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Article

Geochemistry of stream sediments in the watersheds of Lake Shinji and Lake Nakaumi

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Abstract

Lakes Shinji and Nakaumi are parts of an important fluvio-lacustrine and estuarine system in Shimane prefecture, SW Japan. The Hii River provides much of the detrital load to these lakes, but other smaller rivers and streams could also contribute significant detrital flux. To characterize the composition of this locally derived detritus, 33 stream sediment samples were collected form the Iinashi and Iu Rivers, which feed into Lake Nakaumi. Thirty-one samples were also collected from the Tamayu and Kimachi Rivers, which enter Lake Shinji from the south, and from small streams that enter from the north. Twenty-five basement whole-rock samples (granitoids and volcanics) were also collected. Two size fractions (< 180 and 180-2000 μm) of the stream sediment samples and the whole rocks were analyzed by X-ray fluorescence for major element and 14 trace elements. Bulk compositions of the stream sediments were also calculated, based on the proportions of the size fractions. The results show that compositions of bulk main channel sediments and 180-2000 μm fractions in the Iinashi, Iu, Tamayu and Kimachi Rivers are highly depleted relative to Upper Continental Crust (UCC), reflecting the composition of the granitoids that dominate their watersheds. In contrast, the < 180 μm fractions in these rivers have compositions very similar to UCC, reflecting their clay and heavy mineral content. Bulk sediments and fractions in sediments from North Shinji streams show little internal contrast and UCC-like composition, reflecting their derivation mainly from Josoji and Furue Formation mudrocks. Stream sediments in tributaries containing only single lithotypes also show variable contrast between size fractions, with greatest fractionation in granitoid-derived sediments, and least in those derived from intermediate-acid volcanic rocks. The results overall show that suspended and bedload sediments supplied to Shinji and Nakaumi will vary spatially according to the geology of the river watersheds. Spatial geochemical variations may thus also occur within the lakes, by storage of coarser 180-2000 μm detritus in the river deltas and at lake margins, and outwash of <180 μm material to more distal sites of deposition.

Key words: Geochemistry, stream sediments, rivers, size fractions, Shimane

Introduction

By their very nature, stream and river sediments broadly reflect the composition of the lithologies present in their drainage basins. Studies of the bulk chemical compositions of river and stream sediments or of fractions of such sediments provide important and valuable baseline data. Such data can be used in many geological and environmental fields, including baseline environmental surveys, mineral exploration, and in construction of geochemical maps. However, the chemical composition of stream sediments does not necessarily directly reflect that of their source rocks. Factors including the extent of source area weathering, sorting and average grain size, localized heavy mineral concentration, and alluvial storage or flushing of fine material can cause large contrasts between the source and sediment composition. Many other factors may also influence compositions. Johnsson (1993) gives an excellent review of the influence exerted by the main factors and processes.

Recent studies of this type in Japan have concentrated on the preparation of geochemical maps, which have applications for environmental assessments and establishment of background levels of many elements, especially those with possible environmental impact (e. g. Shiikawa, 1991). Other studies have used stream sediment data for mineral exploration (e. g. Moritsuna, 1974; Yamamoto, 1999). Stream sediment data thus represents basic information which can be put to a number of uses.

Stream sediment studies are normally based on analyses of the <180 μm fraction of the bulk sediment (e. g. Koval *et al.*, 1995; Licht and Tarvainen 1996; Ferreira *et al.*, 2001; Amorosi *et al.*, 2002). This is done to minimize the effects of grain size, so that differences between the mean grain sizes of individual samples are reduced. However, the composition of the <180 μm fractions may not necessarily reflect the bulk composition of the source rocks, and hence original provenance signatures may be obscured.

Recent work in the San'in district by Ortiz and Roser (2006a, b) examined major and trace element provenance signatures in stream sediments from the Kando, Hino, and Hii Rivers. Major element and trace element analyses were made of two size fractions (<180 and 180-2000 μm). The <180 μm fractions were found to be depleted in SiO_2 and enriched in most other major and trace elements relative to the 180-2000 μm fractions. These studies characterized the composition of the bedload in these three significant river

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systems. They also identified characteristic fingerprints of individual rock types in proximal tributaries, especially of adakitic detritus derived from Mt. Daisen and Mt. Sambe, of ultrabasic rocks in the headwater of the Hino River, and of Hata and Omori Formation volcanic rocks. The intensity of these provenance signatures varied depending on the position in the river, and the extent to which the sediments had been diluted by detritus derived from the granitoids that formed most of the basement in the area.

These studies aside, the data available for stream sediments from local rivers entering Lake Nakaumi and Lake Shinji is limited. The aim of this study is to report the geochemical compositions of stream sediments (< 180 and 180-2000 μm fractions) from the Iu and Iinashi Rivers, both of which enter Lake Nakaumi, and from the Tamayu and Kimachi Rivers and small streams that supply sediments directly to Lake Shinji (Fig. 1). Nakaumi and Shinji collectively form a very important brackish lagoon system. Many studies of these lakes have examined their paleontology, hydrology, organic geochemistry and other aspects, but the only information on the composition of the sediments entering these water bodies is that for the Hii River given by Ortiz and Roser (2005). Although the Hii River supplies the bulk of the sediment flux to the Shinji-Nakaumi lagoon system, it is also useful to characterize the composition of the sediments supplied from the smaller rivers listed above. We also examine the fractionation between the size fractions, and elemental contrasts between source rocks and the stream sediments. The data contained in this report are a valuable resource for future studies of the Shinji-Nakaumi system.

Catchments and sample suites

Samples for this study were collected between March and May, 2008. Sampling was carried out only on fine days and when stream were clear, a minimum of two days after any significant rainfall.

Iinashi River

The Iinashi River valley lies to the west of the Hino River watershed, and is adjacent to that watershed in the southeast. The Iinashi flows into Lake Nakaumi (Fig. 1), whereas the Hino River discharges into Miho Bay. The Iinashi drainage basin has an area of ～208 km^2, and therefore is much smaller than that of the Hino River (870 km^2) and the Kando River basins (471.3 km^2) studied by Ortiz and Roser (2006a, 2006b).

Hata Formation andesite is widely distributed in the west of the Iinashi catchment, whereas most of the rest consists of granitoids. Hata Formation is exposed in a small range of hills trending NW-SE and lying to the west of the main channel of the Iinashi River. Lithotypes in the Hata Formation include aphyric andesite and common hornblende plagioclase andesite; amphibole hornblende dacite lava is also present. Dacite pyroclastic flow sediments and volcanoclastic sediments also occur.

Fube granite is widely distributed over the southern part of the catchment, as are the Shimokuno and Hiyodori granites (Kano *et al*., 1993). Fube granite is distributed around Yasugi town in the Yasugi city district, and in Okutawara and Hirose town of the Yokota area, in a belt 22 km in length and 10 km in width, trending in a northeast-southwest direction. The lithofacies consists of medium-grained biotite granite, although some finer-grained varieties also occur in the eastern part. Petrologically the Fube granite is described as medium-grained biotite granite. The major minerals are quartz, K-feldspar, plagioclase, and biotite. QPK ratios are Q = 50% P = 30%, K = 40% (Kano *et al*., 1993). Accessory minerals include iron oxide (magnetite), muscovite, apatite, and zircon.

Shimokuno granite is distributed in a long and slender belt running from the vicinity of Kisuki town (Sakamizu) to Daito, to the Yokota area northwest, and in the Matsue area. The belt trends to the northeast, and is over 23 km in length and 2-3 km in width. The Shimokuno granite is a fine-grained biotite granite, and major minerals include quartz, plagioclase, and K-feldspar, in the proportions Q = 40% P = 30%, K = 50% (Kano *et al*., 1993). Accessory minerals are represented by biotite, muscovite, iron oxide (magnetite), allanite, and zircon.

Hiyodori granite is distributed around the margins of the Daito granodiorite, and consists of biotite granite with accompanying amphibole-biotite granite. The type locality is in Daito town (Hiyodori) in the Imaichi area. The typical lithofacies consists of medium grained biotite granite. Plagioclase, quartz, K-feldspar, and biotite are the major minerals, along with iron oxides, apatite, and zircon as accessory minerals.

The sample suite for the Iinashi River consists of 16 stream sediment samples and seven basement rock samples (Fig. 1). Seven of the stream sediment samples were collected from the main channel (MC), and the remainder from tributaries dominated by single rock types (andesite or granite) or a mixture of the two. The basement rocks samples comprise two Hata andesites and five granitoids. Some granitoids were collected from mildly weathered outcrops, but would be representative of the material supplied to the river. Basement rock analyses contained in this report should not, however, be used for petrogenetic interpretation.

Iu River

The Iu River catchment is much smaller than that of the Iinashi (Fig. 1), with a drainage basin with an area of only ～33.1 km^2. Although the Iu River drainage basin is small, its geology is locally complex. The catchment is mainly floored by three rock types. Omori Formation dacite dominates in the lower reaches, and Kuri Formation rhyolites crop out in both the upstream and downstream regions. Hiyodori granite occupies the central part. The geological description given below is based on the report of Kano *et al.* (1993).

Omori Formation dacite is distributed in Okusa town, east

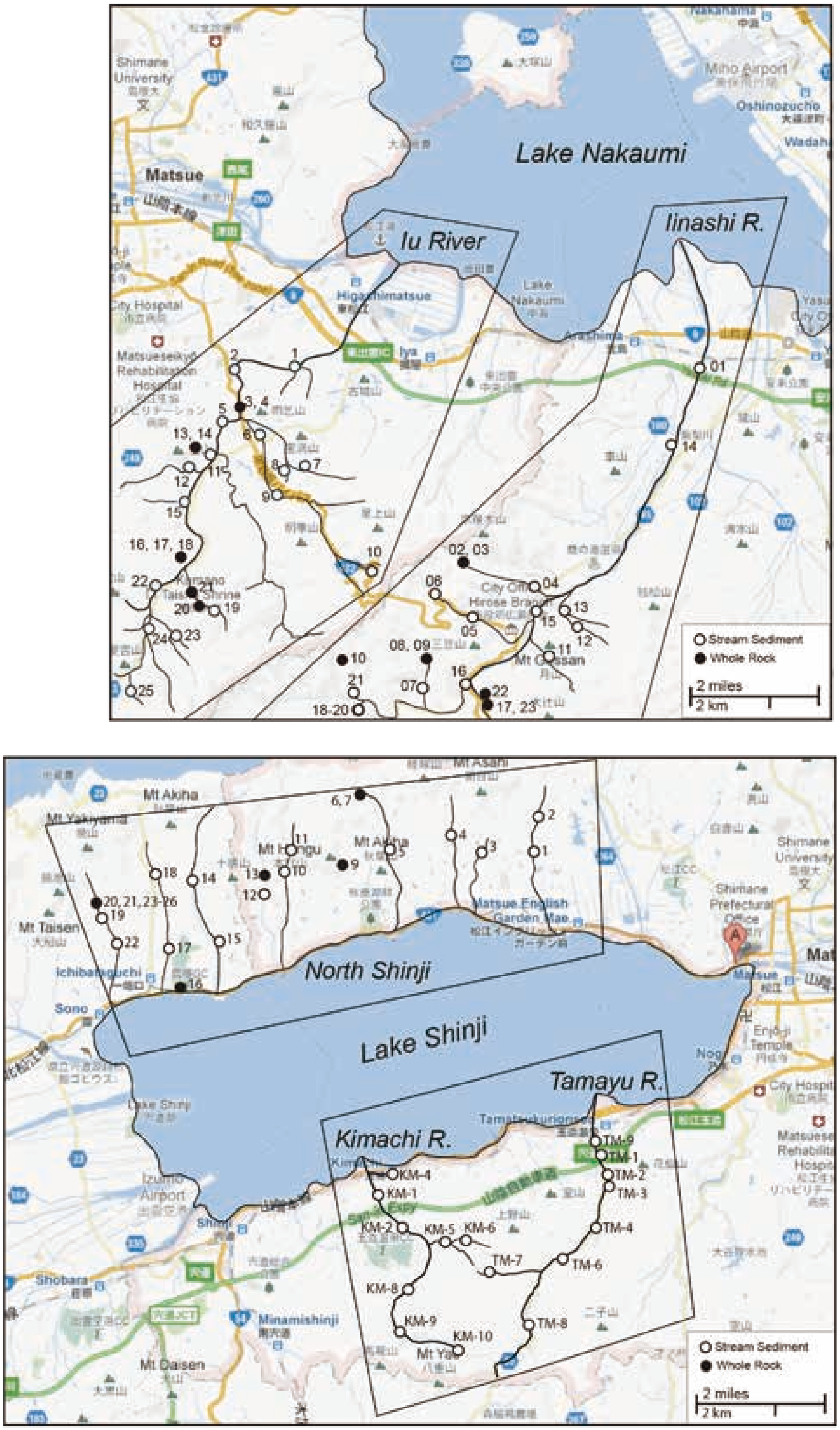

Fig. 1. Locations of Lakes Nakaumi and Shinji, the rivers sampled, and sample sites. Base figures from Google Maps.

Adakae, the east Matsue area, and Sakusa town to Tamayu town in Kasenzan. The Omori dacites are massive, but blocky andesite lavas with platy joints also occur. Kuri Formation rhyolite is distributed intermittently in the south of the Shinji belt. The Kuri rhyolites are represented by lavas and rhyolite volcanic breccia. The lithofacies consist of mudstone and rhyolite lava, along with pyroclastic rocks. Hiyodori granite is distributed around the margins of the Daito granodiorite in Daito, from Yakumo village (Kumano) north to Higashi Izumo town (Ichihara area).

The Iu River sample set consists of 17 stream sediments and eight outcrop samples. Four of the stream sediment samples were collected from the main channel, and the remainder from tributaries dominated by Kuri rhyolite (n = 5), granite (4), or a mixture of lithologies. The basements rocks samples consist of granites (4), Omori dacite (2) and Kuri rhyolite (2).

Tamayu and Kimachi Rivers

The Tamatsukuri and Kimachi valleys lie on the southern shore of Lake Shinji (Fig. 1). The Tamayu and Kimachi Rivers run almost perpendicular to the shore of Lake Shinji, and have catchments composed of Miocene volcanic and sedimentary rocks adjacent to the lake, and Paleogene granitoids further inland. The Miocene rocks occur in a strip 3-5 km wide, striking parallel to the southern shoreline of Lake Shinji and dipping gently to the north. The Miocene rocks distributed in the field area are mainly composed of the Kawai, Kuri, Omori and Fujina Formations, in ascending stratigraphic order (Kano *et al.,* 1991).

The Kawai Formation accumulated in terrestrial environments and is composed of conglomerate, sandstone derived from granites and andesite lavas, dacite pyroclastic flows and volcanic sediments. Kawai Formation is distributed from Matsue to the Imaichi area (Kano *et al.,* 1988, 1991). The Kuri Formation is of similar age, and interfingers with the Kawai Formation. The Kuri strata accumulated in a marine environment. Kuri Formation is composed of mudstone, dacite, rhyolite pyroclastic flow sediments, and lavas.

The Omori Formation unconformably overlies the Kuri Formation. The lower part of the Omori Formation is composed of andesite and dacite lavas erupted on-land or in a shallow sea, which are succeeded by conglomerate. The upper part of the formation is composed of sandstones deposited in beach or shallow marine environments. The sedimentary rocks are derived from the andesite lavas beneath, and some are interpreted as gravity flow sediments. The conglomerates contain abundant angular to subrounded andesite clasts, and pass upwards into medium grained volcaniclastic sandstones of the "Kimachi" horizon, noted locally as a building stone.

The Omori sandstones pass upward into the Fujina Formation, which is composed of siltstones and very fine-grained sandstones containing abundant plant material. Fujina Formation accumulated in a shallow sea to offshore marine environment.

The catchments of the Tamayu and Kimachi Rivers also contain Cretaceous to Paleogene granitoids in their upper reaches (as described above), and these more felsic lithotypes would have supplied the bulk of the bedload, especially in the Tamayu River. The sediments supplied from these two rivers will thus be a mixture of chemically intermediate and more felsic detritus.

Seventeen stream sediment samples were collected from the Tamayu (n = 8) and Kimachi (9) rivers. Of these nine were from the main channels, and the remainder from tributaries dominated by granitoids (n = 6) or Miocene sediments (2). The stream sediments in the lower reaches of the Tamayu River differed from those in the Kimachi River. The Tamayu sediments were quite fine grained (fine-medium sand), and were obviously rich in quartz and feldspar. In contrast, the Kimachi River sediments were often coarser, and had a greater proportion of rock fragments, and contained much less fine-grained material.

North Shinji Rivers

Shimane Peninsula trends roughly east-west, and consists of a rugged range of hills ranging up to 358 m (Mt. Honguusan) in altitude. Streams running into Lake Shinji thus trend roughly north-south, and are relatively straight and evenly spaced along the northern shore of the lake (Fig. 1). Steepest gradients occur in the northern part of the peninsula. Streams in the southern part have shallow gradients and occupy valleys with flat floors that are used for rice cultivation. Samples were collected from a 30 km by 10 km rectangular zone on the northern shore of Lake Shinji. Three main formations crop out in the field area. These are the Koura, Josoji and Furue Formations, in ascending stratigraphic order. The formations also trend east to west, following the topographic trend of the peninsula.

Koura Formation is mainly distributed along the northern coast of Shimane Peninsula. These outcrops lie on the northern side of the drainage divide in the peninsula, and so would not contribute any sediment to Lake Shinji. However, two bodies of Koura Formation occur in uplands in the headwaters of the Ono and Aika Rivers, and these could contribute some detritus to the middle part of Lake Shinji. The Koura Formation consists mainly of interbedded sandstones and argillaceous rocks (Kano *et al.,* 1991). Some conglomerates also occur, and 10-20 m beds of acid tuff and andesite volcanic breccia are also present.

Josoji Formation is extensively distributed in the study area, running in an east-west belt in the mountainous districts in the central part of the peninsula. The formation is lithologically complex, consisting of black argillaceous rocks, rhyolite lavas, volcaniclastic rocks, and some andesite lava (Kano *et al.,* 1991). The rhyolites from a large mass in the west of the field area around Ofunayama and Higasen near Hirata town; a second mass is also found in the east around Josoji and Asahiyama. Several smaller bodies also occur in the Ono and Ino rivers. The rhyolite pyroclastic rocks consist of graded pumice lapilli tuffs and tuff. These form layers of several centimeters to several meters in thickness, alternating with tuffaceous sandstone and argillaceous rocks. However, black shales form the bulk of Josoji Formation in the central part of the peninsula.

Furue Formation is widely distributed in Shimane Peninsula, cropping out in a series of low hills in an east-west trending belt running along the northern shore of Lake Shinji. The thickness of the formation is about 600-900 m in the west, thinning to about 450 m in the east side (Kano *et al.*, 1991). The lithofacies are mainly black or grey mudstones or siltstones. Lamellae of rhyolite tuff and sandstone may also be present.

Miocene dolerites occur as sheets and intrusive bodies in the Josoji and Koura Formations. The largest body is found in the hills between the headwaters of the Ono and Aika rivers, intruding both the Koura and Josoji Formations. Although the dolerites are not volumetrically abundant, their more mafic chemistry may impact on the composition of the stream sediments.

Most of the Furue outcrops observed in this area were moderately weathered and bleached to a pale grey or cream shade, and slaking and incipient spheroidal weathering were common. The ease with which Furue mudstones weather accounts for the form of the low rounded hills in this belt. The distribution of the Furue Formation also corresponds with the widest parts of the valleys, and cultivation of rice in paddy fields. In much of this zone the watercourses were completely concreted, and no stream sediment samples could be collected.

Fourteen stream sediment samples were collected from the upper reaches of eight small rivers that flow into Lake Shinji, along with 10 samples from source rock outcrops. Of the stream sediments analyzed, three were derived from streams draining mixed Josoji mudstone-rhyolite source rocks, three from Josoji rhyolites, five from Josoji mudstones, and three from Furue mudstones. The fine-grained nature of the source rocks meant insufficient 180-2000 μm fraction could be separated for analysis at six sites, and in one sample insufficient < 180 μm fraction could be recovered. The basement rocks analyzed comprise five Josoji rhyolites, four Josoji mudstones, and one Furue mudstone.

Sampling Method and Treatment

Stream sediment sampling was carried out using the same method in all four areas. At each site 4-8 sub-samples were collected from free-flowing active channels, using a plastic water scoop. The sub-samples were collected over a channel length of ~50 m, where possible from both sides of the stream, and combined as a single representative sample. Sites where sediments were impounded by dams or weirs were avoided, as were sites where heavy minerals could accumulate. Sample weights varied according to the texture of the sediments at individual sites, with as little as 500 g collected from sites where sediments were well-graded, and up to 1500-2000 g where bedload was coarse.

The bulk stream sediment samples were dried in stainless steel trays at 110˚C for several days, and then homogenized by coning and quartering. Samples were then dry sieved to remove granules and pebbles coarser than 2 mm. The resulting < 2 mm fraction was then split using a simple aluminum chute. The splits of the < 2 mm fractions were then hand sieved through stainless steel sieves to separate the <180 and 180-2000 μm fractions. The number of splits sieved varied with the grain size of the individual sample, with sieving continuing until sufficient weight (10 g) of the <180 μm had been separated. Weights of the two fractions at each site were recorded so the bulk compositions at each site could be approximated based on their proportions. Ten gram splits of the < 180 μm fractions were then ground in an automatic agate pestle and mortar for 15 min. The larger 180-2000 μm fractions were crushed for approximately 30-45 seconds in a tungsten carbide ring mill.

Whole rock samples were reduced to < 1 cm chip using a manual hydraulic rock splitter. Chip containing veins or strongly weathered samples, but pervasively weathered chip was retained, as representative of the material transported to the rivers. The chipped samples were washed in distilled water to remove any dust, and dried at 110˚C for 24 h before crushing in a tungsten carbide ring mill as above.

XRF analysis

Splits of both fractions were then stored in glass vials and dried at 110˚C for at least 24 hours before determination of loss on ignition (LOI). Gravimetric LOI determinations were made by weighing the dried samples into ceramic crucibles, followed by ignition in a muffle furnace at 1000˚C for at least 2 hours. Loss of ignition was then calculated from the net weight loss. The ignited material was then manually crushed in an agate pestle, and dried at 110˚C for at least 24 hours. This ignited material was used for preparation of glass fusion beads for the XRF analysis.

All analyses were made on beads prepared with an alkali flux consisting of 80% lithium tetraborate and 20% lithium metaborate, using a sample to flux ratio of 1:2 (Kimura and Yamada, 1996). The beads were then analyzed for major elements and 14 trace elements using a Rigaku RIX2000 XRF at Shimane University, based on the instrument conditions and calibration described by Kimura and Yamada (1996). In each batch of samples, calibration and drift were monitored using a secondary set of 10 rock standards produced by the Geological Survey of Japan, with compositions ranging from basalt to granite, and also two shales. This range in composition matched that observed in the stream sediments and the whole rock samples. Additional descriptions of the sample preparation and analytical methods used here are given by Roser *et al*. (1998, 2000, 2003), and Ortiz and Roser (2004a, b; 2005).

Results

The results for each river are summarized in Table 1 (anhydrous basis), with averages given for bulk sediments, and for the 180-2000 and < 180 μm fractions. Separate averages are given for main channel samples (MC), for tributaries dominated by single lithologies, including granitoids (GD), volcanic rocks (VD), and sedimentary rocks (SD), and for the granitoids and volcanic rocks analyzed. No averages are given for tributaries with mixed sources, but compositions of these are likely to be close to those of the main channels. The main channel samples are most representative of the bulk sediment bedload entering Lakes Shinji and Nakaumi from these local sources. Averages for the < 180 μm fractions are more likely to represent the composition of the suspended sediment carried into distal parts of the lakes, whereas the 180-2000 μm fractions will be representative of the coarser bedload deposited in the river deltas and around the lake shores.

Results for the two fractions and calculated bulk compositions are listed in Table 2. Results for both fractions are reported for all samples except for six from North Shinji, in which insufficient sample could be recovered for analysis of both fractions. In these cases the fraction analyzed is also reported as the bulk composition. Proportions of the fractions in individual samples are listed in Table 3. In the Iinashi, Iu, Tamayu and Kimachi Rivers the 180-2000 μm fraction was by far the largest, ranging from 63.6% to 99.7% of the total < 2000 μm sample, averaging 94.1%. The 180-2000 μm fraction also formed 96.6% of the sample in the 10 North Shinji samples from which both fractions could be recovered.

Discussion

The results show that average compositions of the fractions and bulk sediments show considerable variation between the rivers (Table 1). Average SiO_2 contents range from 63.10 wt% (Tamayu MC < 180 μm) to 81.46 wt% (Iinashi GD 180-2000 μm), and those for Al_2O_3 from 10.54 wt% (Iinashi GD 180-2000 μm) to 18.62 wt% (Kimachi MC < 180 μm). Ranges of averages for other major elements show even greater proportional contrast (e.g. TiO_2 0.15-0.87 wt%; Fe_2O_3 0.95-10.65 wt%; MgO 0.25-2.34 wt%; CaO 0.24-2.47 wt%; Na_2O 0.97-4.09 wt%; K_2O 1.89-4.29 wt%; Table 1). For these elements, average abundances are higher in the < 180 μm fractions, reflecting association with the clay fraction. Several trace elements show comparatively limited contrasts between fractions, with averages for Ba ranging from 401-550 ppm, Rb from 65-170 ppm, and Sr from 55-242 ppm (Table 1), suggesting presence both in feldspars and in clays. Elements likely to reside in heavy minerals (Zr, 52-786 ppm; Ce 18-103) and Fe-oxides or ferromagnesian phases (Cr, 5-149 ppm; Ni 4-52 ppm; V, 7-197 ppm) also show very large variations, with highest concentrations in the < 180 μm fractions. This is also the case for most of the remaining trace elements.

The differences in the averages noted above are caused by a combination of the varying proportions of lithotypes in individual catchments, variable weathering, and mineralogical fractionation between quartz, feldspar and lithic-rich 180-2000 μm fractions and clay-rich < 180 μm fractions. To compare the compositions of the sediments in the individual rivers, average MC values were normalized against the Upper Continental Crust (UCC) composition of Taylor and McLennan (1985).

The UCC_N patterns for the MC bulk compositions of the Iinashi, Iu, Tamayu and Kimachi Rivers have very similar shapes, with nearly all elements except SiO_2 being depleted relative to UCC (Fig. 2). Depletion is particularly marked for the mobile elements CaO, Na_2O and Sr, all of which are liable to loss during weathering (Nesbitt and Young, 1984), and for ferromagnesian elements (MgO, Fe_2O_3, TiO_2, Ni, Cr, V) which are typically strongly depleted in felsic volcanic rocks such as granites. The Iinashi MC sediments, with the largest area of granitoids in its source, show the greatest depletion in these elements, whereas the Kimachi River shows the least. These features suggest the bulk sediment composition in these four rivers is mainly determined by the volume of granitoids in their sources south of Lake Shinji and Lake Nakaumi. In contrast, the UCC_N pattern for the MC sediments in the small streams north of Lake Shinji is almost flat, with elements in the segment Nb-Al_2O_3 being present in abundances similar to or slightly less than UCC, whereas the ferromagnesians Sc-V are only slightly enriched (Fig. 2). The most notable depletion is for CaO. This depletion and the flat pattern overall is consistent with inheritance from the Josoji and Furue shales which form most of the Shimane Peninsula source. The contrast between the patterns for North Shinji and Tamayu-Kimachi shows the sediments

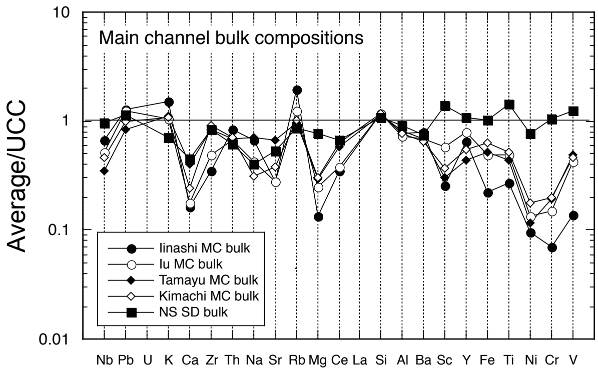

Fig. 2. Average compositions of main channel bulk sediments normalized against the average Upper Continental Crust (UCC) values of Taylor and McLennan (1985). Elements are arranged from left to right following increasing order of normalized abundance (UCC_N) in average Mesozoic-Cenozoic greywacke (Condie, 1993), following the method of Dinelli *et al.* (1999). Major elements are normalized as oxides, trace elements as ppm. Stream sediment averages from Table 1.

entering Lake Shinji from the north and south have very different compositions. This could lead to spatial variation in the composition of sediments deposited within the lake.

Spidergrams were also prepared to examine the composition of the two fractions in the MC sediments in each river (Fig. 3). For all except the Tamayu and Kimachi Rivers, these were also compared with average whole-rock data for the main lithotypes in the catchments. The patterns for the two fractions in the Iinashi River show marked separation, with the 180-2000 μm fraction showing significant depletion relative to UCC, and an overall pattern closely matching that for the granitoids in the catchment (Fig. 3a). In contrast, the < 180 μm pattern is more UCC-like, similar to that for Iinashi volcanics, and shows marked enrichment in Zr and Th relative to both UCC and the 180-2000 μm fraction. These features suggest the composition of the coarser fraction is dominated by quartz and feldspar derived from the source granitoids, whereas that of the finer fraction is controlled by clays derived from both the granitoids and the bimodal (andesite-rhyolite) volcanics, plus heavy mineral concentration (zircon) contributing higher amounts of Zr and Th. Preferential deposition of the 180-2000 μm fraction in the Iinashi delta, and more distal deposition of the < 180 μm fraction in central Lake Nakaumi will increase geochemical fractionation in this fluvial-lacustrine system. Provenance signature in the finer size grade will thus be obscured.

A similar pattern is observed for the Iu River fractions, with the 180-2000 μm fraction average closely matching the composition of the granitoids in the catchment (Fig. 3b). The Iu volcanic average is also a good match, reflecting the highly felsic nature (rhyolite-dacite) of the volcanic rocks in the area, compared to intermediate Hata volcanics in the western Iinashi watershed. As with the Iinashi, the Iu < 180 μm fraction average is compositionally similar to UCC, but with no significant depletion in the ferromagnesian elements. Consequently, suspended sediment supplied to central Lake Nakaumi from the Iu River will also have a more mafic (UCC-like) composition than coarser bedload deposited in the Iu delta.

The UCC_N patterns for the Tamayu and Kimachi 180-2000 and < 180 μm fractions are strikingly similar (Fig. 3c). The < 180-2000 μm patterns show an overall downward trend from Nb to V, and only moderate depletion relative to UCC compared to the Iinashi and Iu. This probably reflects dampening of the influence of granitoid detritus by the greater proportion of geochemically intermediate Omori rocks in the area. The < 180 μm fractions have almost flat patterns, close to UCC (Fig. 3c). The most obvious anomaly is strong enrichment in Zr, and to a lesser extent Th. This is most likely due to zircon concentration, which have been shown to be concentrated in this fraction in sediments from the Hino River (Ortiz and Roser, 2006b). The higher peak for Zr than in the Iinashi and Iu Rivers may be due to finer sizing of zircons in Tamayu-Kimachi granitoids, as is most

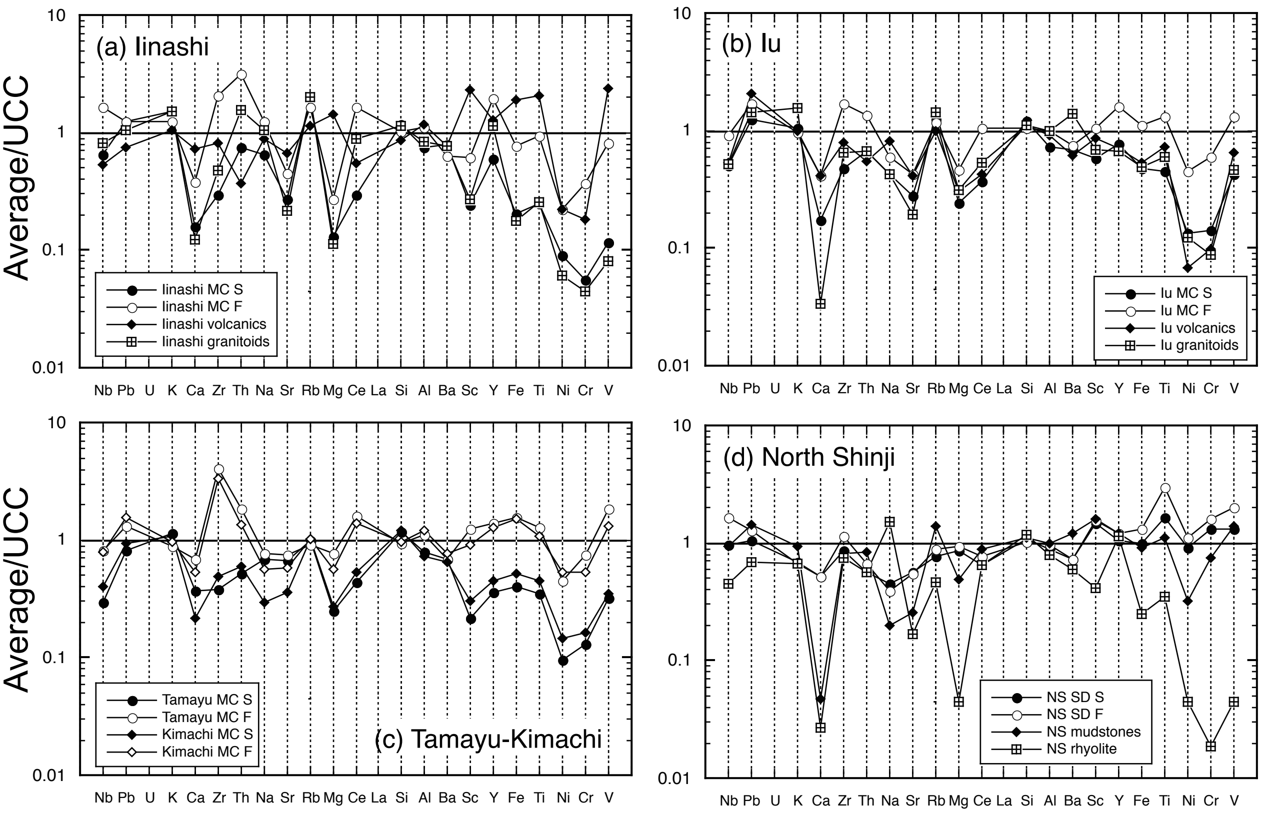

Fig. 3. UCC_N plots for 180-2000 and < 180 μm fraction averages in the (a) Iinashi, (b) Iu, (c) Tamayu and Kimachi Rivers, and (d) North Shinji streams, compared to local granitoid and volcanic source rock averages. Method as in Fig. 2.

of the quartz-feldspar detritus in the rivers draining the latter. The similarity of the trends in the Tamayu and Kimachi, and lesser variation between the fractions, compared to the variability and fraction contrast in the Iinashi and Iu, is also probably a product of their smaller catchment areas, and significant extent of Omori rocks on the south side of Lake Shinji.

The single-channel 180-2000 and < 180 μm fractions from North Shinji show almost identical trends, with slightly concave patterns, close to UCC composition (Fig. 3d). Fractionation between the two fractions is low, with a relative enrichment in CaO in the < 180 μm fractions being the only major difference. This apart, the average pattern for Josoji and Furue mudstones is quite similar, whereas Josoji rhyolites show very evolved patterns, with strong depletion in CaO, Sr, MgO, and ferromagnesian elements in the segment Sc-V. The patterns for the North Shinji stream sediments are compatible with a mix of these three main sources, although Josoji mudstones obviously dominate the source. The apparent enrichment in CaO in the < 180 μm fractions cannot be accounted for by such a mix, however. The cause of this anomaly is unknown. Nevertheless, the patterns for the North Shinji fractions compared to those from the Tamayu and Kimachi Rivers further highlight the differing compositions of sediments supplied to Lake Shinji from its northern and southern shores.

Potential fractionation between source rocks and stream sediment fractions in tributaries dominated by single rock types was also investigated. UCC_N patterns for granitoid-derived (GD) 180-2000 μm fractions in the Iinashi, Iu, and Tamayu Rivers are highly evolved, with marked depletion for CaO, Sr, MgO and Sc-V (Fig. 4a). These compare very well with the patterns for local granitoids, confirming that the dominant coarse fraction is the best indicator of provenance. The < 180 μm fractions have patterns closer to UCC, with significant depletion only for Ni and Cr, and hence fractionation between the splits is significant. In contrast, patterns for volcanic-sourced (VD) fractions in tributaries in the Iinashi and Iu show little difference, and also compare very well with average volcanic source rocks in these areas (Fig. 4b). These features show that chemical fractionation is more advanced in granitoid-derived suites, with the opportunity to separate coarse-grained unitary quartz and feldspar detritus from finer-grained clay weathering products depleted in mobile elements. In sediments derived from volcanic sources, in the coarser size grades bulk chemistry is determined by the proportions among volcanic lithics, whereas in the < 180 μm fraction composition is controlled by the weathering products of the same lithic assemblage, leading to reduced contrast between the size fractions.

The contrasts in composition seen in the fractions in the tributaries are produced by their contrasting plutonic and volcanic lithotypes. Nevertheless, homogenization of the tributary provenance signatures in the main channels reduces this fractionation, to the extent where original fingerprints of the original volcanic sources may be obscured, as in the lower reaches of the Iinashi and Iu Rivers (Fig. 2). In smaller catchments, such as the Tamayu and Kimachi, higher proportions of volcanic sources may remain evident.

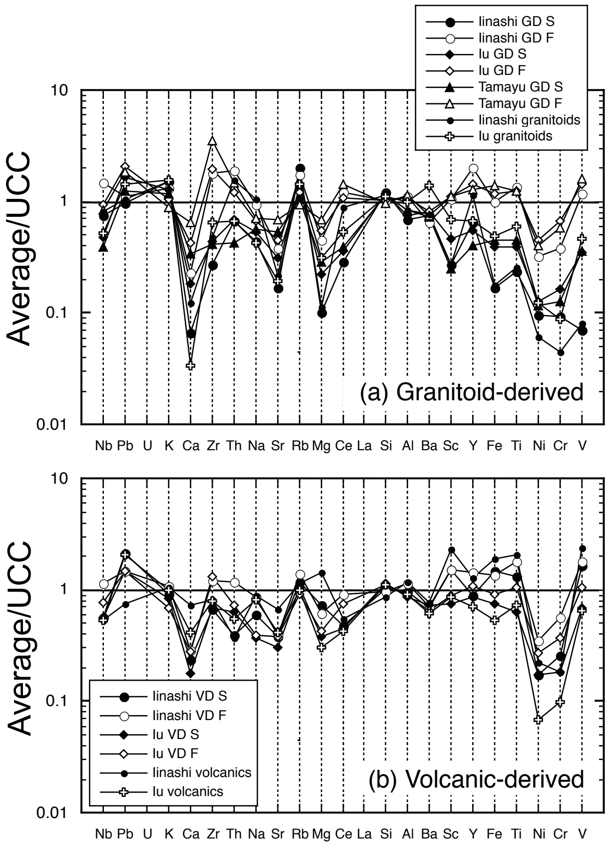

Fig. 4. UCC_N plots for 180-2000 and < 180 μm fraction averages for tributaries draining only (a) granitoids, and (b) volcanic rocks, compared to the local source rock averages. Method as in Fig. 2.

Conclusions

The results show that average compositions of the 180-2000 and < 180 μm fractions and bulk sediments show considerable variation between the rivers. Bulk main channel stream sediments from the Iu, Iinashi, Tamayu and Kimachi Rivers have broadly similar compositions, with depleted UCC_N patterns reflecting derivation from petrogenetically evolved granitoid sources. Fractionation between the 180-2000 and < 180 μm fractions is significant, with granitoid-like signatures in the former, and UCC-like compositions in the latter. In contrast, main channel sediments from small streams in North Shinji have flat UCC_N patterns, reflecting derivation mainly from Josoji Formation shales, and 180-2000 and < 180 μm fractions have similar compositions. Compositions of fractions derived from small tributaries draining only single lithologies also show variation. The coarser fractions of sediments in tributaries draining granitoids have similar composition to their source rocks, whereas the < 180 μm fractions show relative concentration of Zr, Th and elements associated with Fe-oxides and ferromagnesian minerals (Sc, Fe, Ti, Ni, Cr, and V). Fractions derived from volcanic rocks show little contrast in composition. These features suggest that suspended and bedload sediments supplied to Lakes Shinji and Nakaumi vary spatially, and that spatial geochemical variations may also occur in the lakes. Such variation would be produced by storage of coarser 180-2000 μm detritus in the river deltas and at lake margins, and outwash of < 180 μm material to more distal sites of deposition.

References

Amorosi, A., Centineo, M. C., Dinelli, E., Lucchini, F. and Tateo, F., 2002, Geochemical and mineralogical variations as indicators of provenance changes in Late Quaternary deposits of SE Po Plain. *Sedimentary Geology*, **151,** 273-292.

Condie, K. C., 1993, Chemical composition and evolution of the upper continental crust: contrasting results from surface samples and shales. *Chemical Geology*, **104,** 1-37.

Dinelli, E., Lucchini, F., Mordenti, A. and Paganelli, L., 1999, Geochemistry of Oligocene-Miocene sandstones of the northern Apennines (Italy) and evolution of chemical features in relation to provenance changes. *Sedimentary Geology*, **127,** 193-207.

Ferreira, A., Inacio, M. M., Morgado, P., Batista, M. J., Ferreira, L., Pereira, V. and Pinto, M. S., 2001, Low-density geochemical mapping in Portugal. *Applied Geochemistry*, **16,** 1323-1331.

Johnsson, M. J., 1993, The system controlling the composition of clastic sediments. *Geological Society of America Special Paper*, **284,** 1-19.

Kano, K., Takeuchi, K. and Matsuura, T., 1991, Geology of the Imaichi district. *Quadrangle series (scale 1: 50 000) Okayama*, **12,** 16.

Kano, K., Yamauchi, S., Takayasu, K. and Matsuura, H., 1993, Geology of the Matsue district. *Quadrangle series (scale 1:50,000) Okayama*, **12,** 17.

Kimura, J-I. and Yamada, Y., 1996, Evaluation of major and trace element analyses using a flux to sample ratio of two to one glass beads. *Journal of Mineralogy, Petrology and Economic Geology*, *Japan*, **91,** 62-72.

Koval, P. V., Burenkov, E. K. and Golovin, A. A., 1995, Introduction to the program 'Multipurpose Geochemical Mapping of Russia'. *Journal of Geochemical Exploration,* **55,** 115-23.

Licht, O. A. B. and Tarvainen, T., 1996, Multipurpose geochemical exploration data sets in the Parana Shield, Brasil. *Journal of Geochemical Exploration*, **56,** 167-182.

Moritsuna, S., 1974, Relationship between the percentages of cold-extractable copper to total copper in stream sediments and copper deposits. *Mining Geology*, *Japan*, **24,** 401-406.

Nesbitt, H. W. and Young, G. M., 1984, Prediction of some weathering trends of plutonic and volcanic rocks based on thermodynamic and kinetic considerations. *Geochimica et Cosmochimica Acta*, **48,** 1523-1534.

Ortiz, E. and Roser, B. P., 2004a, Major and trace element abundances in the sand fractions of stream sediments from the Kando River, Shimane Prefecture, Japan. *Geoscience Reports of Shimane University*, **23,** 17-25.

Ortiz, E. and Roser, B. P., 2004b, Major and trace element abundances in the fine and sand fractions of stream sediments from the Hino River, northern San-in District, Japan. *Geoscience Reports of Shimane University*, **23,** 27-37.

Ortiz, E. and Roser, B. P., 2005, Major and trace element abundances in < 180 and 180-2000 μm fractions of stream sediments from the Hii River, Shimane Prefecture, Japan. *Geoscience Reports of Shimane University*, **24,** 53-58.

Ortiz, E. and Roser, B. P., 2006a, Major and trace element provenance signatures in modern stream sediments from the Kando River, San'in district, SW Japan. *The Island Arc*, **15,** 223-238.

Ortiz, E. and Roser, B. P., 2006b, Geochemistry of stream sediments from the Hino River, SW Japan: source rock signatures, downstream compositional variations, and influence of sorting and weathering. *Chikyu Kagaku (Earth Science)*, **60,** 131-146.

Roser, B. P., Sawada, Y. and Kabeto, K., 1998, Crushing performance and contamination trials of a tungsten carbide ring mill compared to agate grinding. *Geoscience Reports of Shimane University*, **17,** 1-11.

Roser, B. P., Kimura, J.-I. and Hisatomi, K., 2000, Whole-rock elemental abundances in sandstones and mudrocks from the Tanabe Group, Kii Peninsula, Japan. *Geoscience Reports of Shimane University*, **19,** 101-112.

Roser, B. P., Kimura, J. I. and Sifeta, K., 2003, Tantalum and niobium contamination from tungsten carbide ring mills: much ado about nothing. *Geoscience Reports of Shimane University*, **22,** 107-110.

Shiikawa, M., 1991, Geochemical maps of various areas. *Chikyu Kagaku (Geochemistry)*, **25,** 101-125.

Taylor, S. R. and McLennan, S. M., 1985. The continental crust: its composition and evolution. Oxford, Blackwell Scientific, 312 p.

Yamamoto, K., 1999, Stream sediment exploration at the Esashi prospect, Hokkaido, Japan. *Resource Geology*, **49,** 109-116.

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（要　旨）

Roser, Barry P.・松浦圭祐・貝野陽介・松尾典彦・戸田雄峰・Purevjav, Narantuya, 2012 宍道湖・中海流域河川堆積物の地球化学．島根大学地球資源環境学研究報告，31，33-48.

宍道湖及び中海は島根県における重要な汽水湖－河口システムを形成している．斐伊川は多量の砕屑物をこれらの湖に供給しているが，他の小規模な河川も砕屑物の供給に重要な役割を果たしている．地域ごとの砕屑物の組成を特徴づけるために，中海に流入する飯梨川と意宇川から 33 の河川堆積物試料を採取した．また，宍道湖に南方から流入する玉湯川及び来待川，北方から流入する小河川から 21 試料を採取した．さらに基盤岩（花こう岩類及び火山岩類）を 25 試料採取した．2 つに区分した粒径（<180 μm と 180-2000 μm）の河川堆積物試料と基盤岩について蛍光 X 線分析装置を用いて主要元素及び 14 の微量元素の分析が行われた．また，粒径分布をもとにして河川堆積物の全岩組成も計算された．飯梨川，意宇川，玉湯川及び来待川の堆積物全岩組成及び 180-2000 μm 粒径の組成は，流域に広く分布する花こう岩類の組成を反映して上部大陸地殻（UCC）に比べて著しく枯渇している．対照的に <180 μm の粒径のものは，粘土及び重鉱物含有量を反映して UCC の組成によく似ている．宍道湖北方の小河川堆積物の全岩及び粒径別組成はいずれもよく似た組成傾向を示し，UCC に似た組成である．これはこれらの堆積物が主に成相寺累層及び古江累層の泥岩に由来することを反映している．単一岩相中の支流の河川堆積物は，粒径の違いによりさまざまな相違を示す．花こう岩類から由来する河川堆積物では最も分別が大きく，反対に中性～酸性火山岩に由来する堆積物では分別が最小となる．これらの結果は宍道湖・中海に供給された懸濁物質及び堆積物は河川流域の地質の違いによって地域的に多様性をもつことを示している．湖における地域的な地球化学的性質の多様性は，180-2000 μm 粒径の粗粒の砕屑物は湖沿岸の河川デルタに堆積し，粒径 <180 μm の細粒砕屑物はより沖合に堆積することによって引き起こされる．

Table 1. Average compositions of individual fractions of stream sediments, calculated bulk compositions, and whole rock samples from the Iinashi, Iu, Tamayu, and Kimachi Rivers, and streams in the North-Shinji area. Data reported on an as-analyzed basis (anhydrous), major elements wt%, trace elements ppm.

Abbreviations: S = 180-2000 micron fraction; F = <180 micron; Bulk -bulk compositions calculated from fraction proportions; MC = main channel; VD = volcanic-derived;GD - granitoid derived; SD = sediment derived.
n - number of samples.

Group	*n*	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr
Iinashi MC bulk	7	78.79	0.18	11.81	1.23	0.05	0.33	0.59	2.16	4.26	0.02	99.41	495	22	6	9	8	4	21	166	3.6	89	8.9	13	14	68
Iinashi MC S	7	79.06	0.16	11.66	1.14	0.04	0.32	0.57	2.12	4.29	0.01	99.39	498	19	5	9	8	4	21	168	3.4	87	7.9	11	12	56
Iinashi MC F	7	68.26	0.60	17.11	4.31	0.14	0.68	1.38	4.09	3.48	0.06	100.10	401	103	34	18	20	11	21	139	8.5	146	33.0	78	41	402
Iinashi GD bulk	3	81.16	0.17	10.67	1.05	0.03	0.27	0.25	1.47	4.22	0.02	99.31	472	20	9	9	9	5	17	169	4.1	56	7.4	9	14	59
Iinashi GD S	3	81.46	0.15	10.54	0.95	0.03	0.25	0.24	1.44	4.23	0.02	99.30	473	18	9	9	9	5	17	170	3.8	55	7.1	7	14	52
Iinashi GD F	3	67.32	0.87	17.23	5.63	0.15	1.10	0.83	3.05	3.65	0.12	99.96	410	76	35	18	18	15	19	146	14.8	120	19.8	114	43	343
Iinashi VD bulk	3	68.34	0.85	15.14	8.30	0.23	1.80	0.84	2.00	2.59	0.13	100.23	433	31	24	17	7	8	36	100	21.2	122	4.4	160	19	133
Iinashi VD S	3	68.41	0.85	15.07	8.36	0.23	1.81	0.84	1.97	2.56	0.13	100.25	431	30	24	17	7	8	36	99	21.3	122	4.1	161	19	130
Iinashi VD F	3	64.93	1.15	17.57	7.58	0.20	1.52	1.04	2.79	3.01	0.14	99.94	449	58	52	19	14	16	25	118	21.5	126	12.5	173	30	231
Iinashi volcanics	2	57.24	1.31	18.00	10.77	0.25	3.51	2.63	2.92	2.97	0.28	99.87	482	34	17	21	6	10	13	95	32.6	212	3.9	233	27	159
Iinashi granitoids	5	76.79	0.17	12.95	0.98	0.02	0.28	0.45	3.39	4.29	0.01	99.33	488	55	4	12	10	3	18	168	3.8	70	16.5	8	24	93
Iu MC bulk	4	79.29	0.31	11.35	2.72	0.20	0.62	0.63	1.41	2.97	0.05	99.54	438	24	14	8	6	6	21	104	8.3	90	7.0	42	17	94
Iu MC S	4	79.54	0.29	11.19	2.69	0.17	0.61	0.62	1.40	2.97	0.05	99.53	438	23	13	8	6	6	21	105	8.3	89	7.0	41	16	92
Iu MC F	4	69.68	0.85	15.19	6.26	0.45	1.16	1.48	1.98	2.71	0.14	99.89	475	66	56	13	11	21	29	100	14.8	137	14.3	129	34	324
Iui GD bulk	4	78.55	0.26	11.78	2.30	0.07	0.57	0.67	1.74	3.59	0.04	99.57	517	24	16	8	6	7	28	111	6.5	100	7.5	36	12	91
Iu GD S	4	78.76	0.25	11.69	2.22	0.07	0.56	0.66	1.73	3.61	0.04	99.56	517	23	15	8	6	6	28	112	6.5	99	7.3	34	12	86
Iu GD F	4	67.38	0.79	16.72	6.59	0.24	1.37	1.54	2.18	2.93	0.15	99.89	514	68	61	16	11	21	35	101	15.8	144	12.8	139	30	374
Iu VD bulk	5	76.62	0.41	13.46	4.20	0.15	0.96	0.65	1.22	2.36	0.06	100.08	456	29	18	13	7	8	25	87	10.8	99	6.8	68	18	136
Iu VD S	5	76.72	0.40	13.44	4.16	0.14	0.95	0.63	1.22	2.37	0.06	100.10	458	29	17	13	7	8	25	87	10.6	97	6.6	66	18	131
Iu VD F	5	74.75	0.67	13.71	5.06	0.18	1.05	1.00	1.27	1.94	0.09	99.72	408	48	34	12	9	13	25	77	12.6	121	7.6	101	23	251
Iu volcanics	4	74.70	0.46	14.13	2.97	0.04	0.76	1.47	2.69	2.79	0.05	100.06	387	27	9	14	7	3	35	83	12.0	134	5.8	63	15	152
Iu granitoids	4	74.92	0.38	15.33	2.72	0.05	0.79	0.12	1.41	4.32	0.05	100.07	872	33	8	15	6	6	25	122	9.8	63	7.0	45	14	124
Tamayu MC bulk	4	76.09	0.28	12.44	2.91	0.06	0.73	1.44	2.29	3.11	0.03	99.38	430	36	18	11	4	6	14	82	4.3	215	7.3	47	9	161
Tamayu MC S	4	77.36	0.23	12.12	2.25	0.04	0.62	1.33	2.25	3.18	0.02	99.39	433	28	12	11	4	5	14	83	3.0	213	5.5	31	8	73
Tamayu MC F	4	63.10	0.81	16.99	8.83	0.23	1.92	2.47	2.49	2.46	0.16	99.47	430	102	69	18	10	21	22	78	17.3	242	19.5	179	29	786
Tamayu GD bulk	4	75.50	0.35	13.32	3.07	0.09	0.79	1.31	1.86	3.23	0.04	99.56	460	31	16	13	5	7	22	89	4.5	182	5.8	47	10	129
Tamayu GD S	4	76.62	0.29	12.92	2.54	0.07	0.70	1.22	1.84	3.32	0.03	99.56	461	25	12	13	5	6	21	90	3.5	173	4.5	35	9	79
Tamayu GD F	4	64.10	0.80	17.74	7.88	0.26	1.71	2.31	2.30	2.46	0.16	99.71	468	90	54	19	10	19	31	79	15.8	220	15.5	155	27	689
Kimachi MC bulk	5	78.24	0.33	11.81	3.54	0.13	0.75	0.88	1.02	2.99	0.06	99.76	412	40	18	10	6	8	17	86	5.2	121	7.4	45	11	177
Kimachi MC S	5	79.89	0.29	11.09	2.92	0.11	0.68	0.77	0.97	3.03	0.04	99.80	404	34	15	10	5	7	16	87	4.2	115	6.2	34	10	96
Kimachi MC F	5	63.46	0.70	18.62	8.55	0.36	1.41	1.92	1.86	2.72	0.20	99.82	487	88	49	18	10	25	26	86	12.8	188	14.4	128	27	639
Kimachi GD bulk	2	75.02	0.39	12.72	4.87	0.19	0.92	1.24	1.16	2.94	0.09	99.53	475	35	18	11	5	7	19	85	8.5	148	7.0	78	15	134
Kimachi GD S	2	77.08	0.34	11.83	3.91	0.15	0.76	1.21	1.21	3.04	0.05	99.57	465	29	15	11	5	5	19	86	6.5	148	5.5	64	12	100
Kimachi GD F	2	61.60	0.84	18.21	10.66	0.45	1.86	1.90	1.29	2.53	0.26	99.61	550	80	50	17	9	21	22	86	19.0	173	14.0	183	31	518
NS SD bulk	8	71.66	0.92	14.08	5.66	0.11	1.90	1.61	1.32	1.98	0.15	99.39	474	43	97	15	12	36	19	73	19.2	169	6.4	120	23	163
NS SD S	5	71.25	1.04	13.82	5.50	0.12	2.15	1.86	1.48	1.92	0.14	99.28	461	41	121	14	12	43	18	65	20.9	183	5.9	127	22	169
NS SD F	8	67.65	1.93	14.77	7.40	0.16	2.34	1.85	1.27	1.89	0.21	99.46	463	49	149	16	20	52	22	74	21.9	174	7.1	197	25	222
NS mudstones	5	73.74	0.71	15.18	5.15	0.02	1.20	0.17	0.65	2.66	0.06	99.53	751	57	69	18	11	15	25	118	22.5	81	8.9	136	26	159
NS rhyolite	5	79.00	0.22	12.23	1.40	0.02	0.11	0.10	5.00	1.88	0.01	99.96	370	41	2	12	5	2	12	39	5.8	54	5.9	4	24	144

Table 2. XRF analyses of individual fractions of stream sediments, calculated bulk compositions, and whole rock samples from the Iinashi, Iu, Tamayu, and Kimachi Rivers, and streams in the North Shinji area. Data reported on an as-analyzed basis (anhydrous), major elements wt%, trace elements ppm.

Abbreviations: *Fract* - fraction (S = 180-2000 μm; F = <180 μm; Bulk -bulk compositions calculated from fraction proportions; WR = whole rock); Type - MC = main channel; VD = volcanic-derived; GD - granitoid derived; SD = sediment derived; MX = mixed source; *Source* - Andes = andesite; Rhyo = rhyolite; Gran = granitoid; Mst=mudstone; *LOI* - original loss on ignition.

Iinashi River (IN)

Sample #	Fract	Type	Source	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI
Stream sediments																													
IN01-S	S	MC	Mixed	79.90	0.15	11.16	0.86	0.03	0.27	0.58	1.89	4.49	0.00	99.34	513	22	3	9	8	4	15	171	2.6	95	5.7	4	12	57	0.87
IN01-F	F	MC	Mixed	69.02	0.57	17.31	3.61	0.12	0.63	1.63	4.10	3.52	0.04	100.55	398	90	32	18	20	10	18	138	8.9	175	28.8	63	38	376	2.87
IN01 bulk	Bulk	MC	Mixed	79.79	0.15	11.22	0.89	0.04	0.27	0.60	1.92	4.48	0.00	99.35	512	23	3	9	8	4	15	171	2.7	96	5.9	5	12	61	0.89
IN02-S	S	VD	Andes	66.63	0.90	15.33	9.50	0.33	2.25	0.51	1.64	2.79	0.13	100.01	499	26	22	17	6	11	67	105	23.2	78	2.8	194	17	118	6.94
IN02-F	F	VD	Andes	62.92	1.48	18.12	9.52	0.26	2.17	0.98	2.59	2.34	0.19	100.56	428	46	56	20	10	18	26	95	28.0	119	5.3	241	28	192	13.63
IN02 bulk	Bulk	VD	Andes	66.56	0.91	15.38	9.50	0.33	2.25	0.52	1.65	2.79	0.13	100.02	498	26	22	17	6	11	66	105	23.3	78	2.8	195	17	120	7.06
IN04a-S	S	MX	Mixed	80.88	0.23	9.94	2.17	0.13	0.47	0.38	1.49	3.51	0.04	99.25	498	17	23	8	7	5	67	135	7.5	64	4.8	27	13	58	2.06
IN04a-F	F	MX	Mixed	62.29	1.36	16.97	9.71	0.84	1.73	1.67	2.20	2.64	0.43	99.85	1757	77	590	19	18	31	572	103	19.9	141	16.8	208	18	369	15.70
IN04 bulk	Bulk	MX	Mixed	80.82	0.24	9.96	2.19	0.14	0.47	0.39	1.49	3.51	0.04	99.25	502	17	25	8	7	5	68	135	7.5	64	4.8	27	13	59	2.10
IN05-S	S	MX	Mixed	71.80	0.59	14.62	5.44	0.14	1.26	0.90	2.26	3.14	0.11	100.24	473	24	33	15	6	9	20	117	17.5	135	5.0	91	16	101	3.75
IN05-F	F	MX	Mixed	63.37	1.39	17.05	9.91	0.22	1.84	1.45	2.84	2.30	0.18	100.54	377	66	84	19	14	20	39	91	23.2	162	14.7	235	31	269	9.37
IN05 bulk	Bulk	MX	Mixed	71.71	0.60	14.64	5.48	0.14	1.27	0.91	2.26	3.13	0.11	100.24	472	25	33	15	6	9	20	117	17.6	136	5.1	93	16	103	3.81
IN06-S	S	VD	Andes	69.25	0.84	14.78	8.06	0.18	1.55	0.91	2.03	2.62	0.12	100.33	404	28	24	16	6	7	25	102	21.3	135	4.3	160	18	135	4.51
IN06-F	F	VD	Andes	62.99	1.48	17.16	10.20	0.19	1.82	1.27	2.46	2.16	0.15	99.88	369	50	62	18	10	15	27	88	26.5	157	9.5	239	25	257	10.12
IN06 bulk	Bulk	VD	Andes	69.13	0.85	14.83	8.10	0.18	1.55	0.92	2.03	2.61	0.12	100.32	403	29	24	16	6	7	25	101	21.4	136	4.4	162	18	137	4.61
IN07a-S	S	MX	Mixed	83.49	0.26	8.13	2.30	0.04	0.52	0.51	1.22	2.27	0.04	98.77	307	19	10	5	8	6	12	98	5.7	63	9.3	37	13	60	1.45
IN07-F	F	MX	Mixed	66.07	0.92	17.11	6.67	0.15	1.18	1.13	3.18	3.17	0.14	99.73	435	82	67	17	18	32	16	127	17.1	116	19.6	136	45	303	9.95
IN07 bulk	Bulk	MX	Mixed	83.41	0.26	8.17	2.32	0.04	0.52	0.51	1.23	2.28	0.04	98.77	308	19	10	5	8	6	12	98	5.7	63	9.4	37	13	61	1.49
IN08-S	S	VD	Andes	69.35	0.81	15.10	7.52	0.19	1.64	1.11	2.25	2.28	0.13	100.39	391	35	25	18	8	7	17	89	19.4	154	5.1	129	21	138	4.37
IN08-F	F	VD	Andes	68.89	0.48	17.44	3.03	0.15	0.58	0.88	3.32	4.52	0.07	99.37	551	78	40	18	21	16	21	172	9.9	103	22.6	39	37	245	15.67
IN08 bulk	Bulk	VD	Andes	69.33	0.79	15.22	7.30	0.19	1.59	1.10	2.31	2.39	0.13	100.34	399	37	26	18	8	7	17	93	18.9	152	6.0	125	22	143	4.92
IN11-S	S	GD	Gran	80.27	0.16	11.34	0.94	0.04	0.25	0.24	1.58	4.47	0.01	99.28	587	15	9	10	10	4	19	172	3.4	51	7.1	4	13	60	1.94
IN11-F	F	GD	Gran	61.21	1.53	18.56	10.94	0.24	2.13	1.17	2.44	1.81	0.20	100.22	369	55	51	21	11	18	15	76	29.8	154	9.6	232	33	322	21.22
IN11 bulk	Bulk	GD	Gran	79.87	0.19	11.49	1.14	0.04	0.29	0.26	1.59	4.42	0.02	99.30	583	15	10	10	10	4	19	170	4.0	53	7.2	9	14	65	2.34
IN12a-S	S	GD	Gran	83.66	0.13	9.14	0.77	0.03	0.25	0.21	1.25	3.64	0.01	99.09	450	19	5	6	8	5	16	147	4.5	52	6.9	7	13	40	1.12
IN12-F	F	GD	Gran	69.46	0.55	17.39	2.93	0.12	0.67	0.73	3.81	4.18	0.08	99.94	449	73	31	18	20	17	24	166	7.3	110	22.2	56	37	299	5.02
IN12 bulk	Bulk	GD	Gran	83.56	0.13	9.20	0.78	0.03	0.26	0.21	1.27	3.64	0.01	99.09	450	19	5	6	8	5	16	147	4.5	52	7.0	7	13	42	1.15
IN13-S	S	GD	Gran	80.43	0.17	11.13	1.15	0.03	0.26	0.26	1.49	4.58	0.03	99.53	381	21	12	10	10	5	16	190	3.6	61	7.2	9	15	56	1.70
IN13-F	F	GD	Gran	71.28	0.52	15.74	3.03	0.09	0.52	0.59	2.92	4.96	0.09	99.73	413	100	22	15	22	10	18	198	7.3	97	27.6	56	58	407	4.19
IN13 bulk	Bulk	GD	Gran	80.06	0.18	11.32	1.23	0.04	0.27	0.27	1.55	4.59	0.03	99.54	382	24	12	10	10	5	16	190	3.7	63	8.0	11	17	71	1.80
IN14-S	S	MC	Mixed	80.40	0.14	10.90	0.87	0.03	0.26	0.65	1.82	4.24	0.01	99.31	491	18	2	9	7	3	15	162	3.6	106	6.0	10	10	48	0.81
IN14-F	F	MC	Mixed	67.86	0.75	16.23	5.63	0.17	0.70	1.58	3.99	3.39	0.06	100.34	410	128	46	17	27	12	18	133	10.6	163	39.0	111	46	538	3.70
IN14 bulk	Bulk	MC	Mixed	80.32	0.15	10.93	0.89	0.03	0.26	0.65	1.83	4.24	0.01	99.32	490	18	2	9	7	3	15	161	3.7	106	6.2	11	11	51	0.83
IN15-S	S	MC	Mixed	79.87	0.10	11.63	0.79	0.03	0.25	0.56	2.11	4.53	0.01	99.88	525	7	4	9	6	4	42	177	2.1	94	6.2	4	9	42	1.07
IN15-F	F	MC	Mixed	68.34	0.46	17.69	3.13	0.13	0.63	1.50	4.67	3.43	0.06	100.05	393	118	30	19	17	10	21	141	7.1	152	40.0	48	44	370	3.61
IN15 bulk	Bulk	MC	Mixed	79.60	0.11	11.77	0.84	0.03	0.26	0.58	2.17	4.51	0.01	99.89	522	10	4	9	6	4	42	176	2.2	95	7.0	5	10	50	1.13
IN16-S	S	MC	Mixed	79.74	0.13	11.41	0.86	0.03	0.29	0.47	2.02	4.41	0.01	99.36	524	16	3	5	8	5	17	172	0.8	78	10.6	9	11	50	1.04
IN16-F	F	MC	Mixed	68.89	0.58	17.10	3.47	0.11	0.66	1.23	4.12	3.60	0.05	99.81	396	92	29	17	20	10	22	143	7.0	133	33.4	60	38	309	3.43
IN16 bulk	Bulk	MC	Mixed	79.63	0.14	11.47	0.89	0.03	0.29	0.47	2.04	4.40	0.01	99.37	523	17	3	5	8	5	17	172	0.8	78	10.8	9	11	53	1.06
IN17-S	S	MC	Mixed	80.29	0.09	10.93	0.58	0.02	0.22	0.46	2.16	4.42	0.01	99.18	507	17	4	8	6	4	21	174	2.8	77	6.6	1	9	41	0.78
IN17-F	F	MC	Mixed	67.70	0.43	18.08	3.40	0.15	0.60	1.37	4.79	3.70	0.06	100.29	417	100	26	19	17	12	21	149	6.2	147	33.5	62	39	359	4.35
IN17 bulk	Bulk	MC	Mixed	80.25	0.09	10.96	0.59	0.02	0.22	0.46	2.17	4.42	0.01	99.19	507	18	5	8	6	4	21	174	2.8	77	6.7	1	9	42	0.79
IN18-S	S	MC	Mixed	72.94	0.22	14.93	1.81	0.10	0.44	0.78	3.29	4.46	0.03	99.00	481	27	13	14	10	5	20	175	4.3	98	10.1	20	16	75	2.53
IN18-F	F	MC	Mixed	67.78	0.52	17.85	3.69	0.15	0.62	1.17	4.05	3.74	0.07	99.64	411	104	45	18	18	10	22	149	7.5	131	33.9	65	44	346	4.70
IN18 bulk	Bulk	MC	Mixed	71.82	0.28	15.57	2.22	0.11	0.48	0.87	3.45	4.30	0.04	99.14	466	44	20	15	11	6	20	169	5.0	105	15.3	30	22	134	3.00
IN21-S	S	MC	Mixed	80.29	0.29	10.68	2.23	0.05	0.54	0.47	1.53	3.49	0.04	99.62	444	24	6	8	10	5	20	143	7.8	66	10.1	31	19	82	1.97
IN21-F	F	MC	Mixed	68.22	0.85	15.51	7.24	0.13	0.90	1.19	2.93	2.97	0.08	100.02	382	89	31	17	18	11	27	122	12.4	119	22.0	139	38	517	5.14
IN21 bulk	Bulk	MC	Mixed	80.13	0.30	10.74	2.30	0.05	0.55	0.48	1.55	3.48	0.04	99.63	443	25	6	8	10	5	20	143	7.8	66	10.2	33	20	88	2.01

Table 2 (Ctd).

Iinashi River (IN)

Sample #	Fract	Type	Source	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI
Whole rock samples																													
IN03-B	WR	Andes	Hata	53.67	1.55	19.08	13.36	0.31	4.91	0.72	1.57	4.41	0.22	99.79	606	23	32	24	7	17	11	158	38.7	36	2.0	348	21	124	5.78
IN09-B	WR	Andes	Hata	60.80	1.06	16.92	8.17	0.19	2.12	4.54	4.26	1.54	0.34	99.95	359	46	2	19	6	3	14	33	26.4	387	5.8	118	32	194	2.01
IN10-B	WR	Gran	Gran	76.71	0.22	12.43	1.43	0.02	0.32	0.57	2.48	5.22	0.02	99.43	399	101	4	11	7	2	11	202	5.2	100	16.6	20	35	94	1.09
IN19-B	WR	Gran	Gran	76.02	0.17	14.14	0.79	0.00	0.24	0.30	3.14	4.29	0.01	99.11	517	53	2	15	11	3	18	166	5.9	56	17.9	4	23	105	1.78
IN20-B	WR	Gran	Gran	77.56	0.13	12.57	0.83	0.02	0.26	0.45	3.82	3.95	0.01	99.60	502	35	5	12	11	5	21	161	0.3	59	15.6	2	19	82	0.71
IN22-B	WR	Gran	Gran	76.98	0.14	12.58	0.83	0.01	0.24	0.45	3.80	4.02	0.01	99.07	508	42	6	12	10	2	21	162	2.5	60	16.1	3	20	82	0.68
IN23-B	WR	Gran	Gran	76.69	0.17	13.03	1.04	0.03	0.32	0.46	3.73	3.95	0.01	99.44	515	47	4	12	10	2	19	148	4.9	75	16.3	9	23	101	1.11

Iu River (IU)

Sample #	Fract	Type	Source	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI
Stream sediments																													
IU-01S	S	MC	Mixed	84.55	0.16	8.22	1.51	0.04	0.38	0.45	1.32	2.68	0.02	99.33	412	15	7	6	4	4	13	89	7.0	70	4.0	20	11	61	1.30
IU-01F	F	MC	Mixed	69.27	0.76	15.21	6.19	0.28	1.26	1.69	2.26	2.51	0.15	99.57	489	70	107	14	10	39	37	89	14.0	132	17.0	124	30	308	8.01
IU-01 bulk	Bulk	MC	Mixed	83.87	0.22	8.71	1.50	0.16	0.43	0.45	1.32	2.67	0.04	99.38	408	16	11	6	5	4	13	88	7.0	71	4.0	21	11	62	1.32
IU-02S	S	MC	Mixed	77.66	0.27	12.11	2.63	0.05	0.67	0.95	1.72	2.95	0.04	99.04	435	22	7	10	5	4	26	92	7.0	104	5.0	44	13	88	2.68
IU-02F	F	MC	Mixed	68.00	1.09	15.16	7.71	0.16	1.31	1.85	2.10	2.44	0.12	99.93	441	64	38	13	11	11	33	81	18.0	146	12.0	189	28	371	5.60
IU-02 bulk	Bulk	MC	Mixed	77.57	0.28	12.14	2.68	0.05	0.67	0.96	1.72	2.95	0.04	99.05	435	22	7	10	5	4	26	92	7.0	105	5.0	45	13	91	2.71
IU-05S	S	MX	Mixed	81.89	0.20	9.60	1.96	0.06	0.45	0.51	1.40	3.01	0.03	99.11	456	23	12	7	6	5	19	97	4.0	79	5.0	27	12	74	1.62
IU-05F	F	MX	Mixed	68.10	0.93	15.73	7.69	0.27	1.36	1.44	1.82	2.53	0.17	100.04	461	76	45	15	12	20	35	94	17.0	127	15.0	167	35	380	9.64
IU-05 bulk	Bulk	MX	Mixed	81.68	0.21	9.69	2.05	0.06	0.46	0.52	1.41	3.00	0.03	99.12	456	24	12	7	6	5	19	97	4.2	80	5.2	29	12	79	1.74
IU-06S	S	MX	Mixed	79.45	0.26	10.59	2.37	0.06	0.61	0.66	1.70	3.26	0.06	99.01	493	25	20	8	5	5	17	100	3.0	87	6.0	35	13	83	2.15
IU-06F	F	MX	Mixed	68.06	0.84	16.07	6.06	0.23	1.46	1.19	2.03	2.83	0.28	99.06	484	52	47	15	11	16	27	102	17.0	122	10.0	132	28	262	9.96
IU-06 bulk	Bulk	MX	Mixed	68.93	0.80	15.66	5.78	0.22	1.39	1.15	2.01	2.86	0.26	99.05	485	50	45	14	11	15	26	102	16.0	119	10.0	125	27	248	9.37
IU-07S	S	VD	Rhyo	83.89	0.16	10.26	2.60	0.11	0.80	0.23	0.56	1.57	0.02	100.21	331	25	12	8	6	7	21	62	7.0	34	7.0	29	23	111	4.80
IU-07F	F	VD	Rhyo	80.31	0.40	10.98	3.73	0.17	1.03	0.66	0.83	1.30	0.04	99.45	351	40	25	9	7	10	24	54	10.0	73	7.0	65	20	186	7.47
IU-07 bulk	Bulk	VD	Rhyo	83.57	0.18	10.33	2.71	0.11	0.82	0.27	0.58	1.54	0.02	100.14	333	26	14	8	6	7	21	61	8.0	37	7.0	32	22	118	5.04
IU-08S	S	VD	Rhyo	81.39	0.22	11.40	2.28	0.15	0.64	0.46	1.53	2.46	0.01	100.54	449	30	9	10	7	5	23	83	5.0	65	7.0	26	18	111	3.34
IU-08F	F	VD	Rhyo	78.95	0.64	11.09	4.02	0.20	0.77	0.64	1.17	1.75	0.03	99.26	405	59	42	8	12	11	32	64	5.0	77	9.0	65	25	398	4.74
IU-08 bulk	Bulk	VD	Rhyo	81.33	0.23	11.40	2.32	0.16	0.64	0.46	1.52	2.45	0.01	100.51	448	30	10	10	7	5	23	82	5.0	65	7.0	27	18	118	3.37
IU-09S	S	GD	Gran	77.30	0.23	12.12	2.30	0.06	0.61	0.85	2.13	3.77	0.05	99.42	536	24	20	9	5	5	22	114	6.0	106	7.0	37	12	77	1.92
IU-09F	F	GD	Gran	66.25	0.73	16.69	6.94	0.24	1.57	1.72	2.56	3.01	0.23	99.95	557	66	67	15	12	18	33	103	14.0	143	13.0	114	31	312	8.36
IU-09 bulk	Bulk	GD	Gran	77.01	0.24	12.25	2.43	0.07	0.63	0.87	2.14	3.75	0.06	99.44	537	26	21	9	5	6	22	113	6.0	107	7.0	39	12	83	2.09
IU-10S	S	MX	Mixed	71.13	0.60	14.64	5.01	0.15	1.66	1.02	2.04	3.43	0.11	99.79	528	33	15	14	8	8	32	111	14.0	117	7.0	102	23	149	3.56
IU-10F	F	MX	Mixed	69.31	0.72	15.57	5.57	0.16	1.62	1.28	2.62	2.64	0.11	99.61	426	68	27	15	11	11	41	92	15.0	111	16.0	116	34	241	4.88
IU-10 bulk	Bulk	MX	Mixed	71.03	0.61	14.69	5.04	0.15	1.66	1.03	2.07	3.38	0.11	99.78	523	35	15	14	8	8	33	110	14.0	117	8.0	103	23	154	3.63
IU-11S	S	GD	Gran	81.10	0.24	10.41	2.26	0.07	0.51	0.59	1.63	3.04	0.04	99.88	454	24	13	6	6	7	46	101	7.0	93	8.0	31	11	85	1.74
IU-11F	F	GD	Gran	68.26	0.95	15.19	7.55	0.27	1.43	1.60	1.92	2.50	0.15	99.83	458	70	61	15	12	26	43	90	18.0	137	13.0	172	30	374	8.09
IU-11 bulk	Bulk	GD	Gran	80.99	0.25	10.44	2.30	0.07	0.52	0.60	1.63	3.03	0.04	99.88	454	25	13	6	6	7	46	101	7.0	93	8.0	32	11	87	1.79
IU-12S	S	MX	Mixed	73.28	0.34	14.48	4.34	0.10	0.84	1.46	1.85	2.84	0.08	99.62	468	31	26	12	6	14	58	88	7.0	168	8.0	68	13	105	3.49
IU-12F	F	MX	Mixed	68.20	1.01	14.91	8.67	0.22	1.54	1.61	1.09	2.15	0.14	99.55	432	71	94	15	12	33	79	117	21.0	124	13.0	192	21	372	7.55
IU-12 bulk	Bulk	MX	Mixed	73.18	0.36	14.49	4.43	0.11	0.85	1.46	1.83	2.83	0.08	99.62	467	31	28	12	6	14	59	89	7.0	167	8.0	70	13	111	3.57
IU-15S	S	GD	Gran	79.17	0.29	11.68	2.27	0.09	0.57	0.57	1.78	3.48	0.05	99.94	527	22	11	8	5	7	26	110	7.0	100	7.0	36	14	100	2.10
IU-15F	F	GD	Gran	68.97	0.68	16.62	5.44	0.27	1.14	1.35	2.28	2.99	0.16	99.91	499	69	62	15	10	24	28	105	15.0	145	12.0	104	35	323	9.15
IU-15 bulk	Bulk	GD	Gran	79.06	0.29	11.73	2.30	0.09	0.58	0.57	1.78	3.48	0.05	99.94	527	22	11	8	5	7	26	110	7.0	100	7.0	37	15	102	2.18
IU-16S	S	GD	Gran	77.45	0.24	12.54	2.04	0.05	0.53	0.62	1.37	4.13	0.01	99.00	549	22	16	10	7	5	18	121	6.0	97	7.0	31	9	81	3.05
IU-16F	F	GD	Gran	66.03	0.81	18.38	6.41	0.17	1.33	1.50	1.94	3.22	0.07	99.86	541	67	55	18	11	16	35	104	16.0	149	13.0	167	23	487	9.65
IU-16 bulk	Bulk	GD	Gran	77.13	0.26	12.71	2.16	0.06	0.56	0.65	1.39	4.10	0.02	99.02	549	23	17	10	7	6	19	120	6.0	98	8.0	35	10	93	3.23
IU-19S	S	VD	Rhyo	74.14	0.58	14.37	4.58	0.14	0.84	0.54	1.28	3.20	0.10	99.78	501	37	14	13	7	7	34	118	13.0	99	6.0	69	20	159	4.16
IU-19F	F	VD	Rhyo	70.27	0.96	15.76	6.37	0.23	1.05	0.87	1.13	2.82	0.17	99.63	447	61	28	13	11	15	38	112	20.0	115	9.0	106	30	263	8.81
IU-19 bulk	Bulk	VD	Rhyo	73.99	0.60	14.43	4.65	0.15	0.85	0.56	1.27	3.18	0.10	99.77	499	38	14	13	7	8	34	118	13.0	100	7.0	70	20	163	4.34
IU-22S	S	MC	Mixed	77.18	0.35	12.56	3.41	0.21	0.73	0.64	1.39	3.15	0.07	99.70	484	28	16	9	7	8	24	110	10.0	111	8.0	57	16	108	3.15
IU-22F	F	MC	Mixed	71.67	0.64	15.02	5.24	0.38	1.03	1.25	1.77	2.65	0.15	99.81	468	51	29	13	10	13	27	99	13.0	151	12.0	97	27	270	7.43
IU-22 bulk	Bulk	MC	Mixed	77.10	0.35	12.60	3.44	0.22	0.74	0.65	1.40	3.14	0.07	99.70	484	29	16	9	7	8	24	109	10.0	111	8.0	57	17	111	3.21

Table 2 (Ctd).

Iu River (IU) ctd

Sample #	Fract	Type	Source	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI
Stream sediments (ctd)																													
IU-23S	S	MC	Mixed	78.78	0.38	11.87	3.22	0.36	0.64	0.45	1.18	3.11	0.05	100.03	422	28	22	7	8	9	22	128	9.0	70	11.0	43	25	109	3.07
IU-23F	F	MC	Mixed	69.77	0.89	15.35	5.89	0.97	1.05	1.12	1.80	3.24	0.15	100.24	501	78	49	12	13	21	19	130	14.0	118	16.0	104	50	345	8.10
IU-23 bulk	Bulk	MC	Mixed	78.62	0.39	11.93	3.26	0.37	0.65	0.46	1.19	3.11	0.06	100.03	423	29	22	7	8	9	22	128	9.0	71	11.0	44	25	113	3.16
IU-24S	S	VD	Rhyo	72.85	0.49	14.94	5.55	0.16	1.17	0.99	1.39	2.36	0.09	99.98	502	28	26	15	7	11	21	87	12.0	148	7.0	97	16	134	4.45
IU-24F	F	VD	Rhyo	72.56	0.69	14.86	5.72	0.17	1.21	1.44	1.60	1.91	0.10	100.26	409	43	45	16	8	15	23	75	14.0	171	7.0	138	20	212	6.49
IU-24 bulk	Bulk	VD	Rhyo	72.84	0.49	14.94	5.56	0.16	1.17	1.00	1.39	2.35	0.09	99.99	500	28	26	15	7	11	21	86	12.0	149	7.0	97	16	136	4.49
IU-25S	S	VD	Rhyo	71.34	0.55	16.21	5.79	0.15	1.31	0.94	1.33	2.28	0.07	99.97	507	23	24	17	7	11	25	87	16.0	140	6.0	111	14	140	5.71
IU-25F	F	VD	Rhyo	71.67	0.67	15.88	5.47	0.13	1.18	1.39	1.61	1.93	0.09	100.02	429	36	30	15	8	13	10	80	14.0	170	6.0	129	18	195	10.64
IU-25 bulk	Bulk	VD	Rhyo	71.36	0.55	16.19	5.77	0.15	1.31	0.97	1.34	2.26	0.07	99.97	502	23	24	17	7	11	24	87	16.0	142	6.0	112	14	143	6.00
Whole rock samples																													
IU-03B	WR	DacB	Dacite	72.35	0.41	14.75	3.06	0.06	0.67	3.16	3.36	1.86	0.07	99.74	390	24	10	15	5	4	12	50	15.0	186	5.0	73	20	122	1.71
IU-04B	WR	DacB	Dacite	72.32	0.44	16.79	3.26	0.04	0.41	2.30	2.79	1.83	0.03	100.20	362	26	10	15	5	2	15	51	14.0	155	5.0	78	10	132	3.58
IU-13B	WR	GraB	Gran	76.22	0.22	13.46	0.98	0.01	0.37	0.21	3.22	4.74	0.03	99.46	574	58	8	13	7	3	34	134	3.0	82	11.0	13	9	144	1.15
IU-14B	WR	GraB	Gran	66.78	0.83	19.67	5.78	0.08	0.87	0.04	0.29	5.97	0.13	100.44	1563	6	8	21	5	8	40	157	29.0	71	1.0	114	23	122	6.11
IU-17B	WR	GraB	Gran	74.48	0.38	16.48	2.85	0.06	1.12	0.19	1.73	3.02	0.01	100.31	362	58	18	17	9	9	18	101	4.0	70	12.0	49	13	149	4.65
IU-18B	WR	GraB	Gran	82.19	0.09	11.69	1.25	0.03	0.78	0.05	0.41	3.55	0.01	100.05	987	11	-2	10	4	3	6	94	3.0	27	4.0	2	12	82	2.32
IU-20B	WR	RhyB	Rhyo	71.95	0.79	15.46	4.09	0.06	1.69	0.37	4.14	1.73	0.07	100.36	210	40	10	17	11	4	8	67	16.0	148	11.0	84	20	256	2.75
IU-21B	WR	RhyB	Rhyo	82.19	0.20	9.53	1.47	0.01	0.25	0.05	0.48	5.73	0.01	99.92	585	18	6	10	5	3	106	163	3.0	48	2.0	18	10	99	1.43

Tamayu (TM) and Kimachi (KM) Rivers

Sample #	Fract	Type	Source	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI
Stream sediments																													
TM-01S	S	MC	Mixed	77.42	0.20	11.93	1.97	0.04	0.56	1.26	2.22	3.37	0.02	98.98	430	28	10	12	3	4	11	86	1.0	212	4.0	27	7	68	n.a.
TM-01F	F	MC	Mixed	64.97	0.71	16.56	7.13	0.18	1.78	2.47	2.63	2.53	0.13	99.09	423	88	54	18	9	17	22	79	17.0	254	16.0	129	26	706	n.a.
TM-01 Bulk	Bulk	MC	Mixed	76.37	0.24	12.32	2.41	0.06	0.66	1.37	2.25	3.29	0.03	98.99	429	33	14	12	4	5	12	86	2.0	215	5.0	35	8	123	n.a.
TM-02 S	S	MC	Mixed	73.95	0.38	12.93	3.96	0.05	0.89	1.56	2.45	3.15	0.04	99.35	434	30	29	13	5	7	14	85	6.0	219	7.0	67	10	92	n.a.
TM-02 F	F	MC	Mixed	63.19	0.90	13.89	11.32	0.14	1.79	2.50	2.77	2.49	0.08	99.08	376	137	100	15	10	15	17	67	15.0	224	25.0	268	29	1226	n.a.
TM-02 Bulk	Bulk	MC	Mixed	71.65	0.49	13.13	5.54	0.07	1.08	1.76	2.52	3.01	0.05	99.29	422	53	44	13	6	9	14	81	8.0	220	11.0	110	14	335	n.a.
TM-03 S	S	GD	Gran	75.26	0.35	13.83	3.28	0.06	0.67	1.16	1.62	3.35	0.04	99.60	479	28	14	14	6	5	25	97	7.0	125	5.0	51	12	97	n.a.
TM-03 F	F	GD	Gran	67.79	0.93	17.01	6.66	0.13	1.22	1.58	1.51	2.47	0.11	99.42	467	74	39	18	10	15	33	85	15.0	164	13.0	149	26	455	n.a.
TM-03 Bulk	Bulk	GD	Gran	73.55	0.48	14.56	4.05	0.07	0.79	1.25	1.59	3.15	0.06	99.56	476	38	20	15	7	8	26	95	9.0	154	7.0	73	15	179	n.a.
TM-04 S	S	GD	Gran	77.60	0.25	12.24	2.04	0.04	0.68	1.29	1.97	3.43	0.01	99.56	449	19	4	12	4	5	9	89	0.0	196	4.0	27	7	76	n.a.
TM-04 F	F	GD	Gran	61.83	0.74	18.25	8.82	0.23	2.04	2.61	2.59	2.36	0.13	99.60	419	94	58	20	10	18	15	76	17.0	238	16.0	172	29	794	n.a.
TM-04 Bulk	Bulk	GD	Gran	76.50	0.28	12.66	2.52	0.06	0.78	1.38	2.01	3.35	0.02	99.56	447	24	8	12	4	6	10	88	1.0	199	5.0	37	8	126	n.a.
TM-06 S	S	MC	Mixed	77.60	0.20	12.38	1.69	0.05	0.59	1.34	2.31	3.20	0.02	99.37	460	27	3	12	3	4	19	81	2.0	223	4.0	18	7	69	n.a.
TM-06 F	F	MC	Mixed	59.87	0.93	19.23	9.94	0.39	2.21	2.42	2.07	2.35	0.24	99.67	499	91	82	21	11	30	27	82	21.0	230	21.0	207	34	585	n.a.
TM-06 Bulk	Bulk	MC	Mixed	77.14	0.22	12.56	1.91	0.06	0.63	1.37	2.30	3.18	0.02	99.38	461	28	5	12	3	4	20	81	3.0	223	5.0	23	8	82	n.a.
TM-07 S	S	GD	Gran	80.13	0.16	11.11	1.61	0.07	0.49	1.05	1.72	3.16	0.02	99.53	431	25	11	10	3	3	16	82	1.0	171	4.0	15	6	53	n.a.
TM-07 F	F	GD	Gran	61.89	0.83	17.26	9.53	0.45	1.86	2.59	2.53	2.66	0.30	99.91	525	114	72	18	11	23	34	81	19.0	243	18.0	172	29	986	n.a.
TM-07 Bulk	Bulk	GD	Gran	79.82	0.17	11.22	1.75	0.08	0.51	1.08	1.73	3.16	0.03	99.54	433	27	12	10	3	4	16	82	1.0	172	5.0	18	7	69	n.a.
TM-08 S	S	GD	Gran	73.50	0.39	14.50	3.23	0.10	0.97	1.39	2.06	3.35	0.03	99.54	486	28	18	15	6	9	34	90	6.0	199	5.0	48	9	91	n.a.
TM-08 F	F	GD	Gran	64.88	0.70	18.43	6.48	0.22	1.72	2.44	2.55	2.38	0.11	99.91	462	77	46	20	9	20	43	75	12.0	236	15.0	128	24	522	n.a.
TM-08 Bulk	Bulk	GD	Gran	72.12	0.45	14.83	3.98	0.14	1.08	1.54	2.12	3.26	0.06	99.58	483	34	22	16	6	10	35	89	7.0	204	6.0	58	10	142	n.a.
TM-09 S	S	MC	Mixed	80.45	0.13	11.22	1.36	0.03	0.45	1.15	2.04	3.01	0.02	99.86	408	26	6	7	3	3	11	80	3.0	197	7.0	12	6	61	n.a.
TM-09 F	F	MC	Mixed	64.38	0.71	18.26	6.91	0.20	1.91	2.51	2.49	2.45	0.20	100.02	420	92	38	18	9	22	23	82	16.0	260	16.0	112	27	626	n.a.
TM-09 Bulk	Bulk	MC	Mixed	79.23	0.18	11.76	1.78	0.04	0.56	1.25	2.07	2.97	0.03	99.87	409	31	9	8	4	4	11	81	4.0	202	8.0	20	7	104	n.a.
KM-01 S	S	MC	Mixed	82.51	0.22	9.91	2.02	0.07	0.48	0.82	1.11	2.87	0.03	100.04	374	35	10	7	4	3	16	83	1.0	119	7.0	19	9	70	n.a.
KM-01 F	F	MC	Mixed	65.54	0.84	16.70	8.73	0.34	1.40	1.95	1.68	2.61	0.19	99.97	462	95	48	16	11	19	37	84	13.0	184	15.0	146	26	722	n.a.
KM-01 Bulk	Bulk	MC	Mixed	81.79	0.24	10.20	2.30	0.08	0.52	0.87	1.14	2.86	0.03	100.03	378	37	11	7	5	4	17	83	2.0	122	8.0	24	9	97	n.a.
KM-02 S	S	MC	Mixed	80.24	0.26	10.87	2.63	0.08	0.70	0.71	0.78	3.10	0.03	99.39	394	33	15	11	4	6	17	92	4.0	109	5.0	28	9	73	n.a.
KM-02 F	F	MC	Mixed	61.95	0.75	19.59	9.95	0.31	1.65	1.56	1.18	2.53	0.28	99.75	466	76	52	20	10	29	28	96	15.0	156	15.0	136	32	359	n.a.
KM-02 Bulk	Bulk	MC	Mixed	79.20	0.29	11.37	3.04	0.09	0.75	0.76	0.80	3.07	0.05	99.41	398	35	17	11	5	7	18	92	5.0	111	5.0	34	10	89	n.a.

Table 2 (Ctd).

Tamayu (TM) and Kimachi (KM) Rivers (ctd)

Sample #	Fract	Type	Source	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI
Stream sediments (ctd)																													
KM-04 S	S	SD	Omori	74.27	0.47	13.91	4.22	0.05	0.77	2.25	1.94	2.04	0.07	99.99	391	27	14	13	5	4	15	63	12.0	235	5.0	72	15	119	n.a.
KM-04 F	F	SD	Omori	70.48	0.92	14.94	6.74	0.09	1.16	2.52	1.18	1.49	0.12	99.64	461	48	37	14	8	9	13	54	18.0	310	7.0	133	22	347	n.a.
KM-04 Bulk	Bulk	SD	Omori	73.52	0.56	14.11	4.72	0.06	0.85	2.30	1.79	1.93	0.08	99.92	405	31	19	13	6	5	15	61	13.0	250	5.0	84	17	164	n.a.
KM-05 S	S	SD	Kuri	81.68	0.15	10.06	1.45	0.12	0.33	0.47	0.74	3.81	0.01	98.82	436	23	6	9	4	2	22	109	3.0	88	6.0	5	8	61	n.a.
KM-05 F	F	SD	Kuri	66.34	0.57	17.98	6.28	0.47	0.96	1.47	1.98	3.55	0.12	99.73	536	81	24	17	10	15	44	117	10.0	166	16.0	69	23	521	n.a.
KM-05 Bulk	Bulk	SD	Kuri	80.79	0.17	10.52	1.73	0.14	0.36	0.53	0.81	3.79	0.02	98.87	442	26	7	9	5	3	23	110	3.0	92	6.0	8	9	88	n.a.
KM-06 S	S	GD	Gran	80.21	0.19	10.60	2.15	0.07	0.47	1.00	1.54	3.11	0.03	99.37	409	28	17	9	4	4	18	82	3.0	154	5.0	26	7	72	n.a.
KM-06 F	F	GD	Gran	61.23	0.91	18.03	9.90	0.40	1.74	2.37	2.16	2.80	0.24	99.78	522	96	76	18	11	25	30	91	17.0	216	17.0	187	27	768	n.a.
KM-06 Bulk	Bulk	GD	Gran	79.40	0.22	10.92	2.48	0.08	0.52	1.06	1.57	3.10	0.04	99.39	414	31	19	9	4	5	19	82	4.0	157	6.0	33	8	102	n.a.
KM-07 S	S	MC	Mixed	74.30	0.44	13.09	5.73	0.19	0.85	1.08	1.19	2.92	0.12	99.91	424	53	27	12	8	11	18	83	8.0	135	8.0	75	17	193	n.a.
KM-07 F	F	MC	Mixed	60.82	0.80	18.57	11.16	0.39	1.47	1.93	1.43	2.50	0.28	99.34	482	117	54	18	11	23	24	82	15.0	176	17.0	168	33	1096	n.a.
KM-07 Bulk	Bulk	MC	Mixed	69.39	0.57	15.09	7.71	0.26	1.08	1.39	1.28	2.77	0.18	99.71	445	77	37	14	9	15	20	82	11.0	150	12.0	109	23	522	n.a.
KM-08 S	S	GD	Gran	73.94	0.48	13.06	5.66	0.23	1.06	1.41	0.87	2.97	0.08	99.77	520	29	12	12	5	5	20	89	10.0	142	6.0	101	17	127	n.a.
KM-08 F	F	GD	Gran	61.97	0.78	18.38	11.42	0.50	1.99	1.44	0.43	2.26	0.28	99.44	577	63	24	16	7	17	14	81	21.0	129	11.0	178	34	268	n.a.
KM-08 Bulk	Bulk	GD	Gran	70.64	0.57	14.53	7.25	0.31	1.31	1.42	0.75	2.77	0.14	99.68	536	39	16	13	6	9	18	87	13.0	139	8.0	122	22	166	n.a.
KM-09 S	S	MC	Mixed	80.95	0.21	10.67	1.79	0.08	0.59	0.68	1.15	3.51	0.01	99.64	425	20	10	10	4	6	12	93	2.0	120	4.0	17	6	61	n.a.
KM-09 F	F	MC	Mixed	65.15	0.49	18.25	6.28	0.33	1.20	2.13	3.08	3.10	0.11	100.12	495	79	49	16	8	21	21	86	9.0	227	13.0	96	18	582	n.a.
KM-09 Bulk	Bulk	MC	Mixed	80.69	0.22	10.79	1.86	0.09	0.60	0.70	1.18	3.51	0.01	99.65	426	21	11	10	4	6	12	92	2.0	121	5.0	19	6	70	n.a.
KM-10 S	S	MC	Mixed	81.49	0.30	10.91	2.45	0.11	0.78	0.57	0.63	2.75	0.03	100.01	401	27	14	10	4	8	17	82	6.0	94	7.0	33	7	81	n.a.
KM-10 F	F	MC	Mixed	63.87	0.62	20.01	6.64	0.44	1.35	2.02	1.93	2.88	0.14	99.90	531	75	41	18	8	33	21	84	12.0	199	12.0	93	26	435	n.a.
KM-10 Bulk	Bulk	MC	Mixed	80.15	0.32	11.60	2.76	0.14	0.82	0.68	0.73	2.76	0.03	100.00	411	30	16	10	5	10	17	82	6.0	102	7.0	37	9	108	n.a.

North Shinji (NS)

Sample #	Fract	Type	Source	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI
Stream sediments																													
NS-1M	F	MIX	Mixed	67.52	0.79	16.93	8.66	0.24	1.43	0.78	0.33	1.92	0.43	99.02	529	64	74	20	12	28	54	89	21.0	95	8.9	130	29	220	17.12
NS-1M	Bulk	MIX	Mixed	67.52	0.79	16.93	8.66	0.24	1.43	0.78	0.33	1.92	0.43	99.02	529	64	74	20	12	28	54	89	21.0	95	8.9	130	29	220	17.12
NS-2S	S	VD	Rhyo	72.67	0.47	14.65	4.65	0.18	1.22	1.05	1.84	2.59	0.09	99.42	596	33	19	17	7	9	15	69	15.3	158	5.2	64	24	173	6.13
NS-2S	Bulk	VD	Rhyo	72.67	0.47	14.65	4.65	0.18	1.22	1.05	1.84	2.59	0.09	99.42	596	33	19	17	7	9	15	69	15.3	158	5.2	64	24	173	6.13
NS-3M	F	MIX	Mixed	72.00	0.59	14.34	6.57	0.19	1.28	1.02	0.77	2.19	0.16	99.11	435	43	57	18	9	33	32	88	20.2	95	7.6	102	26	148	8.99
NS-3M	Bulk	MIX	Mixed	72.00	0.59	14.34	6.57	0.19	1.28	1.02	0.77	2.19	0.16	99.11	435	43	57	18	9	33	32	88	20.2	95	7.6	102	26	148	8.99
NS-4S	S	MIX	Mixed	72.08	0.60	13.99	5.48	0.16	1.50	1.44	1.70	2.18	0.10	99.24	440	30	59	16	8	20	17	78	20.8	152	4.7	103	20	130	5.33
NS-4F	F	MIX	Mixed	65.85	1.20	16.15	7.75	0.23	2.25	2.22	1.58	1.85	0.18	99.25	442	51	125	19	13	45	27	71	25.5	183	7.2	170	28	238	10.78
NS-4 bulk	Bulk	MIX	Mixed	71.92	0.61	14.04	5.54	0.16	1.52	1.46	1.70	2.17	0.10	99.24	440	30	61	16	8	20	18	77	20.9	153	4.8	105	20	133	5.60
NS-5S	S	SD	Josoji	69.37	0.82	14.08	5.94	0.12	2.34	2.23	1.88	2.15	0.13	99.07	453	35	150	16	10	47	17	71	25.9	197	5.3	129	18	143	5.32
NS-5F	F	SD	Josoji	56.92	5.12	14.44	11.63	0.24	4.39	3.07	1.59	1.57	0.23	99.20	389	52	425	16	40	134	20	55	33.9	217	6.9	442	25	341	10.34
NS-5 bulk	Bulk	SD	Josoji	69.22	0.87	14.08	6.01	0.13	2.37	2.24	1.87	2.14	0.13	99.07	453	35	153	16	10	48	17	71	26.0	197	5.3	132	18	145	5.57
NS-10S	S	SD	Josoji	65.31	1.63	14.21	6.70	0.09	3.30	3.40	2.30	1.90	0.18	99.03	435	39	228	14	16	64	16	62	28.0	258	5.1	207	21	178	5.74
NS-10F	F	SD	Josoji	52.79	6.55	13.85	12.42	0.22	4.72	4.36	2.05	1.42	0.40	98.79	388	56	384	14	54	112	17	46	40.3	277	5.7	533	27	388	8.44
NS-10 bulk	Bulk	SD	Josoji	64.42	1.98	14.18	7.11	0.10	3.40	3.47	2.28	1.86	0.20	99.01	431	40	239	14	19	67	16	61	28.8	260	5.1	230	21	193	5.88
NS-11S	S	SD	Josoji	64.45	2.10	16.41	7.08	0.19	3.43	2.22	1.67	1.63	0.22	99.40	512	55	192	17	20	85	22	61	27.1	225	6.6	204	29	262	33.94
NS-11F	F	SD	Josoji	69.72	0.73	15.53	5.68	0.14	2.66	1.61	1.93	1.83	0.17	100.00	459	43	107	16	10	53	19	68	17.4	198	5.0	112	24	166	10.78
NS-11 bulk	Bulk	SD	Josoji	64.77	2.02	16.36	6.99	0.19	3.39	2.19	1.69	1.64	0.21	99.44	509	54	187	17	19	83	22	61	26.6	223	6.5	199	28	256	32.31
NS-12M	F	SD	Josoji	71.19	0.57	14.62	6.39	0.11	1.60	1.30	1.17	2.18	0.18	99.30	488	43	50	16	10	27	21	91	15.2	147	7.0	103	22	137	0.05
NS-12M	Bulk	SD	Josoji	71.19	0.57	14.62	6.39	0.11	1.60	1.30	1.17	2.18	0.18	99.30	488	43	50	16	10	27	21	91	15.2	147	7.0	103	22	137	0.05
NS-14M	F	VD	Rhyo	72.40	0.60	14.33	5.66	0.09	1.56	1.30	1.32	2.07	0.15	99.48	475	41	48	16	9	22	20	78	18.9	153	6.3	99	23	136	6.80
NS-14M	Bulk	VD	Rhyo	72.40	0.60	14.33	5.66	0.09	1.56	1.30	1.32	2.07	0.15	99.48	475	41	48	16	9	22	20	78	18.9	153	6.3	99	23	136	6.80
NS-15M	F	SD	Furue	72.82	0.66	14.02	5.71	0.10	1.58	1.46	1.23	1.94	0.14	99.68	516	38	52	15	10	23	20	75	15.2	171	6.1	101	23	149	7.50
NS-15M	Bulk	SD	Furue	72.82	0.66	14.02	5.71	0.10	1.58	1.46	1.23	1.94	0.14	99.68	516	38	52	15	10	23	20	75	15.2	171	6.1	101	23	149	7.50
NS-17M	F	SD	Furue	73.94	0.59	14.88	5.23	0.08	1.21	0.72	0.75	2.14	0.14	99.70	489	52	57	16	12	18	24	90	18.4	115	8.5	97	24	162	9.07
NS-17M	Bulk	SD	Furue	73.94	0.59	14.88	5.23	0.08	1.21	0.72	0.75	2.14	0.14	99.70	489	52	57	16	12	18	24	90	18.4	115	8.5	97	24	162	9.07

Table 2 (Ctd).

North Shinji (NS) ctd																														
Sample #	Fract	Type	Source	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	Ba	Ce	Cr	Ga	Nb	Ni	Pb	Rb	Sc	Sr	Th	V	Y	Zr	LOI
Stream sediments (ctd)																													
NS-18S	S	SD	Josoji	76.31	0.39	13.33	4.56	0.10	1.04	0.67	0.85	2.07	0.10	99.43	459	43	24	15	7	15	20	71	13.6	107	6.5	70	25	132	5.97
NS-18F	F	SD	Josoji	72.18	0.65	15.25	5.77	0.15	1.35	1.12	0.77	2.07	0.16	99.46	474	50	61	17	10	27	20	80	18.1	125	8.3	100	29	210	12.22
NS-18 bulk	Bulk	SD	Josoji	76.20	0.40	13.38	4.60	0.10	1.05	0.69	0.85	2.07	0.10	99.43	460	43	25	15	7	16	20	72	13.7	107	6.5	71	25	134	6.28
NS-19S	S	VD	Rhyo	79.89	0.27	11.56	2.92	0.12	0.65	0.89	1.07	2.13	0.06	99.55	484	42	9	13	6	8	17	68	11.7	128	6.3	36	21	123	4.62
NS-19F	F	VD	Rhyo	71.19	0.60	15.11	5.14	0.28	1.18	2.09	1.70	2.24	0.13	99.66	501	73	42	16	12	31	25	81	14.0	191	12.1	74	35	273	13.18
NS-19 bulk	Bulk	VD	Rhyo	79.70	0.28	11.63	2.97	0.13	0.66	0.91	1.08	2.13	0.06	99.56	484	42	10	13	6	8	17	68	11.7	129	6.4	37	21	126	5.05
NS-22S	S	SD	Furue	80.79	0.27	11.07	3.23	0.10	0.61	0.78	0.72	1.86	0.07	99.49	446	35	10	10	6	5	15	61	9.8	130	6.0	26	19	130	5.41
NS-22F	F	SD	Furue	71.65	0.59	15.54	6.35	0.23	1.19	1.11	0.67	1.95	0.28	99.55	499	54	56	17	11	24	34	84	16.5	141	9.2	89	29	224	13.69
NS-22 bulk	Bulk	SD	Furue	80.68	0.27	11.12	3.26	0.10	0.62	0.79	0.72	1.86	0.07	99.49	447	35	11	10	6	5	15	61	9.9	130	6.0	26	19	131	5.82
Whole rock samples																													
NS-6M	WR	Mst	Josoji	74.04	0.53	13.11	6.20	0.02	0.75	0.12	0.83	3.54	0.06	99.21	2101	14	67	18	7	5	21	113	26.6	92	5.5	158	21	105	5.61
NS-7M	WR	Mst	Josoji	74.14	0.95	15.68	4.64	0.03	1.24	0.32	0.85	1.89	0.03	99.76	538	67	58	20	16	22	32	105	20.5	99	11.1	118	30	230	6.90
NS-9M	WR	Mst	Josoji	75.46	0.56	13.42	4.92	0.02	1.48	0.27	0.99	2.29	0.03	99.46	429	46	65	15	8	30	12	100	22.8	77	6.9	126	18	100	6.44
NS-13M	WR	Mst	Josoji	72.41	0.64	15.72	6.45	0.00	1.28	0.07	0.05	2.74	0.11	99.45	319	68	78	18	10	4	36	142	21.2	53	8.4	152	26	132	8.57
NS-16M	WR	Mst	Furue	72.63	0.85	17.96	3.52	0.00	1.28	0.08	0.54	2.83	0.05	99.75	369	89	75	20	17	13	22	133	21.2	83	12.6	125	33	229	4.03
NS-20B	WR	Rhyo	Josoji	79.49	0.23	12.17	0.86	0.00	0.12	0.06	4.96	2.28	0.01	100.18	442	34	1	12	5	1	20	47	6.6	57	6.6	2	19	148	0.73
NS-21B	WR	Rhyo	Josoji	79.89	0.22	11.05	2.69	0.05	0.01	0.14	4.23	1.79	0.04	100.10	381	40	1	11	6	1	12	39	9.1	52	5.6	7	28	136	1.44
NS-23M	WR	Rhyo	Josoji	77.84	0.23	13.08	1.15	0.01	0.13	0.09	5.49	1.78	0.01	99.79	336	42	1	13	5	4	10	37	2.6	54	6.3	3	25	150	1.05
NS-24M	WR	Rhyo	Josoji	79.68	0.21	11.96	1.06	0.01	0.16	0.08	4.97	1.60	0.01	99.75	312	45	5	12	5	2	6	34	4.7	51	5.3	4	25	140	0.83
NS-25M	WR	Rhyo	Josoji	78.07	0.22	12.88	1.23	0.02	0.15	0.10	5.38	1.93	0.02	100.00	382	47	1	12	6	2	9	39	6.1	58	5.8	7	23	146	1.09

Table 3. Stream sediment sample weight fractions. Abbreviations as in Table 2.

SaNr	Type/Lith	Source	Proportion %	
			180-2000 µm	<180 µm
Iinashi				
IN-01	MC	Mixed	98.99	1.01
IN-02	VD	Andesite	98.18	1.82
IN-04	MX	And-Gran	99.71	0.29
IN-05	MX	And-Gran	98.97	1.03
IN-06	VD	Andesite	98.13	1.87
IN-07	MX	And-Gran	99.56	0.44
IN-08	VD	Andesite	95.10	4.90
IN-11	GD	Granite	97.92	2.08
IN-12	GD	Granite	99.31	0.69
IN-13	GD	Granite	95.87	4.13
IN-14	MC	Mixed	99.42	0.58
IN-15	MC	Mixed	97.68	2.32
IN-16	MC	Mixed	98.96	1.04
IN-17	MC	Mixed	99.64	0.36
IN-18	MC	Mixed	78.20	21.80
IN-21	MC	Mixed	98.65	1.35
Iu				
IU-01	MC	Mixed	99.20	0.81
IU-02	MC	Mixed	98.97	1.04
IU-05	MX	Volc-Gran	98.46	1.54
IU-06	MX	Volc-Gran	92.43	7.57
IU-07	VD	Rhyolite	90.95	9.05
IU-08	VD	Rhyolite	97.58	2.42
IU-09	GD	Granite	97.31	2.75
IU-10	MX	Volc-Gran	94.57	5.43
IU-11	GD	Granite	99.20	0.80
IU-12	MX	Volc-Gran	97.97	2.03
IU-15	GD	Granite	98.87	1.13
IU-16	GD	Granite	97.24	2.76
IU-19	MC	Mixed	96.11	3.89
IU-22	MC	Mixed	98.50	1.50
IU-23	MC	Mixed	98.30	1.70
IU-24	VD	Rhyolite	98.13	1.87
IU-25	VD	Rhyolite	94.08	5.92
Tamayu and Kimachi				
TM-01	MC	Mixed	91.47	8.53
TM-02	MC	Mixed	78.56	21.44
TM-03	GD	Granite	77.15	22.85
TM-04	GD	Granite	93.05	6.95
TM-06	MC	Mixed	97.42	2.58
TM-07	GD	Granite	98.30	1.70
TM-08	GD	Granite	88.14	11.86
TM-09	MC	Mixed	92.37	7.63
KM-01	MC	Mixed	95.77	4.23
KM-02	MC	Mixed	94.26	5.74
KM-04	SD	Omori	80.32	19.68
KM-05	SD	Kuri	94.17	5.83
KM-06	GD	Granite	95.70	4.30
KM-07	MC	Mixed	63.58	36.42
KM-08	GD	Granite	72.44	27.56
KM-09	MC	Mixed	98.42	1.58
KM-10	MC	Mixed	92.41	7.59
North Shinji				
NS-1	MX	Mixed	0.00	100.00
NS-2	VD	Rhyolite	97.35	2.64
NS-3	MX	Mixed	0.00	100.00
NS-4	MX	Mixed	97.40	2.60
NS-5	SD	Josoji	98.81	1.19
NS-10	SD	Josoji	92.90	7.10
NS-11	SD	Josoji	94.08	5.92
NS-12	SD	Josoji	0.00	100.00
NS-14	VD	Rhyolite	0.00	100.00
NS-15	SD	Furue	0.00	100.00
NS-17	SD	Furue	0.00	100.00
NS-18	SD	Josoji	97.25	2.75
NS-19	VD	Rhyolite	0.00	100.00
NS-22	SD	Furue	98.89	1.11