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Article

Laterization of basalts and sandstone associated with the enrichment of Al, Ga and Sc in the Bolaven Plateau, southern Laos

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Abstract: This article reports geochemical behavior and enrichment of Al, Ga and Sc by laterization of basalts and sandstone in the Bolaven Plateau, southern Laos. The Bolaven Plateau consists of Neogene – Quaternary basalts and underlying Cretaceous sedimentary rocks. Laterites derived from the basalts and sedimentary rocks are developed on these parent rocks. With increasing the degree of laterization, loss of mobile elements such as Si, alkali elements and alkaline earth elements lead to the enrichment of immobile elements of Al, Ga and Sc relative to the parent rocks. Accordingly, Al_2O_3 contents range from 10 to 15 % in the basalts, from 16 to 30 % in the saprolites, from 17 to 48 % in the basaltic laterites and from 15 to 47 % in the sedimentary laterite. Ga contents range from 6 to 20 ppm in the basalts, from 9 to 46 ppm in the saprolites, from 24 to 83 ppm in the basaltic laterites and from 22 to 68 ppm in the sedimentary laterites. Sc contents range from 14 to 23 ppm in the basalts, from 14 to 45 ppm in the saprolites, from 14 to 69 ppm in the basaltic laterites and from 13 to 84 ppm in the sedimentary laterites. No significant difference is recognized in the enrichment of these elements between the basaltic laterites and sedimentary laterites. A similar geochemical behavior and positive linear correlation are recognized between Ga and Al and between Sc and Fe, suggesting that Ga and Sc exist by replacing Al and Fe in the laterites, respectively. Ga/Al ratios range widely but Ga is almost no depleted or slightly enriched relative to Al with increasing the degree of laterization. Sc/Fe ratios indicate that Sc may be slightly depleted relative to Fe by strong laterization.

Keywords: weathering, laterite, basalt, bauxite, Al, Ga, Sc, Bolaven Plateau, Laos

1. Introduction

Laterites are near-surface weathering products developed on variable parent rocks (sedimentary rocks, basalt, granitoids, etc), distributed widely in the present tropical belts in the world (Bárdossy and Aleva, 1990). We use an extended terminology "laterite" including plinthite (lateritic soil), laterite and bauxite in this paper. Laterite is geochemically characterized by the depletion of Si and enrichment of Fe and Al. Bauxite, which is more strongly weathered laterite, is characterized by the depletion of Fe and enrichment of Al. Lateritic bauxite deposits account for the majority of aluminum resources in the world (Bárdossy and Aleva, 1990). Other immobile elements of Ga and Sc are also enriched by laterization as well as Al. Ga is mostly produced from bauxite as by-product in the process of refinery in the world (USGS, 2010). It may be also possible to extract Sc economically as by-product from bauxite residue by chemical leaching in the process of refinery (Smirnov and Molchanova, 1997). The present study reports the geochemical data of basalts, saprolites and laterites in the Bolaven Plateau, southern Laos (Fig. 1) and discusses the enrichment of Al, Ga and Sc in order to evaluate their resource potentials.

2. Geologic settings

Laterites distributed in Indochina are derived from the Neogene-Quaternary basalts (Fig. 1; Barr and MacDonald, 1981; Rangin *et al.*, 1995; Hoang and Flower, 1998; Chualaowanich *et al.*, 2008) and

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Mesozoic sedimentary rocks (e.g. Bárdossy and Aleva, 1990). The basaltic volcanism results from the thinning continental crust by extrusion of Indochina to southeast in the Paleogene India-Asia collision (Tapponnier *et al*., 1982; 1986). In southern Laos, the Neogene-Quaternary tholeiitic and alkali basalts are distributed in approximately 50 km × 80 km and form the Bolaven Plateau on the basement rocks of Jurassic-Cretaceous sedimentary rocks (Fig. 2). Sanematsu *et al*. (2011) indicates that both the tholeiites and alkali basalts are classified into within-plate basalt in Ti-Zr-Y diagram for discriminating the tectonic settings (Pearce and Cann, 1973). The tholeiites are larger in eruptive volume, underlying the alkali basalts (Vilayhack *et al*., 2008) although stratigraphy of the basalts is not clear in some locations. The tholeiites are mainly plagioclase (Pl) basalt and clinopyroxene-olivine (Cpx-Ol) basalt (Vilayhack *et al*., 2008). The overlying alkali basalts are composed of Ol basalt and nepheline-olivine (Ne-Ol) basalt, and the Ol basalt locally contains pyroxenite and lherzolite as mantle xenoliths (Vilayhack *et al*., 2008). Thickness of each basalt lava is estimated to be more than 50 m up to 100 m (Vilayhack *et al*., 2008). A zircon fission track age of 1.36 ± 0.09 Ma was reported from the basalt (Barr and MacDonald, 1981) which is assumed to be alkali basalt. Sanematsu *et al*. (2011) classified the basalts into three categories based on normative compositions and groundmass $^{40}Ar/^{39}Ar$ ages: 1) small volumetric alkali basalt (eruption age: 15.7 Ma), large volumetric Ol tholeiite (1.2 Ma) and quartz (Qtz) tholeiite (younger than 0.5 ± 0.2 Ma) accompanied by Ol tholeiite.

The Jurassic-Cretaceous sedimentary rocks underlying the basalt lavas consist of sandstone interbedded by a small amount of mudstone (Vilayhack *et al*., 2008). Parent rock of laterite and bauxite occurs in the Cretaceous Lagnao-Kang Formation and Latsaluay Formation. The Lagnao-Kang Formation overlying unconformably the Jurassic Kanglo Namho Tai Formation consists of hard and massive sandstone interbedded by mudstone beds (Vilayhack *et al*., 2008). The thickness of the formation is estimated to be between 600 m and 1500 m (Vilayhack *et al*., 2008). The Latsaluay Formation overlying unconformably the Lagnao-Kang Formation consists of kaolin-rich clay beds in the lower part and sandstone in the upper part (Vilayhack *et al*., 2008). The area of the Latsaluay Formation cropping out is smaller and the thickness of the formation (~100 m) is thinner compared with the Lagnao-Kang Formation (Vilayhack *et al*., 2008).

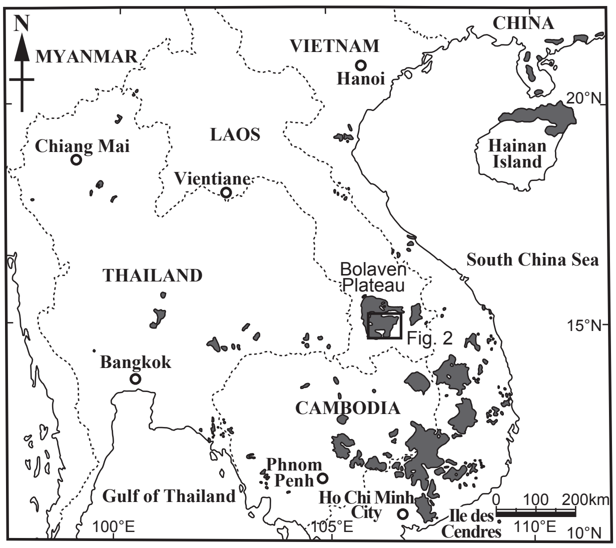

Fig. 1 Map showing the distribution of Cenozoic basalts in the vicinity of the Indochina. Modified after Barr and MacDonald (1981).

3. Laterite profiles

Parent basalts are recognized as core rocks in some laterite profiles or in streamside outcrops. The basalts consist of aphyric nephelinite (Fig. 3A), Ol basalt, Cpx-Ol or Ol-Cpx basalt (Figs. 3B and 3C) and basaltic andesite, Cpx basalt (Fig. 3D) and Cpx-bearing Pl-Ol basaltic andesite (Fig. 3E). The basalts exhibit intersertal and ophitic textures (Figs. 3B and 3C) and groundmass consists of plagioclase, clinopyroxene and volcanic glass. Plagioclase shows euhedral tabular shape in groundmass. Olivine and clinopyroxene phenocrysts show anhedral-euhedral granular shape. Opaque minerals are mostly ilmenite, magnetite and titanomagnetite, showing subhedral granular shape or acicular shape in groundmass. Olivine and clinopyroxene are partly altered to iddingsite (Figs. 3B, 3C and 3D) and talc, and plagioclase is partly altered to smectite and kaolin. The basalts commonly have spherical vesicles ranging from 0.1 to 10 mm in size and some vesicles are filled by carbonate minerals. Some basalt contains corroded quartz xenocryst rimmed by glass and clinopyroxene (Fig. 3F).

Saprolite, which is weathered basalt with remnants of basaltic textures, is recognized as saprolite horizon or core rock in some laterite profiles. Saprolite exhibits pale green to gray colors and they are composed of the similar constituent minerals to the parent basalts. However, the occurrences of iddingsite, talc and clay minerals such as kaolin and smectite are more common.

Laterite is recognized on the parent basalts, saplorites or sedimentary rocks. The thickness of laterite profiles recognized on the surface ranges from 2 to 8 m (Figs. 4A and 4B). The laterite exhibits variable colors from yellow ocher, through red ocher and brown to dark brown (Fig. 4A). Some laterite samples are crumble and soil-like but some others are densely consolidated and pisolitic like bauxite (Fig. 4C). Laterites derived from basalts (basaltic laterites) are composed of gibbsite, magnetite, titanomagnetite, ilmenite, goethite, hematite, kaolinite, halloysite, anatase, opal-CT and amorphous materials. Amorphous materials appear to be Fe oxyhydroxides, Al hydroxydes and others. Crandallite group minerals such as florencite-(Ce) and goyazite are identified in a laterite profile derived from nephelinite (Sanematsu *et al*., 2011). Laterites derived from the sedimentary rock (sedimentary laterites) also contain these minerals, amorphous materials and clastic quartz with a small amount of smectite although some of the sedimentary laterites are almost indistinguishable from the basaltic laterites. Bauxite mineralization is recognized in the lower part of the sedimentary laterites (Figs. 4B, 4C and 4D) whereas the mineralization is scarce in the basaltic laterites in the Bolaven Plateau (Fig. 2). Thickness of the sedimentary laterite profile accompanied by bauxite is about 6 m (Fig. 4B).

4. Analytical Methods

All the samples were dried at 60°C using an oven. The samples were crushed by an iron mortar and were ground by a vibration mill with alumina holders. Glass beads were made by fusing the powdered rock samples using lithium metaborate and/or tetraborate as flux. Major elements of basalt samples were analyzed by using X-ray fluorescence (XRF). Trace elements of basalt samples and major and trace elements of saprolite and laterite samples were digested by four

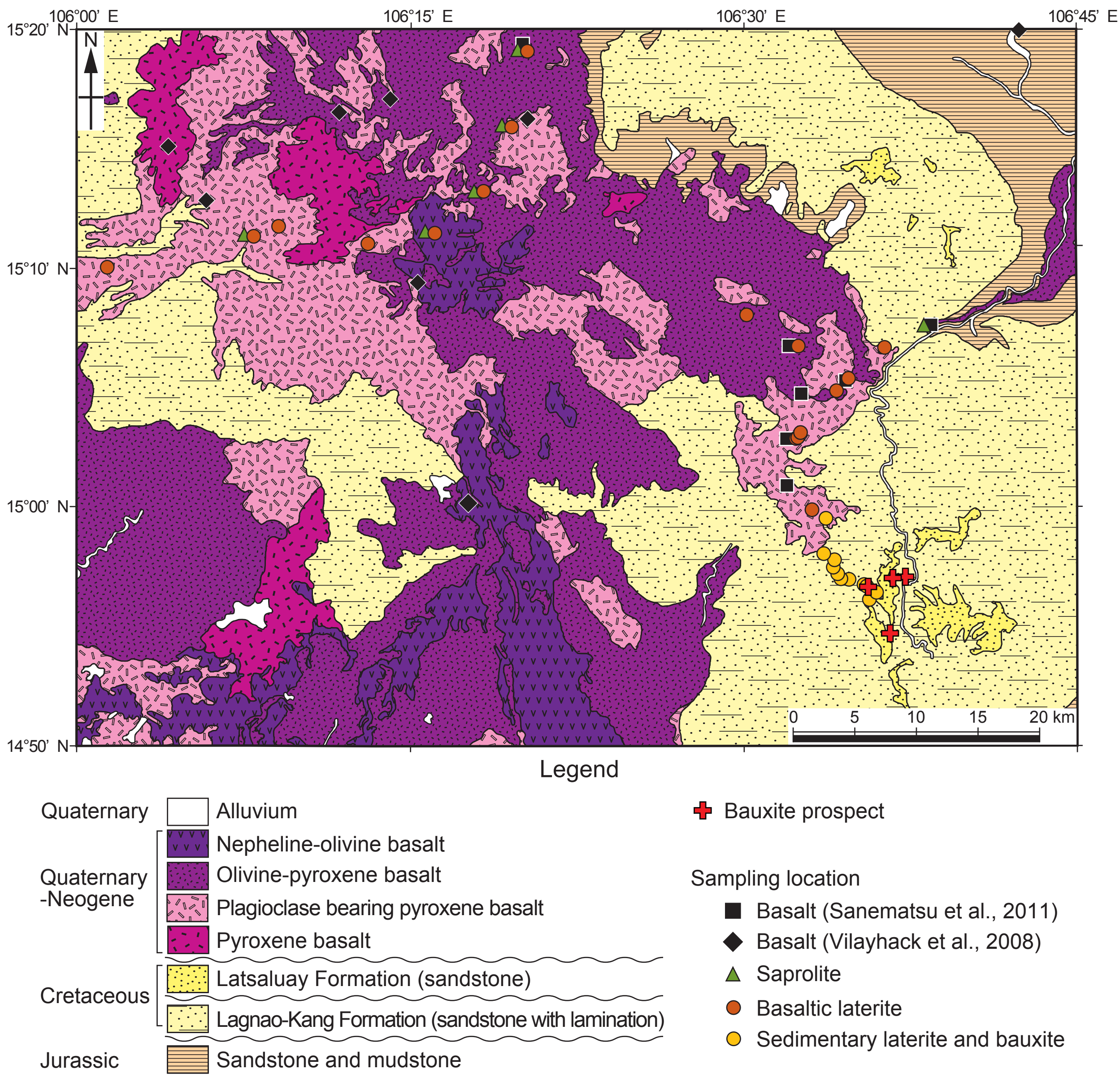

Fig. 2 Geologic map showing the distribution of basalts and sample locations in the Bolaven Plateau, southern Laos. Modified after Vilayhack *et al*. (2008).

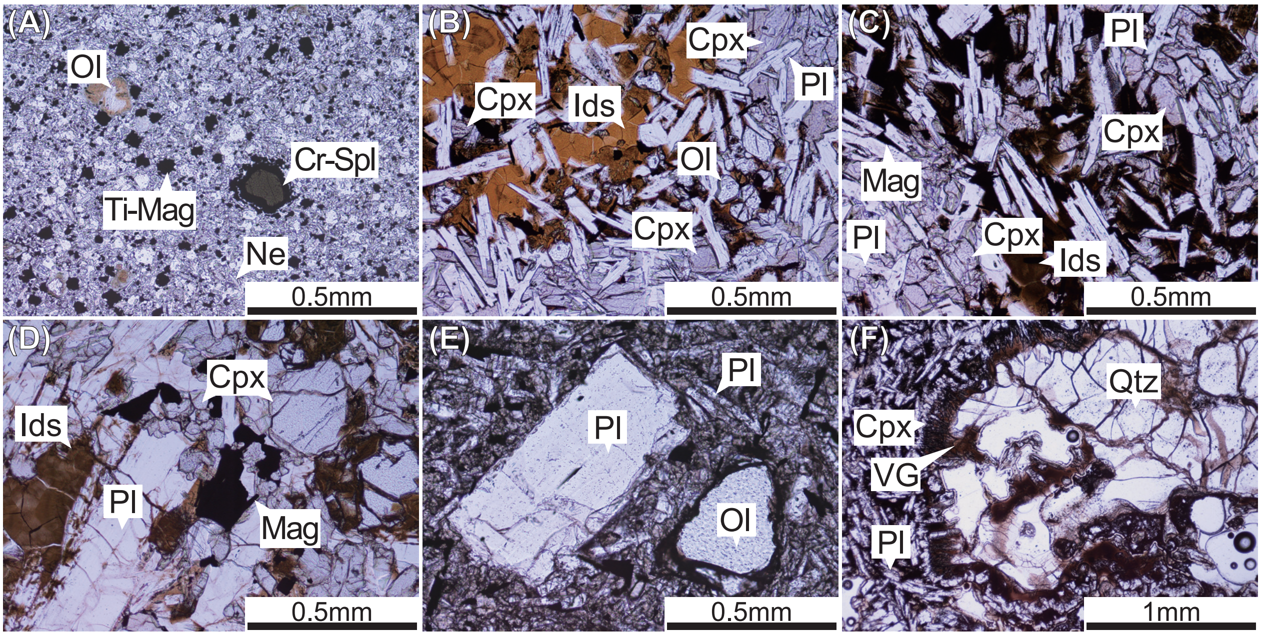

Fig. 3 Photomicrographs of basalt samples from the Bolaven Plateau. (A) Aphyric nephelinite consisting of nepheline, olivine, titanomagnetite, chromspinel and volcanic glass (1705H). (B) Ol-Cpx basalt showing ophitic texture (1815). Cpx is altered to iddingsite. (C) Cpx-Ol basalt showing ophitic texture (1710A). (D) Relatively coarse-grained Cpx basalt (1619E). (E) Cpx bearing Pl-Ol basaltic andesite (1712E). (F) Irregular-shaped corroded quartz xenocryst rimmed by glass and Cpx in Cpx-Ol basalt (1707). Ne: nepheline, Ti-Mag: titanomagnetite, Cr-Spl: chromspinel, Ol: olivine, Cpx: clinopyroxene, Pl: plagioclase, Mag: magnetite, Ids: iddingsite, Qtz: quartz, VG: volcanic glass.

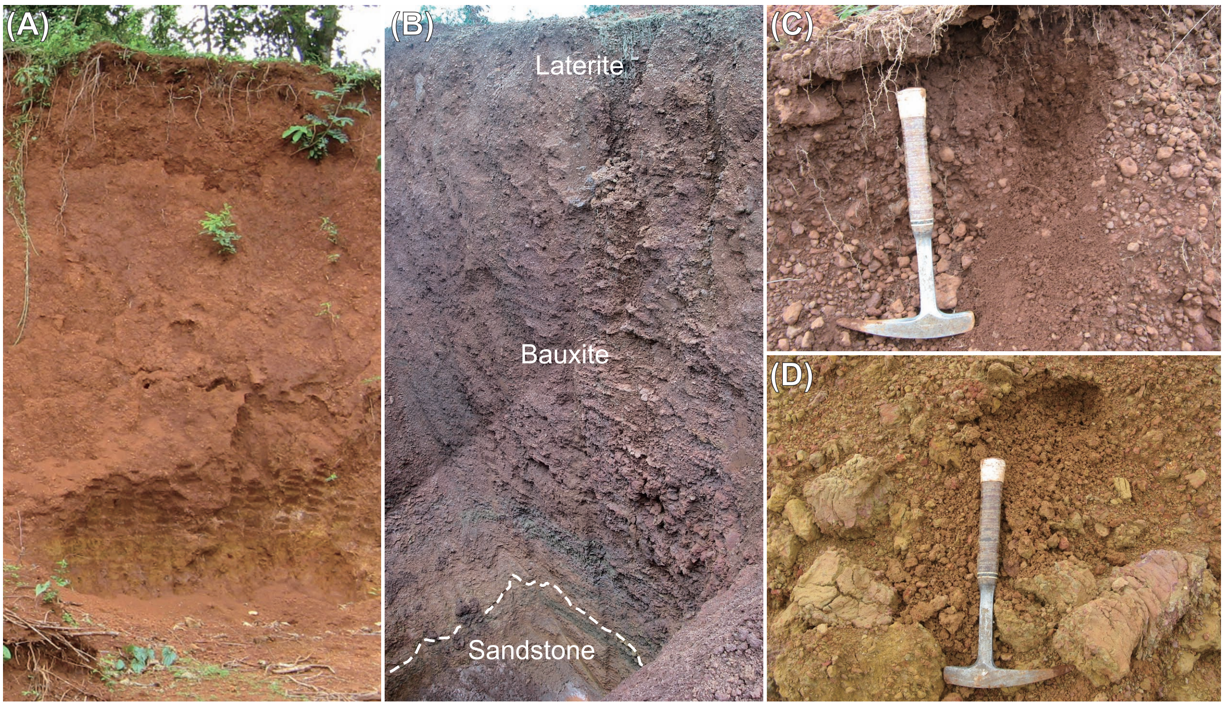

Fig. 4 Photographs of laterite profiles in the Bolaven Plateau. (A) Weakly-laterized profile 1806 derived from Cpx-Ol basalt, consisting of reddish to yellowish crumble laterites. The height of the exposed profile is about 8 m. (B) Strongly-laterized profile 1604 derived from the Cretaceous sandstone at a trench of a bauxite prospect. The laterite and bauxite profile is about 6 m in thickness, showing brown, dark brown and black color. (C) Consolidated pisolitic Fe-rich laterite and bauxite with lateritic soil near the surface of the profile 1604. (D) Crumble kaolin-rich parent sandstone with khaki color beneath the bauxite horizon of the profile 1604. Geochemical compositions of the basalts are reported by Sanematsu *et al*. (2011).

acids (hydrofluoric acid, nitric acid, perchloric acid and hydrochloric acid), and were analyzed by using inductively coupled plasma mass spectrometry (ICP-MS) of the Perkin Elmer SCIEX ELAN 6000 or 6100 at the Activation Laboratories Ltd., Canada. Sc contents in basalt samples were measured by using ICP-MS of the Agilent Technologies 7500cs at the Magnetic Materials Research Center of Shin-Etsu Chemical Co., Ltd., Japan.

Powder X-ray diffraction (XRD) analysis was conducted on the all the samples to identify rock-forming minerals and alteration products using the Rigaku INT-2000 X-ray diffractometer at the Geological Survey of Japan, AIST. The analysis was carried out using CuKα radiation, a accelerating voltage of 40 kV and a beam current of 100 mA. The scan range (2θ) was from 3 to 60° with scan step 0.02° and scan speed 2°/min.

5. Results

A total of 134 samples from the Bolaven Plateau were analyzed and they consist of 18 saprolite samples, 86 basaltic laterite samples, 3 sedimentary rock samples and 27 sedimentary laterite samples. Chemical compositions of major and trace elements for these samples are listed in Appendix. Chemical compositions of basalts and basaltic andesites on this plateau were reported by Vilayhack *et al*. (2008) and Sanematsu *et al*. (2011). Statistical data of Al_2O_3, Ga and Sc contents are listed in Table 1 and the histograms are illustrated in Figure 5. Each histogram shows normal distribution and average values are about equal to median values (Table 1).

Al_2O_3 contents of the basalt samples range from 10.5 to 15.1 % with the average of 13.8 %. The saprolite and laterite samples show higher Al_2O_3 contents of 15.6 – 29.9 % (average: 22.5 %) and 17.3 – 47.9 % (average: 29.0 %), respectively. Al_2O_3 contents of the sedimentary laterite samples are as high as those of the basaltic laterite samples, ranging from 15.4 to 46.9 % with the average of 26.7 % (Fig. 5). Bauxite ores collected from bauxite prospects shows higher Al_2O_3 contents ranging from 28 to 47 % among the sedimentary laterite samples.

Ga contents of the basalt samples range from 6 to 20 ppm with the average of 16.7 ppm. Saprolite samples show Ga contents of 9 – 46 ppm (average: 31.6 ppm) and laterite samples shows the much higher contents of 24 – 83 ppm (average: 44.4 ppm). The sedimentary laterite samples show Ga contents as high as those of basaltic laterite samples, which range from 22 to 68 ppm with the average of 42.6 ppm (Fig. 5).

Sc contents of the basalt samples range from 14 to 23 ppm with the average of 20.8 ppm. The saprolite samples shows Sc contents of 14 – 45 ppm (average: 31.1 ppm) and the laterite samples shows the higher contents of 14 – 69 ppm (average: 37.6 ppm). The sedimentary laterite samples show Sc contents as high as those of basaltic laterite samples, ranging from 13 to 84 ppm with the average of 38.7 ppm (Fig. 5).

6. Discussion

Hill *et al*. (2000) studied the geochemical compositions and alteration minerals of laterized basalts quantitatively and classified the degree of laterization into four categories: kaolinization, week laterization,

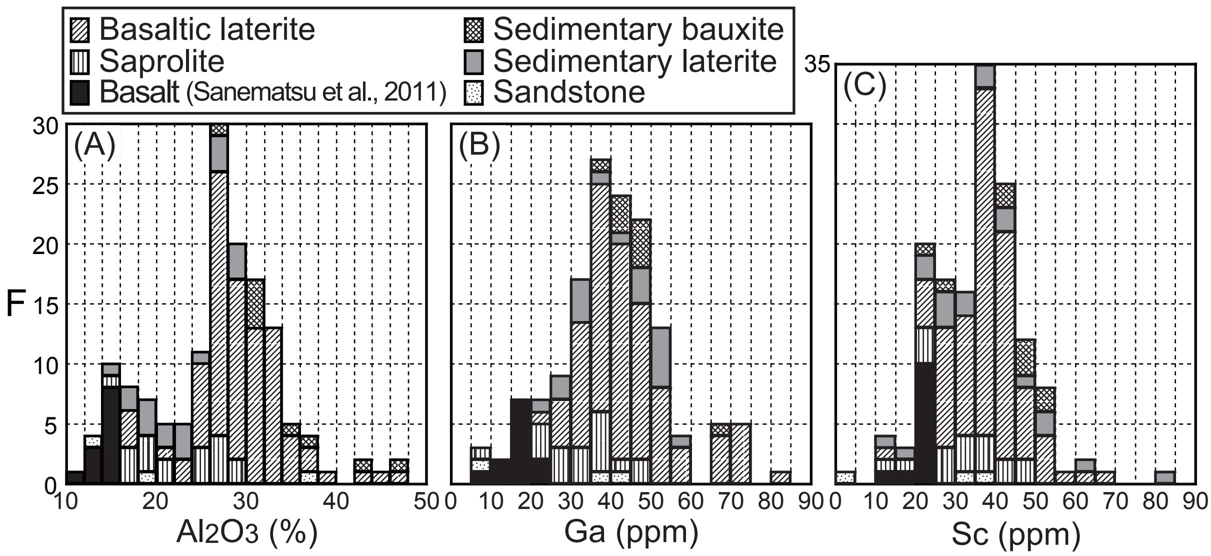

Fig. 5 Histograms showing the distribution of (A) Al_2O_3, (B) Ga and (C) Sc contents of the basalts, saprolites, basaltic laterites, sedimentary rocks, sedimentary laterites and sedimentary bauxites from the Bolaven Plateau.

Table. 1 Statistical data of the analyzed basalts, saprolites and laterites from the Bolaven Plateau.

	SiO_2	Fe_2O_3*	Al_2O_3	TiO_2	Ga	Sc
Basalt (N=12)						
Average	49.8	12.2	13.8	1.84	16.7	20.8
Median	50.4	11.7	14.0	1.66	19	21.2
SD	3.6	1.7	1.2	0.44	4.5	2.4
Min	39.2	10.9	10.5	1.57	6	14.0
Max	52.4	17.4	15.1	3.18	20	22.9
Saprolite (N=18)						
Average	36.0	18.4	22.5	2.78	31.6	31.1
Median	34.8	17.9	22.7	2.97	32	30
SD	7.4	3.7	4.8	0.62	9.2	9.4
Min	23.4	12.9	15.6	1.92	9	14
Max	48.6	23.6	29.9	3.51	46	45
Basaltic laterite (N=86)						
Average	21.8	24.6	29.7	3.85	44.4	37.6
Median	23.1	23.9	29.0	3.49	42	37.5
SD	12.4	6.7	5.1	1.3	12.2	8.9
Min	0.34	5.9	17.3	1.28	24	14
Max	63.2	43.1	47.9	7.77	83	69
Sedimentary laterite including bauxite (N=27)						
Average	20.7	29.2	26.7	3.70	42.6	38.7
Median	16.7	28.0	26.6	3.75	45	40
SD	19.3	15.0	7.7	1.3	10.0	15.4
Min	1.2	6.4	15.4	1.17	22	13
Max	62.0	57.6	46.9	6.31	68	84

Fe_2O_3*: Total iron oxides.

moderate laterization and strong laterization (Fig. 6A). The saprolites of the Bolaven Plateau are plotted in the range between kaolinization and weak laterization and the basaltic laterites are plotted in the wide range between kaolinization and strong laterization (Fig. 6A). The sedimentary laterites are also plotted on the diagrams of Figure 6 to compare the chemical compositions with basaltic laterites. Some of the sedimentary laterites range widely in the ternary diagram because of the variable chemical compositions of the parent sedimentary rocks.

The laterization caused by the scavenging of these major elements leads to an increase of immobile elements such as Al, Ga and Sc relative to the parent rock (Figs. 6B, 6C and 6D). Mobile major elements consisting mainly of SiO_2, alkali elements and alkaline earth elements decrease by 15 – 42 wt % (average: 26 %) during the formation of saprolite by weak weathering. The loss of the major elements leads to the increase of immobile elements relative to the parent basalts. The change of chemical compositions from the basalts to saprolites results in relative increases of 62 % Al_2O_3, 89 % Ga and 49 % Sc increase (Table 1; Figure 6). The loss of the mobile major elements by laterization of the basalts ranges from 37 to 58 %, leading to the relative increases of 115 % Al_2O_3, 166 % Ga and 81 % Sc (Table 1; Figure 6). These results suggest that Ga is more immobile whereas Sc is more mobile than Al by laterization. Nine sedimentary bauxite samples show Al_2O_3 contents ranging from 28 to 47 %, indicating 52 – 156 % increase relative to the parent sandstone (sample 1604D). The bauxite sample are relatively low-grade in Al_2O_3 compared with mined bauxites in the world

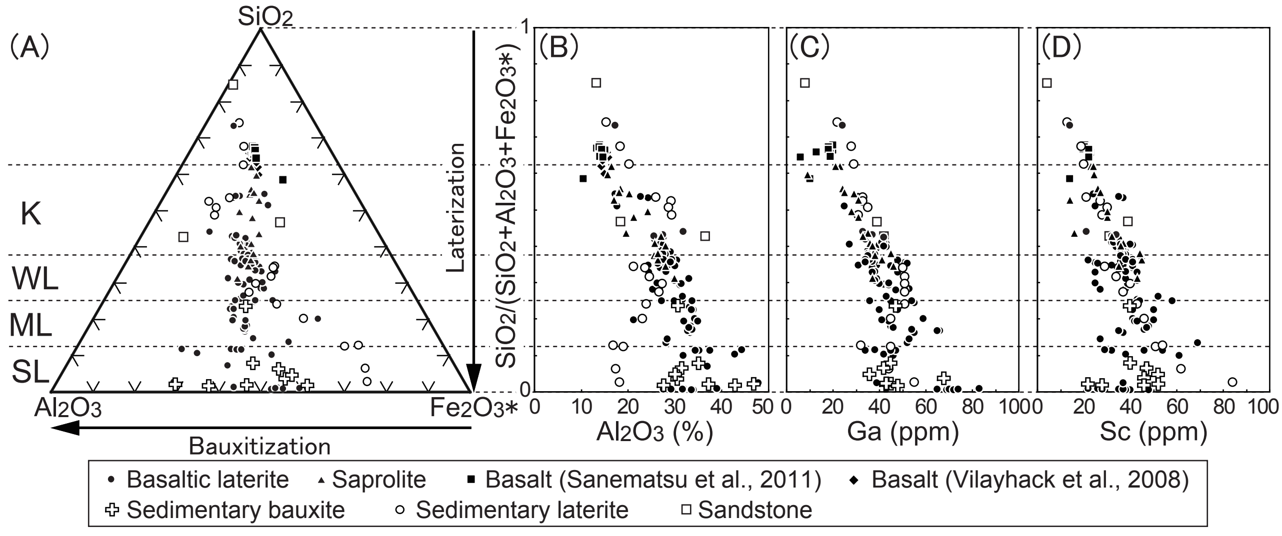

Fig. 6 (A) Ternary SiO_2-Al_2O_3-Fe_2O_3* (total iron oxides) diagram (Hill *et al.*, 2000) and plots of (A) Al_2O_3, (B) Ga and (C) Sc versus SiO_2/(SiO_2+Al_2O_3+Fe_2O_3*) of the analyzed samples. K: Kaolinization, WL: Weak Laterization, ML: Moderate Laterization, SL: Strong Laterization. Note that these diagrams are for evaluating the degree of laterization of basalts and that the sedimentary rocks and sedimentary laterite samples are plotted for a comparison.

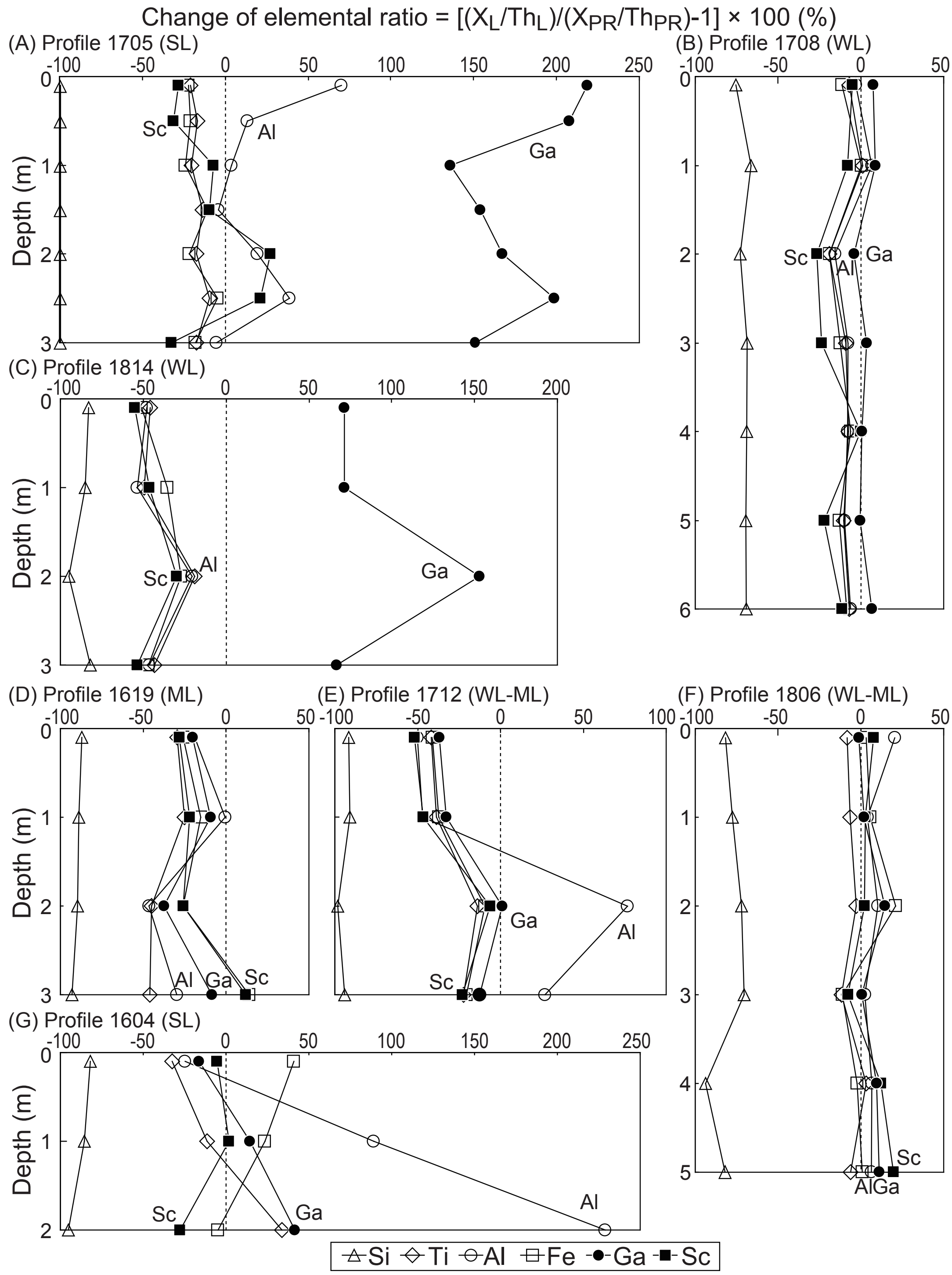

Fig. 7 Diagrams showing the changes of elemental ratios of Si, Ti, Al, Fe, Ga and Sc (represented as X) normalized by Th versus depth in the laterite profiles. Subscripts of L and PR represent laterite and parent rock, respectively. Positive and negative values of the changes indicate enrichment and depletion of elements relative to parent rocks, respectively. (A) Strongly-laterized profile 1705 derived from aphyric nephelinite (sample 1705H). (B) Weakly-laterized profile 1708 derived from Cpx-Ol basalt (sample 1707). (C) Weakly-laterized profile 1814 derived from Ol-Cpx basalt (sample 1815). (D) Moderately-laterized profile 1619 derived from Cpx basalt (sample 1619E). (E) Weakly- to moderately-laterized profile 1712 derived from Cpx-bearing Pl-Ol basaltic andesite (sample 1712E). (F) Weakly-laterized profile 1806 derived from Cpx-Ol basalt (sample 1806G). (G) Strongly-laterized profile 1604 derived from clay-rich sandstone (sample 1604D). See the caption of Figure 6 for the degree of laterization. Geochemical data of the parent basalts are from Sanematsu *et al*. (2011). See the caption of Figure 6 for the degree of laterization of WL, ML and SL.

which indicate the average Al_2O_3 grade of 40 – 52 % and increase by 120 – 300 % relative to the parent rocks by laterization (Bárdossy and Aleva, 1990). The low-grade bauxite mineralization with the insufficient enrichment of Al_2O_3 results from high Fe_2O_3 contents because bauxite derived from mafic and ultramafic rocks are generally Fe-rich and low-grade in Al_2O_3 (Bárdossy and Aleva, 1990).

Geochemical behavior of elements by alteration is represented by change of the elemental ratio of an altered rock to a parent rock normalized by an immobile element (Nexbitt, 1979). Immobile elements such as Al, Ti and Th are generally used for the normalization (Braun *et al.*, 1993, 1998; Braun and Pagel, 1994; Patino *et al.*, 2003; Ma *et al.*, 2007). In this study, Th is not remarkably depleted relative to the other elements except for Al and Ga (Fig. 7) and is not a target element. Therefore, we use Th as an immobile element for the normalization of the elemental ratios. Figure 7 represents that Si is depleted in all the profiles whereas Ti, Al, Fe, Ga and Sc show slight or almost no depletion relative to the parent rocks. Al is significantly enriched or depleted in some samples of the profiles 1705, 1814, 1712 and 1604 (Figs. 7A, 7C, 7E and 7G). This is explained by leaching of Al in low-pH soil water of the upper parts of the profiles (leached zones) and precipitation of Al in the lower parts of the profiles (accumulation zone). The precipitation of Al in the accumulation zone due to the increase of pH (Brookins, 1988), may be attributed to the contact with higher-pH groundwater. The sedimentary laterite profile 1604 of a bauxite prospect indicates that the transportation of Al from the leached zone to the accumulation zone resulted in bauxite mineralization (Fig. 7G). The thickness of the accumulation zone is considered about 5 m (Fig. 4B) although only three laterite and bauxite samples were taken from this profile. Since it is impossible for the present leached zone less than 1 m thick to induce bauxite mineralization (35 and 47 % Al_2O_3 for samples 1604B and 1604C, respectively; Appendix) around 5 m thick, this profile suggests that the paleo-leached zone which had provided Al to the accumulation zone was already eroded. Negative Ce anomalies ($Ce/Ce^* = Ce_N/(La_N \times Pr_N)^{1/2}$ = 0.91 – 0.96, where the subscript N represents normalization by C1-chondrite; Sun and McDonough, 1989) of the laterite bauxite samples from the profile 1604 also suggest that the present leached zone was covered by paleo-leached zone near the surface during laterization and bauxitization. Similar enrichment of Al is recognized in the profile 1705 with negative to slightly positive Ce anomalies (Ce/Ce^* = 0.95 – 1.02), suggesting the transportation of Al (and Ga) from the paleo-leached zone to the present accumulation zone. Geochemical behavior of Ga is similar to that of Al in all the profiles (Fig. 7), suggesting that Ga^{3+} exists by replacing the sites of Al^{3+} in Al-bearing minerals and Al hydroxides. This replacement is explained by a positive linear correlation between the Ga and Al_2O_3 contents of all the studied samples (Fig. 8A). Compared with Ga and Al, Sc is not remarkably enriched or depleted in all the profiles (Fig. 7). Since Sc is considered to be present

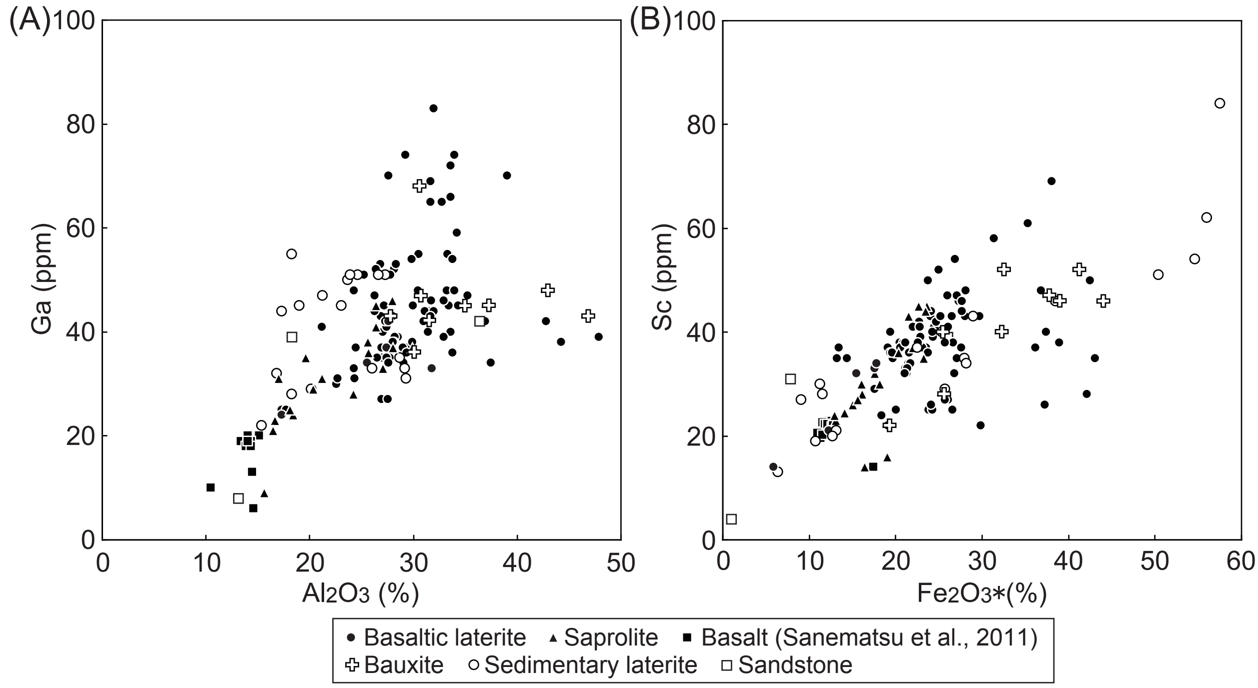

Fig. 8 (A) Ga versus Al_2O_3 and (B) Sc versus Fe_2O_3* (total iron oxides) diagrams of the basalts, saprolites laterites and sedimentary rocks from the Bolaven Plateau.

in basalts and laterites by replacing Fe^{3+} of Fe-bearing minerals, Fe oxides and Fe oxyhydroxides, geochemical behavior of Sc is similar to that of Fe in the most laterite profiles (Fig. 7). A good positive correlation is recognized between Sc and Fe_2O_3* of all the studied samples (Fig. 8B) although Sc behaves differently from Fe in the strongly-laterized profiles 1705 and 1604 (Fig. 7A and 7G).

It is comprehensible to employ 10000Ga/Al and 10000Sc/Fe ratios for evaluating the enrichment of Ga and Sc by laterization in detail (Fig. 9) because Ga and Sc mostly exist by replacing Al and Fe^{3+}, respectively. Ga/Al ratios do not change significantly in most of parent basalts, saprolites and kaolin-rich laterites (10000Ga/Al = 2 – 3), but they become variable with increasing the degree of laterization (Fig. 9A). The Ga/Al ratios are most variable in the strongly-laterized samples (mostly 10000Ga/Al = 1.5 – 5), but Ga is hardly depleted. Laterites appears to be enriched in Ga relative to Al (Fig. 9A), consistent with the relative increases of 166 % Ga and Al_2O_3 115 % (Table 1). Figure 9B indicates that Sc/Fe ratios of the parent basalts are constant (10000Sc/Fe = ~2.6) except for a nephelinite sample. Since Fe^{2+} is dominant in unweathered parent basalts, Sc may replace limited sites of Fe^{3+} in Fe-bearing minerals or glass. The Sc/Fe ratios do not vary widely with increasing the degree of laterization compared with the Ga/Al ratios but they tend to decrease slightly by strong laterization (Fig. 9B). This result suggests that strong laterization may lead to the depletion of Sc relative to Fe. All the geochemical data of the parent basalts, saprolites and laterites suggest that Ga is hardly depleted or is slightly enriched by laterization whereas Sc is slightly depleted by strong laterization among Al, Ga, Fe and Sc. The geochemical behavior during laterization is helpful to evaluate the resource potentials of Ga and Sc in laterites and bauxites.

7. Conclusions

Al_2O_3, Ga and Sc contents increase with increasing the degree of laterization relative to the parent basalts and sandstone in the Bolaven Plateau, southern Laos. The Al_2O_3 contents range from 10 to 15 % in the basalts, from 16 to 30 % in the saprolites and from 17 to 48 % in the basaltic and sedimentary laterites. The sedimentary bauxites in a bauxite prospect show the Al_2O_3 contents ranging from 28 to 47 %. The Ga contents range from 6 to 20 ppm in the basalts, from 9 to 46 ppm in the saprolites and from 22 to 83 ppm in the laterites. The Sc contents range from 14 to 23 ppm in the basalts, from 14 to 45 ppm in the saprolites and from 13 to 84 ppm in the laterites. No significant difference in the Al_2O_3, Ga and Sc contents is recognized between the basaltic laterites and sedimentary laterites.

A similar geochemical behavior and linear positive correlation are recognized between Ga and Al and between Sc and Fe, suggesting that Ga and Sc exist by replacing by Al and Fe in laterites, respectively. Ga/Al and Sc/Fe ratios indicate that Ga is almost no depleted or is slightly enriched relative to Al by laterization whereas Sc tends to be slightly depleted relative to Fe

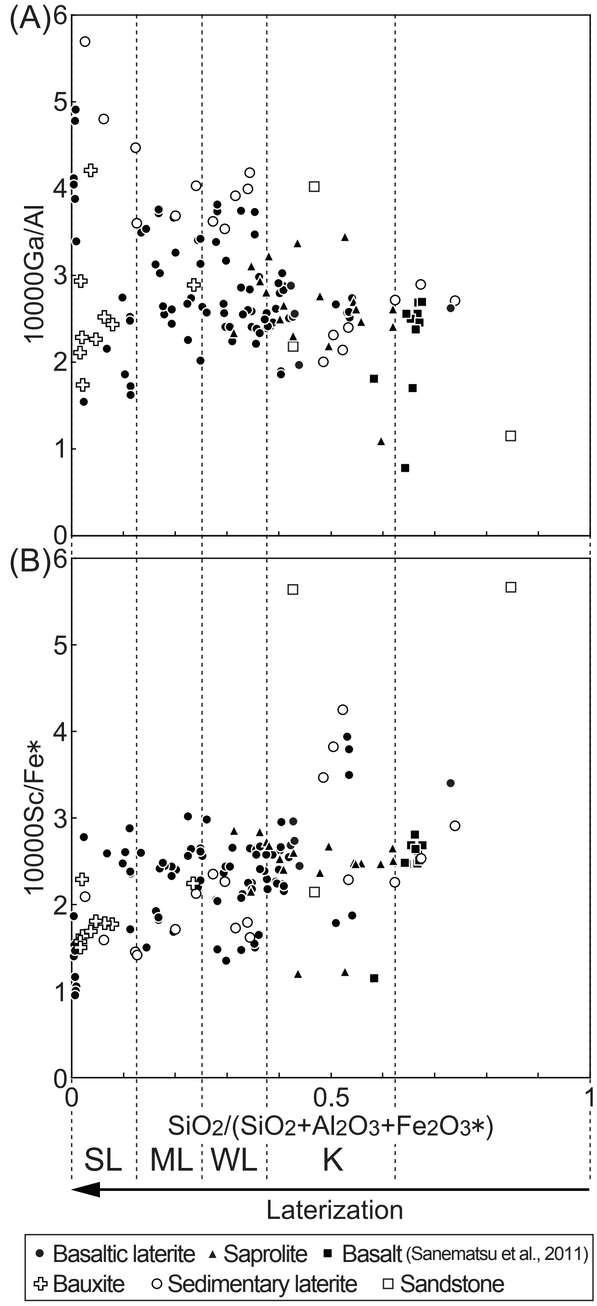

Fig. 9 (A) 10000Ga/Al and (B) 10000Sc/Fe*(total iron) versus $SiO_2/(SiO_2+Al_2O_3+Fe_2O_3*)$ diagrams of the basalts, saprolites, laterites and sedimentary rocks from the Bolaven Plateau.

by strong laterization.

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ラオス南部ボラヴェン台地における Al，Ga，Sc の濃集に関連する玄武岩と砂岩のラテライト化

実松健造・守山　武・Laochou Sotouky・渡辺　寧

要　旨

本稿はラオス南部ボラヴェン台地の玄武岩と砂岩のラテライト化による Al，Ga，Sc の地球化学的挙動と濃集について報告する．ボラヴェン台地は新第三紀から新生代の玄武岩とその下位に位置する白亜紀堆積岩から構成される．玄武岩や堆積岩起源のラテライトはこれらの原岩の上に発達している．ラテライト化の進行によって Si，アルカリ元素，アルカリ土類元素といった移動性元素が失われ，相対的に Al，Ga，Sc といった難移動性元素が原岩に対して富むようになる．その結果，Al_2O_3 含有量は玄武岩で 10 ～ 15 %，サプロライトで 16 ～ 30 %，玄武岩ラテライトで 17 ～ 48 %，堆積岩ラテライトは 15 ～ 47 % である．Ga 含有量は玄武岩で 6 ～ 20 ppm，サプロライトで 9 ～ 46 ppm，玄武岩ラテライトで 24 ～ 83 ppm，堆積岩ラテライトで 22 ～ 68 ppm である．Sc 含有量は玄武岩で 14 ～ 23 ppm，サプロライトで 14 ～ 45 ppm，玄武岩ラテライトで 24 ～ 69 ppm，堆積岩ラテライトで 13 ～ 84 ppm である．玄武岩ラテライトと堆積岩ラテライトの間でこれらの元素の濃集度に有意な違いは認められない．Ga と Al そして Sc と Fe の間には地球化学的挙動の類似性と線的な正の相関が確認され，これらはラテライト中で Ga と Sc がそれぞれ Al と Fe を置換して存在していることを示唆する．Ga/Al 比はラテライト化の進行に伴って様々な値をとるようになるが，Ga は Al に対してほとんど枯渇することはない．Sc/Fe 比は強いラテライト化によって Sc が Fe に対して若干枯渇することがあることを示す．

Appendix. 1 Geochemical data of the analyzed saprolites, basaltic laterites, sedimentary laterites and sedimentary rocks.

Sample #	1601	1612A	1612B	1613A	1613B	1615A	1615B	1615C	1617A	1617B
Rock type	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite
Depth(m)	Surface(F)	0.1	0.5	1.0	1.5	0.1	0.7	1.2	0.1	1.0
Northing	15°08'0.3"	14°59'29.9"	14°59'29.10"	14°59'52.0"	14°59'52.0"	15°02'47.1"	15°02'47.1"	15°02'47.1"	15°02'51.3"	15°02'51.3"
Easting	106°30'16.4"	106°33'45.0"	106°33'45.0"	106°33'10.0"	106°33'10.0"	106°32'10.2"	106°32'10.2"	106°32'10.2"	106°32'14.3"	106°32'14.3"
SiO_2(%)	0.40	20.4	21.0	63.2	34.6	30.7	33.2	34.2	16.9	16.5
TiO_2	6.87	5.34	5.42	1.28	1.80	3.28	3.55	3.60	4.26	4.29
Al_2O_3	33.9	26.3	26.8	17.3	31.8	25.6	27.6	27.4	33.2	34.0
Fe_2O_3*	37.4	26.5	26.7	5.9	12.3	15.5	17.6	17.8	22.8	22.9
MnO	0.280	0.101	0.109	0.020	0.026	0.034	0.039	0.041	0.041	0.044
MgO	0.22	0.26	0.28	0.64	0.34	0.16	0.18	0.17	0.10	0.10
CaO	0.03	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01
Na_2O	0.03	0.05	0.04	0.08	0.08	0.06	0.05	0.06	0.06	0.03
K_2O	< 0.01	0.02	0.07	1.49	0.65	0.08	< 0.01	0.09	< 0.01	< 0.01
P_2O_5	0.84	0.33	0.29	0.08	0.14	0.13	0.15	0.14	0.19	0.18
LOI	20.2	20.5	17.9	9.76	17.5	23.0	16.9	16.8	22.5	20.9
Total	100.10	99.86	98.57	99.73	99.24	98.43	99.28	100.20	100.00	98.93
Sc(ppm)	40	38	38	14	21	32	33	34	42	41
V	394	375	385	117	201	278	308	311	413	413
Cr	260	420	440	130	600	320	370	360	440	440
Co	50	15	17	5	8	21	25	25	12	12
Ni	< 20	< 20	40	< 20	< 20	90	150	120	< 20	< 20
Cu	30	60	70	20	40	50	80	60	50	50
Zn	470	140	130	40	60	100	210	110	130	120
Ga	74	47	53	24	33	34	42	37	48	48
Ge	1.3	1.5	2.0	1.5	1.3	1.6	2.2	1.4	1.5	1.5
As	6	< 5	8	7	10	< 5	< 5	< 5	< 5	< 5
Sr	587	52	56	32	27	7	8	7	5	5
Y	58.2	10.9	13.3	28.1	21.7	19.5	17.1	17.2	5.7	4.7
Zr	672	410	353	470	325	220	265	268	324	321
Nb	157	69.4	64.7	27.3	31.3	25.1	30.2	28.6	43.3	43.1
Ba	257	69	79	177	105	37	39	40	12	12
Hf	15.4	10.9	9.2	12.7	8.8	6.2	7.0	7.1	8.3	8.5
Ta	8.26	4.52	3.90	2.25	2.33	1.80	1.94	2.15	3.12	3.06
Pb	6	8	< 5	19	17	< 5	7	6	11	7
Th	33.3	9.58	10.5	22.7	22.4	6.24	7.06	6.25	8.14	8.15
U	11.5	2.62	2.87	3.89	3.82	1.67	1.87	1.94	2.35	2.29
La	296	35.8	47.1	38.1	30.6	13.1	13.6	12.5	5.01	4.67
Ce	626	53.7	72.3	72.6	52.6	38.0	41.9	35.4	12.3	11.1
Pr	74.9	8.88	10.2	8.44	6.73	3.89	3.44	3.56	1.11	0.96
Nd	305	32.7	39.3	27.2	22.7	16.2	15.3	14.6	4.17	3.55
Sm	74.9	7.22	8.68	5.34	4.78	4.16	4.21	3.75	0.98	0.78
Eu	23.6	2.20	2.69	1.10	1.27	1.40	1.35	1.25	0.289	0.233
Gd	56.1	5.74	7.03	4.47	4.37	4.33	4.01	3.94	0.96	0.77
Tb	7.02	0.83	0.95	0.86	0.79	0.77	0.66	0.67	0.19	0.15
Dy	27.7	3.84	4.12	5.21	4.57	4.50	3.84	3.86	1.22	0.98
Ho	3.40	0.55	0.63	1.01	0.87	0.81	0.73	0.71	0.24	0.20
Er	6.47	1.27	1.55	3.03	2.52	2.23	2.09	1.94	0.70	0.61
Tm	0.655	0.173	0.212	0.481	0.389	0.324	0.313	0.280	0.110	0.095
Yb	2.57	1.06	1.27	3.24	2.49	2.03	1.93	1.79	0.73	0.65
Lu	0.210	0.146	0.169	0.493	0.367	0.281	0.279	0.276	0.109	0.101
LREE	1400.4	140.5	180.3	152.8	118.7	76.8	79.8	71.1	23.9	21.3
HREE	104.1	13.6	15.9	18.8	16.4	15.3	13.9	13.5	4.3	3.6
REE	1504.5	154.1	196.2	171.6	135.0	92.0	93.7	84.5	28.1	24.8
LREE/HREE	13.45	10.32	11.32	8.13	7.25	5.02	5.76	5.28	5.60	5.99
Ce/Ce*	1.03	0.74	0.81	0.99	0.90	1.31	1.50	1.30	1.28	1.29
Eu/Eu*	1.11	1.04	1.05	0.69	0.85	1.01	1.00	0.99	0.91	0.92
La/Yb	115.2	33.8	37.1	11.8	12.3	6.5	7.0	7.0	6.9	7.2
10000Ga/Al	4.12	3.38	3.73	2.62	1.96	2.51	2.88	2.55	2.73	2.67
10000Sc/Fe*	1.53	2.05	2.04	3.40	2.44	2.95	2.68	2.73	2.64	2.56

(F): Float sample
B. laterite: Basaltic laterite
S. laterite: Sedimentary laterite
S. bauxite: Sedimentary bauxite
Fe_2O_3* = Total iron oxides
Ce/Ce* = $Ce_N / (La_N \times Pr_N)^{1/2}$ and Eu/Eu* = $Eu_N / (Sm_N \times Gd_N)^{1/2}$, where N is normalized by C1-chondrite (Sun and McDonough, 1989).

Appendix. 1 Continued.

Sample #	1617C	1618A	1618B	1618C	1619A	1619B	1619C	1619D	1701A	1701B
Rock type	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite
Depth(m)	2.0	0.1	1.0	2.0	0.1	1.0	2.0	3.0	0.1	1.0
Northing	15°02'51.3"	15°03'06.0"	15°03'06.0"	15°03'06.0"	15°04'17.2"	15°04'17.2"	15°04'17.2"	15°04'17.2"	15°10'04.1"	15°10'04.1"
Easting	106°32'14.3"	106°32'34.0"	106°32'34.0"	106°32'34.0"	106°32'33.9"	106°32'33.9"	106°32'33.9"	106°32'33.9"	106°01'31.3"	106°01'31.3"
SiO_2(%)	14.8	11.8	12.3	12.1	18.9	14.3	19.4	10.3	23.2	23.0
TiO_2	4.29	4.54	4.53	4.49	3.83	3.66	3.91	3.03	3.49	3.52
Al_2O_3	34.2	33.3	33.6	32.7	31.6	34.9	27.2	28.2	31.0	31.1
Fe_2O_3	24.5	27.6	27.5	27.1	24.0	24.7	31.4	38.1	24.4	24.3
MnO	0.047	0.037	0.043	0.044	0.083	0.052	0.039	0.028	0.086	0.089
MgO	0.10	0.09	0.09	0.09	0.10	0.09	0.11	0.11	0.10	0.11
CaO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01
Na_2O	0.05	0.04	0.06	0.07	0.07	0.06	0.03	0.06	0.05	0.05
K_2O	0.06	0.08	0.05	0.05	< 0.01	< 0.01	0.02	< 0.01	0.06	0.13
P_2O_5	0.19	0.23	0.23	0.26	0.18	0.20	0.23	0.39	0.28	0.26
LOI	20.6	22.8	20.5	20.8	19.6	21.5	16.3	18.6	17.7	17.5
Total	98.83	100.50	98.89	97.77	98.35	99.42	98.65	98.74	100.30	100.10
Sc(ppm)	41	37	35	35	43	42	58	69	39	40
V	432	426	417	413	389	390	524	514	334	336
Cr	500	520	600	590	400	510	480	830	390	400
Co	13	7	9	8	22	15	15	19	13	14
Ni	< 20	< 20	< 20	< 20	80	70	30	80	70	60
Cu	70	30	50	50	80	70	110	170	70	70
Zn	150	100	110	100	110	110	120	140	120	130
Ga	59	55	66	65	44	45	45	52	42	44
Ge	1.9	0.8	1.2	1.2	2.0	1.5	1.6	1.7	2.0	2.0
As	5	11	12	17	< 5	< 5	< 5	< 5	5	6
Sr	5	10	12	11	5	4	10	3	5	6
Y	6.2	8.9	9.0	10.0	7.5	4.4	7.3	5.6	3.7	3.9
Zr	362	445	448	443	251	233	260	232	262	272
Nb	48.2	58.9	58.0	56.1	30.1	26.4	39.9	38.9	28.6	29.6
Ba	12	13	18	16	28	16	18	8	22	23
Hf	9.1	11.8	12.5	11.9	6.8	6.3	7.1	6.2	6.9	7.3
Ta	3.15	4.40	2.72	2.68	1.99	1.93	2.72	2.27	2.35	2.33
Pb	< 5	8	< 5	< 5	7	9	< 5	8	7	9
Th	9.55	16.5	18.9	19.3	5.87	5.28	7.67	6.05	6.60	7.10
U	2.54	3.99	4.46	4.63	1.75	1.74	2.24	3.27	1.75	1.88
La	5.75	9.83	14.8	14.0	7.13	4.43	12.1	7.32	3.67	3.86
Ce	15.0	16.0	21.3	21.4	31.8	15.3	26.4	21.8	9.51	11.1
Pr	1.09	1.89	2.07	2.18	1.90	1.11	2.65	1.52	0.70	0.76
Nd	4.21	5.97	6.29	6.78	7.71	4.43	9.54	6.88	2.47	2.73
Sm	0.99	1.12	1.13	1.26	1.93	1.10	2.11	1.89	0.54	0.59
Eu	0.268	0.274	0.266	0.308	0.622	0.338	0.644	0.624	0.151	0.159
Gd	0.93	1.05	1.00	1.16	2.03	1.12	1.94	1.89	0.58	0.60
Tb	0.18	0.22	0.21	0.23	0.33	0.19	0.33	0.31	0.11	0.12
Dy	1.18	1.55	1.46	1.54	1.88	1.16	1.84	1.71	0.75	0.78
Ho	0.26	0.34	0.33	0.35	0.35	0.21	0.33	0.31	0.16	0.16
Er	0.81	1.05	1.12	1.20	0.99	0.62	0.96	0.90	0.48	0.51
Tm	0.126	0.166	0.182	0.194	0.148	0.098	0.148	0.144	0.076	0.080
Yb	0.82	1.13	1.23	1.30	0.98	0.67	1.00	1.00	0.53	0.56
Lu	0.126	0.179	0.188	0.201	0.152	0.105	0.154	0.176	0.083	0.090
LREE	27.3	35.1	45.9	45.9	51.1	26.7	53.4	40.0	17.0	19.2
HREE	4.4	5.7	5.7	6.2	6.9	4.2	6.7	6.4	2.8	2.9
REE	31.7	40.8	51.6	52.1	58.0	30.9	60.1	46.5	19.8	22.1
LREE/HREE	6.16	6.17	8.02	7.44	7.45	6.40	7.97	6.22	6.15	6.62
Ce/Ce*	1.47	0.91	0.94	0.95	2.12	1.69	1.14	1.60	1.45	1.59
Eu/Eu*	0.85	0.77	0.77	0.78	0.96	0.93	0.97	1.01	0.82	0.82
La/Yb	7.0	8.7	12.0	10.8	7.3	6.6	12.1	7.3	6.9	6.9
10000Ga/Al	3.26	3.12	3.71	3.75	2.63	2.44	3.13	3.49	2.56	2.67
10000Sc/Fe*	2.40	1.92	1.82	1.85	2.56	2.43	2.64	2.59	2.29	2.36

Appendix. 1 Continued.

Sample #	1701C	1702A	1702B	1702C	1702D	1702E	1702F	1702G	1702H1	1702H2
Rock type	B. laterite	B. laterite	B. laterite	B. laterite	Saprolite	B. laterite	B. laterite	B. laterite	Saprolite	Saprolite
Depth(m)	2.0	0.1	1.0	2.0	3.0	4.0	5.0	6.0	6.5	6.5
Northing	15°10'04.1"	15°11'22.1"	15°11'22.1"	15°11'22.1"	15°11'22.1"	15°11'22.1"	15°11'22.1"	15°11'22.1"	15°11'22.1"	15°11'22.1"
Easting	106°01'31.3"	106°07'53.0"	106°07'53.0"	106°07'53.0"	106°07'53.0"	106°07'53.0"	106°07'53.0"	106°07'53.0"	106°07'53.0"	106°07'53.0"
SiO_2(%)	23.0	7.36	13.5	27.8	27.1	16.6	27.4	32.9	29.6	27.9
TiO_2	3.51	3.41	3.93	3.48	3.37	3.48	3.32	3.10	3.42	3.33
Al_2O_3	31.4	31.7	33.4	28.5	28.0	33.6	26.9	26.9	25.6	26.4
Fe_2O_3	22.9	35.3	28.1	23.6	23.3	23.8	26.1	21.1	23.6	22.7
MnO	0.102	0.096	0.128	0.144	0.139	0.089	0.065	0.074	0.183	0.105
MgO	0.11	0.07	0.08	0.09	0.08	0.05	0.10	0.08	0.16	0.12
CaO	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01
Na_2O	0.04	0.05	0.05	0.07	0.05	0.03	0.04	0.03	0.02	0.03
K_2O	0.01	0.03	< 0.01	0.03	0.05	0.02	< 0.01	0.09	0.06	0.07
P_2O_5	0.22	0.56	0.39	0.32	0.31	0.47	0.31	0.32	0.57	0.46
LOI	17.8	21.5	21.0	16.3	16.4	19.8	15.3	14.6	14.3	15.4
Total	99.15	100.10	100.50	100.30	98.72	97.85	99.50	99.18	97.54	96.44
Sc(ppm)	39	61	48	37	35	50	41	33	45	45
V	334	569	447	321	317	358	383	306	374	431
Cr	380	800	490	300	320	1200	380	300	350	350
Co	12	26	25	31	34	47	16	25	48	37
Ni	40	< 20	50	360	440	120	360	590	470	710
Cu	60	120	110	150	190	110	150	140	100	160
Zn	80	120	130	130	170	120	150	190	170	100
Ga	40	46	45	39	46	40	37	43	38	41
Ge	1.4	1.0	1.6	2.5	2.9	1.4	2.8	4.3	2.3	3.5
As	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6
Sr	5	3	4	2	2	< 2	< 2	2	< 2	8
Y	3.7	7.7	5.8	6.1	7.0	3.4	7.0	7.9	6.8	6.0
Zr	253	203	228	194	224	199	182	183	240	169
Nb	27.4	22.0	24.9	20.7	23.1	21.0	19.6	18.6	42.0	35.5
Ba	23	15	28	84	84	78	138	446	398	523
Hf	6.7	5.6	6.4	5.3	6.0	5.6	5.0	4.8	5.9	4.3
Ta	2.61	1.66	1.91	1.56	1.40	1.49	1.49	1.14	2.76	2.50
Pb	< 5	7	9	6	< 5	< 5	< 5	< 5	< 5	< 5
Th	6.90	3.49	3.77	2.59	3.01	2.61	2.51	2.34	5.01	4.79
U	1.84	1.73	1.30	0.74	0.79	1.17	0.90	0.76	1.28	1.65
La	4.22	4.32	5.15	4.13	5.38	2.09	3.93	4.93	6.23	15.9
Ce	13.2	19.1	27.4	20.5	26.0	16.1	13.8	25.5	61.9	52.4
Pr	0.82	1.22	1.19	1.21	1.38	0.60	1.07	1.58	1.60	2.41
Nd	2.92	5.93	5.23	5.35	6.29	3.02	4.96	7.45	7.73	9.44
Sm	0.65	1.75	1.43	1.45	1.75	0.93	1.44	2.17	2.30	2.40
Eu	0.191	0.660	0.518	0.533	0.616	0.330	0.532	0.778	0.771	0.787
Gd	0.68	2.21	1.64	1.69	1.99	1.13	1.65	2.45	2.54	2.49
Tb	0.12	0.40	0.30	0.30	0.33	0.20	0.30	0.37	0.39	0.38
Dy	0.79	2.47	1.79	1.76	1.88	1.13	1.78	2.01	1.96	1.89
Ho	0.16	0.46	0.32	0.32	0.35	0.19	0.32	0.36	0.35	0.34
Er	0.51	1.26	0.89	0.92	1.02	0.53	0.89	1.00	0.99	0.95
Tm	0.084	0.183	0.138	0.136	0.153	0.081	0.133	0.152	0.146	0.147
Yb	0.57	1.14	1.01	0.92	0.97	0.55	0.85	0.97	0.94	0.92
Lu	0.091	0.160	0.166	0.144	0.145	0.087	0.118	0.131	0.126	0.121
LREE	22.0	33.0	40.9	33.2	41.4	23.1	25.7	42.4	80.5	83.3
HREE	3.0	8.3	6.3	6.2	6.8	3.9	6.0	7.4	7.4	7.2
REE	25.0	41.3	47.2	39.4	48.3	27.0	31.8	49.9	88.0	90.6
LREE/HREE	7.32	3.98	6.54	5.36	6.06	5.92	4.26	5.70	10.82	11.51
Ce/Ce*	1.74	2.04	2.71	2.25	2.34	3.53	1.65	2.24	4.81	2.08
Eu/Eu*	0.88	1.03	1.03	1.04	1.01	0.98	1.06	1.03	0.98	0.98
La/Yb	7.4	3.8	5.1	4.5	5.5	3.8	4.6	5.1	6.6	17.3
10000Ga/Al	2.41	2.74	2.55	2.58	3.11	2.25	2.60	3.02	2.81	2.94
10000Sc/Fe*	2.44	2.47	2.44	2.25	2.15	3.01	2.25	2.23	2.72	2.84

Appendix. 1 Continued.

Sample #	1702I	1703A	1703B	1703C	1704A	1704B	1704C	1704D	1704E	1704F
Rock type	Saprolite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite
Depth(m)	7.5	0.3	1.0	2.0	2.5	3.5	4.5	5.5	6.5	7.5
Northing	15°11'22.1"	15°11'43.8"	15°11'43.8"	15°11'43.8"	15°11'01.3"	15°11'01.3"	15°11'01.3"	15°11'01.3"	15°11'01.3"	15°11'01.3"
Easting	106°07'53.0"	106°09'14.1"	106°09'14.1"	106°09'14.1"	106°13'13.7"	106°13'13.7"	106°13'13.7"	106°13'13.7"	106°13'13.7"	106°13'13.7"
SiO_2(%)	30.7	12.6	12.9	14.0	20.1	28.3	22.5	28.1	23.6	27.6
TiO_2	3.51	4.17	4.10	3.98	4.76	4.28	4.61	3.54	4.53	4.44
Al_2O_3	26.4	33.8	33.0	32.0	25.3	27.8	26.3	30.5	24.3	26.4
Fe_2O_3	23.5	27.3	27.1	26.5	26.1	23.8	26.6	19.1	24.3	24.1
MnO	0.219	0.111	0.113	0.094	0.214	0.341	0.271	0.287	0.207	0.323
MgO	0.20	0.17	0.19	0.24	5.49	1.21	0.61	1.57	5.78	2.97
CaO	< 0.01	0.01	< 0.01	< 0.01	1.34	0.05	< 0.01	0.26	2.70	0.77
Na_2O	0.04	0.04	0.02	0.02	0.08	0.05	0.02	< 0.01	0.09	0.02
K_2O	0.03	0.04	< 0.01	< 0.01	0.05	0.04	0.06	< 0.01	0.07	0.08
P_2O_5	0.58	0.35	0.28	0.23	2.67	1.11	0.92	1.07	1.91	1.59
LOI	14.1	22.2	20.7	19.4	14.2	13.7	15.0	15.9	13.5	12.7
Total	99.22	100.70	98.40	96.34	100.30	100.70	96.84	100.30	101.00	100.90
Sc(ppm)	44	46	47	43	27	25	25	22	25	26
V	402	372	354	334	336	333	354	264	332	335
Cr	380	420	410	370	370	320	250	230	290	280
Co	67	22	21	24	84	97	85	125	94	138
Ni	360	80	70	90	410	1110	690	860	270	290
Cu	130	110	120	130	170	330	190	150	100	110
Zn	230	160	210	110	350	270	130	280	360	470
Ga	45	54	46	44	51	51	44	48	48	52
Ge	3.4	2.0	2.0	1.9	3.2	4.0	2.6	3.3	2.3	2.7
As	< 5	6	6	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Sr	2	4	3	< 2	82	101	119	85	130	121
Y	11.7	4.9	4.9	5.1	26.4	16.2	15.2	29.5	34.5	35.1
Zr	262	268	237	201	500	425	215	388	467	457
Nb	45.0	28.3	24.7	21.5	116	101	71.3	91.4	111	108
Ba	364	16	24	21	177	525	446	874	295	1003
Hf	6.3	6.9	6.3	5.8	10.8	9.2	5.2	8.0	9.9	9.9
Ta	2.85	1.88	1.49	1.10	6.27	5.67	4.72	4.97	5.60	5.50
Pb	< 5	8	6	< 5	7	7	< 5	< 5	5	6
Th	5.33	4.82	3.95	3.35	12.6	11.3	10.6	9.81	11.8	12.0
U	1.77	1.30	1.13	0.97	3.1	2.62	2.92	2.59	2.64	3.20
La	8.77	3.81	4.15	3.96	91.2	70.6	86.4	55.7	83.7	69.4
Ce	92.2	18.2	23.0	23.2	171	149	148	126	158	146
Pr	2.77	0.82	0.73	0.73	22.2	16.7	18.4	13.2	19.5	16.1
Nd	12.30	3.03	3.18	3.30	78.6	59.2	67.3	54.4	66.8	54.2
Sm	3.42	0.69	0.87	0.92	16.5	12.9	14.6	13.8	13.9	11.5
Eu	1.170	0.227	0.300	0.324	5.35	4.07	4.50	5.03	4.64	3.97
Gd	3.54	0.80	1.04	1.15	12.8	8.84	10.3	13.8	11.9	10.9
Tb	0.58	0.15	0.18	0.20	1.79	1.20	1.35	1.91	1.71	1.62
Dy	2.99	0.99	1.11	1.21	8.33	5.31	5.79	8.84	8.02	8.30
Ho	0.53	0.21	0.23	0.25	1.21	0.75	0.82	1.29	1.25	1.35
Er	1.47	0.61	0.70	0.78	2.79	1.71	1.86	2.93	2.95	3.37
Tm	0.229	0.095	0.113	0.125	0.344	0.219	0.228	0.364	0.355	0.434
Yb	1.37	0.67	0.80	0.80	1.89	1.25	1.31	2.01	1.96	2.39
Lu	0.177	0.110	0.128	0.114	0.232	0.166	0.175	0.247	0.238	0.284
LREE	120.6	26.8	32.2	32.4	384.9	312.5	339.2	268.1	346.5	301.2
HREE	10.9	3.6	4.3	4.6	29.4	19.4	21.8	31.4	28.4	28.6
REE	131.5	30.4	36.5	37.1	414.2	331.9	361.0	299.5	374.9	329.8
LREE/HREE	11.08	7.37	7.49	7.01	13.10	16.07	15.54	8.54	12.21	10.51
Ce/Ce*	4.59	2.52	3.24	3.35	0.93	1.06	0.91	1.14	0.96	1.07
Eu/Eu*	1.03	0.93	0.96	0.96	1.13	1.17	1.12	1.11	1.10	1.08
La/Yb	6.4	5.7	5.2	5.0	48.3	56.5	66.0	27.7	42.7	29.0
10000Ga/Al	3.22	3.02	2.64	2.60	3.82	3.47	3.16	2.98	3.74	3.73
10000Sc/Fe*	2.68	2.41	2.48	2.32	1.48	1.50	1.35	1.65	1.47	1.54

Appendix. 1 Continued.

Sample #	1705A	1705B	1705C	1705D	1705E	1705F	1705G	1706A	1706B	1706C
Rock type	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite
Depth(m)	0.1	0.5	1.0	1.5	2.0	2.5	3.0	0.1	1.0	2.0
Northing	15°06'32.6"	15°06'32.6"	15°06'32.6"	15°06'32.6"	15°06'32.6"	15°06'32.6"	15°06'32.6"	15°04'53.2"	15°04'53.2"	15°04'53.2"
Easting	106°32'15.1"	106°32'15.1"	106°32'15.1"	106°32'15.1"	106°32'15.1"	106°32'15.1"	106°32'15.1"	106°34'16.3"	106°34'16.3"	106°34'16.3"
SiO_2(%)	0.66	0.55	0.37	0.50	0.34	0.49	0.48	15.7	8.27	8.02
TiO_2	5.50	7.15	7.41	7.58	7.10	6.26	7.77	2.88	2.80	4.42
Al_2O_3	39.1	32.0	31.7	27.6	33.6	31.7	29.3	21.2	37.4	44.3
Fe_2O_3	29.9	37.3	38.9	43.1	36.8	36.2	42.2	42.5	26.8	17.6
MnO	0.263	0.280	0.280	0.297	0.313	0.265	0.323	0.101	0.943	0.035
MgO	0.28	0.24	0.24	0.27	0.33	0.31	0.25	0.06	0.08	0.06
CaO	0.01	0.03	0.03	0.02	0.03	0.03	0.04	0.01	0.01	< 0.01
Na_2O	< 0.01	0.02	0.01	< 0.01	0.03	0.02	0.05	0.02	0.03	0.01
K_2O	0.01	0.08	0.03	< 0.01	0.02	< 0.01	0.09	0.09	0.06	0.04
P_2O_5	0.48	0.73	0.86	0.81	1.17	1.01	0.82	0.34	0.25	0.32
LOI	22.1	19.1	19.0	17.1	19.8	19.8	18.2	15.6	22.4	24.6
Total	98.26	97.41	98.77	97.21	99.57	96.03	99.47	98.46	99.13	99.33
Sc(ppm)	22	26	38	35	48	37	28	50	32	29
V	357	430	447	476	413	372	477	567	308	279
Cr	240	270	240	270	250	250	280	3140	620	410
Co	44	56	47	55	57	48	58	22	674	7
Ni	70	< 20	< 20	< 20	< 20	< 20	< 20	< 20	300	< 20
Cu	40	40	40	30	20	40	50	90	110	30
Zn	300	470	490	510	510	210	550	110	120	150
Ga	70	83	69	70	72	65	74	41	34	38
Ge	0.6	1.0	< 0.5	1.1	0.6	1.0	0.6	< 0.5	< 0.5	< 0.5
As	< 5	7	< 5	8	6	7	6	< 5	< 5	< 5
Sr	243	645	633	689	692	521	986	34	78	101
Y	27.5	110	70.8	83.8	93.5	68.3	96.6	11.9	12.1	30.3
Zr	836	1030	1030	797	974	466	1070	380	319	426
Nb	221	299	313	219	300	144	323	53.5	50.9	78.6
Ba	228	313	315	393	287	239	622	189	597	435
Hf	17.9	22.5	20.7	18.2	19.6	10.6	20.7	7.9	6.6	9.1
Ta	10.8	14.4	15.8	11.7	14.7	9.53	16.8	3.80	3.02	4.31
Pb	< 5	8	12	11	10	< 5	15	9	16	18
Th	25.9	31.8	34.5	32.5	31.8	25.7	34.8	15.2	9.09	10.0
U	10.7	9.69	9.37	8.34	11.8	8.86	8.16	4.06	2.90	3.03
La	119	255	279	255	272	202	264	28.7	35.0	85.1
Ce	222	509	551	510	586	415	511	164	80.7	204
Pr	25.9	66.7	70.4	58.9	85.1	50.5	65.7	6.97	8.95	26.8
Nd	82.4	245	237	210	307	184	240	25.0	33.4	114
Sm	15.6	53.6	48.2	45.1	67.7	40.8	54.3	5.75	7.84	29.1
Eu	4.74	17.4	15.0	14.0	21.1	12.6	18.4	1.86	2.49	10.4
Gd	11.2	43.7	36.5	36.1	50.2	31.0	54.5	4.86	6.04	30.1
Tb	1.49	5.56	5.06	4.98	6.50	4.21	8.36	0.77	0.91	4.37
Dy	6.68	25.0	22.7	22.8	30.0	18.3	40.0	4.07	4.42	18.3
Ho	0.98	3.90	3.19	3.55	4.37	2.88	4.93	0.62	0.64	2.09
Er	2.17	8.67	6.86	8.01	9.15	6.63	8.91	1.59	1.50	3.73
Tm	0.232	0.883	0.702	0.832	0.877	0.683	0.811	0.217	0.204	0.364
Yb	1.06	3.67	3.01	3.37	3.64	2.77	3.14	1.36	1.21	1.55
Lu	0.105	0.312	0.260	0.295	0.303	0.231	0.256	0.184	0.159	0.150
LREE	469.6	1146.7	1200.6	1093.0	1338.9	904.9	1153.4	232.3	168.4	469.4
HREE	23.9	91.7	78.3	79.9	105.0	66.7	120.9	13.7	15.1	60.7
REE	493.6	1238.4	1278.9	1172.9	1443.9	971.6	1274.3	246.0	183.5	530.1
LREE/HREE	19.64	12.51	15.34	13.67	12.75	13.57	9.54	16.99	11.16	7.74
Ce/Ce*	0.98	0.96	0.96	1.02	0.94	1.01	0.95	2.84	1.12	1.05
Eu/Eu*	1.10	1.10	1.09	1.06	1.11	1.08	1.03	1.08	1.11	1.07
La/Yb	112.3	69.5	92.7	75.7	74.7	72.9	84.1	21.1	28.9	54.9
10000Ga/Al	3.39	4.91	4.12	4.79	4.05	3.88	4.78	3.66	1.72	1.62
10000Sc/Fe*	1.05	1.00	1.40	1.16	1.86	1.46	0.95	1.68	1.71	2.36

Appendix. 1 Continued.

Sample #	1708A	1708B	1708C	1708D	1708E	1708F	1708G	1710B	1711A	1711B
Rock type	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	Saprolite	Saprolite	Saprolite
Depth(m)	0.1	1.0	2.0	3.0	4.0	5.0	6.0	4.0	0.1	1.3
Northing	15°05'21.6"	15°05'21.6"	15°05'21.6"	15°05'21.6"	15°05'21.6"	15°05'21.6"	15°05'21.6"	15°07'34.4"	15°26'31.4"	15°26'31.4"
Easting	106°34'46.7"	106°34'46.7"	106°34'46.7"	106°34'46.7"	106°34'46.7"	106°34'46.7"	106°34'46.7"	106°38'12.8"	106°28'05.4"	106°28'05.4"
SiO_2(%)	27.4	32.4	32.7	34.1	33.3	33.8	32.5	43.4	42.3	40.9
TiO_2	3.22	3.00	3.00	3.05	3.04	3.05	3.03	2.17	2.04	2.17
Al_2O_3	30.0	28.2	28.0	27.7	27.1	27.4	27.3	20.3	18.4	18.1
Fe_2O_3	22.2	21.5	21.7	21.3	22.3	21.4	21.5	16.1	15.0	15.6
MnO	0.376	0.067	0.112	0.085	0.127	0.078	0.095	0.135	0.178	0.181
MgO	0.16	0.13	0.13	0.29	0.22	0.11	0.22	4.27	7.66	7.85
CaO	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.53	4.48	4.92
Na_2O	0.04	0.02	0.03	0.03	0.04	0.04	0.04	0.02	0.89	0.95
K_2O	0.08	0.04	0.05	0.07	< 0.01	0.07	0.03	0.08	0.06	0.10
P_2O_5	0.35	0.22	0.20	0.10	0.19	0.18	0.14	0.03	0.24	0.28
LOI	16.3	15.1	15.0	14.1	14.1	13.7	13.9	13.0	8.31	9.9
Total	100.20	100.70	101.00	100.70	100.40	99.80	98.80	100.10	99.57	101.00
Sc(ppm)	41	34	34	32	41	33	36	28	26	27
V	300	265	255	175	243	212	165	105	197	214
Cr	590	430	380	280	320	390	330	230	260	250
Co	261	12	29	19	31	16	18	49	57	59
Ni	250	150	90	100	100	100	90	130	180	150
Cu	150	110	110	80	100	90	100	100	90	80
Zn	240	170	210	150	160	170	140	220	100	200
Ga	45	39	43	42	40	41	42	29	24	25
Ge	1.8	2.9	3.0	2.9	2.6	2.3	2.5	1.7	1.8	1.3
As	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Sr	6	3	2	2	< 2	< 2	9	41	140	105
Y	5.1	4.2	4.8	3.6	4.9	3.7	3.9	40.7	22.9	26.3
Zr	326	273	300	283	271	282	274	130	98	124
Nb	45.2	38.0	39.1	37.3	35.3	35.2	35.8	11.4	11.5	11.9
Ba	149	32	51	30	52	32	49	71	130	49
Hf	6.8	7.0	6.7	6.1	5.9	6.2	5.9	3.2	2.7	2.9
Ta	3.35	2.66	3.12	2.59	2.52	2.53	2.41	1.07	0.63	0.81
Pb	10	6	6	< 5	6	< 5	< 5	< 5	< 5	< 5
Th	7.23	6.19	7.74	7.01	6.87	7.10	6.80	2.37	1.47	1.70
U	1.88	1.93	2.22	1.03	1.32	1.75	1.58	0.41	0.40	0.45
La	12.2	8.77	7.72	6.19	5.31	5.09	15.2	17.3	10.5	10.9
Ce	65.1	44.3	55.1	43.2	63.4	33.0	40.4	16.1	22.6	23.4
Pr	1.95	1.27	1.53	1.23	1.29	1.08	2.25	5.33	2.91	3.49
Nd	6.59	4.92	5.81	4.35	5.36	4.12	7.19	23.4	14.2	16.0
Sm	1.42	1.21	1.40	1.00	1.34	1.01	1.46	6.30	4.23	4.42
Eu	0.473	0.402	0.470	0.302	0.444	0.326	0.437	2.34	1.63	1.76
Gd	1.50	1.28	1.47	0.96	1.42	1.10	1.37	7.73	4.99	5.25
Tb	0.27	0.22	0.26	0.17	0.26	0.19	0.22	1.29	0.83	0.94
Dy	1.57	1.20	1.58	1.02	1.54	1.07	1.22	7.41	4.61	5.48
Ho	0.28	0.22	0.29	0.18	0.28	0.20	0.21	1.41	0.86	0.98
Er	0.80	0.66	0.82	0.54	0.81	0.57	0.57	3.68	2.38	2.63
Tm	0.127	0.104	0.124	0.083	0.138	0.088	0.089	0.472	0.327	0.352
Yb	0.85	0.71	0.83	0.57	0.93	0.60	0.64	2.74	1.88	2.06
Lu	0.131	0.113	0.128	0.088	0.135	0.093	0.099	0.407	0.266	0.277
LREE	87.7	60.9	72.0	56.3	77.1	44.6	66.9	70.8	56.1	60.0
HREE	5.5	4.5	5.5	3.6	5.5	3.9	4.4	25.1	16.1	18.0
REE	93.3	65.4	77.5	59.9	82.7	48.5	71.4	95.9	72.2	77.9
LREE/HREE	15.87	13.51	13.09	15.58	13.99	11.41	15.15	2.82	3.47	3.34
Ce/Ce*	3.27	3.25	3.93	3.84	5.94	3.45	1.69	0.41	1.00	0.93
Eu/Eu*	0.99	0.99	1.00	0.94	0.98	0.95	0.94	1.03	1.08	1.12
La/Yb	14.4	12.4	9.3	10.9	5.7	8.5	23.8	6.3	5.6	5.3
10000Ga/Al	2.84	2.61	2.90	2.87	2.79	2.83	2.90	2.70	2.46	2.61
10000Sc/Fe*	2.64	2.26	2.24	2.15	2.63	2.21	2.40	2.49	2.48	2.47

Appendix. 1 Continued.

Sample #	1712A	1712B	1712C	1712D	1801A	1801B	1801C	1803D	1802A	1802B
Rock type	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	Saprolite	Saprolite	Saprolite	B. laterite	Saprolite
Depth(m)	0.1	1.0	2.0	3.0	0.1	1.0	1.8	2.0	0.1	1.0
Northing	15°26'16.2"	15°26'16.2"	15°26'16.2"	15°26'16.2"	15°11'31.8"	15°11'31.8"	15°11'31.8"	15°11'31.8"	15°13'12.7"	15°13'12.7"
Easting	106°25'48.3"	106°25'48.3"	106°25'48.3"	106°25'48.3"	106°16'00.5"	106°16'00.5"	106°16'00.5"	106°16'00.5"	106°18'12.5"	106°18'12.5"
SiO_2(%)	19.0	19.1	1.67	7.37	9.14	29.9	37.2	23.5	4.66	36.2
TiO_2	4.86	4.74	3.19	3.58	4.73	3.44	2.98	3.39	3.28	2.18
Al_2O_3	30.5	29.9	47.9	42.8	28.3	19.6	17.0	29.9	36.9	21.2
Fe_2O_3	28.0	27.6	19.1	20.9	25.7	19.0	16.4	21.5	26.0	18.1
MnO	0.080	0.097	0.039	0.060	0.140	0.226	0.216	0.168	0.256	0.247
MgO	0.13	0.13	0.13	0.14	0.33	7.38	8.03	1.42	0.10	6.98
CaO	< 0.01	< 0.01	< 0.01	< 0.01	0.12	5.03	7.35	0.41	< 0.01	2.91
Na_2O	0.04	0.03	0.04	0.03	0.06	0.47	1.00	0.08	0.02	0.23
K_2O	0.07	0.14	0.11	0.06	0.14	0.23	1.37	0.01	< 0.01	0.11
P_2O_5	0.34	0.31	0.32	0.27	0.96	1.73	1.47	0.56	0.36	0.31
LOI	17.4	17.9	27.4	24.2	30.9	13.8	7.60	18.7	25.5	11.8
Total	100.40	99.90	99.87	99.38	100.50	100.80	100.60	99.62	97.11	100.30
Sc(ppm)	43	44	37	38	27	16	14	43	47	30
V	391	381	260	279	330	222	193	334	397	236
Cr	490	500	670	420	320	190	150	330	430	300
Co	20	29	14	17	31	65	59	75	102	80
Ni	< 20	< 20	< 20	< 20	< 20	110	110	250	< 20	210
Cu	70	70	60	80	50	50	50	130	80	110
Zn	200	190	150	170	200	280	240	350	90	220
Ga	55	54	39	42	53	35	31	37	42	31
Ge	1.2	1.2	< 0.5	< 0.5	< 0.5	1.3	1.3	1.9	0.6	1.7
As	6	< 5	< 5	< 5	9	< 5	< 5	< 5	< 5	< 5
Sr	7	6	< 2	3	25	313	738	9	< 2	104
Y	4.9	4.8	2.0	2.6	22.0	39.9	35.3	20.9	7.5	32.2
Zr	349	333	213	236	387	429	376	230	187	147
Nb	42.5	41.5	27.1	29.3	89.3	104	90.4	29.3	21.5	16.3
Ba	19	20	3	8	38	254	528	313	13	220
Hf	8.1	7.6	5.1	5.4	7.2	7.9	6.8	6.2	5.0	3.2
Ta	2.79	2.61	2.05	2.42	3.09	6.71	5.84	2.03	1.01	1.08
Pb	6	8	6	< 5	9	8	< 5	18	< 5	< 5
Th	9.10	8.41	4.03	5.02	19.0	12.4	10.2	4.27	5.21	2.80
U	2.16	1.97	2.16	1.80	5.30	3.02	2.49	1.12	1.87	0.75
La	9.00	9.15	2.36	6.58	34.7	91.2	81.8	14.9	3.69	17.7
Ce	18.3	20.6	4.84	10.9	187	167	144	42.7	62.1	39.4
Pr	1.61	1.63	0.50	1.01	10.3	21.2	19.4	4.23	1.42	5.42
Nd	5.15	5.28	2.07	3.15	41.5	73.5	67.6	18.7	7.16	22.9
Sm	1.01	1.05	0.52	0.62	10.2	15.1	13.7	5.16	2.20	5.98
Eu	0.289	0.306	0.168	0.192	3.23	5.03	4.45	1.87	0.805	2.18
Gd	0.88	0.94	0.56	0.58	8.56	13.3	11.8	5.69	2.59	6.93
Tb	0.18	0.17	0.11	0.11	1.31	1.92	1.72	0.87	0.43	1.21
Dy	1.11	1.09	0.68	0.70	7.01	9.75	8.54	4.89	2.31	7.09
Ho	0.22	0.21	0.12	0.13	1.13	1.53	1.31	0.89	0.43	1.33
Er	0.67	0.66	0.32	0.38	2.82	3.43	3.01	2.45	1.23	3.55
Tm	0.108	0.106	0.049	0.058	0.391	0.402	0.360	0.349	0.185	0.472
Yb	0.70	0.70	0.31	0.37	2.29	2.08	1.85	2.13	1.18	2.80
Lu	0.107	0.105	0.046	0.053	0.309	0.264	0.230	0.312	0.170	0.388
LREE	35.4	38.0	10.5	22.5	286.9	373.0	331.0	87.6	77.4	93.6
HREE	4.0	4.0	2.2	2.4	23.8	32.7	28.8	17.6	8.5	23.8
REE	39.3	42.0	12.7	24.8	310.8	405.7	359.8	105.1	85.9	117.4
LREE/HREE	8.90	9.55	4.76	9.43	12.05	11.42	11.48	4.98	9.08	3.94
Ce/Ce*	1.18	1.31	1.09	1.04	2.43	0.93	0.89	1.32	6.65	0.99
Eu/Eu*	0.94	0.94	0.95	0.98	1.06	1.09	1.07	1.06	1.03	1.04
La/Yb	12.9	13.1	7.6	17.8	15.2	43.8	44.2	7.0	3.1	6.3
10000Ga/Al	3.41	3.42	1.54	1.85	3.53	3.37	3.45	2.34	2.15	2.76
10000Sc/Fe*	2.20	2.28	2.77	2.60	1.50	1.20	1.22	2.86	2.59	2.37

Appendix. 1 Continued.

Sample #	1802C	1803A	1803B	1803C	1804A	1804B	1805A	1805B	1805C	1806A
Rock type	Saprolite	B. laterite	Saprolite	B. laterite	B. laterite	Saprolite	B. laterite	B. laterite	Saprolite	B. laterite
Depth(m)	2.0	0.1	0.5	1.0	0.1?	1.5	0.1	1.0	1.5	0.1
Northing	15°13'12.7"	15°15'59.3"	15°15'59.3"	15°15'59.3"	15°19'09.1"	15°19'09.1"	15°25'59.2"	15°25'59.2"	15°25'59.2"	15°28'31.8"
Easting	106°18'12.5"	106°19'28.3"	106°19'28.3"	106°19'28.3"	106°20'11.5"	106°20'11.5"	106°22'38.6"	106°22'38.6"	106°22'38.6"	106°21'37.4"
SiO_2(%)	33.0	32.8	48.6	31.4	24.2	44.0	27.2	24.1	39.6	19.2
TiO_2	2.68	2.97	1.92	2.93	3.08	2.03	3.53	3.82	2.97	3.05
Al_2O_3	25.6	25.7	16.6	26.9	24.4	15.6	29.4	33.0	24.2	33.8
Fe_2O_3	22.0	19.7	13.1	19.4	21.1	14.1	19.6	20.5	16.1	24.1
MnO	0.307	0.181	0.178	0.14	0.241	0.173	0.244	0.142	0.203	0.083
MgO	1.25	0.14	6.85	0.12	4.51	7.89	0.15	0.15	3.21	0.14
CaO	0.10	< 0.01	6.81	< 0.01	1.71	7.33	0.04	0.03	1.81	0.02
Na_2O	0.05	0.03	2.21	0.02	0.32	2.14	0.03	0.03	0.62	0.03
K_2O	0.04	0.02	0.63	0.07	0.05	0.27	0.10	0.03	0.48	0.05
P_2O_5	0.33	0.31	0.29	0.26	0.37	0.30	0.34	0.36	0.52	0.29
LOI	13.8	18.8	3.50	18.0	16.1	5.81	17.9	17.9	11.3	19.4
Total	99.16	100.50	100.70	99.33	96.02	99.67	98.48	100.10	101.00	100.10
Sc(ppm)	37	35	23	36	32	24	36	38	30	44
V	293	282	190	280	307	144	308	336	269	314
Cr	330	310	220	320	320	170	150	150	100	350
Co	91	36	51	16	77	17	53	45	56	15
Ni	350	90	100	< 20	160	< 20	30	140	80	130
Cu	140	70	70	40	110	20	70	70	290	90
Zn	340	100	150	80	90	70	180	250	280	130
Ga	36	34	23	27	31	9	37	39	28	36
Ge	3.0	1.6	1.2	< 0.5	1.5	< 0.5	1.9	1.8	1.9	1.4
As	< 5	5	26	< 5	< 5	13	5	< 5	< 5	< 5
Sr	112	5	363	5	68	285	21	13	102	3
Y	46.6	14.8	26.4	10.0	24.1	22.0	41.4	19.7	45.8	9.4
Zr	174	242	131	269	134	120	222	312	215	197
Nb	19.3	25.7	18.2	27.9	20.0	12.7	31.5	39.9	29.9	29.3
Ba	471	55	190	43	130	141	244	271	532	28
Hf	3.9	6.3	2.9	6.0	4.2	3.3	6.3	8.0	5.5	5.4
Ta	1.26	1.73	1.09	2.24	1.39	1.03	2.09	2.59	1.89	1.88
Pb	< 5	< 5	< 5	< 5	< 5	< 5	< 5	39	25	12
Th	3.36	6.49	2.57	7.48	3.70	2.12	6.89	7.64	4.79	5.28
U	1.10	1.67	0.69	1.99	1.06	0.59	2.09	2.61	1.56	1.87
La	31.7	13.4	16.9	9.74	15.5	13.7	31.8	22.1	51.1	9.71
Ce	50.3	57.1	33.9	51.8	42.2	27.6	84.7	80.1	54.1	41.5
Pr	9.57	3.41	4.39	2.54	4.03	3.74	7.75	4.99	12.2	2.29
Nd	38.7	14.6	17.7	9.95	18.4	16.0	34.0	20.7	47.6	10.1
Sm	9.57	3.82	4.47	2.31	5.17	4.18	9.05	5.28	11.5	2.66
Eu	3.41	1.28	1.64	0.715	1.91	1.54	3.10	1.81	3.91	0.846
Gd	10.3	3.47	5.17	2.03	5.91	4.64	9.32	5.40	11.7	2.22
Tb	1.86	0.59	0.88	0.37	1.05	0.73	1.59	0.83	1.76	0.37
Dy	11.1	3.33	5.05	2.33	5.94	4.11	8.88	4.72	9.59	2.19
Ho	2.00	0.63	0.94	0.45	0.99	0.79	1.57	0.88	1.80	0.41
Er	5.35	1.81	2.59	1.24	2.66	2.24	4.11	2.50	4.82	1.13
Tm	0.734	0.258	0.352	0.176	0.377	0.311	0.540	0.358	0.655	0.161
Yb	4.21	1.59	2.00	1.12	2.25	1.73	3.16	2.15	3.76	0.97
Lu	0.583	0.223	0.270	0.164	0.307	0.243	0.444	0.304	0.538	0.142
LREE	143.3	93.6	79.0	77.1	87.2	66.8	170.4	135.0	180.4	67.1
HREE	36.1	11.9	17.3	7.9	19.5	14.8	29.6	17.1	34.6	7.6
REE	179.4	105.5	96.3	84.9	106.7	81.6	200.0	152.1	215.0	74.7
LREE/HREE	3.96	7.87	4.58	9.78	4.48	4.51	5.75	7.87	5.21	8.84
Ce/Ce*	0.71	2.07	0.96	2.55	1.31	0.95	1.32	1.87	0.53	2.16
Eu/Eu*	1.05	1.07	1.04	1.01	1.06	1.07	1.03	1.04	1.03	1.06
La/Yb	7.5	8.4	8.5	8.7	6.9	7.9	10.1	10.3	13.6	10.0
10000Ga/Al	2.65	2.50	2.61	1.90	2.40	1.09	2.38	2.24	2.18	2.01
10000Sc/Fe*	2.40	2.55	2.51	2.66	2.17	2.47	2.63	2.65	2.67	2.61

Appendix. 1 Continued.

Sample #	1806B	1806C	1806D	1806E	1806F	1807A	1807B	1807C	1808A	1808B
Rock type	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite	Saprolite
Depth(m)	1.0	2.0	3.0	4.0	5.0	0.1	1.0	2.0	0.1	1.0
Northing	15°28'31.8"	15°28'31.8"	15°28'31.8"	15°28'31.8"	15°28'31.8"	15°33'47.0"	15°33'47.0"	15°33'47.0"	15°29'09.7"	15°29'09.7"
Easting	106°21'37.4"	106°21'37.4"	106°21'37.4"	106°21'37.4"	106°21'37.4"	106°17'28.9"	106°17'28.9"	106°17'28.9"	106°13'52.4"	106°13'52.4"
SiO_2(%)	24.3	26.6	31.1	7.90	20.0	42.7	42.9	41.5	31.9	47.8
TiO_2	3.18	2.94	2.96	4.04	3.30	3.18	3.24	3.09	3.12	2.00
Al_2O_3	29.9	28.2	29.0	35.2	31.7	22.6	24.3	22.7	27.5	16.4
Fe_2O_3	25.2	25.7	20.9	26.9	25.0	14.4	13.5	13.2	19.4	12.9
MnO	0.097	0.058	0.063	0.077	0.087	0.170	0.134	0.134	0.237	0.166
MgO	0.13	0.12	0.29	0.16	0.34	0.66	0.34	0.50	0.19	6.96
CaO	0.04	0.03	0.02	< 0.01	0.03	0.40	0.16	0.33	0.07	6.72
Na_2O	0.02	0.02	0.04	< 0.01	0.06	0.21	0.12	0.12	0.07	2.21
K_2O	0.05	0.01	0.04	< 0.01	0.04	0.32	0.27	0.33	0.06	0.44
P_2O_5	0.27	0.25	0.22	0.43	0.50	0.33	0.26	0.29	0.32	0.29
LOI	17.6	15.7	14.9	21.8	18.6	15.0	14.9	15.3	16.0	3.55
Total	100.70	99.54	99.58	96.53	99.60	99.86	100.1	97.50	98.86	99.49
Sc(ppm)	43	38	38	54	52	35	37	35	40	24
V	324	324	230	385	345	270	266	249	317	193
Cr	380	310	160	530	560	340	340	350	250	200
Co	20	18	15	24	29	47	45	45	51	45
Ni	210	250	180	40	370	180	190	110	170	160
Cu	120	110	100	140	150	70	80	70	60	70
Zn	190	150	190	70	180	260	220	190	170	210
Ga	38	38	37	47	43	30	33	31	27	21
Ge	2.2	2.5	2.4	1.4	2.8	1.9	2.0	2.2	< 0.5	1.5
As	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Sr	5	2	2	< 2	3	28	17	26	13	283
Y	10.2	8.8	11.3	7.9	19.4	24.3	27.9	24.2	30.7	40.4
Zr	234	192	219	178	246	253	273	250	194	128
Nb	30.7	27.2	35.9	32.7	39.0	27.0	28.8	25.2	22.1	15.6
Ba	56	79	45	21	93	122	94	106	65	172
Hf	6.5	5.1	5.6	5.6	6.5	6.3	6.7	6.9	5.1	3.3
Ta	2.09	1.77	2.38	1.35	2.68	1.67	1.79	1.51	1.52	0.97
Pb	46	45	24	< 5	16	34	20	9	< 5	8
Th	5.41	4.81	5.33	6.23	5.61	5.77	6.14	5.63	4.02	2.16
U	1.71	1.35	1.35	2.06	1.97	1.98	2.13	1.81	1.39	0.62
La	11.4	8.92	12.3	5.65	19.3	18.4	20.9	20.9	14.7	21.0
Ce	52.4	57.0	110	29.6	72.7	55.5	59.5	61.1	49.0	28.6
Pr	2.65	2.11	2.65	1.24	5.21	4.44	4.94	4.56	4.49	4.70
Nd	11.4	8.91	11.2	6.08	23.2	18.1	20.7	18.6	20.0	20.8
Sm	2.90	2.31	2.92	1.84	6.01	4.63	5.25	4.59	5.85	5.59
Eu	0.983	0.805	0.975	0.679	2.05	1.61	1.85	1.54	2.27	2.17
Gd	3.01	2.43	3.07	2.20	5.32	4.81	5.52	4.84	6.86	7.18
Tb	0.47	0.38	0.49	0.37	0.86	0.81	0.92	0.88	1.13	1.13
Dy	2.43	2.08	2.49	2.03	4.72	4.61	5.17	5.21	6.32	6.34
Ho	0.45	0.39	0.46	0.39	0.85	0.88	0.95	0.92	1.18	1.23
Er	1.28	1.15	1.26	1.15	2.31	2.48	2.68	2.51	3.25	3.40
Tm	0.186	0.172	0.183	0.170	0.332	0.348	0.370	0.346	0.455	0.436
Yb	1.16	1.07	1.14	1.06	2.07	2.07	2.22	2.12	2.64	2.39
Lu	0.159	0.153	0.153	0.148	0.308	0.302	0.319	0.295	0.368	0.335
LREE	81.7	80.1	140.0	45.1	128.5	102.7	113.1	111.3	96.3	82.9
HREE	9.1	7.8	9.2	7.5	16.8	16.3	18.1	17.1	22.2	22.4
REE	90.9	87.9	149.3	52.6	145.2	119.0	131.3	128.4	118.5	105.3
LREE/HREE	8.94	10.23	15.15	6.00	7.66	6.30	6.23	6.50	4.34	3.69
Ce/Ce*	2.34	3.22	4.72	2.74	1.78	1.51	1.44	1.53	1.48	0.71
Eu/Eu*	1.02	1.04	1.00	1.03	1.11	1.04	1.05	1.00	1.10	1.05
La/Yb	9.8	8.3	10.8	5.3	9.3	8.9	9.4	9.9	5.6	8.8
10000Ga/Al	2.40	2.55	2.41	2.52	2.57	2.51	2.57	2.58	1.85	2.41
10000Sc/Fe*	2.44	2.12	2.60	2.87	2.98	3.49	3.93	3.79	2.95	2.65

Appendix. 1 Continued.

Sample #	1809A	1809B	1809C	1810A	1810B	1814A	1814B	1814C	1814D	1816A
Rock type	B. laterite	B. laterite	B. laterite	Saprolite	Saprolite	B. laterite	B. laterite	B. laterite	B. laterite	B. laterite
Depth(m)	0.1	1.0	2.0	0.1	1.0	0.1	1.0	2.0	3.0	0.1
Northing	15°27'50.8"	15°27'50.8"	15°27'50.8"	15°24'27.7"	15°24'27.7"	15°15'46.5"	15°15'46.5"	15°15'46.5"	15°15'46.5"	15°12'05.5"
Easting	106°09'50.9"	106°09'50.9"	106°09'50.9"	106°05'21.4"	106°05'21.4"	105°56'01.4"	105°56'01.4"	105°56'01.4"	105°56'01.4"	105°57'16.6"
SiO_2(%)	30.2	29.5	29.3	32.4	33.4	30.9	26.4	7.95	31.2	28.6
TiO_2	2.83	3.02	3.18	3.37	3.15	3.33	3.02	3.99	3.28	3.04
Al_2O_3	27.	27.7	29.4	28.0	27.1	28.1	24.5	34.3	27.4	26.5
Fe_2O_3	20.6	21.2	22.0	20.3	17.6	23.1	29.7	27.7	23.7	21.6
MnO	0.301	0.280	0.349	0.300	0.265	0.144	0.180	0.186	0.173	0.314
MgO	0.10	0.10	0.10	0.28	0.14	0.10	0.09	0.12	0.10	0.11
CaO	0.03	0.02	0.03	0.07	0.04	< 0.01	< 0.01	< 0.01	0.01	< 0.01
Na_2O	0.03	< 0.01	0.03	0.06	0.19	0.03	< 0.01	0.07	0.03	0.02
K_2O	< 0.01	0.04	0.05	0.16	0.12	0.09	< 0.01	< 0.01	0.05	0.05
P_2O_5	0.28	0.21	0.20	0.43	0.33	0.22	0.29	0.38	0.21	0.23
LOI	16.3	15.1	15.0	15.8	14.9	14.7	14.0	21.6	13.8	16.4
Total	97.62	97.15	99.60	101.29	97.15	100.7	98.12	96.26	100.00	96.93
Sc(ppm)	37	38	41	36	32	37	43	46	36	36
V	294	307	328	334	288	339	407	388	347	289
Cr	300	290	320	360	240	790	390	440	370	290
Co	67	63	75	89	68	39	42	33	32	39
Ni	200	180	240	290	170	190	90	< 20	180	150
Cu	90	100	100	110	80	100	130	70	100	90
Zn	210	190	270	290	90	250	190	150	230	80
Ga	35	35	36	37	33	38	37	45	35	35
Ge	2.4	2.3	2.5	2.3	2.2	2.4	2.1	0.6	2.4	2.3
As	< 5	< 5	< 5	< 5	5	< 5	< 5	< 5	< 5	< 5
Sr	5	6	5	9	9	4	3	7	4	4
Y	25.8	22.9	23.8	25.7	24.7	9.3	11.5	3.7	9.3	8.3
Zr	184	186	199	233	158	211	186	235	200	149
Nb	19.0	19.7	21.0	31.0	24.0	21.6	18.9	23.1	21.0	15.0
Ba	84	77	82	114	47	28	95	27	55	34
Hf	5.6	5.7	5.5	6.3	5.1	5.7	5.6	6.8	5.5	4.7
Ta	1.16	1.21	1.44	2.25	1.68	1.54	1.18	1.49	1.50	0.99
Pb	5	< 5	23	20	< 5	21	10	< 5	19	< 5
Th	4.24	4.24	4.31	5.09	4.82	4.80	4.67	3.85	4.54	3.75
U	1.10	1.14	1.38	1.44	1.36	1.28	1.92	1.56	1.16	3.94
La	17.0	16.1	17.0	22.6	22.8	6.82	8.01	2.62	7.62	5.85
Ce	56.7	57.7	60.6	68.5	58.6	34.8	44.4	13.3	47.1	32.6
Pr	4.42	3.99	4.90	6.56	5.52	2.15	2.02	0.66	2.29	1.57
Nd	20.1	18.0	20.5	25.9	23.8	9.16	9.56	3.38	9.53	7.74
Sm	5.56	5.07	5.32	6.18	6.27	2.35	2.73	1.04	2.44	2.31
Eu	2.02	1.80	1.95	2.24	2.15	0.827	0.943	0.358	0.878	0.818
Gd	6.01	5.35	5.73	6.25	6.44	2.56	2.96	1.22	2.71	2.61
Tb	1.07	0.93	0.91	1.06	1.09	0.40	0.53	0.20	0.41	0.43
Dy	6.20	5.49	5.31	5.93	6.28	2.29	3.16	1.07	2.34	2.39
Ho	1.07	1.00	1.04	1.13	1.08	0.45	0.56	0.18	0.45	0.43
Er	2.87	2.68	2.78	3.10	2.83	1.30	1.59	0.52	1.29	1.21
Tm	0.400	0.370	0.375	0.418	0.390	0.186	0.252	0.083	0.185	0.178
Yb	2.47	2.27	2.27	2.49	2.34	1.21	1.57	0.53	1.14	1.14
Lu	0.362	0.310	0.316	0.360	0.325	0.181	0.216	0.076	0.166	0.163
LREE	105.8	102.7	110.3	132.0	119.1	56.1	67.7	21.4	69.9	50.9
HREE	20.5	18.4	18.7	20.7	20.8	8.6	10.8	3.9	8.7	8.6
REE	126.3	121.1	129.0	152.7	139.9	64.7	78.5	25.2	78.5	59.4
LREE/HREE	5.17	5.58	5.89	6.36	5.73	6.54	6.24	5.51	8.04	5.95
Ce/Ce*	1.60	1.77	1.63	1.38	1.28	2.23	2.71	2.48	2.76	2.64
Eu/Eu*	1.07	1.06	1.08	1.10	1.03	1.03	1.01	0.97	1.04	1.02
La/Yb	6.9	7.1	7.5	9.1	9.7	5.6	5.1	4.9	6.7	5.1
10000Ga/Al	2.45	2.39	2.32	2.50	2.30	2.56	2.86	2.48	2.41	2.49
10000Sc/Fe*	2.57	2.57	2.67	2.53	2.60	2.29	2.07	2.38	2.17	2.39

Appendix. 1 Continued.

Sample #	1816B	1816C	1812A	1812B	1602A	1602B	1603A	1603B	1603C	1603D
Rock type	B. laterite	B. laterite	B. laterite	B. laterite	S. laterite	S. bauxite	S. laterite	S. laterite	S. bauxite	S. bauxite
Depth(m)	1.0	2.0	0.1	1.0	0.1	1.1	0.1	1.0	2.0	3.0
Northing	15°12'05.5"	15°12'05.5"	15°20'48.0"	15°20'48.0"	14°56'08.2"	14°56'08.2"	14°56'17.1"	14°56'17.1"	14°56'17.1"	14°56'17.1"
Easting	105°57'16.6"	105°57'16.6"	105°59'50.5"	105°59'50.5"	106°35'46.6"	106°35'46.6"	106°35'52.3"	106°35'52.3"	106°35'52.3"	106°35'52.3"
SiO_2(%)	28.7	28.7	42.2	39.4	15.5	1.43	4.92	2.04	2.66	1.28
TiO_2	3.18	3.24	2.15	2.20	3.75	2.93	3.01	3.41	4.69	3.22
Al_2O_3	27.6	29.1	17.3	17.7	23.1	37.3	17.3	18.3	30.6	27.8
Fe_2O_3	22.6	22.8	18.4	20.1	38.5	32.5	56.0	57.6	38.9	44.0
MnO	0.321	0.358	0.269	0.363	0.053	0.061	0.032	0.019	0.037	0.062
MgO	0.10	0.11	3.28	2.36	0.08	0.05	0.02	0.03	0.07	0.04
CaO	< 0.01	0.02	3.69	2.60	0.01	< 0.01	0.01	0.01	0.03	< 0.01
Na_2O	< 0.01	0.04	1.73	0.99	0.04	0.02	0.04	0.04	0.02	0.03
K_2O	0.08	0.12	0.77	0.57	< 0.01	< 0.01	< 0.01	0.02	0.02	0.03
P_2O_5	0.22	0.20	0.35	0.19	0.54	0.48	1.29	1.53	0.76	0.59
LOI	15.3	15.7	10.9	14.3	18.1	24.2	17.0	17.3	21.2	20.7
Total	98.04	100.40	101.03	100.80	99.60	98.95	99.56	100.20	98.98	97.77
Sc(ppm)	38	41	24	25	46	52	62	84	46	46
V	303	318	258	281	647	400	773	712	569	522
Cr	310	300	270	280	1540	1100	1710	1160	1010	950
Co	40	43	84	106	7	19	13	6	10	14
Ni	220	220	230	220	< 20	40	< 20	< 20	< 20	< 20
Cu	100	100	110	100	70	120	140	170	120	130
Zn	240	240	200	270	80	80	160	90	160	80
Ga	34	34	25	25	45	45	44	55	68	43
Ge	2.2	2.5	1.6	1.8	0.8	0.6	0.7	0.6	0.7	0.6
As	< 5	< 5	< 5	< 5	8	9	34	14	15	6
Sr	4	5	237	203	64	64	91	142	107	79
Y	7.5	8.2	27.0	26.0	12.2	13.7	17.1	23.2	20.1	18.3
Zr	175	186	162	155	476	204	398	406	644	248
Nb	17.3	17.1	31.3	29.5	62.7	39.3	66.7	81.6	120	50.1
Ba	37	45	374	366	66	73	107	232	130	87
Hf	5.2	5.2	4.2	4.0	12.0	5.4	9.2	9.0	15.1	6.1
Ta	1.24	1.21	2.06	1.93	3.98	1.43	3.68	4.77	6.23	1.95
Pb	19	19	8	17	< 5	< 5	21	27	15	< 5
Th	3.90	3.85	4.53	4.49	14.7	8.18	19.1	13.8	19.5	8.28
U	0.95	1.00	0.92	0.95	3.45	3.67	4.34	5.03	5.11	4.48
La	6.22	5.99	33.2	30.2	39.8	41.7	41.0	65.2	74.5	42.7
Ce	37.2	38.0	80.7	82.4	80.0	85.2	87.9	139	150	82.8
Pr	2.05	2.04	8.31	7.58	10.9	9.41	10.7	17.1	16.4	9.44
Nd	8.91	9.31	29.2	26.9	40.0	37.6	42.0	67.3	59.8	36.8
Sm	2.40	2.54	6.66	6.25	8.90	9.09	9.82	16.2	13.5	8.67
Eu	0.835	0.901	2.28	2.14	2.72	2.81	3.19	5.14	4.16	2.73
Gd	2.43	2.65	6.53	6.21	6.64	7.46	8.06	13.2	10.8	7.28
Tb	0.37	0.42	1.04	1.00	1.00	1.05	1.22	1.92	1.41	1.02
Dy	2.10	2.24	5.82	5.67	4.61	4.79	5.74	8.76	6.37	5.03
Ho	0.40	0.43	1.11	1.10	0.61	0.71	0.83	1.16	0.95	0.86
Er	1.18	1.24	2.98	2.95	1.42	1.68	2.01	2.56	2.30	2.27
Tm	0.174	0.182	0.386	0.382	0.185	0.207	0.264	0.321	0.289	0.318
Yb	1.11	1.19	2.33	2.29	1.10	1.14	1.54	1.63	1.67	2.02
Lu	0.162	0.172	0.314	0.316	0.152	0.159	0.190	0.175	0.228	0.298
LREE	57.6	58.8	160.4	155.5	182.3	185.8	194.6	309.9	318.4	183.1
HREE	7.9	8.5	20.5	19.9	15.7	17.2	19.9	29.7	24.0	19.1
REE	65.5	67.3	180.9	175.4	198.0	203.0	214.5	339.7	342.4	202.2
LREE/HREE	7.27	6.90	7.82	7.81	11.60	10.81	9.80	10.43	13.26	9.59
Ce/Ce*	2.55	2.67	1.19	1.34	0.94	1.05	1.03	1.02	1.05	1.01
Eu/Eu*	1.06	1.06	1.06	1.05	1.08	1.04	1.10	1.07	1.05	1.05
La/Yb	5.6	5.0	14.2	13.2	36.2	36.6	26.6	40.0	44.6	21.1
10000Ga/Al	2.33	2.21	2.73	2.66	3.68	2.28	4.80	5.69	4.21	2.93
10000Sc/Fe*	2.40	2.57	1.87	1.78	1.71	2.29	1.58	2.09	1.69	1.49

Appendix. 1 Continued.

Sample #	1604A	1604B	1604C	1604D	1605A	1605B	1605C	1605D	1606A	1606B
Rock type	S. laterite	S. bauxite	S. bauxite	Sandstone	S. laterite	S. laterite	S. laterite	S. bauxite	S. bauxite	S. laterite
Depth(m)	0.1	1.0	2.0	7.0	0.1	1.0	2.0	3.0	0.1	1.0
Northing	14°56'34.2"	14°56'34.2"	14°56'34.2"	14°56'34.2"	14°56'41.4"	14°56'41.4"	14°56'41.4"	14°56'41.4"	14°56'56.0"	14°56'56.0"
Easting	106°35'33.1"	106°35'33.1"	106°35'33.1"	106°35'33.1"	106°35'19.6"	106°35'19.6"	106°35'19.6"	106°35'19.6"	106°34'43.0"	106°34'43.0"
SiO_2(%)	9.81	5.78	1.44	39.0	24.7	26.6	24.5	4.73	17.4	22.2
TiO_2	3.50	3.37	3.92	3.76	4.70	5.13	5.35	3.55	4.78	4.82
Al_2O_3	19.0	35.0	46.9	18.3	21.3	23.7	24.6	31.5	30.8	27.3
Fe_2O_3	50.4	32.3	19.3	26.0	25.7	28.0	28.2	37.8	25.5	25.3
MnO	0.036	0.032	0.046	0.097	0.048	0.046	0.059	0.340	0.180	0.213
MgO	0.06	0.07	0.08	0.05	0.10	0.10	0.10	0.05	0.27	0.56
CaO	0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	0.01	< 0.01	0.02	< 0.01
Na_2O	0.04	0.05	0.04	0.03	0.08	0.05	0.07	0.02	0.04	0.03
K_2O	0.03	< 0.01	< 0.01	0.03	0.04	0.04	0.04	0.02	0.04	0.08
P_2O_5	0.83	0.49	0.21	0.21	0.33	0.33	0.33	0.63	0.47	0.46
LOI	16.4	21.9	26.9	11.6	20.6	16.3	15.9	21.1	21.3	18.3
Total	100.10	99.01	98.85	99.05	97.53	100.30	99.09	99.70	100.80	99.26
Sc(ppm)	51	40	22	39	29	35	34	47	40	40
V	698	480	317	406	400	439	449	515	381	401
Cr	1170	1070	380	700	450	490	470	1630	510	570
Co	11	9	9	9	6	7	8	18	46	101
Ni	< 20	< 20	< 20	30	< 20	< 20	< 20	< 20	90	170
Cu	100	60	50	90	40	30	40	90	90	110
Zn	110	100	130	100	90	120	110	90	170	210
Ga	45	45	43	39	47	50	51	42	47	51
Ge	1.1	0.8	0.6	1.6	1.0	0.9	0.9	0.6	1.6	2.1
As	21	11	< 5	5	15	11	11	9	< 5	< 5
Sr	37	36	43	40	85	97	106	83	46	34
Y	11.2	7.8	7.6	14.7	19.6	19.9	20.9	15.0	46.5	71.4
Zr	385	350	357	401	457	567	548	366	391	421
Nb	61.6	52.6	60.3	58.6	70.7	91.3	92.7	59.4	64.2	66.8
Ba	43	40	46	237	119	135	148	638	100	80
Hf	9.5	8.9	9.0	10.3	12.4	14.2	14.1	8.9	9.8	10.4
Ta	3.42	3.48	3.57	4.06	5.24	6.34	6.43	3.09	4.21	4.15
Pb	17	13	7	< 5	< 5	19	12	19	13	< 5
Th	14.2	10.4	8.02	10.3	17.2	17.4	17.7	12.2	8.58	9.14
U	3.40	2.86	2.15	4.04	3.94	3.66	3.88	3.64	2.12	2.30
La	31.9	26.2	38.8	42.7	49.6	45.5	49.9	39.1	38.7	47.7
Ce	61.8	50.0	64.8	76.2	95.9	87.2	94.6	86.8	92.0	118
Pr	7.89	6.45	7.90	8.74	10.6	11.0	12.0	9.76	10.7	12.0
Nd	28.5	24.0	30.3	32.5	41.1	40.6	44.5	37.2	42.8	51.9
Sm	6.25	5.22	7.06	7.29	9.62	9.19	9.95	8.69	11.2	14.1
Eu	1.97	1.60	2.19	2.15	2.87	2.89	3.10	2.75	3.90	5.07
Gd	4.79	3.91	5.35	5.79	8.25	7.78	8.50	7.05	11.1	15.2
Tb	0.77	0.59	0.72	0.82	1.17	1.22	1.30	1.06	1.87	2.32
Dy	4.00	2.88	3.13	4.27	5.48	5.90	6.40	5.10	10.4	13.1
Ho	0.60	0.43	0.45	0.72	0.87	0.89	0.95	0.70	1.77	2.48
Er	1.56	1.02	1.03	1.98	2.22	2.16	2.27	1.64	4.48	6.76
Tm	0.224	0.141	0.124	0.286	0.293	0.299	0.306	0.211	0.585	0.898
Yb	1.36	0.90	0.67	1.83	1.73	1.80	1.80	1.17	3.59	5.09
Lu	0.188	0.136	0.094	0.251	0.244	0.241	0.252	0.146	0.537	0.688
LREE	138.3	113.5	151.1	169.6	209.7	196.4	214.1	184.3	199.3	248.8
HREE	13.5	10.0	11.6	15.9	20.3	20.3	21.8	17.1	34.3	46.5
REE	151.8	123.5	162.6	185.5	229.9	216.7	235.8	201.4	233.6	295.3
LREE/HREE	10.25	11.34	13.06	10.63	10.35	9.68	9.83	10.79	5.81	5.35
Ce/Ce*	0.96	0.94	0.91	0.97	1.03	0.96	0.95	1.09	1.11	1.21
Eu/Eu*	1.10	1.08	1.09	1.01	0.98	1.04	1.03	1.07	1.07	1.06
La/Yb	23.5	29.1	57.9	23.3	28.7	25.3	27.7	33.4	10.8	9.4
10000Ga/Al	4.47	2.43	1.73	4.02	4.18	3.99	3.91	2.52	2.89	3.53
10000Sc/Fe*	1.45	1.77	1.63	2.15	1.61	1.79	1.73	1.78	2.24	2.26

Appendix. 1 Continued.

Sample #	1607	1608	1609	1610	1611A	1611B	1709A	1709B	1709C	1813A
Rock type	S. laterite	S. laterite	S. bauxite	S. laterite	S. laterite	S. bauxite	S.(?) laterite	S.(?) laterite	S.(?) laterite	S.(?) laterite
Depth(m)	Surface	0.1	0.1	0.1	0.3	1.0	2.0	3.0	4.0	0.1
Northing	14°56'56.4"	14°57'07.6"	14°57'26.7"	14°57'43.1"	14°58'00.2"	14°58'00.2"	15°06'37.8"	15°06'37.8"	15°06'37.8"	15°16'59.7"
Easting	106°34'23.9"	106°34'14.3"	106°34'06.5"	106°34'07.45"	106°33'41.9"	106°33'41.9"	106°36'20.2"	106°36'20.2"	106°36'20.2"	105°57'06.2"
SiO_2(%)	10.4	16.7	1.20	18.5	62.1	3.53	44.9	54.6	60.2	42.0
TiO_2	2.35	6.31	4.40	5.72	1.17	2.37	2.06	1.90	1.68	3.92
Al_2O_3	16.8	23.9	43.0	26.6	15.4	30.1	26.0	20.2	18.3	29.2
Fe_2O_3	54.6	29.0	25.6	22.5	6.40	41.3	13.2	12.7	10.8	9.10
MnO	0.066	0.108	0.118	0.071	0.012	0.026	0.027	0.036	0.024	0.052
MgO	0.04	0.14	0.08	0.12	0.59	0.04	0.15	0.18	0.21	0.19
CaO	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03
Na_2O	0.02	0.06	0.05	0.03	0.05	0.04	0.05	0.05	0.04	0.02
K_2O	< 0.01	0.06	< 0.01	0.03	1.23	0.02	0.36	0.51	0.59	0.04
P_2O_5	0.97	0.70	0.36	0.36	0.08	0.79	0.11	0.11	0.10	0.11
LOI	14.2	22.1	25.3	22.2	11.3	21.0	13.3	10.0	8.57	14.0
Total	99.46	99.11	100.10	96.13	98.28	99.18	100.10	100.30	100.40	98.63
Sc(ppm)	54	43	28	37	13	52	21	20	19	27
V	502	442	301	397	119	580	182	178	162	236
Cr	540	370	310	500	120	1010	280	230	230	340
Co	28	13	12	8	3	12	5	6	4	23
Ni	30	< 20	< 20	< 20	< 20	50	< 20	< 20	< 20	210
Cu	180	60	50	50	< 10	120	40	40	40	50
Zn	110	170	110	120	< 30	90	90	80	80	200
Ga	32	51	48	51	22	36	33	29	28	33
Ge	1.4	1.1	0.6	1.2	1.3	0.6	1.8	1.6	1.8	1.6
As	7	7	< 5	12	6	15	10	6	8	< 5
Sr	39	134	83	92	30	55	19	25	25	6
Y	11.7	25.0	12.7	21.6	23.3	13.5	13.8	16.0	20.1	34.5
Zr	269	476	390	452	336	283	414	455	535	261
Nb	36.8	86.5	65.7	81.1	25.7	43.0	29.8	27.8	28.3	26.5
Ba	66	279	101	120	161	69	77	104	124	39
Hf	6.9	10.8	9.8	11.4	9.1	7.3	9.4	10.3	11.7	6.9
Ta	2.23	3.58	4.00	4.35	2.20	2.72	2.36	2.50	2.58	1.83
Pb	< 5	16	11	< 5	7	12	12	9	11	6
Th	6.26	13.5	7.68	15.6	19.1	15.4	14.8	16.2	18.0	4.92
U	2.46	2.88	1.89	3.74	2.89	3.51	3.03	3.27	3.82	0.98
La	33.3	63.5	35.3	62.7	33.9	22.2	31.0	38.5	45.0	24.5
Ce	80.5	131	67.3	120	66.5	46.4	60.2	73.2	87.5	35.9
Pr	9.00	17.4	8.99	14.6	7.92	6.00	6.69	8.42	10.2	7.48
Nd	36.5	66.1	33.8	58.5	27.1	23.3	21.0	26.8	32.3	29.9
Sm	9.27	15.2	7.55	13.2	5.59	5.69	3.98	5.13	6.47	7.59
Eu	2.98	4.86	2.31	4.17	1.25	1.83	0.89	1.12	1.41	2.73
Gd	6.86	13.2	6.03	11.1	5.06	5.01	3.25	4.22	5.20	8.53
Tb	0.98	2.02	0.87	1.55	0.90	0.86	0.56	0.70	0.86	1.28
Dy	4.64	9.69	4.06	6.92	5.14	4.47	3.16	3.82	4.71	6.98
Ho	0.69	1.34	0.58	1.00	0.94	0.68	0.58	0.67	0.85	1.34
Er	1.67	2.82	1.31	2.47	2.64	1.80	1.64	1.87	2.38	3.65
Tm	0.228	0.331	0.159	0.309	0.400	0.249	0.249	0.291	0.360	0.485
Yb	1.30	1.72	0.84	1.82	2.55	1.47	1.65	1.89	2.41	2.85
Lu	0.165	0.199	0.104	0.250	0.388	0.191	0.250	0.284	0.360	0.407
LREE	171.6	298.1	155.3	273.2	142.3	105.4	123.8	153.2	182.9	108.1
HREE	16.5	31.3	14.0	25.4	18.0	14.7	11.3	13.7	17.1	25.5
REE	188.1	329.4	169.2	298.6	160.3	120.2	135.1	166.9	200.0	133.6
LREE/HREE	10.38	9.52	11.13	10.75	7.90	7.16	10.91	11.14	10.68	4.24
Ce/Ce*	1.14	0.97	0.93	0.97	1.00	0.99	1.02	1.00	1.00	0.65
Eu/Eu*	1.14	1.05	1.05	1.05	0.72	1.05	0.75	0.74	0.74	1.04
La/Yb	25.6	36.9	42.0	34.5	13.3	15.1	18.8	20.4	18.7	8.6
10000Ga/Al	3.60	4.03	2.11	3.62	2.71	2.26	2.40	2.72	2.89	2.14
10000Sc/Fe*	1.41	2.12	1.56	2.35	2.91	1.80	2.28	2.25	2.53	4.24

Appendix. 1 Continued.

Sample #	1813B	1813C	4056A	4056B
Rock type	S.(?) laterite	S.(?) laterite	Sandstone	Sandstone
Depth(m)	1.0	2.0	Unknown	Unknown
Northing	15°16'59.7"	15°16'59.7"	Unknown	Unknown
Easting	105°57'06.2"	105°57'06.2"	Unknown	Unknown
SiO_2(%)	40.9	38.7	33.0	78.6
TiO_2	3.81	3.94	4.54	0.19
Al_2O_3	28.7	29.3	36.4	13.1
Fe_2O_3	11.2	11.6	7.87	1.01
MnO	0.068	0.026	0.009	0.002
MgO	0.19	0.19	0.02	0.22
CaO	0.03	0.02	0.07	0.02
Na_2O	0.04	0.04	<0.01	0.03
K_2O	< 0.01	0.07	0.14	0.86
P_2O_5	0.13	0.11	0.73	0.17
LOI	14.7	14.1	17.7	5.26
Total	99.65	98.06	100.10	99.50
Sc(ppm)	30	28	31	4
V	239	246	287	18
Cr	410	260	440	30
Co	29	14	5	2
Ni	240	190	340	140
Cu	70	70	70	20
Zn	200	160	120	<30
Ga	35	31	42	8
Ge	2.2	1.8	3.0	2.0
As	5	< 5	11	<5
Sr	5	5	688	181
Y	32.5	30.6	92	46
Zr	255	239	315	77
Nb	25.2	24.0	68	6.0
Ba	43	33	659	260
Hf	7.0	6.5	8.9	2.6
Ta	1.72	1.66	4.4	0.40
Pb	9	6	8	<5
Th	4.75	4.24	7.1	5.3
U	1.08	0.82	4.0	0.70
La	22.9	22.6	364	91.6
Ce	37.1	21.6	1050	265
Pr	7.05	6.40	112	31.4
Nd	28.8	25.0	493	171
Sm	7.25	5.97	136	56.5
Eu	2.58	2.18	44.7	20.8
Gd	8.02	7.16	109	55.3
Tb	1.21	1.06	13.5	7.10
Dy	6.59	5.95	54.0	28.8
Ho	1.27	1.17	6.2	3.6
Er	3.55	3.25	11.0	6.1
Tm	0.476	0.436	1.02	0.60
Yb	2.88	2.53	4.0	2.7
Lu	0.421	0.365	0.33	0.26
LREE	105.7	83.8	2199.7	636.3
HREE	24.4	21.9	199.1	104.5
REE	130.1	105.7	2398.8	740.8
LREE/HREE	4.33	3.82	11.05	6.09
Ce/Ce*	0.72	0.44	1.28	1.21
Eu/Eu*	1.03	1.02	1.12	1.14
La/Yb	8.0	8.9	91.0	33.9
10000Ga/Al	2.31	2.00	2.18	1.15
10000Sc/Fe*	3.82	3.46	5.64	5.67