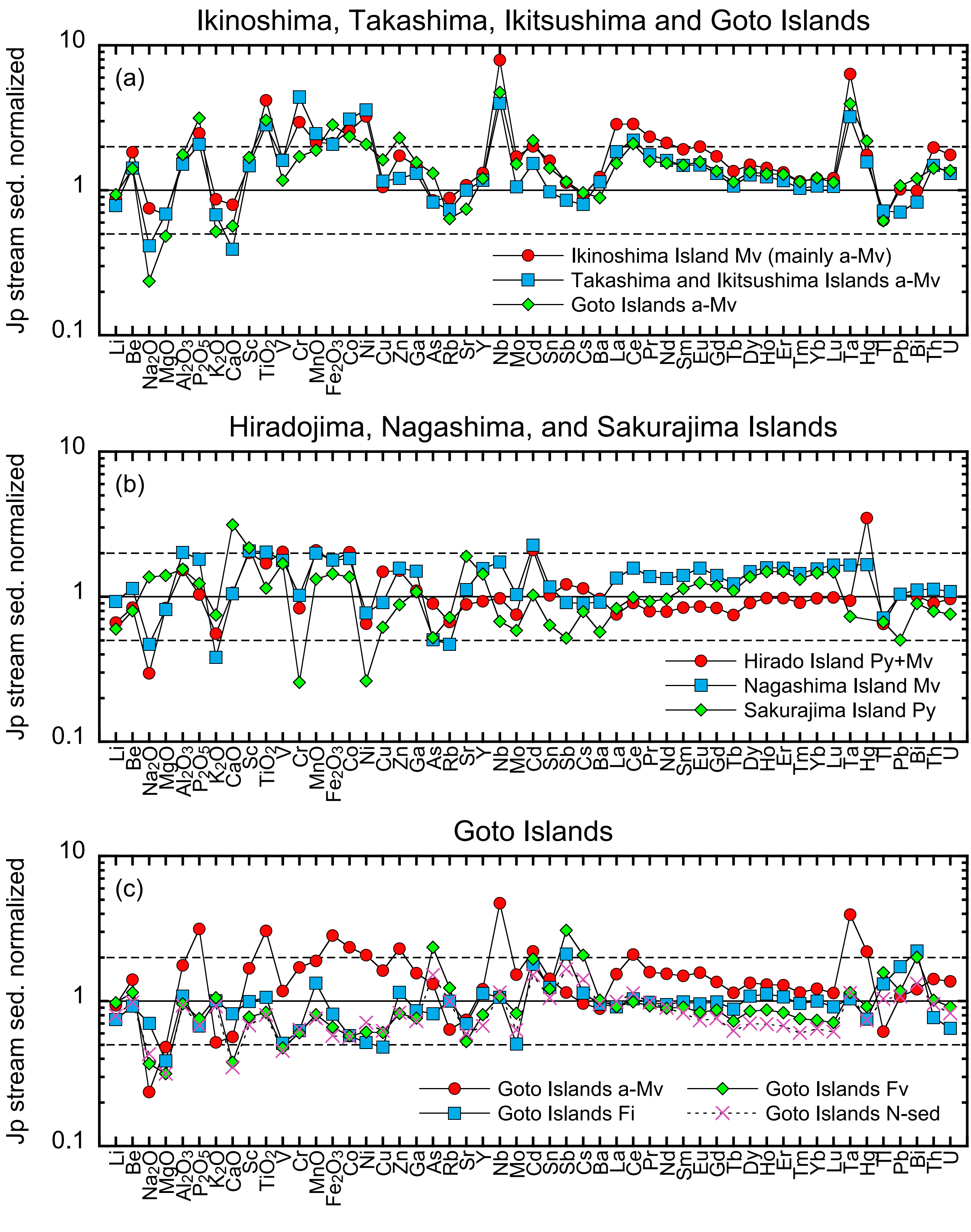

Fig. 10 Chemical composition of stream sediments on isolated islands located in the northern Kyushu region, classified by parent lithology and normalized to median concentrations for Japanese stream sediments, expressed as "Jp stream sed." Stream sediments (a) on Ikinoshima, Takashima, Ikitsushima, and Goto Islands derived from a-Mv; (b) on Hiradojima, Nagashima, and Sakurajima Islands derived from Mv and Py; (c) on Goto Islands derived from a-Mv, Fv, Fi, and N-Sed. [Abbreviations: a-Mv (alkaline mafic volcanic rock), Mv (non-alkaline mafic volcanic rock), Py (pyroclastic rock), Fi (non-alkaline pyroclastic rock), N-Sed (Neogene sediment)]

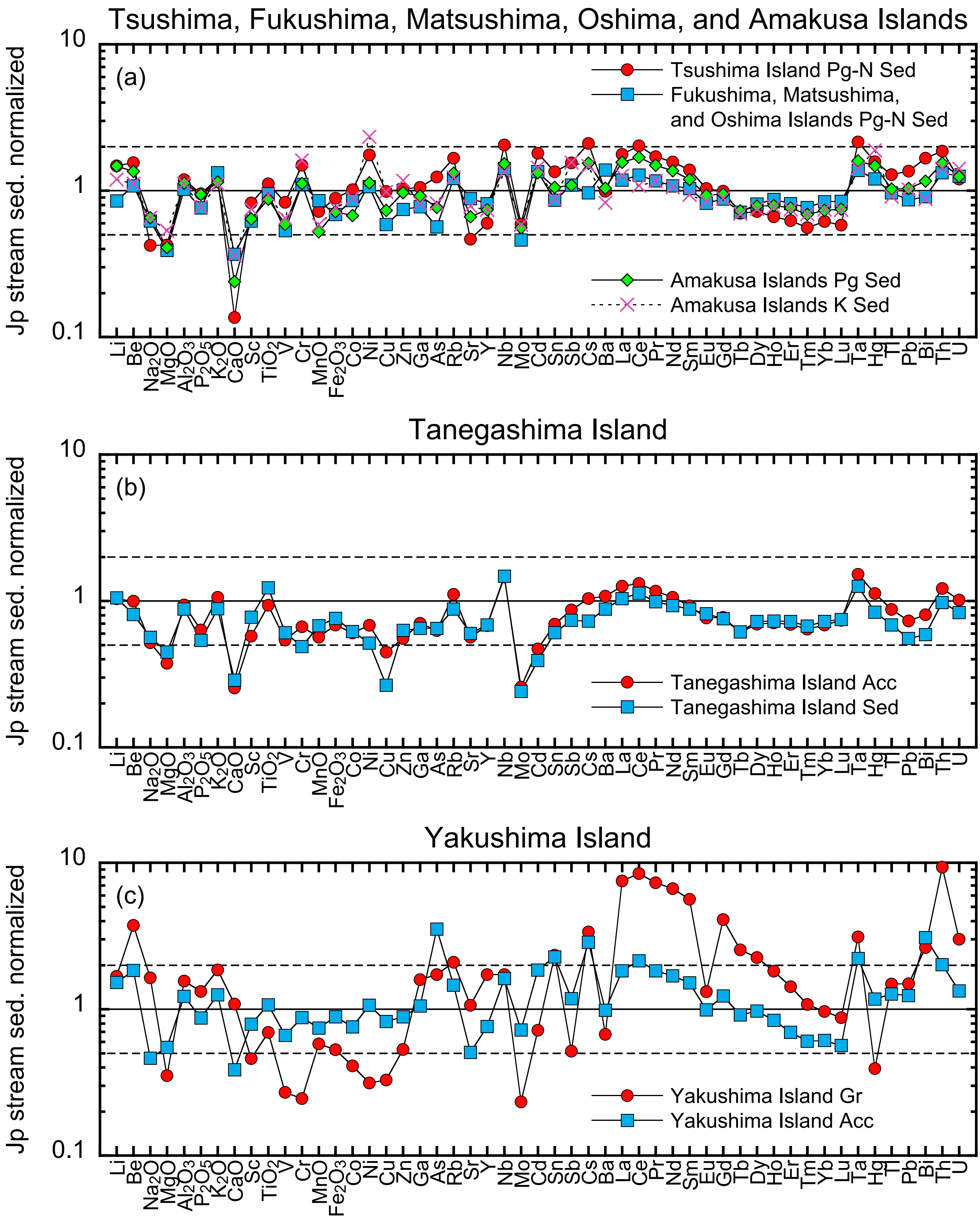

Fig. 11 Chemical composition of stream sediments on (a) Tsushima, Fukushima, Matsushima, Oshima, and Amakusa Islands; (b) Tanegashima Island; and (c) Yakushima Island. Values are classified by parent lithology and normalized to median concentration in Japanese stream sediments, expressed as "Jp stream sed." [Abbreviations: N-Q Sed (Neogene-Quaternary sediment), Pg-N Sed (Paleogene-Neogene sediment), Pg Sed (Paleogene sedimentary rock), K Sed (Cretaceous sedimentary rock), Acc (accretionary complex), and Gr (granitic rock)]

Cr, Ni, Cu, and Zn, but enriched in Na_2O, MgO, CaO, and Sr, and had a low La/Yb ratio compared to stream sediments from Hiradojima Island and Nagashima Island. These different geochemical abundance patterns in stream sediments are caused by the differences in the chemical and mineralogical compositions of the host rocks.

The Goto Islands (Ukujima, Ojikajima, Nakadorijima, Wakamatsujima, Hisakajima, and Fukuejima) are composed of various lithologies (Fig. 2d and Table 2). Stream sediments derived from Neogene non-alkaline felsic volcanic (Fv) and felsic intrusive (Fi) rocks and Neogene sediment (N Sed) have similar abundance patterns (Fig. 10c). Neogene sediments (Sed) in the Goto Islands were deposited in the Late Oligoene to earliest Middle Miocene, and predate the volcanic activity that occurred during the middle to late Middle Miocene. Therefore, the similar abundance patterns indicate that stream sediments in the Goto Islands are simply a mixture of clastic materials derived from the above three lithologies, although the stream sediments were classified into groups according to their representative lithologies. However, stream sediments derived from alkaline mafic volcanic rock (a-Mv) had an abundance pattern different from those for the other lithologies (Fv, Fi, and N Sed) (Fig. 10c) because alkaline mafic volcanic rocks are geographically separated on Ojikajima and Ukujima Islands and are located at separate ends of Fukuejima Island (Fig. 2d).

Stream sediments derived from unconsolidated sediment and sedimentary rock were collected from isolated islands located in distant places (Fig. 11a). However, their geochemical abundance patterns were similar; they all were poor in Na_2O, MgO, CaO, Sc, and V, and rich in Nb and Ta, and had high La/Yb ratios. On the Amakusa Islands, stream sediments derived from Cretaceous sedimentary rock (K Sed) had a chemical composition very similar to that for Paleogene sedimentary rock (Pg Sed), although there was a lower La/Yb ratio in the former. On Tanegashima Island, the geochemical abundance patterns for stream sediments derived from Paleogene accretionary complex (Acc) resembled those for Neogene-Quaternary sediment (N-Q Sed) (Fig. 11b). These results suggest that sediments deposited during the Neogene-Quaternary age originated from the Paleogene accretionary complex, which is found on both Tanegashima and Yakushima Islands. Stream sediments derived from the accretionary complex (Acc) on Yakushima Island had abundance patterns similar to those for the accretionary complex in Tanegashima Island but at greater concentrations (Figs. 11b, c). Sandstone and alternating sandstone and mudstone, a mélange matrix, are the dominant facies on both Tanegashima Island and Yakushima Island (Kawanabe *et al.*, 2004; Saito *et al.*, 2007). However, the exposed areas of mudstone and mud-dominated turbidite in the drainage basins for the Tanegashima and Yakushima samples were 6–27% (10% of median value) and 15–61% (30% of median value), respectively. Consequently, the lower concentrations of elements in the Tanegashima samples must be caused by the dilution effect of quartz because sandstone is more abundant in quartz than in mudstone. Neogene granitic rock that had intruded into the central part of Yakushima Island greatly elevated the Li, Be, Na_2O, CaO, Sr, Y, Ln, Th, and U concentrations in stream sediments, and reduced the MgO, Sc, TiO_2, V, Cr, MnO, T-Fe_2O_3, Co, Ni, Cu, and Zn concentrations (Fig. 11c). The enrichment by Na_2O, CaO, and Sr can be explained by the large amount of plagioclase in stream sediments. The extreme enrichment with Li, Be, Y, Ln, Th, and U was caused by excess accumulation of accessary minerals, such as beryl and monazite, in the fine sand fraction as shown in Fig. 4.

5. Summary

A total of 193 stream sediments were collected from 22 remote islands around Kyushu Island and Uto Peninsula, and 3 volcanic ash deposits were collected from Sakurajima Island. The concentrations of 53 elements in these samples were determined using ICP-AES, ICP-MS, and AAS. The results indicated that 12, 9, 31, 20, and 19 of the stream sediments were derived predominantly from alkaline mafic volcanic rock, Cretaceous sedimentary rock, Paleogene sedimentary rock associated with coal mines, and Neogene granitic rock, respectively. These rock types represent a limited number of outcrops on mainland Japan. The remainder of the samples originated from Neogene-Quaternary sediments, non-alkaline mafic volcanic and pyroclastic rocks, and Paleogene accretionary complexes.

The variation in element concentration with grain size was determined for Sk03, Tn02, Tn09, Tn26, Yk01, and Yk17. The concentrations of many elements in Sk03 showed little change with grain size because sand-sized particles were composed of agglutinated silt-sized volcanic ash. The concentrations of many elements in the remainder of the samples decreased with decreasing grain size from the very coarse sand fraction, reached a minimum for the fine sand fraction, and then increased as the grain size further decreased, resulting in a V-shaped pattern.

Stream sediments derived from mafic volcanic and pyroclastic rocks and volcanic ash deposits were enriched with Al_2O_3, MgO, CaO, P_2O_5, Sc, TiO_2, V, MnO, T-Fe_2O_3, Co, Cu, Zn, and Sr. Alkaline mafic volcanic rock contained highly elevated concentrations of Cr, Ni, Nb, La, Ce, Pr, Nd, and Ta in stream sediments. The stream sediments from Yakushima Island, which are mostly underlain by Neogene granitic rock, were extremely abundant in Be, Na_2O, K_2O, CaO, Sr, Y, Ln, Th, and U. These enrichments can be explained by the large amount of plagioclase and K-feldspar and by accumulation of accessary minerals such as apatite and monazite. Cretaceous–Paleogene sedimentary rocks and Paleogene–Neogene sediments were distributed discretely on Tsushima, Fukushima, Matsushima, Oshima, and Amakusa-kamishima, Amakusa-shimoshima, Goshorajima, and Shishijima Islands.

Nevertheless, stream sediments derived from these rocks had similar geochemical abundance patterns. Furthermore, except for Cr, Ni, and heavy metals, the geochemical abundance patterns for stream sediments originating from Cretaceous-Paleogene sedimentary rocks and Paleogene-Neogene sediments resembled those from Paleogene accretionary complex distributed on Tanegashima and Yakushima Islands. These results suggest that the accretionary and non-accretionary sedimentary rocks have a common origin. Thus, geochemical features of stream sediments on isolated islands are strongly influenced by the parent lithology in their watershed. Finally, although a number of a large-scale metalliferous deposits were limited to remote islands, enrichment with Zn, Cd, and Pb in stream sediments was found near the Zn-Pb mine on Tsushima Island. Similarly, Sb concentrations were significantly greater in stream sediments collected near the Sb mine on Amakusa-shimoshima Island.

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九州離島域の地球化学図作成

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要　旨

本論文では，西南日本離島域を対象とした高密度地球化学図についての報告を行う．九州地方の陸海域地球化学図や現在作成中の広域Sr同位体図における研究調査を補完し強化する事を目的として，193試料の河川堆積物および3試料の火山灰降下堆積物を主に九州周辺の離島から採取し，53元素の分析を行った．堆積物試料中の元素広域分布と地質との関係を地理情報解析ソフトウェアを用いて詳細に調べた．非アルカリ苦鉄質火山岩や火砕岩由来の河川堆積物や火山灰降下堆積物はマグネシウム，カルシウム，スカンジウム，チタン，バナジウム，鉄，コバルト，ストロンチウムに富んでいた．アルカリ苦鉄質火山岩はさらに河川堆積物中のクロム，ニッケル，ニオブ，ランタン，セリウム，プラセオジム，ネオジム，タンタル濃度も増加させた．花崗岩由来の河川堆積物は，ベリリウム，ナトリウム，カリウム，カルシウム，ストロンチウム，イットリウム，スズ，ランタノイド元素，トリウム，ウランに富んでいた．付加帯・非付加帯堆積岩は河川堆積物中のニオブやタンタル濃度を増加させたが，ナトリウム，マグネシウム，カルシウム，ストロンチウム濃度を低下させた．これらの地球化学的な特徴は，砕屑物中の母岩から供給された主要造岩鉱物（例えば石英，斜長石，カリ長石，苦鉄質鉱物）や副成分鉱物（例えば，アパタイトやモナザイト）の相対的な存在量によって説明が可能である．また，亜鉛・鉛鉱床が対馬の河川堆積物中の亜鉛，カドミウム，鉛濃度を高め，アンチモン鉱床が天草下島の河川堆積物中のアンチモン濃度を高めたことが確認された．