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Chemical compositions of the Paleogene granitoids of eastern Shimane Prefecture, Sanin District, Southwest Japan

Shunso Ishihara[1] and Bruce W. Chappell[2]

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Abstact: Magnetite-series Paleogene granitoids of Mo-mineralized region of eastern Shimane Prefecture were studied chemically and compared with ilmenite-series granitoids of the Ryoke belt of the Chubu district. The eastern Shimane granitoids are divided into coarse-grained granodiorite and granite of batholithic bodies, and fine-grained granitoids occurring close to the roof-pendant. The fine-grained ones, varying in composition from quartz diorite to aplite are further subdivided into: Zakka and Kawai types, Rengeji type, leucogranites in the ore horizon, Yamasa type, Shimokuno type, and Ouchidani type. These granitoids are poor in A/CNK, Ga, Ga x 10000/A, K_2O, Rb, Ba, Pb, CaO, Fe_2O_3, Zn, Y, La and Ce, and rich in Na_2O, MgO, V and U, as compared with those of the Ryoke granitoids in the Chubu district. The chemical data indicate that the eastern Shimane granitoids are originated in source rocks with poor continental components, such as Al_2O_3, K_2O, REE, and organic carbon. Some gabbroids which are high in Sr content and Sr/Y ratio may have been derived from slab-melting. Rengeji Older Granite is potassic being $K_2O>Na_2O$, and rich in La, Ce, Y, Nb, Th, U; thus continental in the source rocks.

There occur small metamorphic bodies containing locally spinel and andalusite along the northwestern margin of the Rengeji Granodiorite. Kanenari hornfels is considered mainly psammitic with peraluminous layers. Togiishiyama hornfels has high A/CNK ratio but the K_2O contents are normal as to the SiO_2 contents. This rock contains rock-forming mineral of magnetite and has unusually high amounts of S, Cu, Pb, Zn and MnO. Therefore, the original rocks are considered intermediate to felsic tuffaceous sediments containing very little organic carbon. Mo-contents are high as 2.0 to 6.3 ppm Mo in average of the granitoids that host major molybdenite deposits, such as Kawai mingled rocks (Daito mine), Rengeji-leucogranites (Seikyu and Higashiyama mines) and Yamasa leucogranite (Yamasa mine). Therefore, trace amounts of Mo of fresh granitoids can be used as an exploration indicator.

Keywords: Shimane, Paleogene, granitoids, magnetite-series, major elements, minor elements, molybdenum.

1. Introduction

Eastern Shimane Prefecture is underlain mainly by Paleogene granitoids, which constitute a northern part of the largest granitic batholith of the Inner Zone of Southwest Japan (Fig. 1). These granitoids intrude into the basement with the Hida metamorphic and Sangun metamorphic rocks overlain by Paleozoic and Mesozoic sedimentary and coeval volcanic rocks, then by terrestrial volcanic rocks of late Cretaceous to Paleogene ages. These must have been happened along continental margin of East Asia before the spreading of the Japan Sea in Miocene time. Therefore, the granitic magmatism must have occurred along continental rifting in a northeast direction.

The region became a type locality for magnetite-series granitoids by finding high contents of opaque oxides and high bulk Fe_2O_3/FeO ratio of the granitoids (Ishihara, 1971a), while those of the Sanyo tungsten province contain no magnetite with low bulk Fe_2O_3/FeO ratios. It is also most important region for historical iron-sand mining and molybdenum–quartz vein mining in Japan. Largest three (Higashiyama, Seikyu and Daito) and the fifth (Komaki) molybdenite deposits, all in vein type, are hosted in various leucocratic granites and the Kawai mingled rocks of this region.

Geology of these granitoids and associated molybdenite deposits were studied in 1950-60s, and the results including major and minor chemistry of the granitoids were published in 1971 (Ishihara, 1971b). The major elements were analyzed by wet methods and the minor elements were determined by spectrographic methods

[1]National Institute of Advanced Industrial Science and Technology (AIST), Central 7, AIST, Tsukuba, Japan
[2]School of Earth & Environmental Sciences, University of Wollongong, NSW 2522, Australia

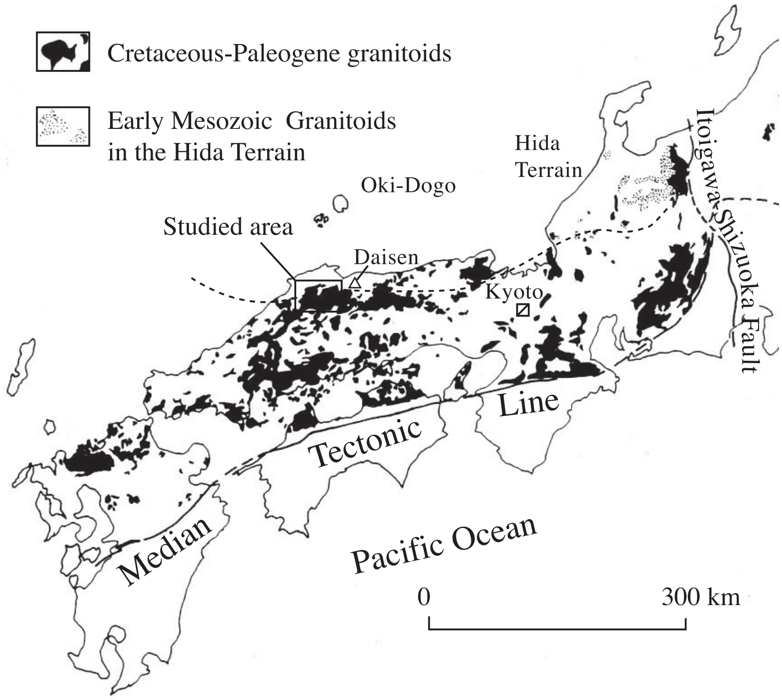

Fig. 1 The Inner Zone batholith of Southwest Japan and locality of the studied region.

at that time. The same samples, which were crushed by jaw and hand crushers made of special steel, then pulverized by agate mortar at the Geological Survey of Japan, were here re-analyzed by polarized XRF method, because of systematic differences between the old wet analyses and new instrumental analyses (Ishihara, 2002).

Major elements were analyzed on Li-borate pellet by XLAB 2000 polarized XRF machine of Heckel and Ryon (2002), using the Al target (Na, Mg), graphite target (Al, Si, P, S, Fe) and Co target (K, Ca, Ti, Mn). Minor elements were analyzed on the powders by using the graphite target (S, Cl), Co target (V, Cr), Mo target (Co, Ni, Cu, Zn, Ga, Ge, As, Br, Rb, Sr, Hf, Ta, W, Tl, Bi), Pd target (Y, Zr, Nb, Mo, Th, U), and Al_2O_3 target (Cd, In, Sn, Sb, Te, Cs, Ba, La, Ce). The obtained results were corrected by the software of the Spectro Analytical Instrument Ltd. H_2O analysis was done by conventional method. All the analyses were made by Bruce W. Chappell and the senior author is responsible for interpretation of the results.

2. Granitoids of eastern Shimane Prefecture

A variety of Paleogene granitic rocks is exposed continuously in eastern Shimane Prefecture, taking a major part of the Chugoku Batholith (Fig. 1). They are local magnetite-free series in muscovite-biotite granite of the Komaki mine area in the south, but all the others belong to magnetite series. Compositionally they are mostly granodiorite and granite, with minor quartz gabbroids including quartz gabbro to tonalite. Texturally they vary from coarse-grained batholithic units to fine-grained smaller bodies, often aplitic and porphyritic, close to the roof pendants. Nishida *et al*. (2005) proposed 24 local intrusion in the studied and surrounding regions, which could be rock facies of larger intrusive bodies. Here, the granitoids are classified essentially into coarse-grained homogeneous units and fine-grained heterogeneous units (Fig. 2), then the fine-grained ones into several intrusive units, if the cross-cutting relationships have been known clearly in the underground tunnels for molybdenum mining (c.f. Ishihara, 1967).

Basement of eastern Shimane Prefecture may regionally belong to the Hida metamorphic terrain to the north (Fig. 1) and Sangun metamorphic rocks to the south. The Hida gneisses are observed in the Oki-Dogo Island in the Japan Sea and near Daisen in Tottori Prefecture (Ishiga et al., 1989, Fig. 1). No such gneisses are present within the studied region, but there is a window of meta-sedimentary volcanic rocks with skarn-type magnetite deposits, both unknown age, at 14 km east-northeast of the Daito township. They are named as Toriyago and Kamiitou metamorphic rocks (Kano *et al*., 1994), but the original rocks are mainly volcanogenic and the metamorphic grades are very low, as compared with the Hida gneisses and Sangun metamorphic rocks.

Two hornfelsic metamorphic masses occur in the studied region. Kanenari Hornfels across the Kanenari stream of the Daito township of Unnan city are spinel-bearing psammitic schistose rocks. This body is called schistose hornfels, implying that it could not be a re-

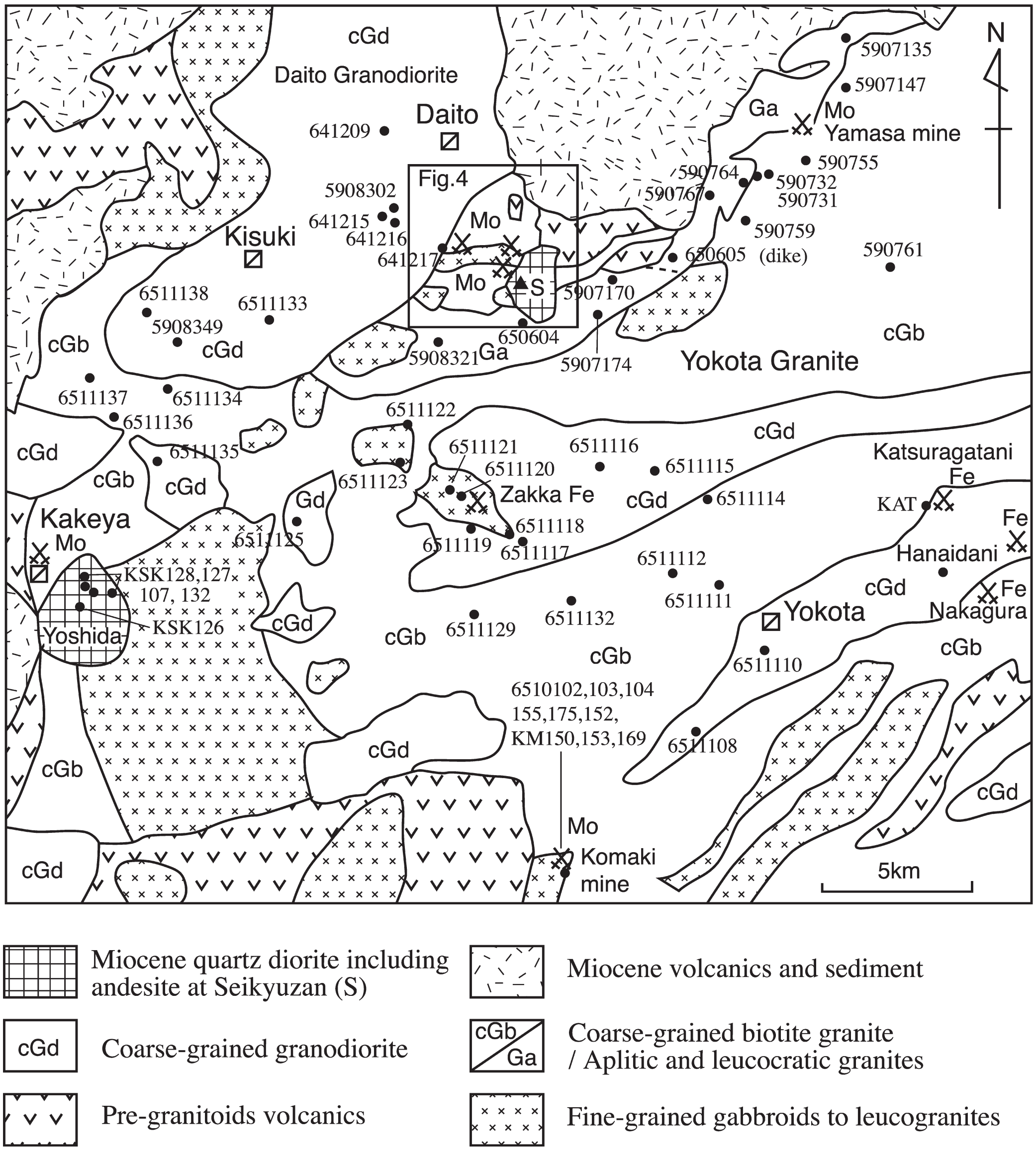

Fig. 2 Distribution of the studied plutonic rocks and localities of analyzed samples, including batholithic units, Yamasa and Shimokuno types and Komaki mine area. cGd, coarse-grained granodiorite; cGb, coarse-grained biotite granite; Ga, aplite and leucogranite (Shimokuno and Yamasa types). Fe, large iron-sand deposits; Mo, molybdenite-quartz vein and pipe deposits.

gional metamorphic rock but a local metamorphic one formed by thermal metamorphism of the granitic intrusion (Ishihara, 1971b). Togiishiyama gneissic hybrid (Yamamoto, 1954) to the south may belong to the same group; thus here called as Togiishiyama hornfels.

In the Yoshitokodani exploration tunnel of the Higashiyama mine, foliated granite was found in the 1960s. This granite is sheared, then the cracks are filled with fresh biotite; thus recrystallized. The granite is chemically different from other granitoids, being potassic and rich in lithophile elements. The granites are called Older Rengeji Granite in this paper. Original rocks of the hornfels and this older granite are the oldest in the studied region.

Late Cretaceous and/or Paleogene ignimbrites are the next oldest rocks, which have been thermally metamorphosed by intrusion of plutonic rocks. One around Shiota community, Daito township, was dated by Rb-Sr isochron method as 66.5±2.4 Ma with initial $^{87}Sr/^{86}Sr$ ratio, Sr*I*=0.70485±0.00014 (Nishida *et al*., 2005).

The other normal granitic rocks are divided into two large groups: (1) coarse- to medium-grained batholithic granodiorite and granite, and (2) fine- to medium-grained small bodies occurring between the batholithic units and near the roof pendant (Fig. 2). These small bodies are classified into seven intrusive units, whose intrusive sequences are summarized in Fig. 3. These Paleogene granitoids are intruded by small stocks and dikes of Miocene gabbroids and andesites. They are supplemented in the Appendix II.

Radiometric ages of K-Ar ages were recently summarized by Matsuura *et al*. (2005). Nishida *et al*. (2005)

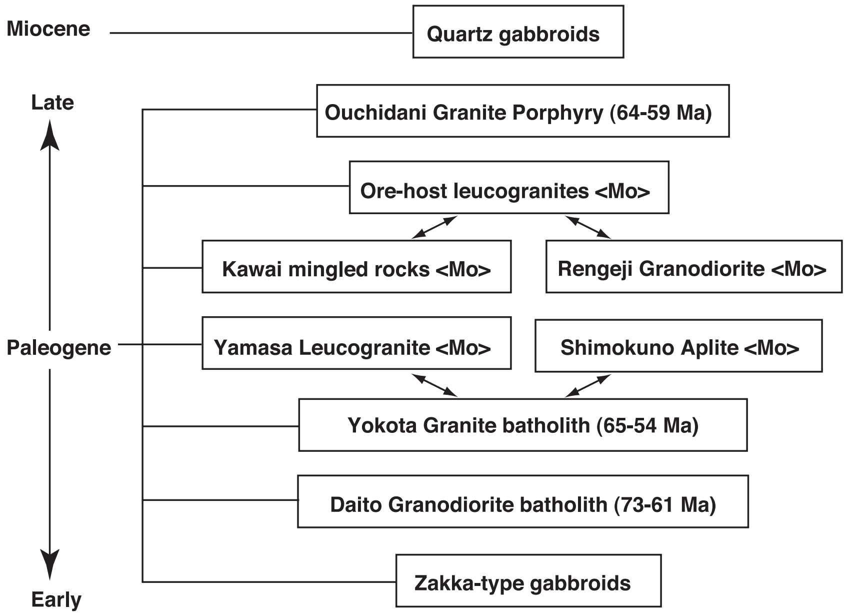

Fig. 3 Intrusive relationship among the Cenozoic plutonic activities in the eastern Shimane region. Absolute ages are whole rock Rb-Sr isochron age range of Nishida *et al*. (2005). Arrow connecting two granitic masses indicates an intimate genetic connection. <Mo> implying to host molybdenite-quartz veins.

reported the following Rb-Sr whole rock isochron ages: 66.8±6.2 Ma for the Daito Granodiorite, 59.6±5.5 Ma for the Yokota Granite, 61.9 ±1.6 Ma for the Yamasa Leucogranite and 61.2±2.4 Ma for the Ouchidani Granite Porphyry, and the mineral isochron age of 54.4±3.8 Ma for the Daito Granodiorite. The analytical errors are fairly large, because of low Rb contents of these granitoids. There are still much disagreement among the field cross-cutting relationships, K-Ar dating on mica minerals, whole rock Rb-Sr ages and Re-Os determination on molybdenites. The largest discrepancy would be either the youngest (Yamamoto, 1968) or the oldest (all the radiometric ages) of the Daito Granodiorite. Further SHRIMP studies are urgently needed on zircon from the studied granitoids.

The Paleogene plutonic rocks have low initial $^{87}Sr/^{86}Sr$ ratios of 0.7050 to 0.7058 (Shibata and Ishihara, 1979). Nishida *et al*. (2005) reported even lower values, ranging from 0.70477±0.00006 for the Daito Granodiorite to 0.70526±0.00020 for the Yamasa Leucogranite. The $\delta^{18}O$ values are also low as 6.5 to 6.9 ‰ at SiO_2 70 % and are considered the granitoids to have a primitive I-type oxidized source (Ishihara and Matsuhisa, 2002), but show no evidence of meteoric water interaction during the solidification of the granitoids and some molybdenite-quartz veins (Ishihara and Matsuhisa, 1975).

Batholithic bodies

The first group is shown by Daito Granodiorite and Yokota Granite (Fig. 2). These granitoids occur in elongated shapes to ENE-WSW and direct cross-cutting relationships are often unclear, because of poor exposure due to matured topography. The Daito granodiorite occurs typically in the Daito area with an ellipsoid of 30 km in NE-SW direction and 10 km wide (Fig. 2), and similar phases with smaller sizes occur within the Yokota Granite to the southeast. Mafic enclaves are common in the granodiorite.

In the Daito township, modal analyses(n=8) indicates the granodiorite as $_{45}$b/hGd$_{11}$, which can be read as a rock having granodioritic feldspar ratios with the color index of 11 vol. %, biotite more than hornblende, and average number of grain boundary per one inch is 45 (Chayes, 1956). The granodiorite has Rb-Sr whole rock isochron age of 66.8±6.2 Ma (Fig. 3) and mineral isochron age of 54.4±3.8 Ma, which are considered as intrusion and cooling (K-feldspar) ages, respectively (Nishida *et al*., 2005). The reported K-Ar biotite ages concentrate between 52.5±1.1 Ma and 54.9±1.1 Ma (Matsuura *et al*., 2005), and hydrothermal sericite ages within this body reveal 48.4±2.4-51 Ma to 50.6±2.5 Ma (Kitagawa *et al*., 1988), implying that the clay deposits were formed by the post magmatic hydrothermal activities.

Eastern Shimane Prefecture is one of the best mining regions for rock-forming magnetite from weathered plutonic rocks. The best iron-sand ore called “Masa” has been mined from weathered crust of the granodiorites from the Yokota area for the very low contents of impurities (P, S, Ti etc) and fairly abundant rock-forming magnetite. The Hanaidani deposits in the Yokota township are the best examples and mined even at present to produce steel for Japanese sward using the traditional technology.

Yokota Granite, which is called Hiyodori Granite in Matsuura *et al*. (2005), occurs to the southeast of the Daito Granodiorite and continues further east to the Tottori Prefecture, where the granite was called as Tottori (or Ogamo) Granite. Within this granite, coarse-grained granodiorite and Zakka-type gabbroic masses occur locally (Fig. 2). The granite is also coarse-grained magnetite-bearing biotite granite characterized by pink K-feldspar. Yet the granite has no syeno- but monzogranite feldspar ratio with a low color index (biotite and magnetite) of 2 vol. %. The grain size is 35/inch.

K-Ar biotite and fission track zircon ages of the Yokota Granite vary from 53.8±2.1 Ma to 55.5±2.0 Ma, but some older ages were reported (Agency of Resource and Energy, 1988). The whole rock Rb-Sr isochron age, 59.6±5.5 Ma (Nishida *et al*., 2005), is the same, within the analytical error, as the K-Ar and fission track ages of this granite. About alteration minerals from clay deposits hosted in this granite, high-temperature greisen muscovite revealed K-Ar ages varying from 52.5±2.1 to 57.3±1.2 Ma and low temperature sericite ranging from 45.6±2.3 and 51.3±1.6 Ma. The iron-sand ores have been also mined locally from weathered crust of this granite, but much less intensively due to low contents of magnetite for the low bulk iron content of this granite.

Fine-grained small bodies

Along the northwestern margin of the Yokota Granite, Yamasa Leucogranite and Shimokuno Aplite occur in 2-3 km wide zone along the west-northwestern margin of the Yokota Granite (Fig. 2). Yet, the Yamasa Leucogranite sharply changes to the Yokota Granite, implying that the two magmas were independent intrusions, although closely related. The Shimokuno Aplite is gradual to and/or later than the Yokota Granite (Ishihara, 1971b).Both the granites contain mafic enclave-dominant portion, which looks like the Kawai-type mingled rocks. The Yamasa Leucogranite has an average color index of 2 vol. % (muscovite >biotite), and grain size of 100/inch, respectively; while the Shimokuno Aplite has those of 1 vol. % (muscovite>biotite) and 102/inch, respectively.

Nishida *et al*. (2005) reported the following Rb-Sr isotopic data: 61.9±1.6 Ma, Sr*I* of 0.70526±0.00020 for the Yamasa Leucogranite and 59.6±5.5 Ma, Sr*I* of 0.70484±0.00022 for the Yokota Granite. These ages are similar but the Sr*I* is much higher in the Yamasa Leucogranite than the Yokota Granite. A medium size of molybdenite-quartz vein deposit of the Yamasa mine is hosted in the Yamasa Granite and that of the Seikyu-Minami mine occurs in Kawai-type mingled rocks in the Shimokuno Aplite. The Shimokuno Aplite has biotite K-Ar age of 53.5±1.1 Ma (Agency of Resource and Energy, 1988), and molybdenite age of the Seikyu-Minami deposit is dated at 50.2±2.3 Ma by Re-Os method (Suzuki *et al*., 1996).

Other fine-grained rocks occur as small bodies, typically close to the roof-pendant, and can be divided into (i) Zakka and Kawai types and (ii) Rengeji type and (iii) other bodies. The Kawai type, which has quartz diorite to leucogranite in composition with commonly magma-mingling texture, occurs many places as small units. The Rengeji type is observed only at Rengeji temple site of the Daito area.

(1) Zakka and Kawai mingled rocks

The most mafic phase of these rocks is quartz gabbro containing no olivine and pyroxene, but hornblende and biotite, occurring as xenolithic small bodies intruded and mingled by leucocratic phases of the Yokota biotite granite at Zakka. This most mafic plutonic rock, called Zakka type after the type locality, is considered as oldest among the Paleogene granitic activities (Fig. 3), because it is trapped in the batholithic bodies although no age data are available. The most mafic phase of a quartz gabbro is 51.3 % SiO_2, seen as mafic enclaves and boulders in the Zakka iron sand deposit (Fig. 2).

Because of the high content of ferromagnesian components in this rock, the weathered soil contained highest magnetite content up to 8 wt. % of magnetite, but also ilmenite and titanite abundantly. This iron sand is called “Akome” for the reddish iron oxide stained color and mined extensively during the past years. Another famous iron-sand deposits of the Katsuragadani (Fig. 2) belongs to the same type, and the original rock is quartz diorite (55.9 % SiO_2).

Similar rocks ranging composition from quartz diorite to leucogranite occur in Kawai community of Daito town, called Kawai hybrid by Yamamoto (1954). They occur in east-west from Kawai to the Seikyu-Higashiyama mines area (Fig. 4). This rock is a magma-mingled rock of basaltic and leucogranitic magmas, but shows generally a plutonic texture (Plate 1A) and locally an intersertal texture of mafic volcanic rocks (Plate 1B). The bulk compositions are more mafic to the west, Daito mine area, but felsic to the east, where quartz dioritic mafic phases occur like “conglomerate” in leucogranites and aplitic granite (see Plates X to XIII of Ishihara 1971b). These were best seen in the drill cores and underground workings of the Seikyu and Higashiyama mines. These rocks host flat-lying (<20^{o} dip) molybdenite-quartz veins of Daito-hi and Eiko-hi of the Daito mine, and some veins of the Seikyu and Higashiyama mines.

Biotite of the felsic phase gives K-Ar ages of 53.6 ±1.1 Ma (Agency of Resource and Energy, 1987), while pegmatitic biotite and alteration muscovites from the Daito and Seikyu mines were dated at 47.7±1.9 Ma, 49.0±1.9 Ma and 51.3±1.6 Ma (Ishihara *et al*., 1980, 1988). Re-Os ages of molybdenites reveal much older ages varying from 56.6±2.0 Ma of the Daito mine to 57.7±3.3 Ma of the Seikyu mine and 62.2±2.1 Ma of the Higashiyama mine (Suzuki *et al*., 1996), on the contrary to younger age of Seikyu-Minami molybdenite

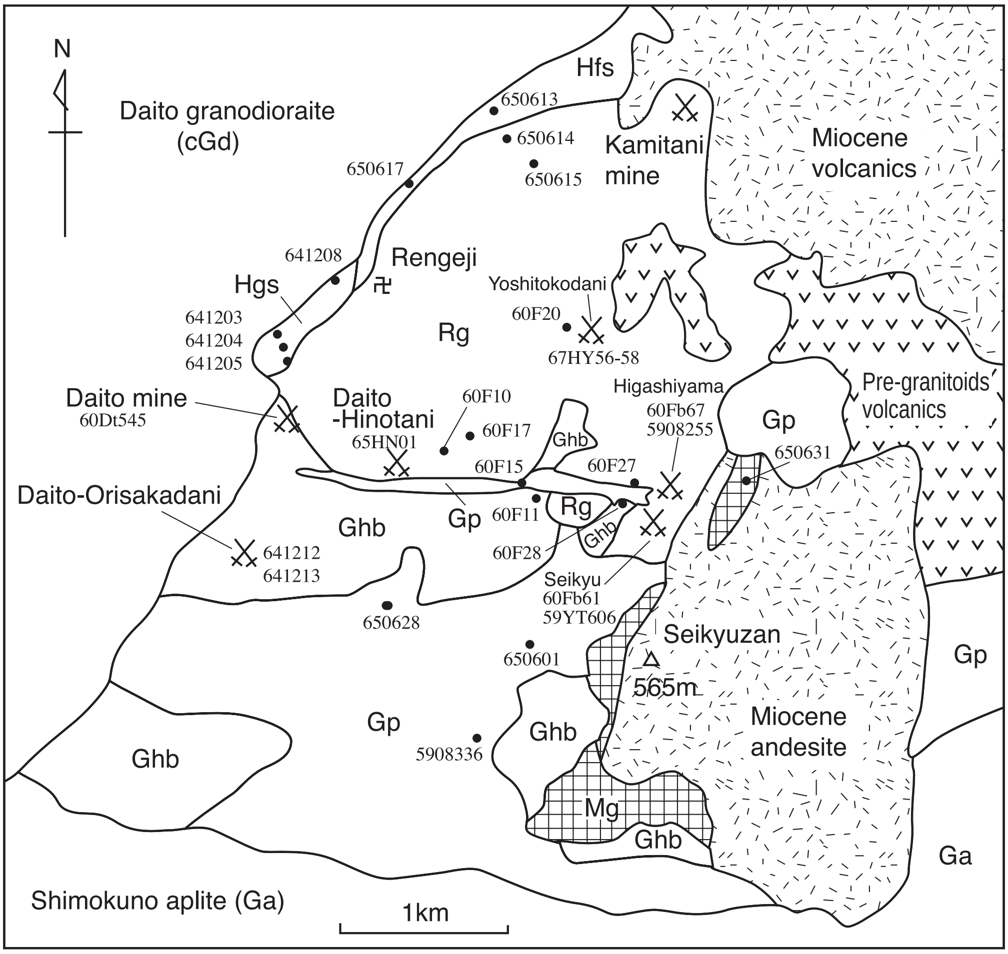

Fig. 4 Distribution of granitoids and analyzed samples in the Daito area. Hfs-Kanenari hornfels; Hgs-Togiishiyama hornfels; Rg-Rengeji granodiorite; Ghb-Kawai mingled granitoid, Gp-Ouchidani granite porphyry, Mg-Miocene gabbroid.

mentioned previously. On molybdenite in the Busetsu Granite, the Re-Os age agrees well to K-Ar and Rb-Sr ages of the host granite (Ishihara *et al*., 2002).

Molybdenite-quartz veins of the major Ohnobe veins of the Higashiyama mine are 150 m down-thrown part of the major Jiri-Yabuchi vein of the Seikyu mine by the Dai-danso (Big Fault). Therefore, the same and/or similar ages should be expected on these molybdenites from the Higashiyama and Seikyu mines. SHRIMP dating on zircon of the host rocks and more Re-Os dating on the molybdenites are necessary on the major veins of Seikyu-Higashiyama mine and their host granites.

(2) Rengeji-type hornfels and granodiorite

This type includes Rengeji Granodiorite and Rengeji Older Granite, and their northwestern part of small xenolithic bodies of the Kanenari hornfels and Togiishiyama hornfels. The Kanenari hornfels is silicic but locally peraluminous, containing spinel and andalusite-bearing layers (see PlateVII-2 of Ishihara, 1971b). This rock is weakly foliated; yet no evidence of stress effect (e.g., protoclastic texture, quartz with wavy extinction etc.) but has an equigranular-granoblastic texture, composed of quartz, plagioclase and K-feldspar, and small amount of biotite. The aluminous layer contains, besides these salic minerals, small amount of muscovite, reddish brown biotite, andalusite, zincian spinel and pyrite (Ishihara, 1971b).

To the southwest of this body, there occurs the Togiishiyama hornfels (Fig. 4). On the contrary to the Kanenari hornfels, this is rather homogeneous body foliated to NE-SW (Plate 2A), having a granodiorite composition with the average color index (biotite, magnetite and minute grains of sulfides) of 8 vol. %. The average grain size is 156/inch. Again, no stress effect has been observed in the rocks. This rock contains phenocrystic quartz and plagioclase with no compositional zoning. Small amounts of sulfides, subhedral to anhedral in shape, are observed between salic minerals and/or associated with biotite. Small clots of pelitic xenoliths, which have aluminous reaction rims containing andalusite, garnet and spinel (Plate XXVI-1, 2, Ishihara, 1971b), were found at one site just west of Rengeji temple (Fig. 4, 641208, see Plate VIII-2 of Ishihara, 1971b). The other parts are quite homogeneous and granodioritic in composition.

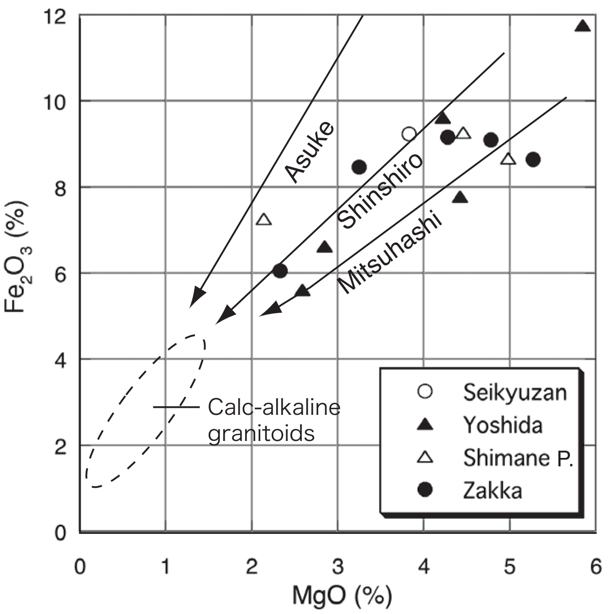

Fig. 5 Total iron as Fe_2O_3 vs. MgO diagram of the studied mafic plutonic rocks, as compared with those in the Ryoke Belt of Mitsuhashi, Shinshiro and Asuke trends. Zakka is Paleogene, but the other three gabbroids are Miocene in age. P stands for peninsula.

The Rengeji Granodiorite occurs to the southeast of these hornfelses with triangle shape of E-W 3 km and N-S 2.5 km (Fig. 4). This rock gradually changes to the hornfelses and contains their xenolithic blocks (see Ishihara, 1971b for details), and has granodiorite feldspar ratio, although average color index is only 5 % of biotite, implying predominance of sodic plagioclase. Average grain size is 57/inch. The biotite is not large flakes but often aggregates of fine crystals, which are similar to those of the Togiishiyama hornfels. The most reliable age data of the Rengeji Granodiorite are K-Ar biotite ages of 51.5, 52.1 and 52.8±1.1 Ma (Agency of Resource & Energy, 1987). At the northeastern margin, this granodiorite hosts clay-rich molybdenite-quartz veins of the Kamitani mine.

Strange-looking rock were found in the Yoshitokodani exploration tunnel of the Higashiyama mine and donated to the authors to examine these rocks. They are mafic phase (67HY58) found at 510 m and recrystallized granites (67HY51, 56 and 57) observed at many places from the mouth of the tunnel. Under the microscope, the mafic rock is also granodiorite in composition with only biotite, although some biotite shows elongated columnar morphology. Most of the felsic phases are biotite granite containing abundant perthitic orthoclase of subhedral to anhedral forms. Needle-shaped biotite occurs along cracks cutting through plagioclase, perthite and quartz, and the biotite has received no chloritization (Plate 2B). Therefore, this rock could be an older granitic block, which was sheared and trapped into the Rengeji Granodiorite and recrystallized during the magmatic stage. SHRIMP zircon age determination is necessary to identify the older age.

Various leucogranites occur between the Kawai hybrid and Rengeji Granodiorite with gentle dip to the north, and no sharp boundaries are observed between felsic phases of the Kawai hybrid and that of the Rengeji Granodiorite. The leucogranites have the feldspar ratio of monzogranite with a granitic and/or aplitic texture. The average color index, composed of biotite and/or muscovite, is 2 vol. %, and the average grain size is 137/inch. These rocks, once called leucogranites complex (Ishihara, 1971b), important host rocks for the major veins of the Seikyu and Higashiyama mines, and also Hinotani veins of the Daito mine; thus could best be called ore-host leucogranites (Fig. 3), where the mineralizations are almost entirely controlled by the cooling joint.

(3) Ouchidani Granite Porphyry and other bodies

Ouchidani Granite Porphyry seems to be the latest intrusion among the fine-grained granites, but prior to the molybdenite-quartz vein mineralizations in the underground Seikyu and Daito mines (Ishihara, 1967). It is porphyritic biotite granite in the main part having the average color index (biotite) of 2 vol. % and the average grain size is 57/inch, but is granodiorite to granite in dikes of the northern fringe and of the eastern extension. Agency of Resource and Energy (1987) noted the biotite K-Ar age of 53.7±1.1 Ma. Whole rock Rb-Sr isochron age is 61.2±2.4 Ma (Nishida *et al*., 2005). Thus, additional SHRIMP dating is necessary to solve the age difference.

Miocene quartz gabbroids occur at the western and northern parts of the Seikyuzan andesite and intruded by the andesite (Fig. 4). Similar mafic intrusion is seen at south of Kakeya township (Fig. 2) as small stock and named as Yoshida body (Sawada, 1978).

Komaki mine area

The Komaki mine is located at the southern end of the studied region (Fig. 2), and has similar geology to that of the Daito-Higashiyama area. That is, the molybdenite- quartz pipe and veins occurring in the marginal fine-grained granites just below the roof rocks of Cretaceous volcanic rocks. The geology is different, however, having magnetite-free muscovite-biotite granite as the host rock and accompanying minable amounts of wolframite and scheelite in the Ichimanko orebody, both of which are characteristics of the ilmenite-series Sanyo Granitic Belt.

The granitoids were classified into three types: (1) coarse-grained granodiorite, abbreviated as cGd, with $37b/hGd_{10}$, (2) fine-grained quartz diorite (fQd) with $71h/bQd_{25}$ to fine-grained granodiorite (fGd) with $95b/hGd_9$, and (3) fine-grained biotite and/or muscovite granite with $74m/bG_5$ (Ishihara, 1971b). An average of mica ages is 64.1±2.6 Ma (Ishihara *et al*., 1988), but a

Re-Os ages of the molybdenites from the ore deposits is 74.3±3.2 Ma of late Cretaceous (Suzuki *et al*., 1996); again, the Re-Os age older than the K-Ar age, thus the radiometric ages need to be re-examined by SHRIMP zircon method.

3. Chemical characteristics of the eastern Shimane granitoids

The samples previously studied were reanalyzed here by polarized XRF apparatus with the analytical procedures previously described. The sample location is shown on Figs. 2 and 3, and also described in Ishihara (1971b). The results are listed in the Appendix I and shown on the Fe_2O_3-MgO diagram (Fig. 5) and Harker's diagram (Figs. 6-12), and are compared with the average of the Ryoke granitoids obtained from a liner-trend analysis (Ishihara and Chappell, 2007). Excluded from the Harker diagram are three unknown-age samples of the Rengeji Older Granites from the Yoshitokodani tunnel, Ouchidani Granite Porphyry and Miocene intrusive rocks.

On the Fe_2O_3-MgO diagram, the Zakka-type mafic plutonic rocks are plotted on an intermediate Fe_2O_3/MgO trend similar to the Shinshiro trend of the Ryoke granitic belt, but two samples of 6511123 and 6511118

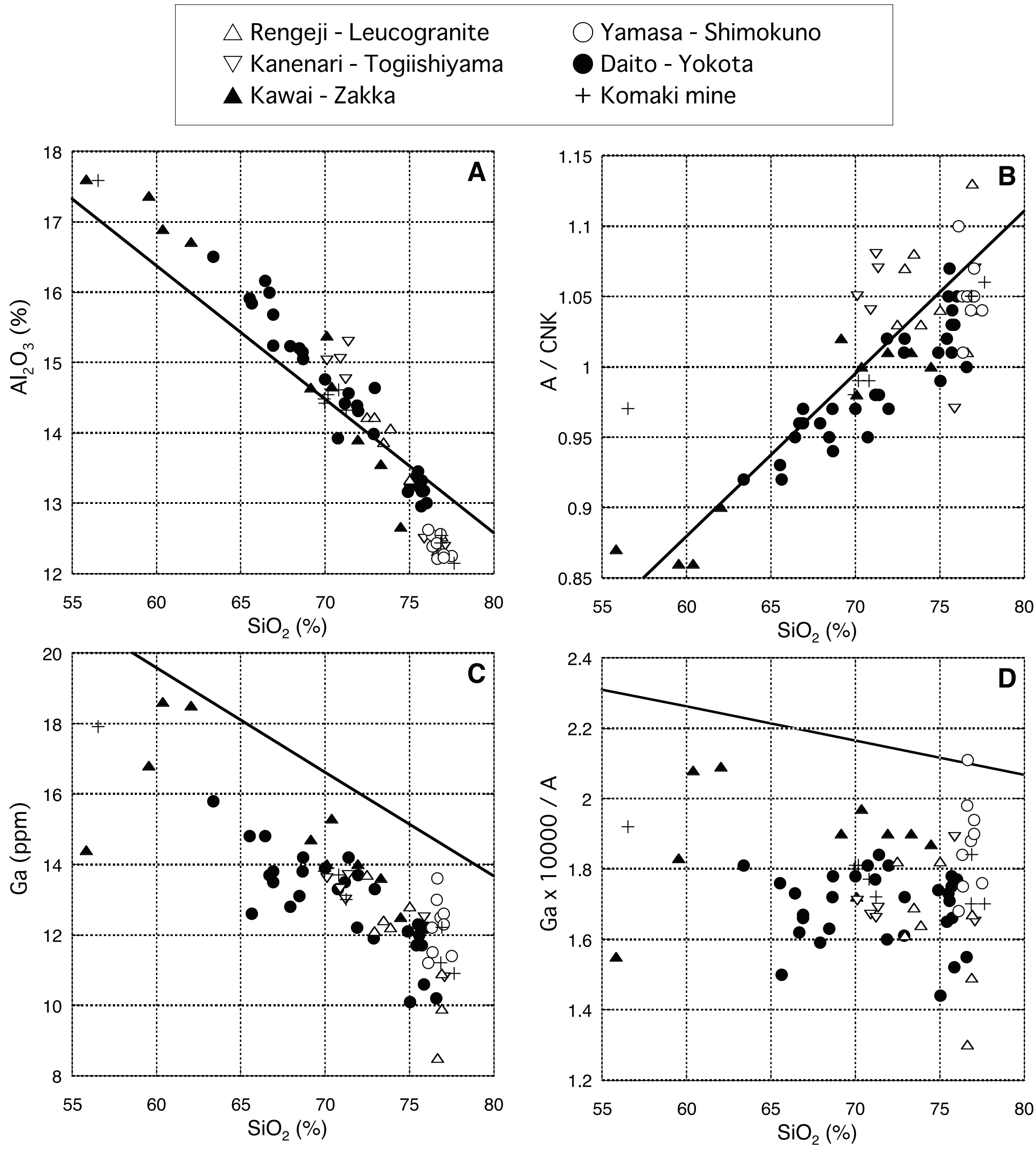

Fig. 6 Silica vs. Al_2O_3, A/CNK. Ga and Ga x 10000/A of the eastern Shimane granitoids. The straight line is regression line of the Ryoke granitoids of Ishihara and Chappell (2007).

are MgO-rich (Fig. 5) and plotted close to the Mitsuhashi trend of the Ryoke granitoids. These rocks have Sr contents of 373-565 ppm and Sr/Y ratio of 17-29, thus only weakly adakitic. Miocene plutonic rocks are supplemented on the diagram, which will be mentioned later.

Al_2O_3 content of the eastern Shimane granitoids are correlated well with the SiO_2 contents showing a smooth curve, crossing the average composition of the Ryoke granitoids (Fig. 6A). The A/CNK ratio is parallel but lower than that of the average of the Ryoke granitoids in general, and the rocks with granitic composition are peraluminous, A/CNK ratio >1.0, but granodiorite and mafic rocks are metaaluminous, A/CNK ratio <1.0 (Fig. 6B). Among the rock units, all the Togiishiyama hornfels and the Rengeji Granodiorite and related ore-host leucogranite (73HY01) have the ratio higher than the average value of the Ryoke granitoids (Fig. 5B). No rocks but one ore-host leucogranite has the A/CNK ratio higher than 1.1. Therefore no S-type, Al-rich characteristics are observed. The Rengeji Older Granites reveal low values of 12.03 and 12.17% Al_2O_3 (67HY56, 57, see Appendix), yet their A/CNK ratios are similar to other rocks of the Rengeji Granodiorite.

The Ga contents, which substitutes aluminum in the rock-forming minerals are lower than the averages

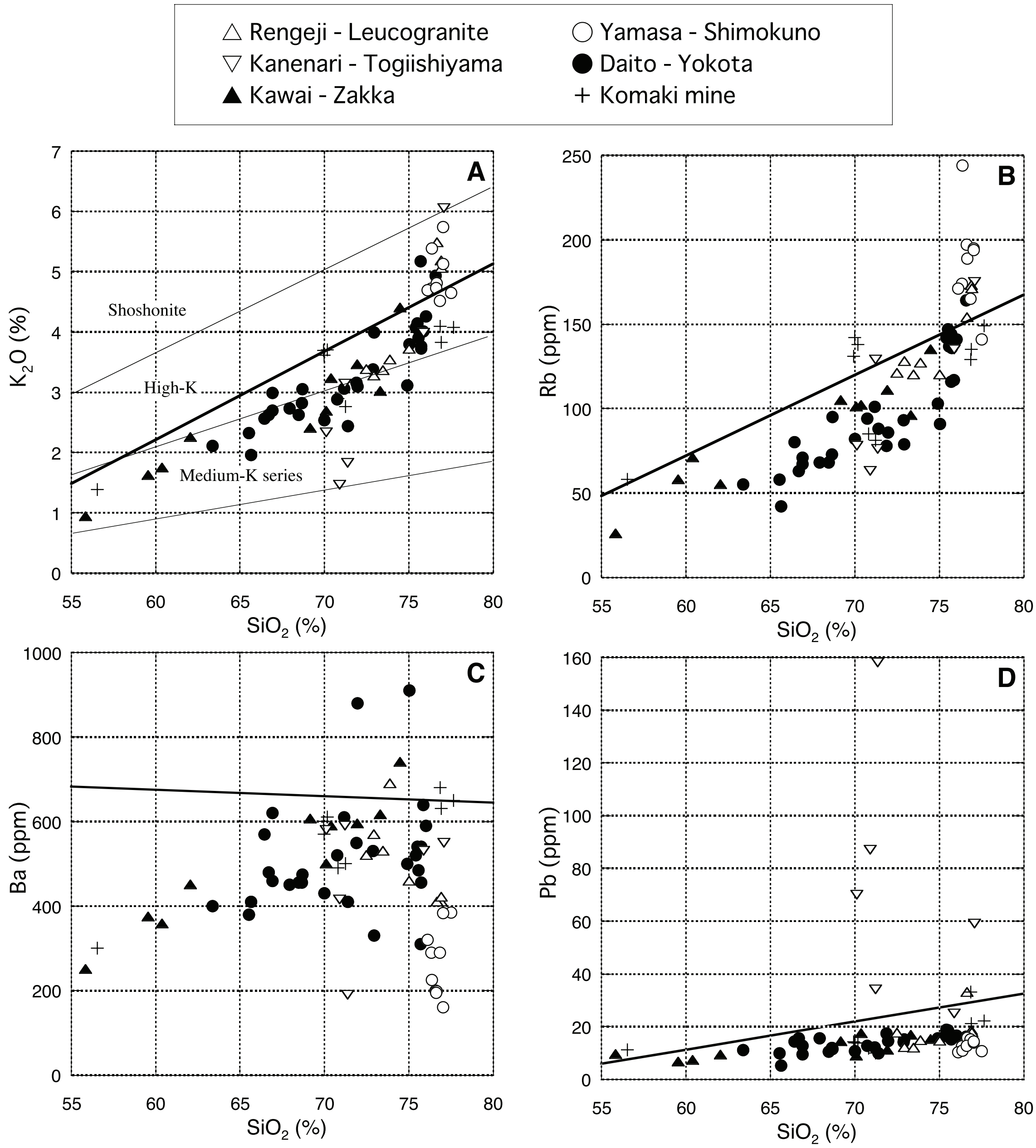

Fig. 7 Silica vs. K_2O, Rb, Ba and Pb of the eastern Shimane granitoids.

of the Ryoke granitoids. Therefore, no indication of A-type characteristics has been observed. Among the low ranges, both Ga contents and Ga/A mole ratios are high in the Zakka and Kawai types and leucogranites of the Yamasa and Shimokuno types (Figs. 6C, D).

In the K_2O-SiO_2 diagram, the studied rocks of quartz diorite and granodiorite compositions belong mostly to medium-K series. The most mafic rocks of the Zakka type, though not plotted in the diagram, have an average of 1.26 % K_2O against 54.6% SiO_2, thus plotted in the same field. The K_2O content increases sharply to the granite composition, thus plotted in the high-K series field (Fig.7A). This must be largely due to magmatic fractionation. The Rengeji Older Granites are plotted in the high-K area separately from the Rengeji granodiorite, implying that the Granites have different source rocks.

The Togiishiyama hybrid is especially low in K_2O and Rb contents. Rb contents are generally lower than the average of the Ryoke granitoids but become enriched in the high silica rocks (Fig. 7B). The high values, 194-244 ppm Rb, are observed in the Shimokuno Aplite, and these rocks have Rb/Sr ratio of 1.9 to 5.5. The ore-host leucogranites of the Seikyu-Higashiyama mines range from 154 to 173 ppm Rb, and their Rb/Sr ratios vary from 2.2 to 2.7. The granites are most

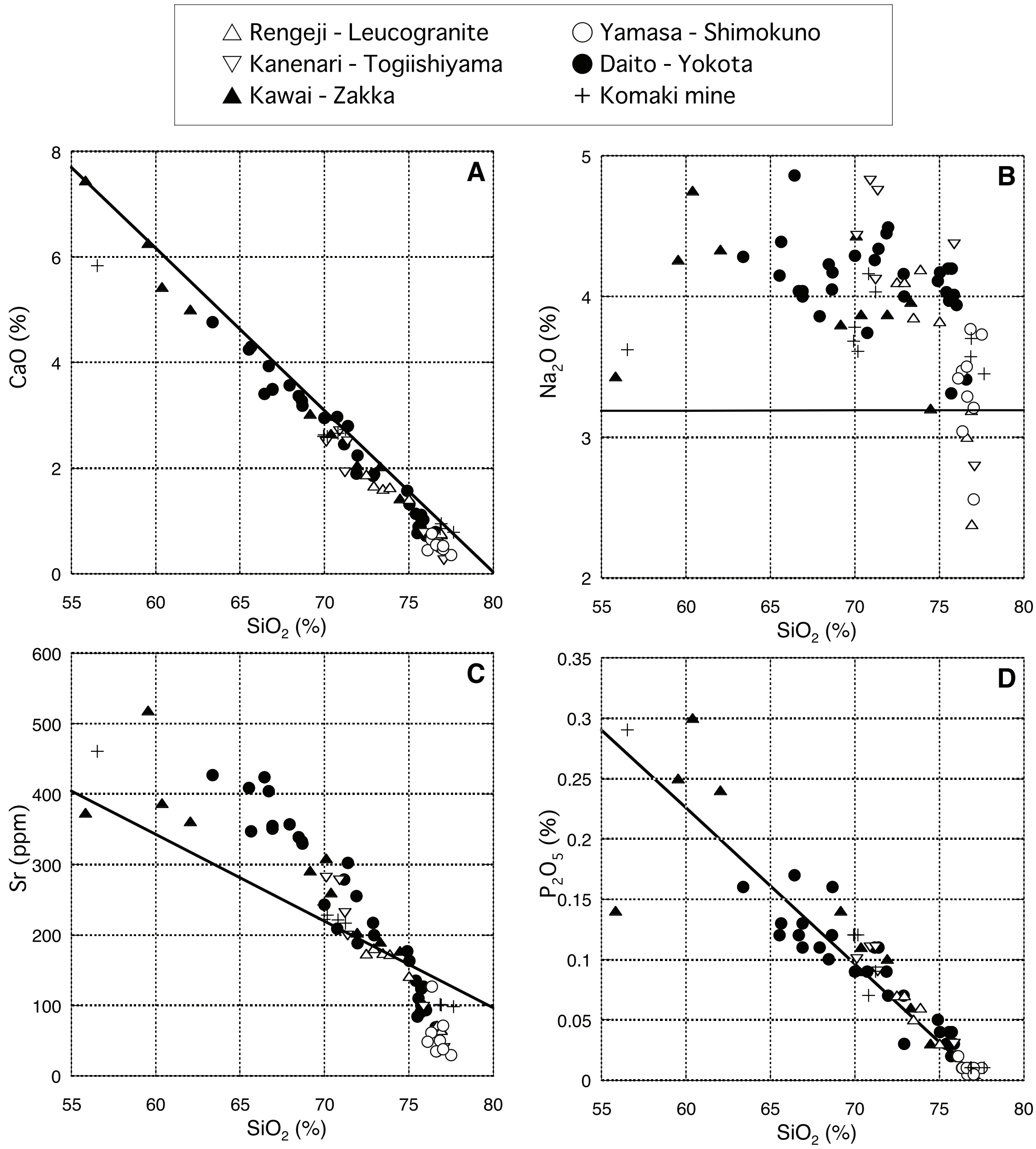

Fig. 8 Silica vs. CaO, Na_2O, Sr and P_2O_5 of the eastern Shimane granitoids.

fractionated rocks in the eastern Shimane region. The Rengeji Older Granite has high Rb/Sr values of 3.7 and 4.7, which are mainly due to low contents of Sr because of abundance of perthitic orthoclase.

Rb contents of fine-grained granodiorites of the Komaki area (SiO_2 ±70 %) are relatively high as 131-142 ppm Rb for their SiO_2 contents. Two-mica granites hosting the ore deposits are low as 129-149 ppm Rb for their high SiO_2 contents around 77 %. The granites have low Rb/Sr ratios of 1.3 to 1.5, thus not well fractionated.

Ba contents of the eastern Shimane granitoids are consistently lower than the average of the Ryoke granitoids (Fig. 7C). The contents increase with increasing of SiO_2, but drop down below 400 ppm Ba in the leucogranites of the Shimokuno and Yamasa types. The ore-host leucogranites related to the Rengeji Granodiorite have also low values of 410 to 421 ppm Ba. Pb contents generally follow K_2O and Rb contents in silicate minerals, but extremely high in the Togiishiyama hornfels, varying from 34 to 158 ppm (Fig. 7D). The Kanenari hornfels is also high as 25-59 ppm Pb. The Pb occurs together with Zn and Cu, and these base metals are considered to be present mainly as sulfide in these rocks by microscopic studies and high contents of sulfur.

CaO contents of the eastern Shimane granitoids

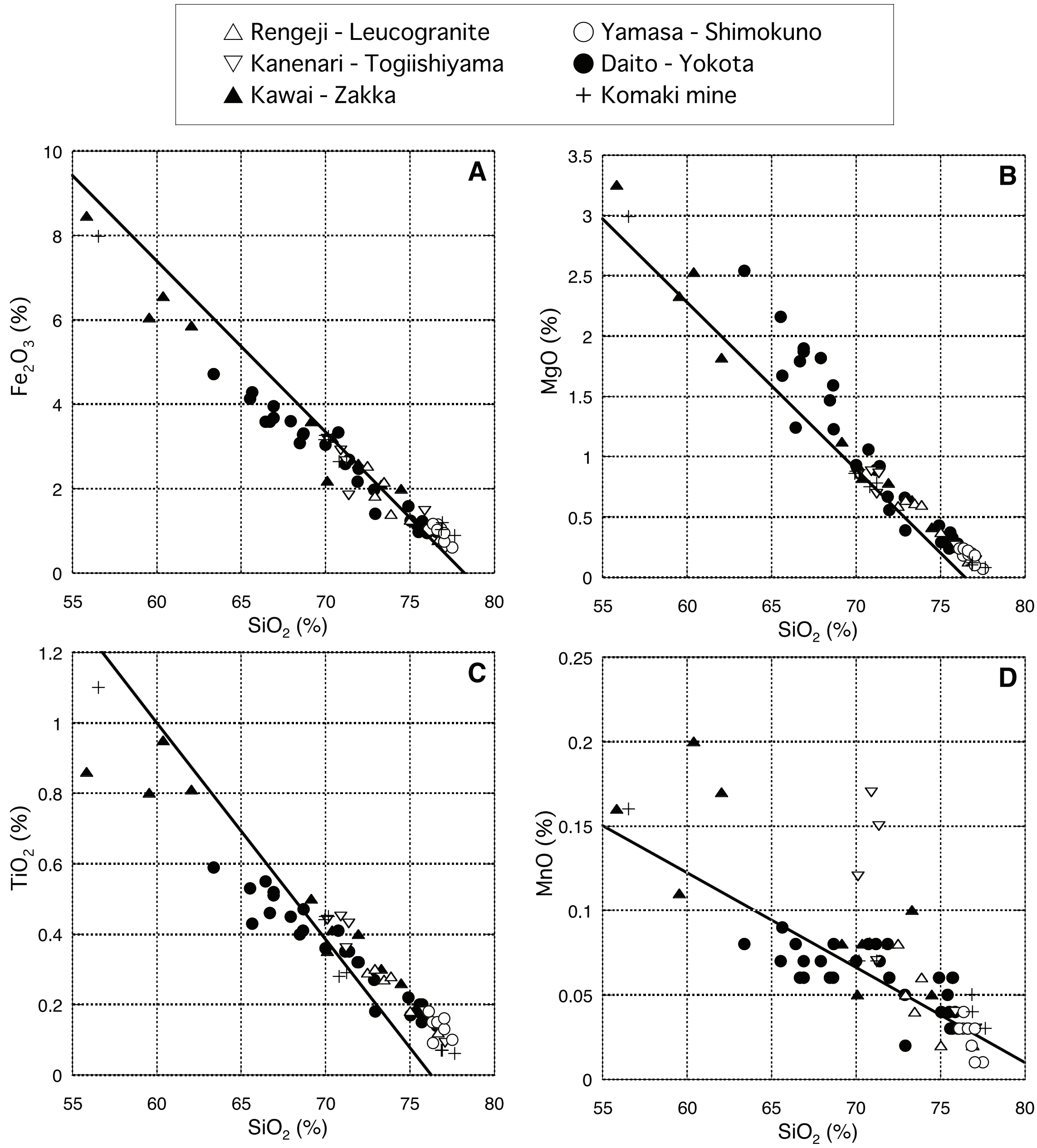

Fig. 9 Silica vs. Fe_2O_3, MgO, TiO_2 and MnO of the eastern Shimane granitoids.

are consistently lower than the average of the Ryoke granitoids and most depleted in the leucogranites (Fig. 8A). On the other hand, Na_2O contents are much higher than the Ryoke average, and decreases with increasing SiO_2 contents, especially on the leucogranites (Fig. 8B). Sr and P_2O_5 contents are correlated well with those of CaO. The two Rengeji Older Granites are very low in CaO (0.38 and 0.40 %, 67HY56 and 57, respectively) and slightly low in Na_2O (3.48 and 3.75 %, 67HY56 and 57, respectively), implying that the rock could be different unit to the Rengeji Granodiorite. Their Sr contents are very low as 24 and 28 ppm, yielding very high Rb/Sr ratios of 4.7 and 3.8 (67HY56 and 57, respectively). The P_2O_5 contents are low as 0.04 % and 0.01 % (67HY56 and 57, respectively), indicating poverty of apatite.

Among mafic components, Fe_2O_3 and TiO_2 contents of the eastern Shimane granitoids are lower than the averages of the Ryoke granitoids in the low SiO_2 range, but higher in the high SiO_2 range (Figs. 9A, C). MgO contents are, however, always higher than the Ryoke average (Fig. 9B). The two Rengeji Older Granites are quite high in Fe_2O_3 and TiO_2 contents and weakly high on MgO contents (see Appendix I). MnO contents are plotted around the Ryoke average, sporadic high values are observed in the Togiishiyama hornfels

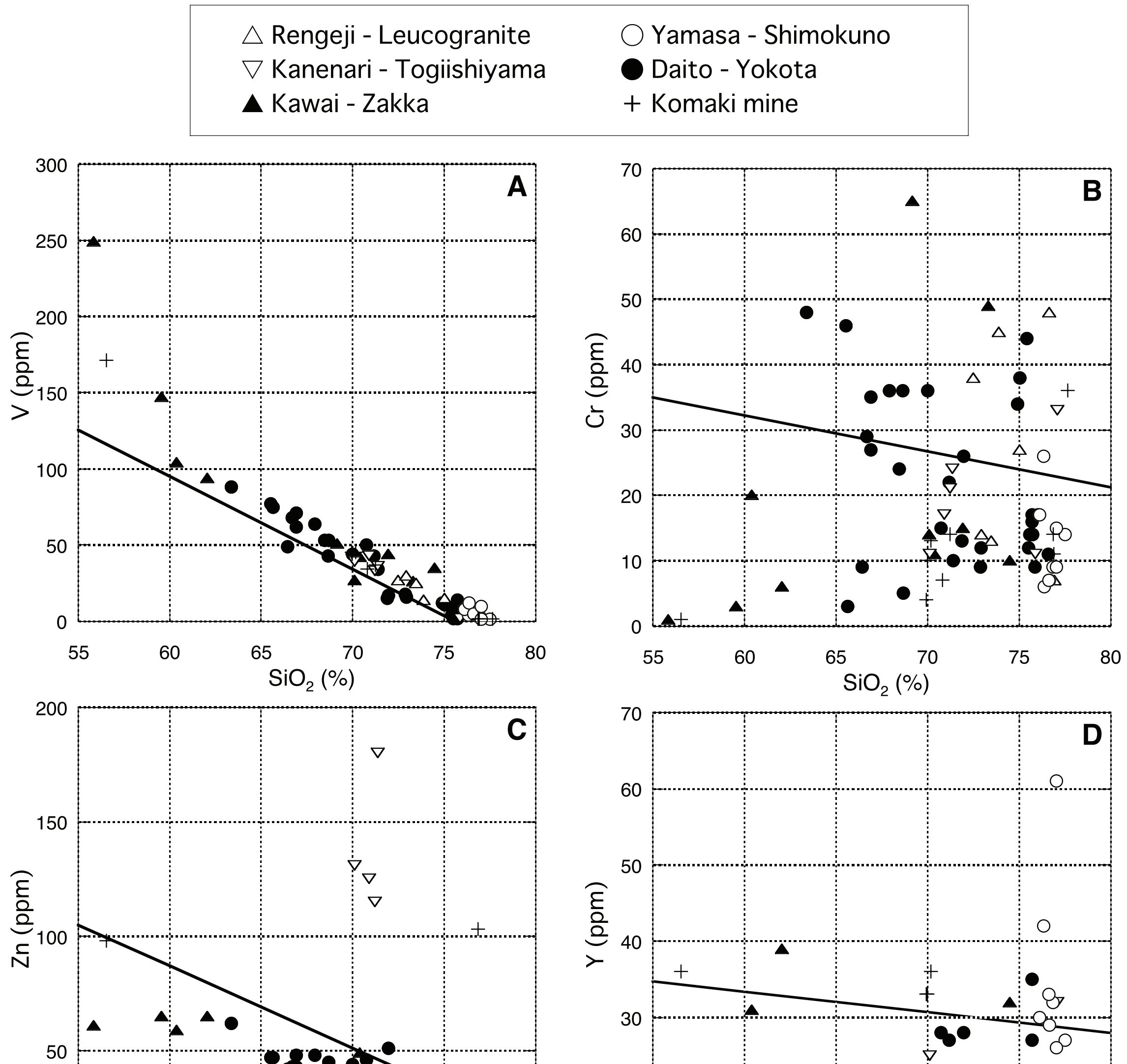

Fig. 10 Silica vs. V, Cr, Zn and Y of the eastern Shimane granitoids.

(641204, 641208) and the Kawai mingled rocks (e.g., 641213, 60F11) (Fig. 9D). The Rengeji Older Granites are also high in MnO.

V contents of the eastern Shimane granitoids are higher than the Ryoke average. The contents are inversely correlated with SiO_2 contents, and are very high in the most mafic phase (Fig. 10A). Vanadium may be V^{3+} (0.65A) in the magnetite-series granitic magma and substitute Fe^{3+} (0.67A) of the rock-forming magnetite mainly. A high value of 249 ppm V on the sample KAT from the Katsuragadani iron-sand deposits may be the best example.

On the other hand, the Cr contents are very erratic against SiO_2 contents and the Zakka-type mafic rocks are very depleted in the element (Fig. 10B). Zn contents of the eastern Shimane granitoids are inversely correlated with those of SiO_2, because it is substituted in mafic silicates, and are generally lower than the Ryoke average (Fig. 10C). The Togiishiyama hornfels contains very high values ranging from 115 to180 ppm Zn. These rocks are also high in S, Pb and Cu, implying original sedimentary accumulation of base metal sulfides in this rock. One high value of the Komaki two-mica granite (103 ppm Zn, 65KM153A) may be due to ore-related alteration, because it occurs right next to mineralized spot.

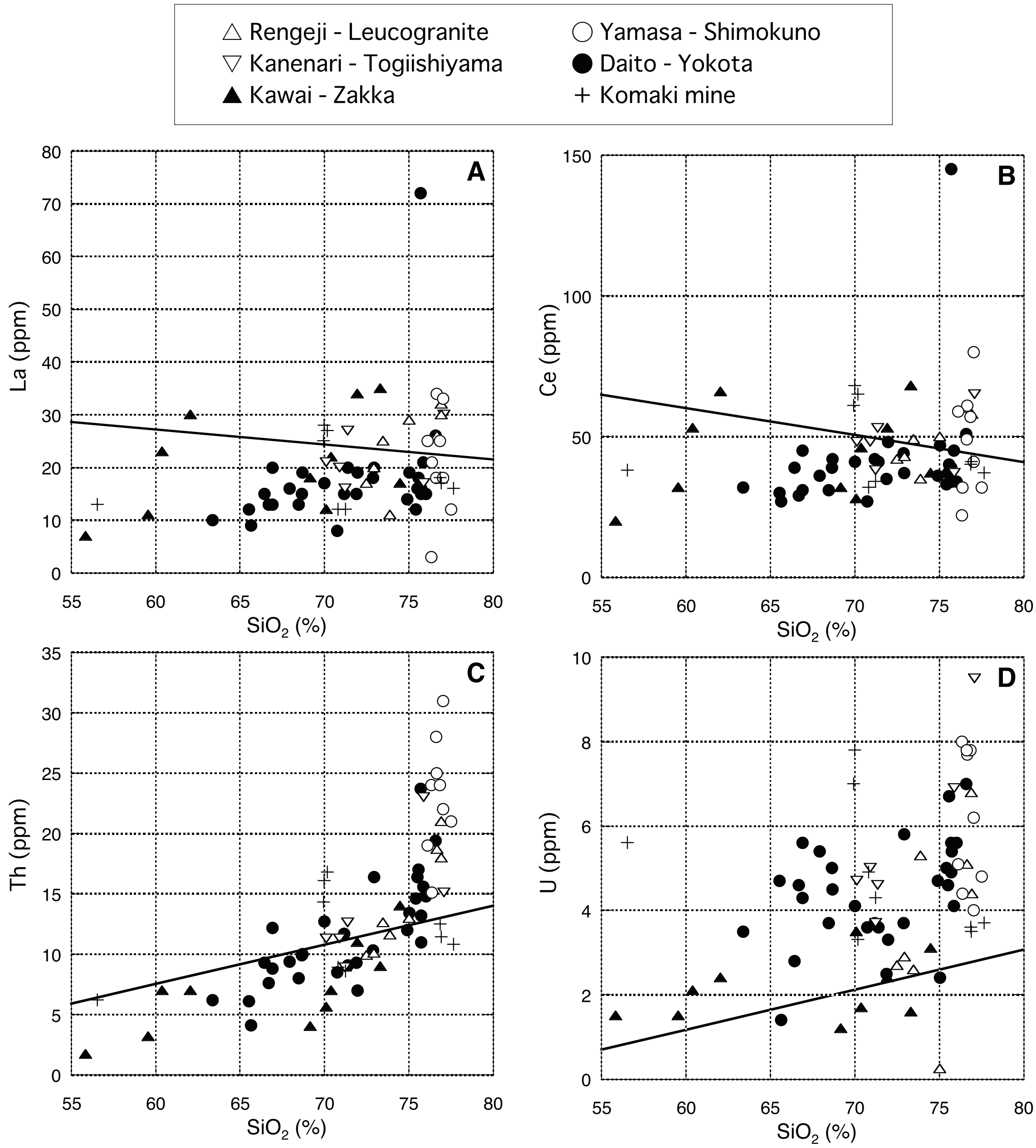

Fig. 11 Silica vs. La, Ce, Th, and U of the eastern Shimane granitoids.

Y contents of the eastern Shimane granitoids are much lower than those of the Ryoke granitoids (Fig. 10D). Two samples, 5907170 (62 ppm Y) and 590764 (42 ppm Y) from Shimokuno Aplite and Yamasa Leucogranite, respectively, show high values. The La and Ce contents are similarly lower than the Ryoke average in general, but these elements increase with increasing SiO_2 contents (Figs. 11 A, B). The highest values are observed in the Yokota Granite (72 ppm La, 145 ppm, Ce, 6511121, Fig. 11 A, B), which should be contained in accessory REE-bearing minerals. The Kawai-type mingled rocks are enriched weakly in these elements. High values are also observed on the Rengeji Older Granite (79 ppm La and 186 ppm Ce, 67HY56; 41 ppm La and 100 ppm Ce, 67HY57, see Appendix) . Minute anhedral to subhedral grains of monazite and allanite are commonly seen in these rocks, implying the light REE are contained in these minerals.

Th contents of the eastern Shimane granitoids are lower than the Ryoke average at quartz diorite-granodiorite compositions but increase sharply with increasing SiO_2 content (Fig. 11C). Th contents of the Rengeji Older Granite are high as 36 ppm (67HY56) and 22 ppm (67HY57), as compared with other granitoids. U contents show a different pattern. The Kawai-type granitoids have similar contents to the Ryoke granitoids, but

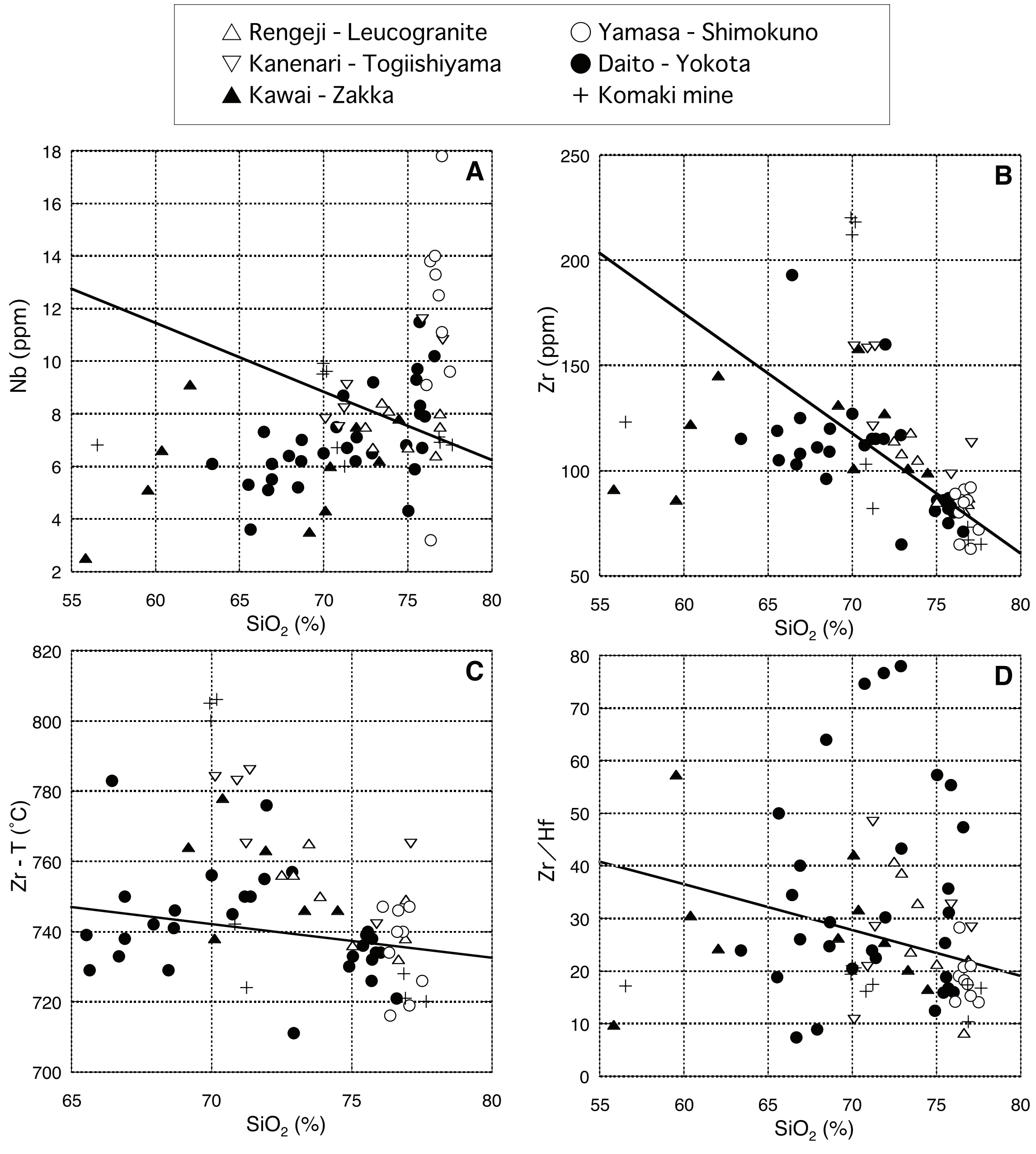

Fig. 12 Silica vs. Nb, Zr, Zr saturation temperature and Zr/Hf of the eastern Shimane granitoids.

all the other rock types are rich in U (Fig. 10D). This fact could be true throughout the whole Sanin District and may be related to the formation of the Ningyotoge uranium deposits in Tottori Prefecture, where leached-out uranium from the basement of similar biotite granites are considered to be concentrated in the overlying paleo-river sediments.

Nb contents of the eastern Shimane granitoids increase generally with increasing SiO_2 contents, on the contrary to the trend of the Ryoke granitoids (Fig. 12A). The contents of the Rengeji Older Granite is about double of that of similar SiO_2 rock of the Rengeji Granodiorite (see Appendix I). The Zr contents are scattered. The Kawai-type granitoids have constant value around 100 ppm, and Komaki mine granitoids were split into high values of 212-220 ppm Zr of hornblende and/or biotite granites (70 % SiO_2) and low values of 65-73 ppm Zr of two-mica granite (76-77% SiO_2). Reflecting this characteristics, zircon saturation temperatures vary widely throughout the studied rocks (Fig. 12C); the Komaki mine rocks are separated to high group of 805°C and low group of 725°C. The Zr/Hf ratios are distributed very widely within the Daito Granodiorite and Yokota Granite (Fig. 12D). There seems to be no systematic decreasing of the Zr/Hf ratio with increasing SiO_2 contents.

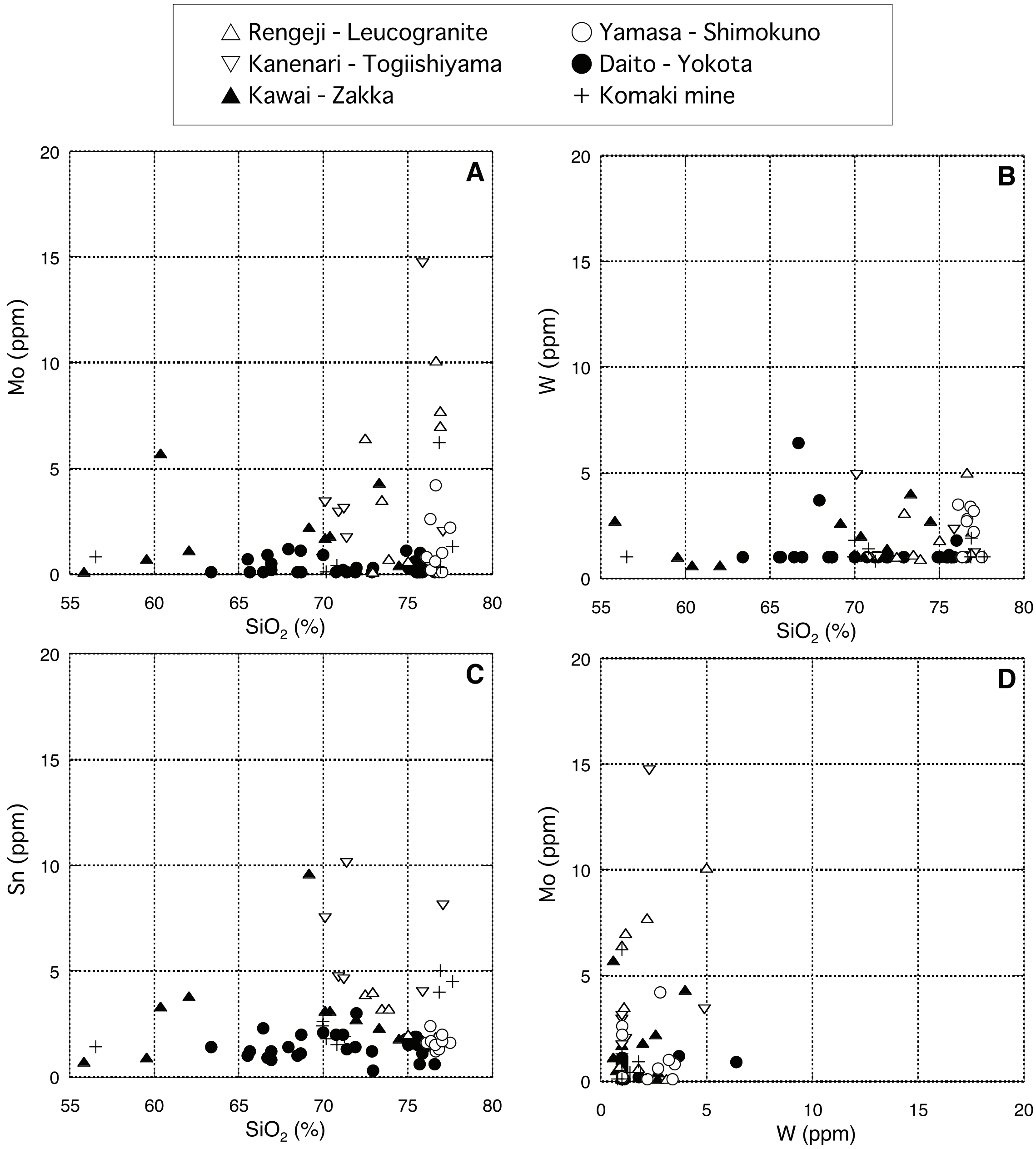

Fig. 13 Silica vs. Mo, W and Sn diagrams, and Mo vs. W diagrams of the eastern Shimane granitoids. A half value is used for the lowest values with symbol of inequality. One high value of 60F28 (31.8 ppm Mo) is excluded.

4. Selected ore components

Ore components of Mo, W and Sn vary depending upon the lithologic units. Batholithic granodiorite and granite contain low values; Mo less than 1.8 ppm and W less than 1.8 ppm. Sn contents are, however, lower than 3.0 ppm in the granodiorite and is low, as less than 1.9 ppm in the biotite granite (Fig. 13). The tin (Sn^{+4} 0.65A) is considered substituting mostly Ti^{+4}(0.60A) of titanite and Fe^{+3} (0.67A) of magnetite in an oxidized magma (Ishihara and Terashima, 1977), both of which are more abundant in the granodiorite than the biotite granite, giving rise to the higher tin values in the granodiorite.

In the fine-grained rocks, Mo contents are variable but higher than those of the batholithic granitoids, and the contents increase generally with increasing of SiO_2 (Fig. 13A). Two hornfelsic bodies have relatively high values as 2.0 to 14.7 ppm (average 8.4 ppm) for the Kanenari hornfels and 1.7 to 3.4 ppm (average 2.8 ppm, n=4) for the Togiishiyama hornfels. The other normal granitoids have the following ranges and averages:

Rengeji Granodiorite: <0.2 - 6.4 ppm (average 2.3 ppm, n=5)

Leucogranites complex: 7.0 - 10.1 ppm (average 8.3 ppm, n=3)

Kawai mingled rock: 0.4 - 31.8 ppm (average 6.1 ppm, n=8)

Yamasa Leucogranite: <0.2 - 4.2 ppm (average 2.0 ppm, n=5)

Shimokuno Aplite: <0.2 - 1.0 ppm (average 0.5 ppm, n=4)

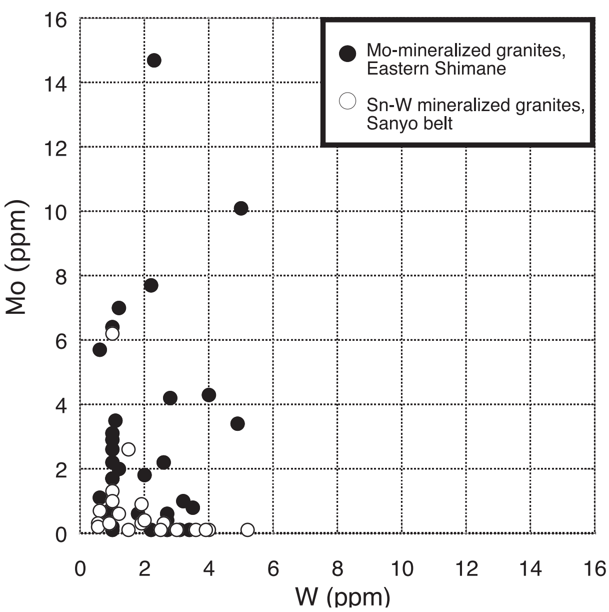

Fig. 14 Mo and W contents of the studied Mo-related granitoids and W-related granitoids of the Sanyo belt. One high value of 31.8 ppm Mo is excluded.
Sanyo belt data from Ishihara (2002) and Ishihara and Murakami (2006).

Komaki mine, two-mica granite 0.3 - 6.2 ppm (average 2.6 ppm, n=3)

Among these granitoids, most intense molybdenite mineralizations are seen in the Kawai mingled rocks (Daito main deposit) and ore-host leucogranites (Seikyu and Higashiyama main deposits). An intermediate size of the Yamasa deposits occur in the Yamasa Leucogranite, small size Mo-deposits are known in the biotite granite of the Rengeji Granodiorite (Kamitani deposit) and in the Shimokuno Aplite (Seikyu-Minamiko deposit). These granitoids are high in the trace amounts of molybdenum. The highest value of 31.8 ppm Mo (72.0 % SiO_2, 60F28) was obtained from fresh river-floor outcrop in front of the old-days Seikyu mine office. The high value is considered molybdenite flake contained, because molybdenite can occur from magmatic rock (see Ishihara 1971b, Plate XI-2) to low-temperature hydrothermal ore deposits (e.g., Seikyu-Minamiko ore deposits).

The molybdenum deposits of the Daito-Yamasa region do not contain even trace amounts of wolframite and scheelite. Among the major three orebodies of the Komaki ore deposits, however, the Ichimanko orebody contains minable amounts of wolframite and scheelite. Trace amounts of tungsten in the studied rocks are not particularly high in any of the granitic rocks (Fig. 13B). As a whole, no systematic variations are seen between the trace amounts of Mo and W (Fig. 13D). Sn-contents are high in the Togiishiyama hornfels. Among the granitoids, tin is weakly enriched in the Rengeji Granodiorite and two-mica granite of the Komaki mine (Fig. 13C).

In comparison with the W-related granitoids of the Sanyo belt (Fig. 14), the studied granitoids have higher Mo-contents and higher Mo/W ratio than the W-related granitoids of the Sanyo belt (Fig. 14). The most important host rocks of the Kawai mingled rocks have averages of 6.6 ppm (n=10) and Mo/W ratio of 3.6. The Rengeji Granodiorite and ore-host leucogranites have the averaged Mo-content of 4.5 ppm Mo and Mo/W ratio of 2.0. The granitoids of major W-mineralized areas of the Sanyo belt (Ishihara, 2002) have averaged Mo-contents of 0.5 ppm and W-contents of 2.1 ppm, with the averaged Mo/W ratio of 0.22. Therefore, Mo- and W-mineralized granitoids are clearly separated by the trace elements studies.

5. Genetic interpretation

5.1 Source of the plutonic rocks

As compared with chemical data of the Ryoke granitoids in the Chubu district (Ishihara and Chappell, 2007), the studied granitoids of the eastern Shimane region are poor in A/CNK, Ga, Ga x 10000/A, K_2O, Rb, Ba, Pb, CaO, Fe_2O_3, Zn, Y, La and Ce, but enriched in Na_2O, MgO, V and U. These chemical difference reflect essentially source rocks of the two terrains where the Ryoke granitoids were generated in sediments-bearing intermediate crust rocks (Ishihara and Matsuhisa, 2002), but the eastern Shimane granitoids had a primitive igneous component of intermediate composition in their source.

Considering exposure of gabbroids, amount of basaltic magmas from the upper mantle into the crust may have been less in the eastern Shimane region than in the Ryoke belt of the Chubu district. Amount of sediments-derived magmas is abundant as "garnet-bearing two-mica Busetsu granite" in the Chubu district. In the studied region, two-mica granite occurs in the Komaki mine area. It's A/CNK ratios are 1.05 to 1.06, not exceeding S-type limit of 1.1. Therefore, there is no true S-type granitoids in the studied region. The two-mica granite of the Komaki mine area hosts Komaki molybdenite-quartz pipe and vein deposits and occurs only in the ore deposit area. Therefore, the contained muscovite may be subsolidus in origin, not reflecting peraluminousness of the source rocks.

In the Hida metamorphic terrain, the major granitoids of Triassic age are adakitic in the inner zone (Tanaka, 1992). In the Chugoku Batholith, adakitic rocks with Sr/Y ratio of 36-75 have been known in small calcic granitoids of the Tanba region, west of Kyoto, which have a Cretaceous K-Ar age around 100 Ma (Kiji *et al*. 2000). The Zakka-type gabbroids have Sr contents of 373-565 ppm and Sr/Y ratio up to 29, i.e., weakly adakitic. Thus, some part of the gabbroid magmas may have been derived from the subducting slab (Defant and Drummond, 1993), and mixed with another source of granitic magmas within the continental crust.

The Zakka-type mafic rocks occur as mafic enclaves in the coarse-grained granitoids. But in fine-grained rocks, mafic phases are filled with leucogranites and are often mingled (Plate X-1, 2 of Ishihara, 1971b), giving rise to various intermediate rocks, which are typically seen in the Kawai mingled rocks. The Kawai-type rocks are also seen in the middle of the Yamasa Leucogranites and the Shimokuno Aplite. The studied granitoids show low Sr*I* ratios. Thus, both mafic and felsic plutonic rocks have had a primitive I-type source in the origin.

On the Fe_2O_3-MgO diagram, Miocene gabbroids of the studied region are plotted similarly to the Zakka trend (Fig.5). Gabbroic sills intruding into thick Miocene sediments in the Shimane Peninsula (Kano et al., 1986) show similar trend in the diagram. About potassium contents, if the Miocene gabbroids are plotted in the K_2O vs. SiO_2 diagram like one in Fig. 7A, these gabbroids are plotted in the low-K and medium-K series fields, because of the following average values:

Yoshida body: 0.46 % K_2O at 55.2 % SiO_2, i.e., low-K series,

Seikyuzan body: 0.74% K_2O at 55.6 % SiO_2, i.e., low-K series,

Shimane Peninsula sill: 0.96 % K_2O at 54.0 % SiO_2, i.e., medium-K series,

Thus, the Yoshida gabbroids of the studied region are most tholeiitic, and different from medium-K series of the Zakka-type quartz gabbroids and also different from Miocene sills in the Shimane Peninsula region. The Yoshida gabbroids have K-Ar age of 16.1 - 16.6±0.4 Ma on biotite (Matsuura *et al*., 2005). Thus, the Miocene magmatism in the land region was initiated with this low-K series tholeiitic activity.

Sr contents and Sr/Y ratios of the Yoshida body are generally low, as 265-336 ppm and 10-34, respectively. One high Sr/Y ratio (103) from the Seikyuzan quartz gabbro requires further analysis, because the Sr content of 378 ppm, is not too high. Gabbroic sills from the Shimane peninsula have low Sr/Y ratios ranging from 12 to 25. Therefore no clear evidence of adakitic activities is seen in the middle Miocene time. Adakites are very well known in the Quaternary Sanbesan and Daisen volcanoes (Morris, 1995).

5.2. Possible older rocks

The most unique rocks in the studied region are seen at the northwestern rim of the Rengeji Granodiorite. The Kanenari schistose hornfels is psammitic rocks metamorphosed and recrystallized. This rock contains peraluminous layers which could have been pelitic layers originally, and no magnetite is observed through the whole body. To the southwest, there occurs the Togiishiyama hornfels. This rock also contains but occasionally pelitic enclaves with aluminosilicate rims at one locality (Plate VIII-2, Ishihara, 1971b), but the majority is homogeneous magnetite-bearing and granodioritic, similarly but more mafic, to the Rengeji Granodiorite.

Both the Kanenari and Togiishiyama hornfelses are considered sedimentary in origin. Their schistosities can be interpreted as the original bedding of the sediments for the lack of stress effect under the microscope. In this point of view, this rock cannot be a regional metamorphic rock correlated to xenolithic block of the Hida metamorphic rocks. Another candidate may be small outcrop of Toriyago metamorphic rocks of unknown age described by Kano *et al*. (1994) occurring as "window" in Neogene rocks at Toriyago, some 14 km east-northeast in the Matsue Quadrangle. These are relatively unmetamorphosed volcanic and sedimentary rocks, looking younger than the Hida metamorphic rocks.

The Kanenari hornfels is essentially psammitic sediments, but the Togiishiyama hornfels may have been sodic tuffaceous sediments with little C-free pelitic components, because of high A/CNK but low K_2O content and presence of magnetite. This hornfels must have contained some amount of sedimentary base metal sulfides, as shown by 0.28-0.43 % S, 125-180 ppm Zn, 34-158 ppm Pb and 9-24 ppm Cu, which are considered not related to later mineralizations but original sulfides contained, for the lack of hydrothermal alteration in this rock.

Remnant of the Togiishiyama blocks are seen in the southwestern part of the Rengeji body and fine aggregates of biotite are observed everywhere. For the aggregates of rock-forming biotite, the Rengeji Granodiorite is considered as a mingled and mixed rock between leucogranitic magmas from the southeast and the Togiishiyma (and Kanenari) hornfels from the northwest. A/CNK ratio of the Togiishiyama hornfels varies from 1.04 to 1.08, while that of the Rengeji Granodiorite is very similar, as 1.02 to 1.08. The Togiishiyama hornfels has low contents of K_2O as 1.46-3.14 % for the high SiO_2 contents (70.1-71.4 % SiO_2), while the Rengeji Granodiorite has 3.27-3.54 % K_2O (72.5-75.1 % SiO_2). The ore-host leucogranites contain 5.1-5.5 % K_2O at 76.7-76.9 % SiO_2. Thus, K_2O would have supplied from the leucogranite magmas.

The Rengeji Older Granite discovered in the underground tunnel of the Yoshitokodani, Higashiyama mine, may be xenolithic block of an older granite generated and solidified in continental region, then trapped into the Rengeji Granodiorite, and cracked and recrystallized. The granite is potassic and different from most of sodic granitoids of the Hida terrain. Further field work and SHRIMP zircon dating are necessary on this rock.

6. Conclusions

Magnetite-series granitoids of eastern Shimane Prefecture were studied chemically and compared with the ilmenite-series granitoids of the Ryoke belt. The eastern Shimane granitoids are generally low in A/CNK and poor in lithophile components, such as K_2O, Rb, Y, La and Ce. Therefore, these granitoids must have been generated not in matured continental crust but in a primitive igneous material within the continental crust having some mafic magmas from the upper mantle.

Molybdenite-quartz vein deposits of the studied region, which are the largest in the Japanese Islands, are formed by various fractionated leucogranites around top and margin of batholithic granitoids. Mineralized fine-grained granites could be identified by trace amounts of molybdenum in the fresh leucogranites.

The largest concentration of molybdenum is seen associated with leucocratic granites around margin of the Rengeji Granodiorite, which has been interacted with some sedimentary rocks of older ages containing ore elements, and also contains Rengeji Older Granite. Therefore, it is most important to identify age and chemical characteristics of these hypothetical old basement.

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西南日本，山陰地方，島根県東部地域における古第三紀花崗岩類の化学組成

石原舜三・ブルース W. チャペル

要　旨

島根県東部の大東－横田－小馬木地域の磁鉄鉱系花崗岩類の主成分と微量成分存在量を明らかにし，中部地方領家帯のチタン鉄鉱系花崗岩類と比較しモリブデン鉱化作用との関連性を追及した．標記の花崗岩類はバソリス状に分布する粗粒の花崗閃緑岩と花崗岩，ルーフ岩石付近の細粒花崗岩類に二大別される．後者は更に，雑家型・川井型・蓮花寺型・鉱化優白花崗岩類・山佐型・下久野型・大内谷花崗斑岩に分けられる．これら花崗岩類は中部地方の領家花崗岩類と比較して，以下の多くの成分：A/CNK, Ga, Ga x 10000/A, K_2O, Rb, Ba, Pb, CaO, Fe_2O_3, Zn, Y, La, Ce に乏しく，Na_2O, MgO, V, U などに富んでいる．以上の性質は島根県東部の花崗岩類が Al_2O_3, K_2O, REE，炭質物などに乏しい深所の火成岩起源物質に由来することを示している．斑れい岩類の一部にはアダカイト質の性質が認められ，スラブ溶融の可能性が推察される．

蓮花寺型の北西縁には小規模に変成岩が産出し，金成ホルンフェルスは一部に頁岩を挟む砂岩質の変成岩類と考えられる．磨石山ホルンフェルスは A/CNK は高いが，K_2O は一般的な値を示し，S, Cu, Pb, Zn, MnO などの堆積性鉱化成分に富み，かつ磁鉄鉱を含む．したがって，有機炭素に乏しい頁岩を挟む中性～酸性の凝灰質堆積岩がその原岩と考えられる．蓮花寺古期花崗岩類は $K_2O > Na_2O$ であり，La, Ce, Y, Nb, Th, U に富み，親石元素が多い起源物質に由来する性格を持っている．主要なモリブデン鉱床を胚胎する川井混交岩（大東）・蓮花寺－優白花崗岩類（清久－東山）・山佐優白花崗岩（山佐）などは，平均2.0 ～ 6.3ppm Mo を示し，他の花崗岩類や山陽タングステン鉱床区の花崗岩類よりも高い．したがって新鮮な花崗岩の微量成分としての Mo は探査指標として利用可能である．

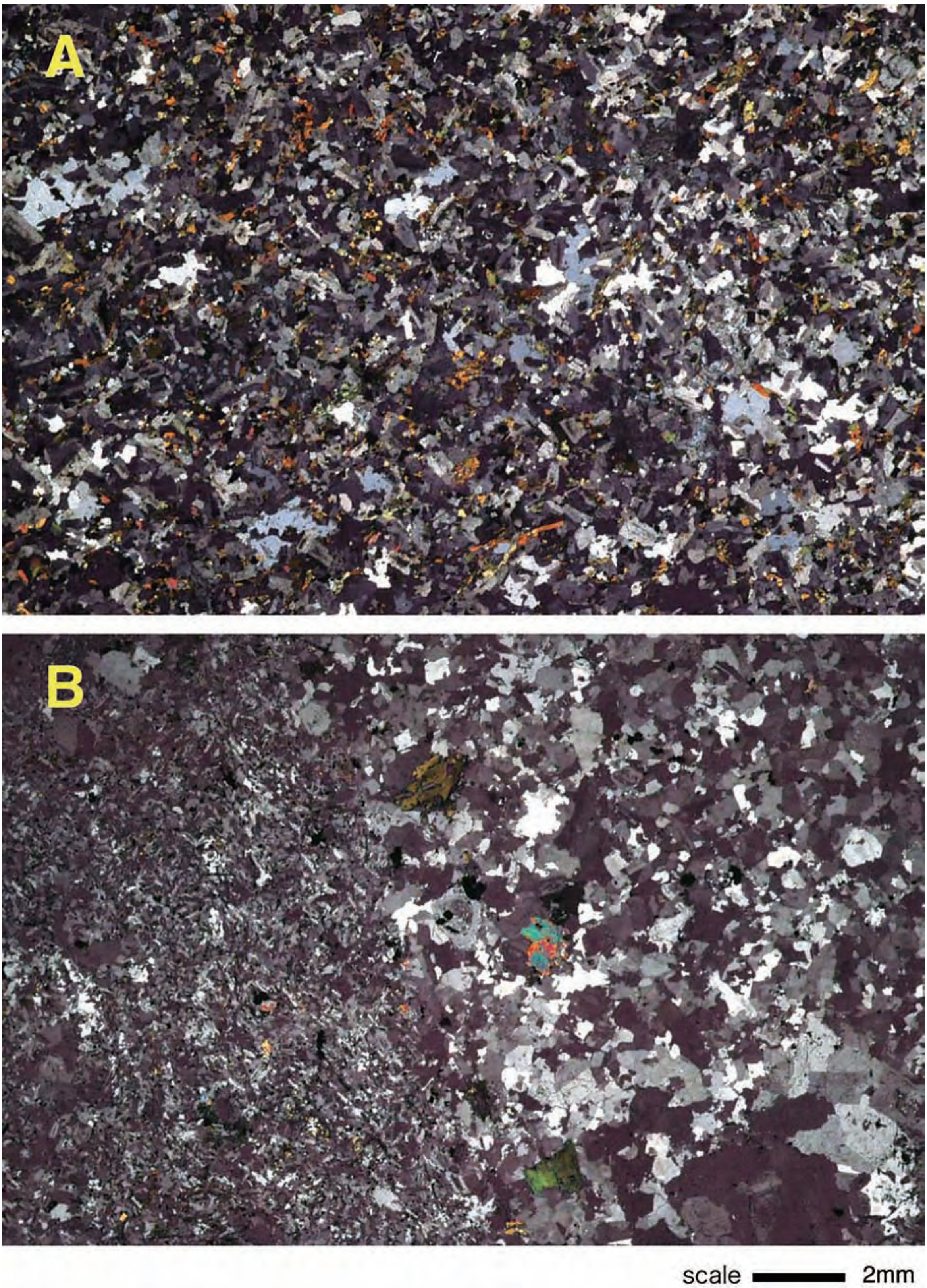

Plate 1A Kawai mingled rock. A mafic phase from the Orisakadani inclined shaft of the Daito mine (641213). Magnetite-titanite-biotite-hornblende quartz diorite. Quartz is abundant, and quartz and K-feldspar filling euhedral-subhedral plagioclase lath. Crossed nicols.

Plate 1B Direct contact between mafic volcanic enclave with an intersertal texture (left half) and Yamasa Leucogranite (right half). The sample 5907133 from mafic enclave-rich portion of the Leucogranite at Okudani, Kamiyamasa. Crossed nicols.

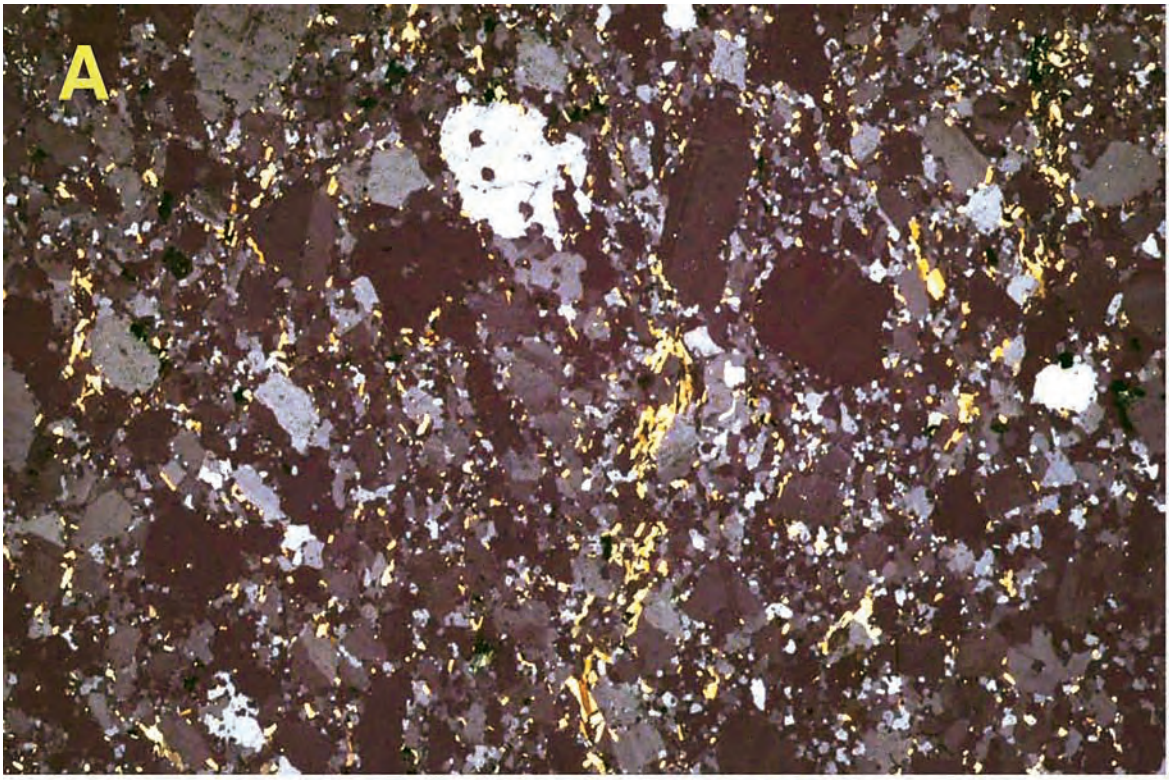

Plate 2A Togiishiyama hornfels at south of Togiishiyama (60F40). A recrystallized rock with some phenocrysts of plagioclase and quartz. Yellow is linear arrangement (top to bottom) of biotite, which could be bedding of the original rocks. Crossed nicols.

Plate 2B Foliated Rengeji Granodiorite from the Yoshitokodani tunnel (67HY51). Here, the linear arrangement (left to right) is shown by fresh biotite filling cracks developed throughout the host granite, which could be an older sheared granite trapped in the Rengeji Granodiorite.

Appendix I Analytical results of the Paleogene granitoids of the eastern Shimane region.

Type	Zakka Quartz Gabbroids					Daito Granodiorite							
Sample no.	6511120	6511118	6511123	KAT	6511122	641217	641215	6511125	6511135	641209	641216	5908302	6511133
SiO_2 (%)	51.28	52.33	53.81	55.86	59.57	63.38	65.53	65.65	66.44	66.91	66.91	66.69	67.93
TiO_2	1.02	0.95	0.86	0.86	0.80	0.59	0.53	0.43	0.55	0.52	0.51	0.46	0.45
Al_2O_3	19	17.43	16.99	17.60	17.36	16.50	15.91	15.84	16.16	15.24	15.68	15.99	15.23
Fe_2O_3	9.16	9.10	8.64	8.46	6.05	4.71	4.13	4.28	3.58	3.95	3.67	3.58	3.60
MnO	0.15	0.16	0.14	0.16	0.11	0.08	0.07	0.09	0.08	0.07	0.06	0.06	0.07
MgO	4.28	4.78	5.27	3.25	2.33	2.54	2.16	1.67	1.24	1.90	1.87	1.79	1.82
CaO	8.46	9.12	8.58	7.44	6.26	4.77	4.25	4.30	3.41	3.49	3.50	3.93	3.57
Na_2O	3.55	3.16	3.00	3.43	4.26	4.28	4.15	4.39	4.86	4.04	4.00	4.04	3.86
K_2O	1.42	1.04	1.28	0.94	1.62	2.11	2.32	1.96	2.56	2.70	2.99	2.63	2.73
P_2O_5	0.24	0.18	0.19	0.14	0.25	0.16	0.12	0.13	0.17	0.13	0.11	0.12	0.11
S	0.08	0.02	0.08	<0.01	0.09	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01
H_2O+	1.02	1.84	1.52	1.77	1.24	0.70	0.62	0.75	0.45	0.87	0.49	0.66	0.71
H_2O-	0.76	0.16	0.14	0.32	0.12	0.20	0.08	0.17	0.17	0.26	0.11	0.08	0.03
CO_2	0.2	0.10	0.11	0.08	0.17	0.11	0.07	0.13	0.10	0.09	0.06	0.09	0.08
Sum	100.66	100.37	100.61	100.31	100.23	100.13	99.94	99.88	99.77	100.17	99.96	100.12	100.19
Rb ppm	51	39	43	26	58	55	58	42	80	67	71	63	68
Cs	3.2	2.9	3.7	<2	4.0	1.9	2.4	1.9	5.0	3.0	1.9	3.1	2.7
Sr	565	508	454	373	518	427	409	347	424	355	351	404	357
Ba	290	165	200	250	375	400	380	410	570	460	620	480	450
Ga	19.5	16.4	15.0	14.4	16.8	15.8	14.8	12.6	14.8	13.5	13.8	13.7	12.8
Ge	1.7	1.5	0.9	1.6	1.2	1.3	0.8	1.0	0.9	0.9	0.6	0.8	1.3
Zr	79	57	89	91	86	115	119	105	193	125	108	103	111
Hf	3	<4	<4	9.4	<3	4.8	6.3	2.1	5.6	4.8	2.7	13.9	12.4
Nb	5.1	3.2	4.1	2.5	5.1	6.1	5.3	3.6	7.3	6.1	5.5	5.1	6.4
Ta	< 3.2	<5	<3	6.8	<3	<3	<3	<2	<2	<3	<3	7.3	7.3
La	12	5	8	7	11	10	12	9	15	13	20	13	16
Ce	34	24	25	20	32	32	30	27	39	31	45	29	36
Y	20	20	20	22	18	20	17	16	20	19	14	16	19
V	224.0	266	236	249	147	88	77	75	49	71	62	68	64
Cr	14.0	33	46	<2	3	48	46	3	9	35	27	29	36
Co	21	25	24	39	8	12	12	<7	<7	12	<7	19	20
Ni	5.0	13.8	8.3	4.2	8.0	24.0	16.8	2.8	2.7	15.1	15.0	20.0	18.5
Cu	25.0	44.0	17.2	47.0	9.7	9.1	8.1	4.6	6.9	6.8	7.6	7.4	9.8
Zn	81	82	78	61	65	62	47	47	42	43	48	43	48
Pb	6.3	5.0	6.7	9.5	6.7	11.1	10.0	5.3	14.4	9.6	12.8	15.5	15.5
As	1.9	2.9	1.6	< 0.4	1.4	1.5	0.9	1.8	1.5	0.4	0.7	< 0.4	< 0.4
Se	< 0.1	< 0.2	< 0.2	0.6	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	1.3	0.8
Mo	0.5	< 0.2	< 0.2	< 0.2	0.7	< 0.2	0.7	< 0.2	< 0.2	0.2	0.5	0.9	1.2
W	< 1.5	<2	<2	2.7	<2	<2	<2	<2	<2	<2	<2	6.4	3.7
Sn	0.9	0.7	1.0	0.7	0.9	1.4	1.0	1.2	2.3	0.8	1.2	0.9	1.4
Bi	< 0.4	< 0.6	< 0.6	1.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	2.4	1.0
Cd	0.3	0.3	0.4	0.8	0.7	0.4	0.4	0.2	0.2	0.2	0.5	0.5	0.6
Th	2.5	2.4	3.2	1.7	3.2	6.2	6.1	4.1	9.3	8.8	12.2	7.6	9.4
U	1.9	1.5	1.6	1.5	1.5	3.5	4.7	1.4	2.8	5.6	4.3	4.6	5.4
A/CNK	0.93	0.76	0.78	0.87	0.86	0.92	0.93	0.92	0.95	0.96	0.97	0.96	0.96
Ga*10000/A	1.94	1.78	1.67	1.55	1.83	1.81	1.76	1.50	1.73	1.67	1.66	1.62	1.59
NK/A	0.39	0.36	0.37	0.38	0.50	0.57	0.59	0.59	0.67	0.63	0.63	0.59	0.61
Rb/Sr	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Sr/Y	28.3	25.4	22.7	17.0	28.8	21.4	24.1	21.7	21.2	18.7	25.1	25.3	18.8
ZrT(˚C)	669	638	675	696	695	731	739	729	783	750	738	733	742

Appendix I Continued.

Type	Daito Granodiorite								Yokota Granite				
Sample no.	5908349	6511138	6511116	6511111	6511110	6511115	6511117	6511108	6511136	6511137	6511119	6511114	6511132
SiO_2 (%)	68.47	68.66	68.69	70.00	70.75	71.18	71.39	71.96	71.89	72.88	72.93	74.91	75.04
TiO_2	0.40	0.41	0.47	0.36	0.41	0.35	0.35	0.32	0.32	0.27	0.18	0.22	0.17
Al_2O_3	15.20	15.15	15.05	14.76	13.92	14.42	14.56	14.31	14.39	13.98	14.64	13.16	13.26
Fe_2O_3	3.08	3.28	3.30	3.04	3.33	2.59	2.68	2.47	2.17	1.97	1.40	1.58	1.24
MnO	0.06	0.06	0.08	0.07	0.08	0.08	0.07	0.06	0.08	0.05	0.02	0.06	0.04
MgO	1.47	1.59	1.23	0.93	1.06	0.89	0.92	0.56	0.67	0.66	0.39	0.43	0.29
CaO	3.37	3.27	3.18	2.95	2.97	2.45	2.80	2.24	1.89	1.85	1.88	1.57	1.32
Na_2O	4.23	4.05	4.17	4.29	3.74	4.26	4.34	4.49	4.45	4.16	4.00	4.11	4.17
K_2O	2.63	2.82	3.05	2.54	2.88	3.06	2.44	3.10	3.16	3.38	3.99	3.11	3.80
P_2O_5	0.10	0.12	0.16	0.09	0.09	0.11	0.11	0.07	0.09	0.07	0.03	0.05	0.04
S	<0.01	<0.01	<0.01	0.13	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
H_2O+	0.80	0.47	0.41	0.52	0.37	0.28	0.38	0.24	0.51	0.42	0.33	0.31	0.22
H_2O-	0.05	0.02	0.03	0.09	0.13	0.08	0.03	0.06	0.19	0.06	0.06	0.15	0.06
CO_2	0.08	0.20	0.18	0.28	0.22	0.17	0.10	0.19	0.09	0.16	0.06	0.22	0.14
Sum	99.94	100.10	100.00	100.05	99.96	99.92	100.17	100.07	99.90	99.91	99.91	99.88	99.79
Rb ppm	68	73	95	82	94	101	88	86	78	93	79	103	91
Cs	3.0	2.0	4.6	3.7	5.4	3.8	4.0	3.3	2.9	<2	4.8	4.6	6.8
Sr	339	333	330	243	209	279	302	188	255	217	200	177	163
Ba	455	455	475	430	520	610	410	880	550	530	330	500	910
Ga	13.1	13.8	14.2	13.9	13.3	13.5	14.2	13.7	12.2	11.9	13.3	12.1	10.1
Ge	1.1	0.8	1.3	1.1	1.3	1.1	1.2	1.0	0.7	0.6	1.0	1.2	0.9
Zr	96	109	120	127	112	115	115	160	115	117	65	81	86
Hf	<3	4.4	4.1	6.2	<3	4.8	5.1	5.3	<3	<3	<3	6.5	<3
Nb	5.2	6.2	7.0	6.5	7.5	8.7	6.7	7.1	6.2	6.5	9.2	6.8	4.3
Ta	<3	<2	<3	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
La	13	15	19	17	8	15	20	19	15	18	20	14	19
Ce	31	39	42	41	27	42	41	48	35	44	37	36	47
Y	15	18	21	23	28	27	18	28	15	16	22	19	12
V	53	43	53	44	50	43	34	17	15	18	16	12	11
Cr	24	36	5	36	15	22	10	26	13	9	12	34	38
Co	<7	13	7	8	8	<6	<6	<6	<5	<5	<4	<4	<4
Ni	10.2	11.7	3.8	5.3	2.9	4.4	2.2	3.7	<1	3.9	1.7	4.9	3.7
Cu	6.2	6.2	7.6	5.5	6.2	5.4	5.6	5.6	4.6	6.1	5.9	6.4	5.1
Zn	38	42	45	44	46	37	34	51	30	29	16	27	18
Pb	10.5	11.9	11.6	10.7	12.8	12.2	9.9	14.6	17.5	14.1	15.1	15.6	15.6
As	1.4	< 0.4	1.6	1.8	1.5	1.2	1.4	2.0	0.8	1.9	0.6	0.4	1.8
Se	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Mo	< 0.2	1.1	< 0.2	0.9	< 0.2	0.2	< 0.2	0.3	< 0.2	< 0.2	0.3	1.1	0.3
W	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sn	1.0	1.1	2.0	2.1	2.0	2.0	1.3	3.0	1.4	1.2	0.3	1.8	1.5
Bi	< 0.5	< 0.5	< 0.5	< 0.4	< 0.5	< 0.5	< 0.5	< 0.5	< 0.4	< 0.4	< 0.4	< 0.5	< 0.4
Cd	0.6	0.3	0.4	0.3	0.3	0.4	0.3	0.5	< 0.2	< 0.2	< 0.2	0.4	0.3
Th	8.0	9.9	10.0	12.7	8.5	11.7	9.1	7.0	9.3	10.3	16.4	12.0	13.4
U	3.7	5.0	4.5	4.1	3.6	3.7	3.6	3.3	2.5	3.7	5.8	4.7	2.4
A/CNK	0.95	0.97	0.94	0.97	0.95	0.98	0.98	0.97	1.02	1.01	1.02	1.01	0.99
Ga*10000/A	1.63	1.72	1.78	1.78	1.81	1.77	1.84	1.81	1.60	1.61	1.72	1.74	1.44
NK/A	0.65	0.64	0.68	0.66	0.67	0.72	0.67	0.75	0.75	0.75	0.74	0.77	0.83
Rb/Sr	0.2	0.2	0.3	0.3	0.4	0.4	0.3	0.5	0.3	0.4	0.4	0.6	0.6
Sr/Y	22.6	18.5	15.7	10.6	7.5	10.3	16.8	6.7	17.0	13.6	9.1	9.3	13.6
ZrT(˚C)	729	741	746	756	745	750	750	776	755	757	711	730	733

Appendix I Continued.

Type	Yokota Granite									Kawai mingled granitoids			
Sample no.	590755	5907147	590732	6511121	6511112	590761	6511129	590731	6511134	641213	641212	60F11	60DT545
SiO_2 (%)	75.41	75.52	75.58	75.70	75.72	75.73	75.86	76.03	76.60	60.4	70.11	62.07	69.18
TiO_2	0.18	0.18	0.20	0.15	0.20	0.18	0.17	0.17	0.14	0.95	0.35	0.81	0.5
Al_2O_3	13.38	13.45	13.23	12.96	13.17	13.32	13.18	13.00	12.41	16.89	15.38	16.71	14.64
Fe_2O_3	1.14	0.97	1.09	1.03	1.23	1.17	1.13	0.95	0.98	6.55	2.18	5.86	3.59
MnO	0.05	0.04	0.03	0.03	0.06	0.06	0.04	0.03	0.03	0.2	0.05	0.17	0.08
MgO	0.33	0.24	0.37	0.25	0.33	0.28	0.25	0.28	0.21	2.53	0.93	1.82	1.12
CaO	1.13	0.77	0.89	0.87	1.11	1.05	1.02	0.72	0.79	5.43	2.98	5	3.02
Na_2O	4.03	4.20	3.97	3.31	4.20	4.20	4.01	3.94	3.41	4.75	4.43	4.33	3.8
K_2O	4.07	4.14	3.90	5.17	3.76	3.73	4.01	4.26	4.93	1.75	2.69	2.25	2.4
P_2O_5	0.03	0.03	0.04	0.02	0.03	0.04	0.03	0.02	0.01	0.3	0.09	0.24	0.14
S	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.05	0.01	0.02
H_2O+	0.17	0.28	0.41	0.33	0.04	0.10	0.25	0.36	0.32	0.19	0.36	0.73	1.39
H_2O-	0.02	0.05	0.06	0.17	0.05	0.09	0.06	0.08	0.12	0.2	0.09	0.18	0.12
CO_2	0.13	0.18	0.07	0.09	0.18	0.10	0.07	0.23	0.07	0.2	0.21	0.1	0.1
Sum	100.07	100.05	99.84	100.08	100.08	100.05	100.08	100.07	100.02	100.32	99.90	100.25	100.06
Rb ppm	142	147	137	144	116	136	117	141	164	71	101	55	105
Cs	3.5	5.4	6.0	3.8	4.1	5.0	5.8	4.6	4.0	3.1	5.6	1.8	5.5
Sr	135	84	110	90	100	124	127	93	69	387	308	361	291
Ba	520	540	485	310	540	455	640	590	200	358	500	451	606
Ga	11.7	12.3	12.0	12.2	12.2	11.7	10.6	12.2	10.2	18.6	14.0	18.5	14.7
Ge	1.0	1.2	1.2	1.6	1.3	1.3	1.0	1.2	1.2	2.1	1.2	2.0	1.7
Zr	86	86	85	75	82	87	83	80	71	122	101	145	131
Hf	5.4	3.4	4.5	2.1	4.9	2.8	<3	5.0	<3	4	2.4	6	5
Nb	5.9	9.3	9.7	11.5	8.0	8.3	6.7	7.9	10.2	6.6	4.3	9.1	3.5
Ta	<2	<2	<2	<2	<2	<2	<2	<2	<2	2	<2	3	2
La	12	16	18	72	16	15	21	15	26	23	12	30	18
Ce	33	37	40	145	39	34	45	34	51	53	28	66	32
Y	22	20	20	35	27	19	19	18	22	31	14	39	12
V	4	<4	6	11	14	<4	9	6	5	104.0	27	94.0	51.0
Cr	44	12	14	17	16	14	9	17	11	20.0	14	6.0	65.0
Co	<4	<4	<4	<4	<4	<4	<4	<4	<4	13	<5	15	10
Ni	3.5	1.3	1.8	1.7	1.2	2.5	2.0	3.7	1.8	2.0	5.7	< 0.9	1.0
Cu	5.9	4.9	4.0	5.6	4.7	4.5	5.0	4.9	5.5	1.0	9.2	< 0.5	< 0.4
Zn	20	12	19	14	26	15	15	14	13	59	26	65	30
Pb	18.9	18.6	16.0	16.7	15.1	16.2	15.9	16.5	16.1	7.3	8.8	9.3	14.4
As	0.4	1.4	1.1	1.0	1.2	1.4	0.7	1.3	1.3	< 0.3	1.8	0.5	< 0.4
Se	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	< 0.2	0.2	0.2
Mo	0.6	< 0.2	< 0.2	< 0.2	1.0	0.6	< 0.2	0.2	< 0.2	5.7	1.7	1.1	2.2
W	<2	<2	1.1	<2	<2	<2	<2	1.8	<2	< 1.2	<2	< 1.2	2.6
Sn	1.9	1.9	1.5	0.6	1.7	1.6	1.1	1.4	0.6	3.3	3.1	3.8	9.6
Bi	< 0.5	< 0.4	< 0.4	< 0.5	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.3	< 0.4	< 0.3	0.7
Cd	0.8	0.3	0.4	< 0.2	0.3	0.3	< 0.2	0.3	0.2	0.4	0.4	0.3	0.2
Th	14.6	16.4	17.0	23.7	11.0	13.2	15.6	14.8	19.4	7.2	5.6	6.8	3.5
U	5.0	4.6	6.7	5.6	4.9	5.4	4.1	5.6	7.0	2.1	3.5	2.4	1.2
A/CNK	1.02	1.05	1.07	1.03	1.01	1.04	1.03	1.05	1.00	0.86	0.98	0.9	1.02
Ga*10000/A	1.65	1.73	1.71	1.78	1.75	1.66	1.52	1.77	1.55	2.08	1.72	2.09	1.90
NK/A	0.82	0.85	0.81	0.85	0.83	0.82	0.83	0.85	0.88	0.57	0.66	0.57	0.60
Rb/Sr	1.1	1.8	1.2	1.6	1.2	1.1	0.9	1.5	2.4	0.2	0.3	0.2	0.4
Sr/Y	6.1	4.2	5.5	2.6	3.7	6.5	6.7	5.2	3.1	12.5	22.0	9.3	24.3
ZrT(˚C)	736	739	740	726	732	738	734	734	721	723	738	745	764

Appendix I Continued.

Type	Kawai mingled granitoids				Kanenari Hfs		Togiishiyama Hfs				Rengeji Older Gran	
Sample no.	60Fb61	60F28	60F27	60Fb67	650613	650617	641203	641204	641205(1)	641208	68HY58	67HY56
SiO_2 (%)	70.4	71.95	74.5	73.33	75.89	77.11	70.13	70.91	71.24	71.38	63.49	71.20
TiO_2	0.41	0.4	0.26	0.3	0.18	0.09	0.44	0.45	0.36	0.43	0.64	0.68
Al_2O_3	14.65	13.9	12.66	13.55	12.49	12.38	15.03	15.05	14.76	15.29	16.64	12.03
Fe_2O_3	3.19	2.58	1.99	2.09	1.47	0.57	3.18	2.90	2.65	1.84	4.37	5.15
MnO	0.08	0.08	0.05	0.1	0.04	0.03	0.12	0.17	0.07	0.15	0.13	0.17
MgO	0.82	0.78	0.41	0.64	0.26	0.14	0.85	0.88	0.69	0.86	1.24	1.25
CaO	2.64	2.05	1.42	2.03	0.77	0.25	2.49	2.70	1.91	2.50	4.37	0.38
Na_2O	3.87	3.87	3.2	3.96	4.37	2.79	4.43	4.82	4.12	4.75	4.26	3.48
K_2O	3.23	3.46	4.4	3.02	3.98	6.05	2.33	1.46	3.14	1.83	2.47	4.78
P_2O_5	0.11	0.1	0.03	0.06	0.03	<0.01	0.10	0.11	0.11	0.09	0.26	0.04
S	0.01	0.02	0.04	0.01	0.03	0.09	0.37	0.28	0.43	0.34	0.06	0.02
H_2O+	0.4	0.54	0.59	0.45	0.08	0.29	0.51	0.38	0.42	0.38	0.70	0.21
H_2O-	0.1	0.17	0.2	0.12	0.20	0.10	0.06	0.13	0.19	0.18	0.26	0.09
CO_2	0.1	0.1	0.1	0.3	0.12	0.08	0.08	0.07	0.07	0.07	1.38	0.64
Sum	100.04	100.01	99.9	99.97	99.91	99.97	100.12	100.31	100.16	100.09	100.27	100.12
Rb ppm	102	111	135	96	135	175	78	63	129	76	73	112
Cs	3	10.7	6.8	3.7	4.2	3.7	3.8	1.0	4.0	2.8	3.6	1.0
Sr	260	203	177	190	98	39	281	277	231	199	382	24
Ba	590	595	741	616	530	550	580	415	590	190	365	520
Ga	15.3	14.0	12.5	13.6	12.5	10.8	13.6	13.3	13.0	13.7	16.2	14.4
Ge	1.4	1.6	1.3	1.5	1.1	1.0	0.8	0.6	1.2	0.9	1.3	1.7
Zr	158	127	99	101	98	113	159	158	121	159	133	111
Hf	5	5	6	5	3.0	4.0	14.8	7.6	2.5	5.6	5.5	5.1
Nb	6	7.5	7.8	6.2	11.6	10.8	7.8	7.5	8.2	9.1	8.0	15.9
Ta	2	2	2	< 1.6	<2	<2	<3	<3	<2	<3	<3	<2
La	22	34	17	35	17	30	21	20	16	27	15	79
Ce	46	53	37	68	37	65	48	48	38	53	42	186
Y	21	22	32	16	19	32	25	23	21	23	35	33
V	42.0	44.0	35.0	26.0	<4	<3	39	43	33	36	82	<6
Cr	11.0	15.0	10.0	49.0	11	33	11	17	21	24	35	26
Co	10	8	9	5	<4	<3	16	8	<6	<5	<8	8
Ni	1.0	2.0	< 0.6	1.0	1.2	3.6	9.9	4.1	4.8	3.8	5.3	1.7
Cu	4.0	3.0	< 0.4	3.0	8.3	8.5	13.5	11.2	8.9	24.0	9.7	3.5
Zn	49	33	17	32	33	16	131	125	115	180	59	83
Pb	17.4	11.1	15.2	16.8	25.0	59.0	70.0	87.0	34.0	158.0	11.1	13.5
As	1.0	1.0	< 0.4	1.2	1.3	1.8	< 0.8	< 0.8	< 0.6	< 1.1	0.7	1.0
Se	0.2	0.2	0.3	0.1	< 0.2	< 0.2	0.5	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Mo	1.8	31.8	0.4	4.3	14.7	2.0	3.4	2.9	3.1	1.7	3.8	0.5
W	2	1.4	2.7	4	2.3	1.2	4.9	<2	<2	<2	1.1	<2
Sn	3.1	2.7	1.8	2.3	4.0	8.1	7.5	4.7	4.6	10.1	]2.0	2.8
Bi	0.5	< 0.3	0.6	0.3	< 0.5	< 0.5	0.9	< 0.6	< 0.5	< 0.6	< 0.5	< 0.5
Cd	0.2	< 0.2	< 0.2	0.3	0.9	0.5	0.7	0.8	0.6	0.4	0.3	0.4
Th	6.7	10.6	14.1	9.4	23.0	15.1	11.3	11.3	8.9	12.6	7.8	36.0
U	1.7	2.4	3.1	1.6	6.9	9.5	4.7	5.0	3.7	4.6	3.3	6.7
A/CNK	1	1.01	1	1.01	0.97	1.07	1.05	1.04	1.08	1.07	0.94	1.04
Ga*10000/A	1.97	1.90	1.87	1.90	1.89	1.65	1.71	1.67	1.66	1.69	1.84	2.26
NK/A	0.67	0.73	0.79	0.72	0.92	0.90	0.65	0.63	0.69	0.64	0.58	0.91
Rb/Sr	0.4	0.5	0.8	0.5	1.4	4.5	0.3	0.2	0.6	0.4	0.2	4.7
Sr/Y	12.4	9.2	5.5	11.9	5.2	1.2	11.2	12.0	11.0	8.7	10.9	0.7
ZrT(˚C)	778	763	746	746	742	765	784	783	765	786	747	759

Appendix I Continued.

Type	Rengeji Granodiorite						Leucogranite Complex			Yamasa Leucogranite			
Sample no.	67HY57	650615	60F20	60F10	650614	60F17	65HN01	5908255	73HY01	590764	650605	590759	590767
SiO_2 (%)	74.68	72.51	72.94	73.48	73.89	75.05	76.92	76.67	76.94	76.34	76.66	76.84	77.51
TiO_2	0.38	0.29	0.30	0.27	0.28	0.18	0.15	0.12	0.16	0.15	0.15	0.15	0.10
Al_2O_3	12.17	14.22	14.22	13.86	14.06	13.33	12.52	12.32	12.35	12.55	12.21	12.56	12.25
Fe_2O_3	2.68	2.54	1.83	2.15	1.39	1.26	0.72	0.77	0.73	1.08	1.15	1.05	0.61
MnO	0.09	0.08	0.05	0.04	0.06	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.01
MgO	0.67	0.59	0.64	0.61	0.60	0.37	0.18	0.13	0.13	0.18	0.19	0.20	0.07
CaO	0.40	1.87	1.66	1.60	1.63	1.41	0.74	0.73	0.76	0.65	0.55	0.51	0.35
Na_2O	3.75	4.10	4.10	3.85	4.19	3.82	3.19	3.00	2.38	3.47	3.29	3.77	3.73
K_2O	4.67	3.38	3.27	3.36	3.54	3.72	5.06	5.48	5.18	4.72	4.81	4.52	4.65
P_2O_5	0.01	0.07	0.07	0.05	0.06	0.03	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
S	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.07	0.04	0.01	0.03	<0.01	0.02
H_2O+	0.11	0.24	0.59	0.51	0.11	0.23	0.11	0.15	0.26	0.56	0.28	0.34	0.31
H_2O-	0.10	0.16	0.11	0.26	0.07	0.46	0.16	0.14	0.54		0.32	0.07	0.12
CO_2	0.43	0.10	0.12	0.10	0.08	0.1	0.11	0.48	0.3	0.13	0.2	0.07	0.08
Sum	100.17	100.15	99.90	100.14	99.96	99.93	99.96	100.09	99.82	99.88	99.91	100.10	99.81
Rb ppm	106	121	128	120	127	120	173	154	171	174	189	165	141
Cs	2.5	6.3	5.4	5.9	1.6	2.5	3.0	2.9	3.2	3.5	4.6	2.5	2.7
Sr	28	173	181	174	172	141	65	71	64	61	35	50	29
Ba	680	520	570	530	690	460	410	410	421	290	198	290	385
Ga	12.4	13.7	12.1	12.4	12.2	12.8	9.9	8.5	10.9	12.2	13.6	12.5	11.4
Ge	1.5	1.3	0.9	1.5	1.2	1.4	1.1	1.2	1.6	1.4	1.9	1.3	1.6
Zr	97	114	108	118	105	85	84	81	87	80	91	86	72
Hf	3.4	2.8	2.8	5.0	3.2	4	3.8	9.9	4	4.2	5	4.9	5.1
Nb	10.3	7.5	6.7	8.4	8.1	6.7	8.0	6.4	7.5	13.8	13.3	12.5	9.6
Ta	<2	<2	<2	<2	<2	3	<2	4.8	3	<2	3	<2	<2
La	41	17	20	25	11	29	30	26	32	3	34	25	12
Ce	100	42	43	49	35	50	58	60	58	22	61	57	32
Y	34	23	23	22	22	21	21	16	19	42	29	32	27
V	<5	27	30	25	14	15.0	7	6	7.0	4	6.0	5	<3
Cr	24	38	14	13	45	27.0	7	48	7.0	26	7.0	9	14
Co	<5	<5	<5	<5	<4	5	<3	<3	3	<4	3	<4	<4
Ni	1.8	5.0	4.1	4.8	7.3	1.0	3.1	8.3	0.0	0.8	1.0	2.1	2.0
Cu	4.0	7.9	5.1	5.8	5.9	0.0	6.0	6.7	< 0.4	4.0	1.0	6.9	4.5
Zn	30	38	26	22	21	16	16	14	14	19	12	15	17
Pb	13.1	17.6	12.2	12.0	14.7	14.6	18.6	33.0	17.9	12.5	15.8	15.1	10.8
As	1.1	1.5	1.5	1.8	1.2	< 0.4	< 0.4	< 0.5	< 0.4	0.9	< 0.4	1.3	1.7
Se	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.4	< 0.2	0.4	< 0.1	< 0.2	0.1	< 0.2	< 0.2
Mo	0.4	6.4	< 0.2	3.5	0.7	0.6	7.0	10.1	7.7	2.6	4.2	< 0.2	2.2
W	<2	<2	3.1	1.1	0.9	1.8	1.2	5.0	2.2	<2	2.8	3.4	<2
Sn	3.6	3.9	4.0	3.2	3.2	2	1.8	1.9	1.6	2.4	1.2	1.3	1.6
Bi	< 0.4	< 0.5	< 0.4	< 0.4	< 0.4	0.5	< 0.5	< 0.5	< 0.3	< 0.4	0.5	< 0.4	< 0.4
Cd	0.5	0.2	0.2	0.3	0.2	0.4	0.3	0.7	< 0.2	0.3	< 0.2	0.4	0.4
Th	22.0	9.9	10.1	12.6	11.6	12.9	21.0	18.7	17.8	24.0	24.6	24.0	21.0
U	5.0	2.7	2.9	2.6	5.3	< 0.5	6.8	5.1	4.4	8.0	7.7	7.8	4.8
A/CNK	1.02	1.03	1.07	1.08	1.03	1.04	1.04	1.01	1.13	1.05	1.05	1.04	1.04
Ga*10000/A	1.93	1.82	1.61	1.69	1.64	1.82	1.49	1.30	1.67	1.84	2.11	1.88	1.76
NK/A	0.92	0.73	0.72	0.72	0.76	0.77	0.86	0.88	0.77	0.86	0.87	0.88	0.91
Rb/Sr	3.8	0.7	0.7	0.7	0.7	0.9	2.7	2.2	2.7	2.9	5.4	3.3	4.9
Sr/Y	0.8	7.5	7.9	7.9	7.8	6.7	3.1	4.4	3.4	1.5	1.2	1.6	1.1
ZrT(˚C)	747	756	756	765	750	736	738	732	749	734	746	740	726

Appendix I　Continued.

Type		Shimokuno Aplite				Ouchidani Granite Porphyry					Komaki area, cGd	
Sample no.	5907135	5908321	5907174	5907170	650604	60F15	60YT606	650601	650628	5908336	6510155	6510175
SiO_2 (%)	76.11	76.37	76.63	77.05	77.05	71.15	74.48	75.23	75.97	77.37	70.83	71.25
TiO_2	0.18	0.09	0.15	0.13	0.16	0.36	0.21	0.17	0.19	0.13	0.28	0.29
Al_2O_3	12.62	12.39	12.43	12.27	12.23	14.40	13.31	13.36	12.84	12.32	14.61	14.32
Fe_2O_3	1.03	1.16	1.03	0.75	0.95	2.73	1.44	1.10	1.19	0.83	2.64	2.61
MnO	0.03	0.04	0.03	0.01	0.03	0.10	0.02	0.03	0.04	0.02	0.08	0.07
MgO	0.24	0.24	0.22	0.10	0.18	0.95	0.40	0.31	0.34	0.26	0.75	0.78
CaO	0.44	0.76	0.55	0.46	0.53	2.41	1.50	0.87	0.89	0.83	2.65	2.73
Na_2O	3.42	3.04	3.50	3.21	2.56	4.03	4.06	4.28	3.91	3.73	4.16	4.03
K_2O	4.69	5.39	4.73	5.13	5.74	2.73	3.37	3.75	4.09	3.94	2.89	2.76
P_2O_5	0.02	<0.01	<0.01	<0.01	<0.01	0.11	0.04	0.03	0.03	0.02	0.07	0.09
S	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
H_2O+	0.68	0.21	0.38	0.46	0.09	0.75	0.44	0.58	0.31	0.42	0.68	0.66
H_2O-	0.20	0.18	0.06	0.11	0.38	0.22	0.22	0.24	0.19	0.10	0.16	0.13
CO_2	0.15	0.08	0.17	0.17	0.0	0.25	0.28	0.10	0.08	0.10	0.32	0.23
Sum	99.90	99.95	99.88	99.85	99.9	100.19	99.77	100.05	100.07	100.07	100.12	99.96
Rb ppm	171	244	197	195	194	84	67	70	168	150	85	81
Cs	3.4	5.1	4.3	3.0	4.1	3.6	<2	<2	5.1	3.3	3.7	4.7
Sr	48	127	35	38	71	276	211	127	95	76	221	216
Ba	320	225	195	160	384	415	1330	660	540	440	490	500
Ga	11.2	11.5	13.0	12.6	12.3	14.4	9.7	10.2	12.1	11.8	13.7	13.0
Ge	1.0	1.4	1.5	1.6	1.6	1.1	0.6	0.9	1.6	1.2	1.3	1.7
Zr	89	65	85	92	63	109	116	86	98	84	103	82
Hf	6.3	2.3	4.1	6.0	3	7.0	12.0	3.6	5.3	3.7	6.4	4.7
Nb	9.1	3.2	14.0	17.8	11.1	7.4	3.7	4.0	12.1	5.8	6.7	6.0
Ta	<2	<2	<2	<2	2	<2	5.5	<2	<2	<2	<2	<2
La	25	21	18	18	33	13	28	19	13	12	12	12
Ce	59	32	49	41	80	37	61	42	36	34	32	34
Y	30	13	33	61	26	20	12	11	35	24	22	20
V	8	12	5	<3	10.0	45	17	6	<4	4	34	37
Cr	17	6	7	9	15.0	54	14	12	20	12	7	14
Co	<4	<4	<4	<3	5	5	9	<4	<4	<4	<6	<6
Ni	2.1	1.5	2.6	2.7	0.0	7.7	6.4	2.0	1.2	2.1	1.2	2.1
Cu	8.0	5.7	6.6	6.4	0.0	8.2	11.2	4.2	4.5	6.0	4.6	4.0
Zn	23	14	11	9	13	49	16	16	16	13	40	38
Pb	10.3	10.9	12.8	13.9	14.3	11.5	18.9	15.3	10.9	11.4	11.8	10.0
As	1.9	1.3	1.3	0.9	< 0.4	1.2	< 0.4	1.1	1.9	1.0	1.1	1.4
Se	< 0.2	< 0.2	< 0.2	< 0.2	0.1	< 0.2	0.5	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Mo	0.8	0.2	0.6	< 0.2	1	0.8	2.1	< 0.2	< 0.2	0.5	0.4	< 0.2
W	3.5	<2	2.7	2.2	3.2	1.4	4.1	0.6	0.7	0.9	1.4	0.8
Sn	1.6	1.7	1.5	1.7	2	2.9	2.6	1.0	2.4	1.9	1.5	1.9
Bi	< 0.4	< 0.4	< 0.4	< 0.4	0.3	< 0.5	0.5	< 0.4	< 0.4	< 0.4	< 0.4	< 0.5
Cd	0.3	0.3	0.4	0.3	< 0.2	0.3	1.0	0.6	0.5	0.3	0.6	0.6
Th	19.0	15.1	28.0	31.0	22.3	14.0	18.2	14.5	15.4	12.6	8.9	8.6
U	5.1	4.4	7.8	6.2	4.0	5.8	4.8	3.5	4.6	3.7	4.9	4.3
A/CNK	1.10	1.01	1.05	1.05	1.07	1.03	1.02	1.05	1.03	1.03	0.99	0.98
Ga*10000/A	1.68	1.75	1.98	1.94	1.90	1.89	1.38	1.44	1.78	1.81	1.77	1.72
NK/A	0.85	0.87	0.88	0.88	0.85	0.67	0.78	0.83	0.85	0.84	0.68	0.67
Rb/Sr	3.6	1.9	5.6	5.1	2.7	0.3	0.3	0.6	1.8	2.0	0.4	0.4
Sr/Y	1.6	9.8	1.1	0.6	2.7	13.8	17.6	11.5	2.7	3.2	10.0	10.8
ZrT(˚C)	747	716	740	747	719	752	759	739	748	738	742	724

Appendix I Continued.

Type	Komaki mine, fQd-fGd				Komaki mine, fGm		
Sample no.	6510104	6510152	6510103	6510102	65KM150A	65KM153A	65KM169
SiO_2 (%)	56.56	69.95	69.99	70.19	77.67	76.88	76.92
TiO_2	1.10	0.44	0.45	0.45	0.06	0.07	0.07
Al_2O_3	17.58	14.48	14.42	14.54	12.14	12.43	12.54
Fe_2O_3	7.98	3.16	3.26	3.23	0.89	1.02	1.19
MnO	0.16	0.07	0.07	0.07	0.03	0.05	0.04
MgO	2.99	0.86	0.88	0.89	0.08	0.10	0.12
CaO	5.83	2.59	2.62	2.59	0.78	0.85	0.94
Na_2O	3.62	3.68	3.78	3.61	3.45	3.57	3.70
K_2O	1.38	3.69	3.61	3.70	4.07	4.09	3.82
P_2O_5	0.29	0.12	0.12	0.12	<0.01	<0.01	<0.01
S	<0.01	0.01	<0.01	<0.01	0.03	0.07	0.02
H_2O+	2.50	0.61	0.66	0.56	0.33	0.58	0.38
H_2O-	0.37	0.20	0.13	0.13	0.11	0.07	0.10
CO_2	0.13	0.28	0.11	0.10	0.14	0.29	0.18
Sum	100.49	100.14	100.10	100.18	99.78	100.07	100.02
Rb ppm	58	131	142	138	149	129	135
Cs	1.2	5.7	4.5	5.6	5.1	<2	2.1
Sr	460	242	222	228	98	101	100
Ba	300	600	570	610	650	680	630
Ga	17.9	13.8	13.8	13.9	10.9	11.2	12.2
Ge	1.2	1.2	0.8	1.2	1.1	1.0	1.4
Zr	123	220	212	218	65	73	67
Hf	7.2	11.4	10.1	10.6	3.9	4.2	6.5
Nb	6.8	9.5	9.9	9.6	6.8	7.1	6.9
Ta	<3	<2	<2	<2	<2	<3	<2
La	13	25	28	27	16	18	17
Ce	38	61	68	65	37	40	41
Y	36	33	33	36	17	18	17
V	171	45	44	45	<3	<3	<3
Cr	1	4	10	13	36	14	11
Co	20	9	7	11	<4	<4	<4
Ni	5.9	3.7	4.1	2.7	4.6	0.8	1.8
Cu	7.5	5.3	5.6	4.8	7.3	22.0	6.1
Zn	98	43	43	42	13	103	13
Pb	11.1	14.1	13.8	13.7	22.0	33.0	21.0
As	1.6	1.0	0.3	< 0.4	0.7	1.2	1.3
Se	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Mo	0.8	0.9	0.9	< 0.2	1.3	6.2	0.3
W	<2	<2	1.8	<2	<2	1.0	1.9
Sn	1.4	2.4	2.6	1.8	4.5	4.0	5.0
Bi	< 0.6	< 0.5	< 0.5	< 0.5	< 0.4	< 0.5	< 0.4
Cd	0.7	0.5	0.8	0.4	0.5	1.2	0.6
Th	6.2	14.3	16.1	16.8	10.8	12.5	11.4
U	5.6	7.0	7.8	3.3	3.7	3.6	3.5
A/CNK	0.97	0.98	0.97	0.99	1.06	1.05	1.05
Ga*10000/A	1.92	1.80	1.81	1.81	1.70	1.70	1.84
NK/A	0.42	0.69	0.70	0.68	0.83	0.83	0.82
Rb/Sr	0.1	0.5	0.6	0.6	1.5	1.3	1.4
Sr/Y	12.8	7.3	6.7	6.3	5.8	5.6	5.9
ZrT(˚C)	737	805	800	806	720	728	721

Appendix II Analytical results of the Miocene plutonic rocks of the eastern Shimane region. The samples from the Yoshida body were collected by H. Matsuura and their localities are shown in Fig. 2. For basalts from the Shimane Peninsula, see Kano et al. (1986).

	Seikyu	Yoshida body collected by H. Matsuura					Shimane Peninsula by K. Kano			
	6506-31	**KSK107**	**KSK126**	**KSK127**	**KSK128**	**KSK132**	**SKDT2**	**SKDT5**	**SKDT6**	**R22437**
SiO2	55.63	51.94	59.12	49.47	53.00	62.62	51.52	59.43	50.54	54.50
TiO2	0.92	0.76	0.96	0.99	0.65	0.66	1.49	1.15	1.06	0.96
Al2O3	16.91	18.74	16.08	17.93	18.67	15.98	17.16	15.86	18.15	17.60
Fe2O3	9.23	9.61	6.63	11.76	7.78	5.61	9.27	7.26	8.66	9.76
MnO	0.18	0.15	0.14	0.16	0.11	0.12	0.17	0.18	0.19	0.19
Mg0	3.83	4.22	2.85	5.85	4.42	2.59	4.46	2.14	4.98	3.76
CaO	7.98	10.04	8.58	10.58	10.52	6.60	7.74	5.63	10.28	8.33
Na2O	3.09	2.91	3.93	2.46	3.15	3.85	4.22	4.38	2.73	2.92
K2O	0.74	0.57	0.21	0.18	0.35	1.01	0.85	1.51	0.80	0.69
P2O5	0.17	0.19	0.17	0.03	0.14	0.14	0.36	0.32	0.21	0.14
S	0.06	0.09	0.24	0.09	0.05	0.04	0.04	0.04	0.03	0.05
H2O+	1.55	1.01	0.98	0.84	1.06	0.95	2.78	2.04	2.17	1.28
H2O-	0.16	0.05	0.01	0.10	0.20	0.15	0.49	0.23	0.49	0.21
CO2	0.22	0.18	0.23	0.16	0.27	0.10	0.14	0.13	0.13	0.10
Total	100.67	100.42	100.01	100.56	100.35	100.40	100.67	100.28	100.41	100.47
Rb	17	16	2	4	9	15	27	51	23	24
Cs	<2	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5	1.6	< 1.5	< 1.5	< 1.5
Sr	378	329	320	336	328	265	420	381	454	325
Ba	185	110	94	52	87	222	167	293	200	155
Ga	71	17.0	17.0	17.3	17.7	15.7	18.6	18.9	18.1	16.4
Ge	3.6	1.5	1.6	1.6	1.4	1.7	1.2	1.2	1.6	1.7
Zr	16.1	70	75	19	53	124	110	164	81	62
Hf	1.4	<3	3.6	<2	<2	3.6	1.8	4.6	<3	3.5
Nb	106	1.3	3.3	0.6	1.5	3.0	7.6	9.2	6.7	1.8
Ta	5.3	<4	3	4	<4	<4	<4	<4	<4	5
La	<3	4	11	2	8	13	11	18	7	5
Ce	7	14	32	6	17	28	29	41	21	17
Y	3.0	21	32	10	19	28	26	32	19	22
V	20	187	182	404	205	128	192	105	219	211
Cr	25	14	<1	12	39	10	43	<1	90	<1
Co	270	26	22	41	28	19	22	12	21	27
Ni	< 1.6	16	5	25	20	4	24	< 1.1	36	< 1.2
Cu	24	57	3.9	15.4	23.9	2.5	25	8.7	64	45
Zn	5.2	52	55	57	33	34	47	79	76	143
Pb	9.1	3.6	5.6	1.7	2.9	5.6	1.3	6.8	2.1	15.0
As	1.7	1.1	2.0	1.0	0.7	1.2	0.9	2.3	1.5	3.9
Se	< 0.2	0.2	0.2	< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	0.3
Mo	0.3	0.2	0.5	0.4	0.7	0.5	0.5	0.8	< 0.2	0.4
W	<2	<2	0.8	<2	1.2	1.2	2.1	1.1	1.9	<2
Sn	0.6	0.4	1.0	< 0.4	0.6	< 0.4	0.9	1.4	0.6	1.6
Tl	< 0.6	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.4	< 0.5	1.2
Bi	0.5	< 0.4	< 0.3	< 0.4	0.3	< 0.3	< 0.3	< 0.4	< 0.4	1.0
Cd	2.4	0.3	0.6	0.4	0.4	< 0.2	0.2	< 0.2	0.4	0.8
Sb	2.8	< 0.5	0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.0
Th	2.4	1.1	3.2	< 0.5	0.8	3.1	1.6	3.1	1.7	0.6
U	2.8	0.7	1.1	0.3	0.7	0.7	0.3	0.6	0.9	< 0.5
A/CNK	0.83	0.79	0.72	0.76	0.76	0.82	0.78	0.83	0.75	0.85
NK/A	0.4	0.3	0.4	0.2	0.3	0.5	0.5	0.6	0.3	0.3
Ga*10000/A	1.8	1.7	2.0	1.8	1.8	1.9	2.0	2.3	1.9	1.8
Rb/Sr	0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1
Sr/Y	126	15.7	9.9	34.2	17.1	9.6	16.1	11.8	24.5	14.8
Zr-T(oC	701	653.6	660.1	567.4	629.2	721.8	687.6	743.0	654.5	664.4