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Cenozoic granitoids of central Hokkaido, Japan —An example of plutonism along collision belt

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Abstract: Cenozoic granitoids of central Hokkaido varying in age from Eocene to Miocene are scattered, closely associated with gabbroids, in the N-S trending axial belt. The northern group plutons are composed generally of granodiorite and granite which partly accompany granophyric granite and suffered tourmalinization. They are products of high-level intrusion of ilmenite-series and very locally intermediate-series magmas. The southern group plutons occur associated with high-grade metamorphic zones, and consist of katazonal tonalite-granodiorite to the west and epizonal granite to the east. The granitoids all belong to ilmenite series.

Magnetic susceptibility is usually as low as 10^{-5} emu/g, which agrees with the general absence of magnetite but the presence of ilmenite and pyrrhotite. Ilmenite and pyrrhotite are sometimes abundant in gabbroids and migmatite, respectively. Pyrrhotite and chalcopyrite are commonest rock-forming sulfides in granitoids and their content is one of the highest ones among Japanese granitoids. Bulk Fe_2O_3/FeO ratio is low but shows three trends within the low range, and Eocene granitoids have the most oxidized trend.

Cenozoic granitoids of central Hokkaido are mineralogically similar to the Outer Zone granitoids of Southwest Japan, but are different in minor element chemistry being depleted in Cl, F, Li, Rb, Pb, Sn, Be and As. Among the studied granitoids, the Eocene ones are most sodic and depleted in Sr and Rb as similarly as gabbroids. Wall rock sediments are, on the other hand, rich in Sr. Commonest ilmenite-series granitoids have intermediate values between the Eocene granitoids and wall rocks.

The largest body of the southern group granitoids exhibits compositional and textural variation laterally, being foliated tonalite and granodiorite with intercalated gneiss and migmatite to the west but locally granophyric massive granite to the east, the Rb/Sr ratio increases drastically toward the eastern end. These variations are considered to indicate a vertical variation at the time of intrusion; the western part was thrusted and tilted up near vertically, when two island arcs were collided. About 10 km of the uppermost part of the crustal section can be seen at present.

Rock sulfur and strontium isotopic data were revisited. It is suggested that the intruded sedimentary rocks of the axial belt were clastics derived from inmatured volcanic island arcs, and mantle-derived primary magmas of tonalitic composition assimilated a large amount of the sedimentary rocks, then intruded. The studied granitoids show some similarities to Cenozoic granitoids in the Himalaya, *e.g.*, increasing tendency of Fe_2O_3/FeO and Na_2O/K_2O ratios toward east in Hokkaido (north in the Himalaya), indicating an eastward tectonic zone related to the granitic magmatism. However, Fe_2O_3/FeO ratio is very low in Hokkaido and initial $^{87}Sr/^{86}Sr$ ratio is extremely high in the Himalaya, suggesting different basement setting in the two regions.

Introduction

Cenozoic granitoids are scattered in the axial belt of central Hokkaido for an area of N-S 300 km and E-W 60 km. The granitoids crop out as small plutons within the Hidaka terrane, 10-20 km to the east of the high-grade metamorphic zone including migmatites in the southern half, but scattered widely (up to 60 km) in the non-metamorphic Hidaka Supergroup in the northern half. The

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** Geochemistry & Technical Service Department granitoids do not accompany coeval volcanic rocks, but gabbroids of similar age do occur spatially close to the granitoids. Mineralizations are nil unless the Shimokawa-type massive sulfide deposits are indeed (MAMBA, 1978) related to the granitic activities.

The granitoids of central Hokkaido are young in age but do not occur parallel to the Kuril Arc. Instead, they tend to occur following the basement suture of the western high P/T type metamorphic rocks of the Kamuikotan terrane and the eastern high T/P type metamorphic rocks of the Hidaka terrane. This apparent reverse zoning, relative to the paired metamorphic zoning of Southwest Japan, made HORIKOSHI (1972) to propose an eastward subduction-collision model. Recently, however, the high P/T type metamorphic terrane appears to be considered coupled with late Cretaceous granitoids of southwestern Hokkaido implying the westward subduction during the late Mesozoic time, then two island arcs collided in Tertiary simply or composite ways (see KIMURA *et al.*, 1983; KOMATSU, 1985).

The Cenozoic granitoids are well mapped in the quadrangle series of 1: 50,000 scale which is nearly completed over the Hokkaido island, yet quantitative data are very much limited. SUZUKI (1957) reported modal analyses on 65 granitoids and 84 migmatites; SOTOZAKI (1967) summarized major chemistry data of 11 granitoids and 20 migmatites; and several age data were available (KAWANO and UEDA, 1967; SHIBATA, 1968).

In 1974 summer, we made 20 days tour in the studied area to observe the granitoids and to collect the specimens for various analyses. The results were partly published in summary forms in the late 1970s (*e.g.*, Sn in ISHIHARA and TERASHIMA, 1977b; magnetic susceptibility in ISHIHARA, 1979; Sr isotopes in SHIBATA and ISHIHARA, 1979b; S isotopes in SASAKI and ISHIHARA, 1979). In this paper, we describe all the available data and intend to discuss genetic background for these granitoids. Locality of the studied granitic plutons and analyzed specimens are illustrated in Figure 1.

General Remarks

Hidaka Supergroup, in which the granitoids intrude, consists mainly of sandstone and shale and partly of chert and basaltic tuffs, and their age has been considered from Permian to Jurassic, but now the majority are identified as Cretaceous, in part successive to Paleogene, by the studies of microfossils (KIMINAMI *et al.*, 1985). Age of the granitoids has long been assigned to Cretaceous-Tertiary (GSJ, 1982). The then-existing age data of 16–36 Ma on biotite (KAWANO and UEDA, 1967) may have been regarded to indicate uplifting age, because they were biotite age obtained from granitoids and migmatites within or close to the high-grade metamorphic belt. SHIBATA (1968) was probably the first to propose a Miocene age for these granitoids by its similarity to the Outer Zone granitoids of Southwest Japan, and additional analyses on our samples indicated a concordant age between K–Ar age on biotite (17 Ma) and Rb–Sr isochron age on whole rock samples (17.3 Ma) in the Nissho pluton (SHIBATA and ISHIHARA, 1979a). Moreover, two Eocene ages (41.5 and 43.4 Ma) were obtained on biotite from two high-level stocks in the easternmost part of the studied area (Table 1). Thus the granitoids are assigned here to Paleogene (strictly Eocene and Oligocene) and Miocene in age, as summarized in Figure 1.

The granitoids are also divisible into the northern and southern groups, based on their characteristics that those in the northern area intrude sporadically into non-metamorphic rocks of the Hidaka Supergroup, whereas those in the southern area occur in narrow zone right next to the metamorphic counterpart associated with nearly equal amount of gabbroids (Fig. 1).

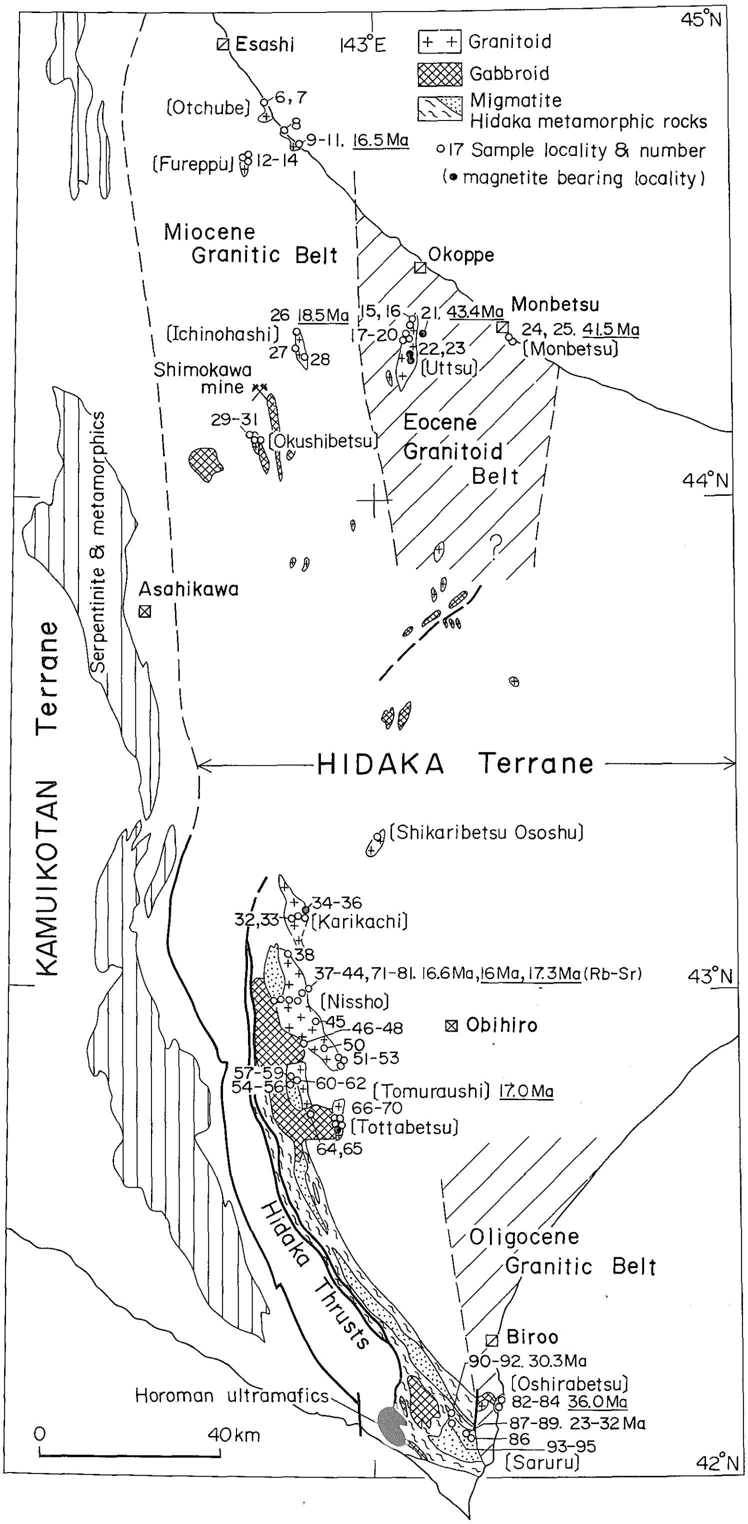

Fig. 1 Index map of the studied area.

Table 1 K-Ar mineral age of granitoids and migmatites from the Hidaka terrane.

Sample No.	Pluton	Rock & Mineral	K_2O (%)	Atm ^{40}Ar (%)	Age (Ma)
74HK21	Uttsu	Granite, biotite	4.67, 4.77	11.1	43.4±1.4
74HK24	Monbetsu	Granite, biotite	7.55	10.8	41.5±1.3
74HK09	Otchube	Granodiorite, biotite	7.41	67.0	16.5+1.0
74HK26	Ichinohashi	Granodiorite, biotite	7.55, 7.36	36.2	18.4±0.6
				21.3	18.6±0.6
74HK59	Tomuraushi	Tonalite, biotite	9.09	14.1	17.0±0.5
74HK76	Nissho	Migmatite, biotite	8.49	49.6	16.6±0.7
74HK90	Saruru	Migmatite, biotite	7.19	53.0	30.3±1.3
2104	Oshirabetsu	Norite, biotite	8.18	10.9	35.3±1.1

$\lambda_\beta=4.962\times10^{-10}/y$, $\lambda_e=0.581\times10^{-10}/y$, $^{40}K/K=0.01167$ atom%. After SHIBATA and ISHIHARA (1981)

Miocene Granitoids—Northern Group

Otchube: The northernmost Otchube body occurs as two separate units along the coastal highway facing the Okhotsk Sea (SAKO *et al.*, 1961). It is composed of mainly biotite monzogranite (hereafter abbreviated as granite) and some hornblende-biotite granodiorite (see appendix table). The granitoids contain in some places fragmental and well digested xenoliths of slate which could have been derived from the intruded Hidaka Supergroup. Stockworked tourmaline is observed in brecciated granite at one place.

Furrepu pluton, E-W 2 km by N-S 5 km, occurs close to the Otchube body. SAKO *et al.*, (1961) described that this pluton is less potassic than the Otchube granitoids. Our study of granitic float from this pluton indicates that it consists mainly of hornblende-biotite granodiorite which contains small amount of mafic inclusions. Aplite which bears tourmaline as spot or ring, is also observed.

Ichinohashi pluton, E-W 2 km by N-S 9 km, is a heterogenous body being composed of clinopyroxene-hornblende-biotite quartz diorite, hornblende-biotite granodiorite and biotite granite. Mafic inclusions are not uncommon in some places.

Okushibetsu pluton, E-W 2 km by N-S 9 km, occurs associated with gabbroids (Fig. 1). SAKO (1952) reported that the granitoids are later than the gabbroids because of gabbroic xenoliths contained in the granitoids, and also gradual boundary between them. In our observation, the Okushibetsu granitoids are felsic, and mafic inclusions are rare but fragmental gabbroids from the wall rocks are seen. It consists of biotite granite which has micrographic texture and contains pegmatitic pool. The granite has been pervasively altered to calcite, sericite and chlorite. Microveinlet of calcite is distinct. The granite is located to the south of the Shimokawa chalcopyrite-pyrrhotite massive sulfide deposits, and galena-chalcopyrite-pyrrhotite-bearing adularia-calcite vein occurring in the southern extension zone of the ore deposits whose adularia was dated at 16.2±0.4 Ma (SHIBATA *et al.*, 1979), is possibly formed by postmagmatic activity of this granite.

All of the above-mentioned granitoids are magnetically weak, falling in the category of ilmenite-series granitoids in their magnetic susceptibility (see appendix, also Fig. 3).

Eocene Granitoids—Northern Group

Uttsu pluton, E-W 6 km by N-S 17 km, is the largest (53 km^2 in exposure) among the northern group plutons and gives thermal metamorphism to sedimentary wall rocks of the Hidaka Supergroup. TAKEUCHI (1938, 1942) noted that the main facies is biotite granite which contains granophyric granite

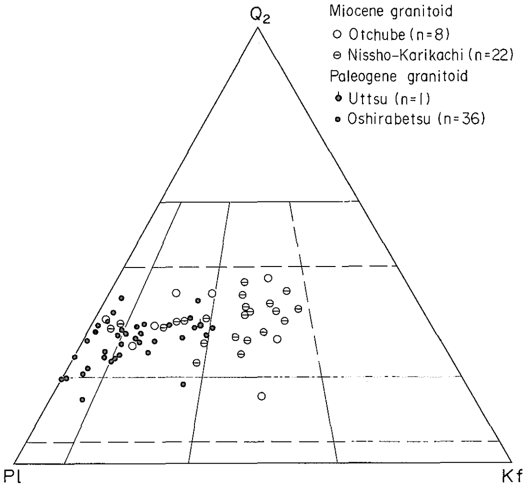

Fig. 2 Modal plagioclase-K-feldspar-quartz ratio of some granitoids of central Hokkaido. The original data, from SUZUKI (1957) and HASHIMOTO (1954).

and aplite dikelet, and marginal quartz diorite. Our observation in the northern half indicates that the main rock type is biotite granite which often contains hornblende. Granophyric texture and myrmekitic intergrowth of K-feldspar and qaurtz are sometimes observed. Tourmaline stockworking is seen in aplitic granite.

River float from Mt. Uttsu indicates that, besides granodiorite, tonalites are quite abundant in the southern half of the body implying that the body is fairly mafic as a whole. These mafic rocks contain some magnetites as accessory opaque minerals. This body indeed is only pluton which contains some amounts of magnetite-bearing rocks whose magnetic susceptibility corresponds to that of magnetite-series granitoids (38% by number of analysis, see appendix, also Fig. 3).

Monbetsu body is seen underneath the basal conglomerate of Miocene Kitami Series at south of Monbetsu harbor. It crops out for about 500 m. It is composed of biotite granite with some tonalite, and contains abundantly subangular xenolith of metasedimentary rocks. Aplite dike of irregular shapes and quartz pool are common. The northern part has been strongly altered to calcite, sericite, chlorite and pyrite.

In summary, the northern group granitoids are small stocks having average composition per individual units of either granodiorite or granite and containing often granophyric granite and pneumatolytic tourmalinization, regardless of their age. They are considered as high-level granitoids formed from ilmenite-series and partly intermediate-series magmas.

Miocene Granitoids—Southern Group

Granitoids of the southern group are seen in a narrow zone to the east of migmatite zone of the Hidaka metamorphic belt (Fig. 1). They are much larger in exposure than in the northern group plutons and intrude into both metamorphic and non-metamorphic sedimentary rocks of the Hidaka Supergroup, and also gabbroids. Almost all the granitoids belong to ilmenite series.

Karikachi body, E-W 4 km and N-S 20 km (55 km^2), is said to be a homogeneous biotite granite (KOUNOYA *et al.*, 1969; SAKO *et al.*, 1967), but in our observation, hornblende-biotite granodiorite and granophyric leucogranite are also seen (see appendix). These granitoids have been altered to chlorite, epidote and sericite.

Nissho pluton is the largest in dimensions (169 km^2). HASHIMOTO (1954) recognized three facies as follows:

I. Massive, medium-grained biotite granite
II. Porphyritic biotite granite, and
III. Biotite-rich rock which is well digested part of trapped migmatite.

In our observed route of the middle part (see Fig. 8), the porphyritic facies occur locally in the eastern part (74HK80, 81) and the biotite-rich rock is seen in minor amount in the westernmost part. The porphyritic granite similar to our 74HK80–81 is clearly contained in massive granite in Karikachi body (Fig. 8 of KOUNOYA *et al.*, 1969), thus an earlier crystallized phase among the granitoids. Most of our samples seem to belong to HASHIMOTO's Facies I granitoids.

The main facies vary in texture and composition generally from west to east in our studied route. In the westernmost part where granitoids occur alternatively with gneisses and migmatites, they are mostly clinopyroxene-hornblende-biotite tonalite and hornblende-biotite granodiorite. Hornblende appears in the western half of the body where the granitoids are sometimes foliated; the foliation parallel to schistosity of the intercalated gneisses and migmatites. The eastern half is massive biotite granite which is partly granophyric, and is generally concordant to the intruded wall rocks of the Hidaka Supergroup (Fig. 8). Thus, the western part shows characteristics of low-level granitoids although the depth parameter is not available, while the eastern part is those of high-level plutons.

Throughout the body, mafic inclusions and metapelites are rare. Xenocryst of garnet-cordierite was found at one place.

Tomuraushi body, E–W 4 km and N–S 11 km (30 km^2), occurs in the southern extensional zone of the westernmost part of the Nissho body (Fig. 1). The constituents are tonalite, granodiorite and granite, which are generally schistosed, and various gneisses are often intercalated. This can also be considered as a low-level body.

Tomuraushi gabbroids occurring around the Tomuraushi granitoids vary from clinopyroxene-hornblende gabbro (74HK64) to biotite-bearing hornblende quartz diorite (74HK48). The least differentiated, 74HK64 gabbro was dated at 25 Ma by whole rock K-Ar method (SHIBATA and ISHIHARA, 1979a). The gabbroids are therefore considered as products of Paleogene plutonism but intruded prior to the granitoid intrusions.

Tottabetsu body, E–W 3 km and N–S 8 km (14 km^2), intrudes between gabbroids and sedimentary rocks of the Hidaka Supergroup. It is composed of biotite-bearing hornblende tonalite and granodiorite and biotite granite.

Oligocene Granitoids—Southern Group

The granitoids occur in the southernmost part of the axial zone. Oshirabetsu body is present surrounding gabbroids intruding them or hornfels of the Hidaka Supergroup. Observation along the coast indicates that the granitoids are mostly hornblende-bearing biotite granodiorite and biotite granite which contain both mafic inclusions and metasedimentary xenoliths. Thirty-six modal analyses of SUZUKI (1957) revealed a strong concentration in the field of tonalite and granodiorite in the plagioclase-K-feldspar-quartz diagram (Fig. 2).

Within the migmatite zone of high-grade metamorphic belt along the Saruru river, there occur also Oligocene granitoids in very small amount, because they are sheet-like irregular lenses of 1–2 m thick intercalated in cordierite-bearing biotite gneisses. The granitoids are massive biotite tonalite in general but change to biotite granite within 5–10 centimeters. These are considered to have crystallized deeper than the low-level granitoids of the westermost Nissho body and the Tomuraushi granitic body, and are tentatively called katazonal granitoids in this paper.

In summary, Cenozoic plutonic rocks in central Hokkaido are represented by approximately an equal amount of gabbroid and granitoid. The granitoids are generally massive and intrude discordantly and partly concordantly into the wall rocks. The age varies from Eocene and Oligocene to Miocene. The Paleogene granitoids are generally more mafic than the Miocene ones.

Magnetic Susceptibility, Opaque Minerals and Fe_2O_3/FeO Ratio

Magnetic Susceptibility

Magnetic susceptibility was measured on the collected samples by Bison Model 3101A and Geoinstruments ky TH-1 devices. The results are listed in the appendix and Figure 3.

The studied granitoids are very low in the

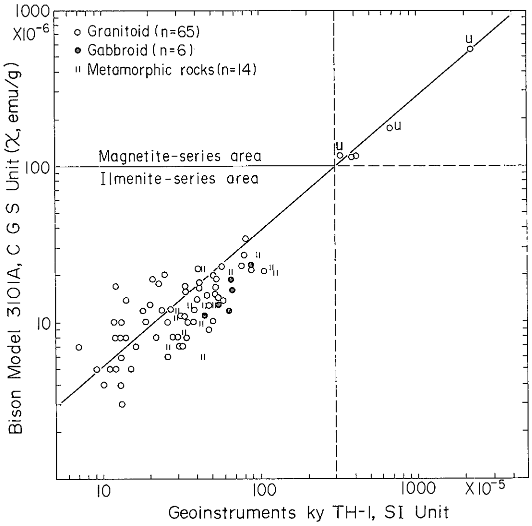

Fig. 3 Magnetic susceptibility of the studied plutonic rocks of central Hokkaido. The original data are given in the appendix.

magnetic susceptibility, being generally below 30×10^{-6} emu/g. Only 5 out of 65 measurements fall in the range of magnetite-series granitoids. In more detail, 3 out of 8 at Uttsu, 1 out of 5 at Karikachi and 1 out of 5 at Tottabetsu exceed the lower limit of 100×10^{-6} emu/g for the magnetite series. The highest value is 555×10^{-6} emu/g of quartz diorite porphyry of the Uttsu pluton is one-third to one-quater of magnetic susceptibility of typical magnetite-series quartz diorite in the Sanin district, Southwest Japan. Therefore, the granitoids studied are considered to have essentially ilmenites-eries characteristics. The Uttsu pluton may belong also to ilmenite series on the basis of magnetic susceptibility but its variation is most close to that of the intermediate series (ISHIHARA *et al.*, 1984), hence called intermediate-series pluton in this paper. It is also interesting to note very low values on gabbroids. The magnetic susceptibility is generally $10\text{–}20 \times 10^{-6}$ emu/g even on fresh rocks which are not affected by granitoid intrusion.

Opaque Minerals

Under the ore-microscope, massive granitoids with magnetic susceptibility lower than 100×10^{-6} emu/g contain only little opaque minerals. Ilmenite is commonest but pyrrhotite, hemoilmenite and chalcopyrite may be present. Ilmenite occurs as stubby columnar crystals mostly in mafic silicates. Pyrrhotite of anhedral forms is fairly common, but hemo-ilmenite occurs only locally.

Highly magnetic quartz diorite porphyry at Uttsu pluton contains polygonal to rounded crystals of magnetite mostly in the groundmass, while ilmenite occurs in phenocryst of hornblende and biotite. Thus magnetite started to crystallize later than ilmenite and should have been formed at the latest stage of the crystallization.

Opaque minerals of the katazonal granitoids in the migmatite zone are generally pyrrhotite and ilmenite, and pyrrhotite sometimes exceeds in amount ilmenite. Chalcopyrite is also present. This mineral assemblage is the same as that of the surrounding gneisses, except graphite which is common in pelitic metamorphic rocks.

Gabbroids, on the other hand, contain abundant ilmenite and little pyrrhotite. The most mafic facies of orthpyroxene-hornblende gabbro contains 0.8 vol. percent ilmenite.

Fe_2O_3/FeO Ratio

Magnetic susceptibility and opaque mineralogy indicate general ilmenite-series characteristics of the studied plutonic rocks. In Fe_2O_3-FeO diagram (Fig. 4), however, the studied rocks have some variations. Ilmenite-series granitoids of the Nissho body and ilmenite-series gabbroids are plotted in the most Fe_2O_3-depleted area, while those from the northern group plutons and Oligocene granitoids of the southern group plutons are more enriched, though faintly, in Fe_2O_3. The intermediate-series Eocene granitoids of the Uttsu pluton, as a matter of fact, has the highest Fe_2O_3/FeO ratio (0.53). The same age group of the Monbetsu pluton, however, has much lower value in the ratio (0.22), which is considered due to reduction by

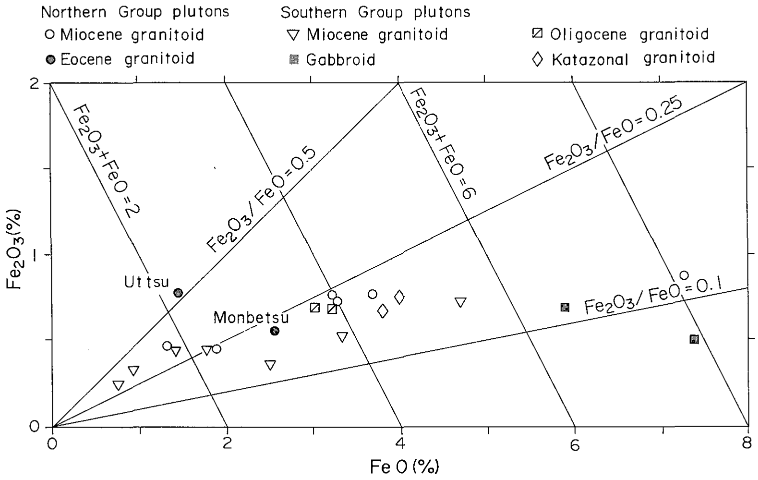

Fig. 4 Ferric/ferrous ratio of the studied plutonic rocks of central Hokkaido. The original data are given in Tables 2–5.

pelitic wall rocks at the time of intrusion, because of many xenoliths observed in this pluton.

Within the low range of Fe_2O_3/FeO, the plutonic rocks of central Hokkaido have some variation on the ferric/ferrous ratio, and appear to have solidified under low but different fO_2 conditions.

Regional Chemical Characteristics

Among the samples collected, major and selected minor elements were determined by conventional wet method and atomic absorption spectrometry by the ways described in the writers' previous papers elswhere (ISHIHARA and TERASHIMA, 1977a). The results are listed in Tables 2 through 5.

Comparison with the Japanese Average Granitoids

Major chemistry of the Cenozoic granitoids of central Hokkaido was once compared with that of the average composition of Japanese granitoids of ARAMAKI *et al.* (1972) by SATO and ISHIHARA (1983). Here, the studied granitoids are compared on both major and minor elements on the HARKER's diagram (though not shown), with the average composition of our own data over the whole Japanese Islands, which were analyzed by the same methods as in this study. The studied granitoids have the following characteristics:

Elements more or less the same as the average: Al_2O_3, Pb and Sn.

Those contained more in the studied rocks than the average: Na_2O, K_2O, MgO, FeO, TiO_2; S, Zn and Li.

Those contained less in the studied rocks than the average: CaO, P_2O_5, Fe_2O_3, MnO, H_2O+; Cu, Cl, F, Rb, Sr, Be and As.

Comparison with the Outer Zone Granitoids of Southwest Japan

Cenozoic granitoids of central Hokkaido are similar to the Outer Zone granitoids of Southwest Japan in the sense that they occur in an outer belt of the island arc with similar petrography (ilmenite series, presence of tourmaline etc.), thus called outer belt plutonic rocks (ISHIHARA, 1979). The analytical results are plotted in binary diagrams and are compared with the average composition of the Outer Zone granitoids of Southwest Japan (Figs. 5a, b).

As is seen in the diagrams, they are similar on the major components, except for Na_2O and K_2O, which are enriched and depleted, respectively, in the Hokkaido rocks, but are quite different on the minor components. The granitoids of central Hokkaido are very much

Table 2 Chemical compositons of the northern group granitoids.

Age	Miocene Granitoids						Eocene Granitoids	
Pluton	Otchube			Ichinohashi		Okushibetsu	Uttsu	Monbetsu
Sample No.	74HK09	74HK07	74HK08	74HK27	74HK26	74HK29	74HK21	74HK24
SiO_2	61.00	67.11	73.04	54.92	67.73	71.83	72.60	69.87
TiO_2	.55	.56	.30	1.51	.55	40	.33	.51
Al_2O_3	17.57	15.33	13.98	17.40	14.85	14.19	14.19	14.88
Fe_2O_3	.76	.71	.44	.86	.76	.44	.76	.55
FeO	3.70	3.27	1.33	7.26	3.23	1.87	1.44	2.55
MnO	.11	.09	.05	.17	.10	.04	.06	.05
MgO	3.18	2.14	.49	4.49	1.26	.78	.33	.76
CaO	5.64	3.15	1.46	7.40	2.58	1.15	1.49	1.62
Na_2O	3.63	3.19	3.76	3.32	3.72	3.90	4.26	3.94
K_2O	1.96	3.24	4.22	1.04	3.63	4.00	3.70	3.18
P_2O_5	.14	.15	.06	.20	.14	.05	.04	.12
H_2O^+	1.21	.67	.30	.94	.83	.97	.38	1.48
H_2O^-	.14	.18	.18	.18	.18	.02	.22	.20
Others	.01	.12	.02	.09	.10	—	—	..19
Total	99.60	99.91	99.63	99.78	99.66	99.64	99.80	99.90
T.C	10	50	30	370	460	110	20	1,800
S	50	1,120	240	460	480	200	5	120
Cu	8	27	1	26	15	4	6	12
Zn	53	60	40	80	63	11	46	56
Pb	13	13	19	11	18	14	20	20
Li	43	47	60	22	53	28	34	13
Cl	80	150	120	160	185	n.d.	290	510
F	220	330	360	100	480	n.d.	330	400
Rb	55	100	125	30	120	149	117	102
Sr	307	216	98	242	136	118	93	118
Sn	1.5	2.6	1.2	2.4	2.8	2.7	2.6	1.4
Be	1.6	2.0	2.0	1.0	2.0	2.0	2.0	2.0
As	.8	2.0	.5	1.0	11.0	n.d.	1.8	2.6
$^{87}Sr/^{86}Sr_0$	0.70464	n.d.	n.d.	0.7053	n.d.	n.d.	0.70407	0.70526
Kai	20	34	22	21	10	18	118	19
Q	13.73	24.52	30.57	6.16	23.10	29.22	29.37	28.93
C	—	1.21	.72	—	.45	1.47	.56	2.30
or	11.58	19.15	24.94	6.15	21.45	23.64	21.87	18.79
ab	30.72	26.99	31.82	28.09	31.48	33.00	36.05	33.34
an	25.86	14.65	6.85	29.50	11.88	5.38	7.13	7.25
wo	—	—	—	—	—	—	—	—
wo-di	.50	—	—	2.46	—	—	—	—
en-di	.29	—	—	1.24	—	—	—	—
fs-di	.20	—	—	1.16	—	—	—	—
en-hy	7.63	5.33	1.22	9.94	3.14	1.94	.82	1.89
fs-hy	5.26	4.66	1.68	9.28	4.58	2.48	1.58	3.48
fo-ol	—	—	—	—	—	—	—	—
fa-ol	—	—	—	—	—	—	—	—
mt	1.10	1.03	.64	1.25	1.10	.64	1.10	.80
hm	—	—	—	—	—	—	—	—
il	1.04	1.06	.57	2.87	1.04	.76	.63	.97
ap	.32	.35	.14	.46	.32	.12	.09	.28
Others	1.36	.97	.50	1.21	1.11	.99	.60	1.87
Total	99.60	99.91	99.63	99.78	99.66	99.64	99.80	99.90
Q+ab+or	56.03	70.66	87.32	40.40	76.03	85.86	87.28	81.06

Throughout Tables 2-5, major elements are wt% and minor elements in ppm. Kai is magnetic susceptibility in emu/g, $\times 10^{-6}$. $^{87}Sr/^{86}Sr_0$ ratio analyzed by K. Shibata. n.d., not determined.

Table 3 Chemical compositions of granitoids and gneisses of the Nissho granitic complex.

Rock Type	Tn	Gneiss	Gneiss	Gd	Gb	Gb	Gb	Gb	Gbp
Sample No.	74HK41	74HK76	74HK42	74HK44	74HK71	74HK73	74HK39	74HK45	74HK81
SiO_2	61.78	65.88	64.65	66.64	69.24	73.43	75.03	76.66	72.13
TiO_2	.84	.62	.68	.55	.37	.27	.23	.16	.30
Al_2O_3	17.38	16.28	16.15	16.13	15.52	13.90	13.12	12.55	14.31
Fe_2O_3	.72	.64	.60	.52	.35	.44	.32	.24	.44
FeO	4.71	3.81	4.17	3.34	2.48	1.40	.93	.75	1.76
MnO	.09	.07	.08	.06	.05	.03	.03	.02	.03
MgO	2.35	1.93	2.35	1.14	.95	.27	.20	.09	.57
CaO	4.18	2.81	2.68	2.61	2.19	1.20	.96	.64	1.84
Na_2O	4.32	3.98	4.01	4.30	4.24	4.10	3.75	3.60	3.97
K_2O	2.23	2.78	3.69	3.70	3.72	4.16	4.71	4.81	3.70
P_2O_5	.22	.14	.17	.14	.11	.07	.05	.07	.10
H_2O^+	.68	.54	.28	.54	.36	.31	.31	.19	.44
H_2O^-	.06	.12	.10	.06	.04	.04	.08	.04	.08
Others	.13	.10	.09	.05	.05	—	—	—	.44
Total	99.69	99.70	99.70	99.78	99.67	99.62	99.72	99.82	100.11
T.C	170	10	20	70	20	5	20	30	4,350
S	1,110	970	940	400	530	10	5	5	60
Cu	4	28	18	16	9	4	1	2	5
Zn	350	86	75	62	45	33	23	21	38
Pb	9	14	21	16	19	18	23	22	18
Li	173	50	52	53	57	56	67	92	57
Cl	35	20	20	10	30	80	35	55	60
F	270	490	400	430	390	320	250	620	420
Rb	77	113	118	111	125	183	148	208	121
Sr	226	197	179	149	167	54	55	21	120
Sn	2.6	3.2	2.6	2.4	2.2	8.2	2.1	4.6	2.2
Be	1.7	2.0	1.4	1.5	1.9	2.6	1.7	2.7	1.6
As	7.2	2.6	.8	1.9	1.5	1.8	.8	7.5	.6
$^{87}Sr/^{86}Sr_0$	0.7046	0.70513	n.d.	n.d.	(0.7046)*	n.d.	n.d.	(0.7046)*	n.d.
Kai	18	6	13	10	11	4	5	7	8
Q	13.17	21.05	15.62	18.34	22.84	30.06	32.47	35.57	29.26
C	.79	1.95	1.09	.64	.80	.64	.23	.43	.67
or	13.18	16.43	21.81	21.87	21.98	24.58	27.83	28.43	21.87
ab	36.55	33.68	33.93	36.39	35.88	34.69	31.73	30.46	33.59
an	19.30	13.03	12.18	12.03	10.15	5.50	4.44	2.72	8.47
wo	—	—	—	—	—	—	—	—	—
wo-di	—	—	—	—	—	—	—	—	—
en-di	—	—	—	—	—	—	—	—	—
fs-di	—	—	—	—	—	—	—	—	—
en-hy	5.85	4.81	5.85	2.84	2.37	.67	.50	.22	1.42
fs-hy	6.83	5.57	6.19	4.91	3.75	1.82	1.12	.95	2.43
fo-ol	—	—	—	—	—	—	—	—	—
fa-ol	—	—	—	—	—	—	—	—	—
mt	1.04	.93	.87	.75	.51	.64	.46	.35	.64
hm	—	—	—	—	—	—	—	—	—
il	1.60	1.18	1.29	1.04	.70	.51	.44	.30	.57
ap	.51	.32	.39	.32	.25	.16	.12	.16	.23
Others	.87	.76	.47	.65	.45	.35	.39	.23	.96
Total	99.69	99.70	99.70	99.78	99.67	99.62	99.72	99.82	100.11
Q+ab+or	62.90	71.15	71.36	76.59	80.70	89.33	92.03	94.46	84.72

( )* Those used in the isochron age determination (Shibata and Ishihara, 1979a). Tn, tonalite; Gd, granodiorite; Gb, biotite granite; Gbp, porphyritic biotite granite

Table 4 Chemical composition of the Oligocene gneisses and granitoids along Saruru river area.

Rock Type	Gneisses					Granite	Tonalites	
Sample No.	74HK93	74HK91A	74HK91B	74HK87	74HK94A	74HK94B	74HK94C	74HK95
SiO_2	62.38	63.63	64.95	66.44	64.79	65.34	63.89	63.96
TiO_2	.69	.70	.62	.48	.51	.49	.75	.66
Al_2O_3	16.93	15.17	16.42	16.92	16.62	16.95	16.82	17.02
Fe_2O_3	1.31	.70	1.04	.68	1.44	.56	.76	.66
FeO	3.81	4.49	4.02	3.09	3.38	3.02	4.02	3.77
MnO	.07	.11	.09	.08	.07	.09	.10	.11
MgO	2.49	3.28	2.32	1.90	2.11	2.03	2.89	2.66
CaO	3.62	3.29	2.58	3.14	3.35	3.10	3.92	3.72
Na_2O	3.59	2.72	3.02	3.32	3.94	3.05	3.10	3.28
K_2O	2.28	3.18	2.40	2.52	2.05	3.63	2.40	2.48
P_2O_5	.06	.18	.16	.07	.05	.29	.13	.18
H_2O^+	1.27	2.07	1.51	.81	.82	.99	.81	.97
H_2O^-	.10	.04	.10	.02	.34	.08	.02	.14
Others	.84	.12	.46	.25	—	.07	—	.07
Total	99.44	99.68	99.69	99.72	99.47	99.69	99.61	99.68
T.C	1,140	1,200	1,700	180	170	70	160	20
S	6,800	220	2,900	2,130	5,600	580	1,400	570
Cu	97	9	31	29	71	8	17	9
Zn	64	76	88	54	58	56	70	78
Pb	13	11	14	22	20	22	13	14
Li	37	27	36	43	33	34	38	45
Cl	80	15	55	50	n.d.	105	n.d.	n.d.
F	340	260	390	190	n.d.	300	n.d.	n.d.
Rb	68	88	82	78	68	73	71	90
Sr	369	350	300	320	335	347	328	322
Sn	.6	.6	1.2	1.4	.2	.2	.2	.8
Be	1.3	1.2	1.2	1.5	2.0	1.0	1.5	1.5
As	.9	.2	.6	.6	n.d.	3.6	n.d.	.4
$^{87}Sr/^{86}Sr_0$	n.d.	n.d.	n.d.	0.7062*	0.7055	0.7047	n.d.	n.d.
Kai	13	11	34	13	28	14	22	15
Q	19.24	21.15	27.08	26.09	21.88	22.83	21.74	21.46
C	2.12	1.70	4.55	3.19	1.95	3.06	2.31	2.61
or	13.47	18.79	14.18	14.89	12.11	21.45	14.18	14.66
ab	30.38	23.02	25.55	28.09	33.34	25.81	26.23	27.75
an	17.57	15.15	11.75	15.12	16.29	13.48	18.60	17.28
wo	—	—	—	—	—	—	—	—
wo-di	—	—	—	—	—	—	—	—
en-di	—	—	—	—	—	—	—	—
fs-di	—	—	—	—	—	—	—	—
en-hy	6.20	8.17	5.78	4.73	5.26	5.06	7.20	6.63
fs-hy	4.90	6.71	5.67	4.47	4.30	4.44	5.70	5.49
fo-ol	—	—	—	—	—	—	—	—
fa-ol	—	—	—	—	—	—	—	—
mt	1.90	1.01	1.51	.99	2.09	.81	1.10	.96
hm	—	—	—	—	—	—	—	—
il	1.31	1.33	1.18	.91	.97	.93	1.42	1.25
ap	.14	.42	.37	.16	.12	.67	.30	.42
Others	2.21	2.23	2.07	1.08	1.16	1.14	.83	1.18
Total	99.44	99.68	99.69	99.72	99.47	99.69	99.61	99.68
Q+ab+or	63.09	62.96	66.82	69.07	67.34	70.09	62.15	63.87

* Value on similar biotite gneiss of 74HK88

Table 5 Chemical compositions of the Oshirabetsu granodiorite, Nissho hornfels and Tomuraushi gabbroids.

Rock Type	Granodiorite		Hornfels	Gabbroids	
Sample No.	74HK84	74HK83	74HK46	74HK64	74HK65
SiO_2	65.97	67.07	63.79	50.76	51.74
TiO_2	.66	.73	.70	1.40	.65
Al_2O_3	16.10	15.39	17.09	18.31	17.95
Fe_2O_3	.68	.68	.52	.47	.67
FeO	3.09	3.23	4.99	7.37	5.89
MnO	.07	.08	.08	.16	.14
MgO	2.09	1.78	2.03	6.31	7.43
CaO	3.17	2.53	2.88	10.74	9.98
Na_2O	3.82	3.86	3.40	3.36	3.47
K_2O	2.56	3.38	2.59	.24	.47
P_2O_5	.13	.14	.17	.19	.11
H_2O^+	.90	.38	.69	.30	1.26
H_2O^-	.18	.06	.28	.06	.06
Others	—	—	—	.06	—
Total	99.42	99.31	99.21	99.73	99.82
T.C	230	120	2,080	320	20
S	350	270	4,880	860	20
Cu	23	29	45	23	5
Zn	56	60	94	72	50
Pb	16	20	27	8	9
Li	46	58	37	9	5
Cl	n.d.	n.d.	n.d.	30	115
F	n.d.	n.d.	n.d.	100	80
Rb	84	120	100	3	9
Sr	271	219	347	270	221
Sn	1.2	1.8	1.0	.2	.8
Be	1.5	1.8	2.0	.6	.7
As	n.d.	n.d.	2.5	.4	.2
$^{87}Sr/^{86}Sr_0$	n.d.	n.d.	0.7051*	0.7033	0.7039**
Kai	8	17	11	23	13
Q	22.52	22.04	21.87	—	—
C	1.59	1.12	3.86	—	—
or	15.13	19.97	15.31	1.42	2.78
ab	32.32	32.66	28.77	28.43	29.36
an	14.88	11.64	13.18	34.17	32.01
wo	—	—	—	—	—
wo-di	—	—	—	7.46	7.01
en-di	—	—	—	4.19	4.36
fs-di	—	—	—	2.97	2.23
en-hy	5.21	4.43	5.06	5.45	6.75
fs-hy	4.15	4.31	7.73	3.86	3.45
fo-ol	—	—	—	4.25	5.18
fa-ol	—	—	—	3.32	2.92
mt	.99	.99	.75	.68	.97
hm	—	—	—	—	—
il	1.25	1.39	1.33	2.66	1.23
ap	.30	.32	.39	.44	.25
Others	1.08	.44	.97	.42	1.32
Total	99.42	99.31	99.21	99.73	99.82
Q+ab+or	69.97	74.67	65.94	29.85	32.14

*Sandstone hornfels of the southernmost, Oshirabetsu area gives low ratio as 0.7043 (SHK51). **Ratio on similar quartz diorite (74HK61) from the same body. Tomuraushi granitoids of biotite tonalite (74HK59) has higher ratio as 0.70503.

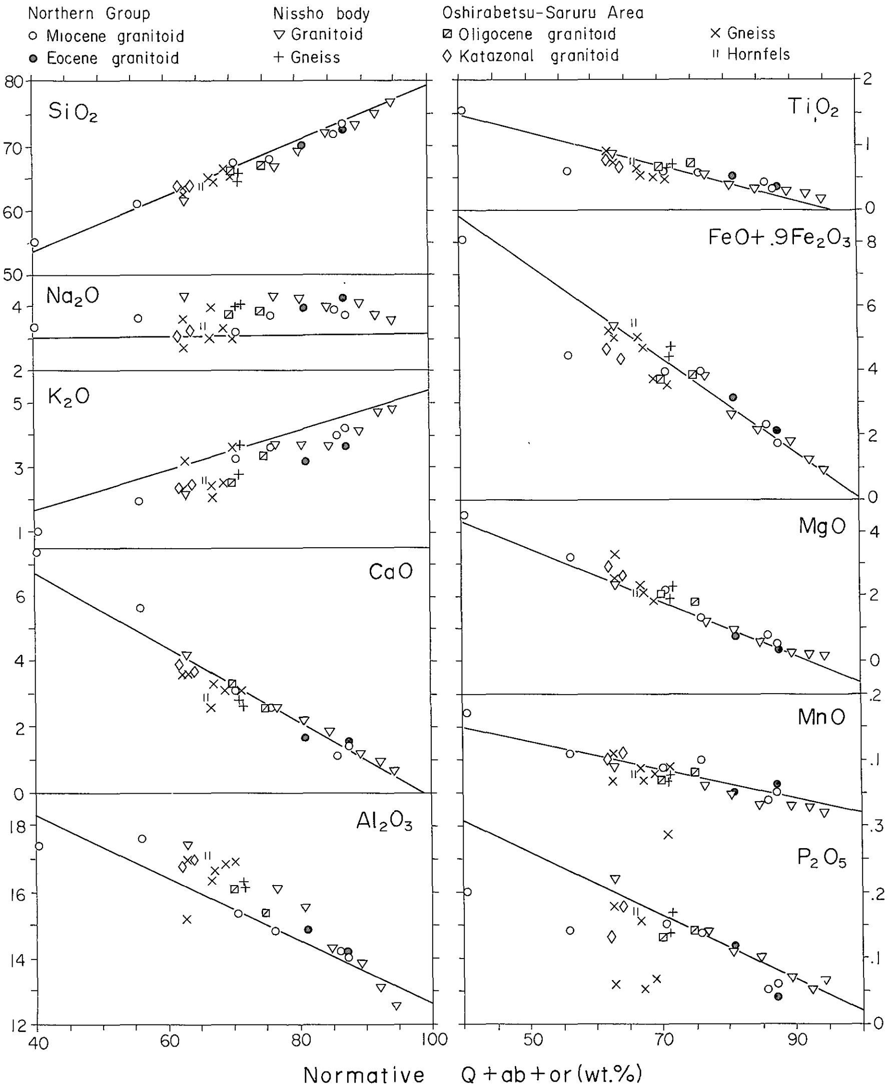

Fig. 5a Variation diagram for major elements of granitoids, central Hokkaido. Straight line indicates regression line of the Outer Zone granitoids of Southwest Japan (Ishihara *et al.* unpublished data).

depleted in Cl, F, Rb, Li, Pb, Sn, Be and As. That is, they are "oceanic" rather than "continental" in their minor element chemistry.

Areal Variation

Cenozoic granitoids of central Hokkaido have areally little variation on their distribution pattern of major elements (Fig. 5a), and appear to have originated in common source rocks. Eocene granitoids of the Uttsu and Monbetsu plutons are, however, lower in K_2O and Li, and higher in Cl than the other rock, having general characteristics of the magnetite-series granitoids in Honshu Islands.

Gneisses of the migmatite zone are different from the granitoids. They have a narrow range of normative Q+ab+or (62–71 wt.%), among which those of the Nissho granitic complex take higher range around 71 wt.%. Even

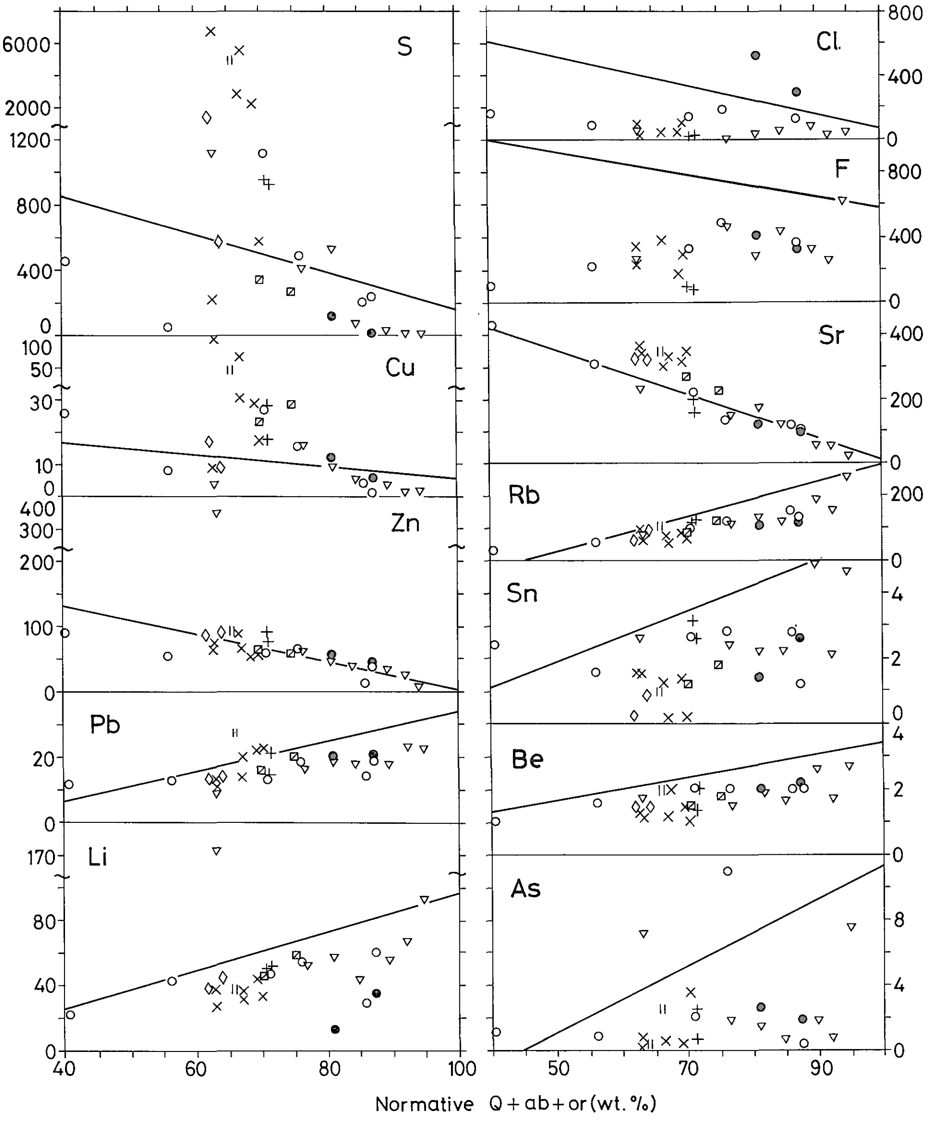

Fig. 5b Variation diagram for minor elements of granitoids, central Hokkaido. Straight line same as in Fig. 5a.

thermally metamorphosed shale (74HK46) fall in the same range, indicating that sandstone and shale of the Hidaka Supergroup contain abundantly igneous fragments of dacitic or more mafic composition.

In the variation diagrams (Figs. 5a, b), the metamorphic rocks are plotted along the differentiation trend of granitoids at tonalite-granodiorite composition, although P_2O_5 is deviated to wide but generally lower range, and S, Cu and Sr are biased to higher range. These again imply that the metamorphic rocks are composed of clatics originated in the source area where mafic igneous rocks are predominant and were homogenized during the metamorphism.

Alkali Ratio and Rb/Sr Content

Additional fresh and least altered rocks were selected for partial chemical analyses. The results are listed in Table 6. In CaO–

Table 6 Partial chemical analyses of Cenozoic granitic and metamorphic rocks from central Hokkaido

Sample No.	Rock name	CaO (%)	Na_2O (%)	K_2O (%)	Total (%)	Sr (ppm)	Ca/Sr	Rb (ppm)	K/Rb	Be (ppm)	Sn (ppm)
Otchube											
74HK09	Hb-Bt Gd	5.32	3.88	2.04	11.24	307	124	55	307	1.6	1.5
74HK06	(Hb-)Bt MzG	3.12	3.04	3.48	9.64	216	103	103	281	2.3	n.d.
74HK07	Bt MzG	3.12	3.00	3.50	9.62	216	103	100	291	2.0	2.6
74HK10	*ditto*	2.36	3.46	3.51	9.33	174	97	123	237	1.6	2.8
74HK08	*ditto*	1.33	3.84	4.20	9.37	98	97	125	279	2.0	1.2
Average		3.05	3.44	3.35	9.84	202	105	101	279	1.9	2.0
Okushibetsu											
74HK29	Bt MzG	1.15	3.90	4.00	9.05	116	71	145	229	2.1	2.7
Ichinohashi											
74HK27	Cpx-Hb-Bt Qd	7.22	3.51	1.04	11.77	242	213	30	287	1.0	2.4
74HK26	Hb-Bt MzG	2.51	3.80	3.56	9.87	136	132	120	247	2.0	2.8
74HK28	(Hb-)Bt MzG	2.19	3.62	3.75	9.56	151	104	126	247	1.8	3.9
Average		3.97	3.64	2.78	10.40	176	150	92	260	1.6	3.0
Uttsu pluton											
74HK21	Hb-Bt MzG	1.40	4.42	3.55	9.37	93	108	117	252	2.0	2.6
74HK16	(Hb-)Bt MzG	1.38	4.00	3.66	9.04	91	107	122	249	1.9	1.2
Monbetsu											
74HK24	Bt MzG	1.56	3.91	3.14	8.61	118	95	102	256	2.0	1.4
74HK25	*ditto*	1.50	4.22	3.18	8.90	128	84	102	259	2.0	2.2
Nissho											
74HK41	Cpx-Hb-Bt Tn	4.04	4.34	2.36	10.74	226	128	77	255	1.7	2.6
74HK79	(Cpx-Hb-)Bt Gd	3.40	3.88	2.86	10.14	202	120	88	269	1.8	n.d.
74HK77	Hb-Bt Gn	2.35	4.00	3.66	10.01	150	112	111	274	1.6	2.4
74HK76	Bt Gn	2.72	4.25	2.90	9.87	197	99	113	213	2.0	3.2
74HK78	Bt Gn	2.10	3.71	4.21	10.02	145	104	125	280	1.5	n.d.
74HK42	Bt Gn	2.56	3.66	3.80	10.02	179	102	118	268	1.4	2.6
74HK43	Bt Ga (20 cm wide)	1.38	3.15	4.87	9.40	116	84	118	342	1.0	2.6
74HK75	Bt MzG	2.33	3.53	3.63	9.49	197	85	108	279	1.3	2.0
74HK44	Cpx-Hb-Bt Gd	2.55	4.35	3.85	10.75	149	122	111	288	1.5	2.4
74HK74	Bt Gd	2.88	3.70	3.05	9.63	221	92	110	230	1.3	n.d.
74HK73	Bt MzG	1.15	4.07	4.27	9.49	54	152	183	194	2.6	8.3
74HK72	Bt SyG (irreg. pool)	1.05	3.63	5.02	9.70	52	144	172	242	2.0	4.6
74HK40	Bt MzG	2.32	3.82	3.66	9.80	176	94	108	282	1.5	2.8
74HK71	*ditto*	2.10	3.90	3.88	9.88	167	90	125	258	1.9	2.2
74HK37	*ditto*	0.80	3.45	4.84	9.09	n.d.	n.d.	n.d.	n.d.	n.d.	2.8
74HK39	*ditto*	0.91	3.38	4.81	9.10	55	118	148	270	1.7	2.1
74HK45	*ditto*	0.58	3.70	4.95	9.23	21	200	208	198	2.7	4.6
74HK81	*ditto*	1.82	3.90	3.82	9.54	120	108	121	262	1.6	2.2
74HK80	*ditto*	1.74	3.84	4.00	9.58	113	110	122	272	1.4	2.4
74HK50	Hb-Bt Gd	2.93	3.93	3.42	10.28	176	119	109	261	2.0	n.d.
Average (granitoids)		2.04	3.83	3.90	9.76	138	120	129	254	1.8	3.1

ditto (*gneisses*)		2.43	3.91	3.64	9.98	168	104	117	259	1.6	2.7
74HK46	Bt hornfels	2.34	3.00	3.14	8.48	347	48	100	261	2.0	1.0
Tomuraushi											
74HK54	Bt Gn	3.06	3.70	2.81	9.57	295	74	84	277	1.6	1.6
74HK55	(Mus-)Bt Gn	2.49	3.17	2.95	8.61	312	57	92	266	2.0	n.d.
74HK62	Bt schist	2.25	3.26	4.37	9.88	201	80	100	363	0.8	0.4
74HK59	Bt Tn	3.62	3.72	2.65	9.99	272	95	80	275	2.0	n.d.
74HK60	Bt Gd	2.28	3.38	4.18	9.84	232	70	120	289	1.3	1.4
74HK57	Hb-Bt SyG	0.76	3.96	4.88	9.60	32	169	170	238	2.1	n.d.
Gabbroids, Tomuraushi											
74HK64	Cpx-Hb gabbro	10.06	3.51	0.24	13.81	270	266	3	667	0.6	0.2
74HK65	Hb gabbro	9.43	3.50	0.48	13.41	221	305	9	444	0.7	0.8
74HK61	Bt-Hb Qd	8.35	3.27	1.12	12.74	254	235	30	310	0.8	0.6
74HK56	Bt-Hb Qd, dike, 20 m	7.25	3.25	1.26	11.79	269	193	36	292	1.1	n.d.
74HK47	(Bt-)Hb gabbro	8.91	3.47	1.16	13.54	181	352	27	356	1.0	n.d.
74HK48	Bt-Hb Tn-Gd	6.00	3.90	2.00	11.90	171	251	60	277	1.5	n.d.
Saruru River											
74HK86	Graph-Bt Gn	3.28	3.41	2.66	9.35	345	68	82	270	1.5	n.d.
74HK87	Bt Gr-Gn	3.10	3.42	2.68	9.20	320	69	78	286	1.5	1.4
74HK88	*ditto*	3.32	3.40	2.45	9.17	345	69	62	294	1.5	n.d.
74HK89	(Mus-)Bt Gn	2.87	3.56	2.51	8.51	293	70	96	217	1.9	1.0
74HK90	Bt Tn	3.35	3.71	2.85	9.91	332	72	88	269	1.5	1.0
74HK91A	Bt Gn	3.10	2.70	3.24	9.04	350	63	88	306	1.2	0.6
74HK91B	Bt Gn	2.42	3.12	2.48	8.02	300	58	82	251	1.2	1.2
74HK92	Bt Gn	2.30	2.97	2.45	7.72	293	56	74	274	1.5	n.d.
74HK93	Graph-Bt Gn	3.38	3.75	2.30	7.43	369	66	68	281	1.3	0.2
74HK94A	Bt Gn	3.35	3.94	2.05	9.34	347	69	64	266	1.5	0.2
74HK94B	Bt MzG	2.91	3.10	3.55	9.56	347	60	73	404	1.0	0.2
74HK94C	Bt Tn	3.92	3.10	2.40	9.42	345	81	72	276	1.0	0.2
74HK95	Bt Tn	3.58	3.41	2.51	9.50	322	80	90	231	1.5	0.8
Average (*Granitoids*)		3.44	3.33	2.87	9.60	337	73	81	295	1.3	0.6
ditto (*gneisses*)		3.09	3.49	2.44	8.96	330	67	75	270	1.5	0.8
Oshirabetsu											
74HK84	Bt Gd	3.17	3.82	2.56	9.55	271	84	84	254	1.5	1.2
74HK85	(Hb-)Bt Gd	3.15	3.64	3.07	9.86	229	98	95	268	1.5	n.d.
74HK82	Bt MzG	2.85	3.85	3.22	9.92	229	89	100	267	1.4	n.d.
74HK83	Bt MzG	2.53	3.86	3.38	9.77	219	83	120	234	1.8	1.8
Average		2.93	3.79	3.06	9.78	237	89	100	256	1.6	1.5
Sediments, Oshirabetsu											
SHK46	Fine sandstone, Hf	2.88	3.40	2.59	8.87	420	49	74	291	1.8	n.d.
SHK47	Fine sandstone, Hf	3.05	3.56	2.60	9.21	415	53	61	354	1.7	1.2
SHK51	Fine sandstone, Hf	3.63	3.93	2.10	9.66	610	43	52	335	1.6	1.2
Average		3.19	3.63	2.43	9.25	482	48	62	327	1.7	1.2

Abbreviation: Cpx, clinopyroxene; Hb, amphibole; Bt, biotite; Mus, muscovite; Graph, graphite; Qd, quartz diorite; Tn, tonalite; Gd, granodiorite; MzG, monzogranite; SyG, syenogranite; Ga, aplite; Gn, gneiss; Gr-Gn, granitic gneiss, Hf, hornfels; n. d., not determined.

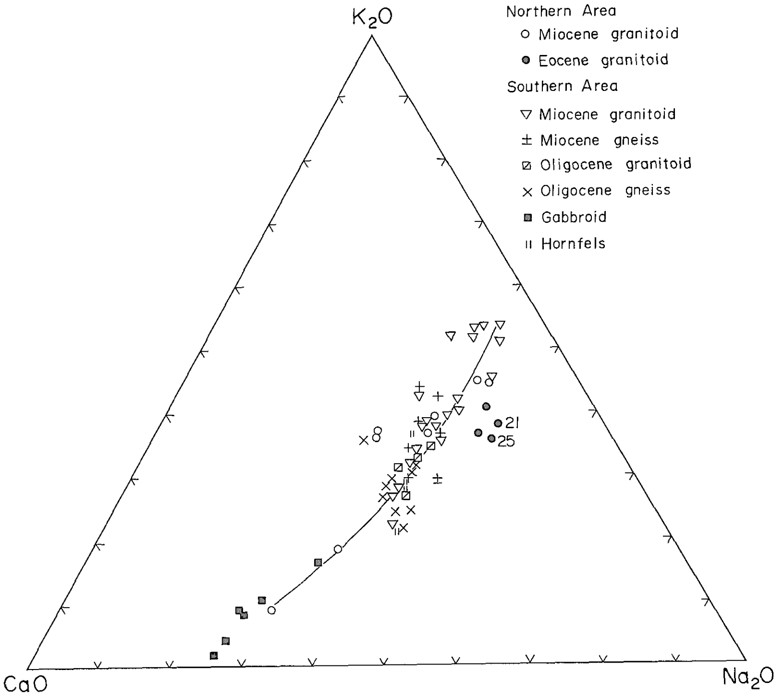

Fig. 6 Alkali variation of the studied plutonic rocks of central Hokkaido.

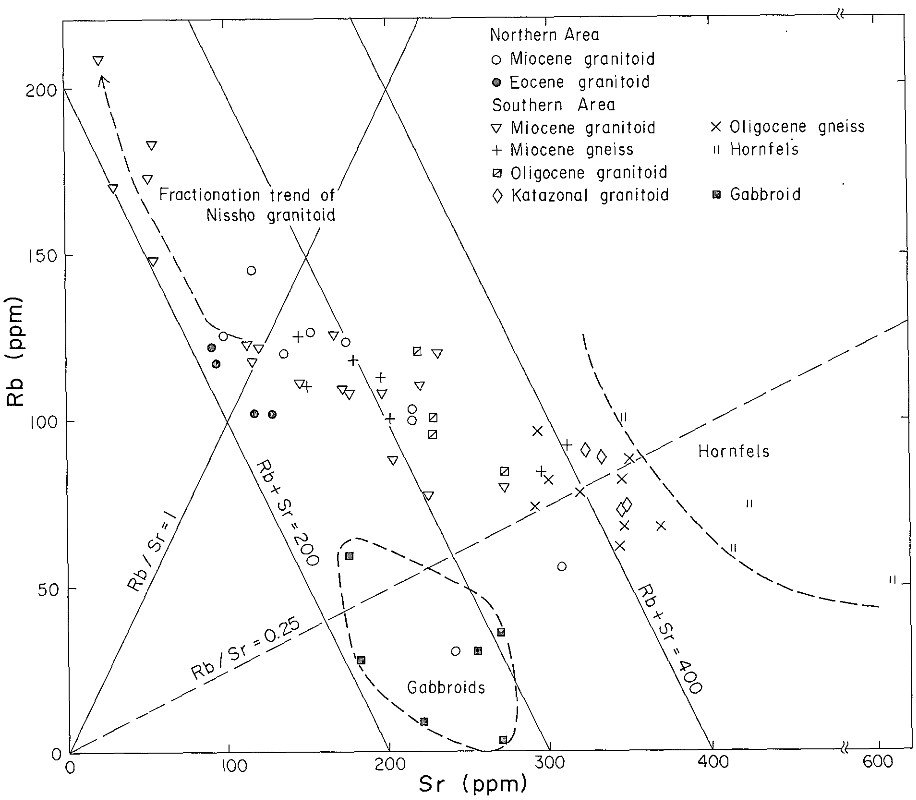

Fig. 7 Rb-Sr variation of the studied plutonic rocks of central Hokkaido.

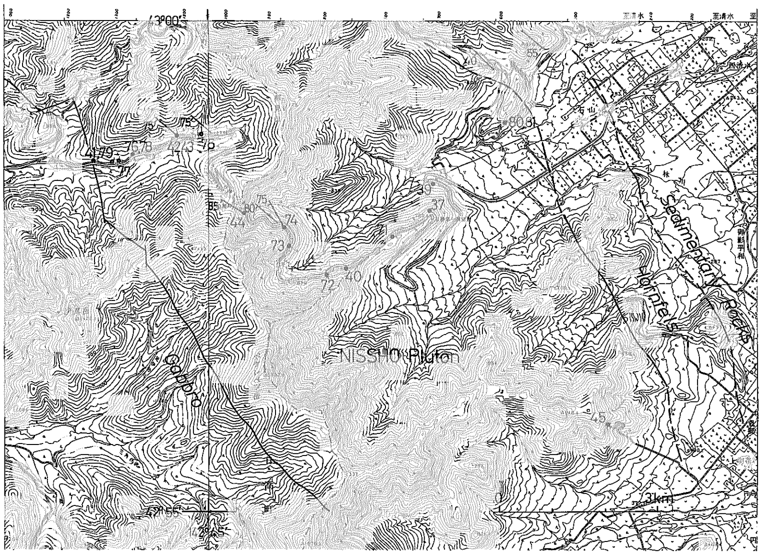

Fig. 8 Sample locality across the Nissho granitic complex. The last two digits of the sample number are shown.

Na_2O-K_2O diagram (Fig. 6), most of the studied rocks are plotted along the trend of average composition of Japanese granitoids by ARAMAKI *et al.* (1972). Among the northern group granitoids, however, Eocene ones are clearly more sodic than the Miocene ones, but this tendency is not observed on the Oligocene-Miocene granitoids pair in the southern group plutons. Thus the sodic characteristics are unique on the granitoids of the Uttsu and Monbetsu plutons. K_{65} value (K_2O % at 65% SiO_2) for the Eocene granitoids is 2.2%, while that of other plutons is 2.7-3.1% (ISHIHARA and TERASHIMA, 1980).

Eocene granitoids are also different in Sr plus Rb contents from the other granitoids (Fig. 7). They are low in the content similarly to gabbroids. On the contrary, sandstone and shale of the Hidaka Supergroup are rich in this content, *i.e.*, Sr plus Rb more than 450 ppm, which is due largely to high content of Sr. All the other granitoids are seen between the contents of gabbroids and hornfels, indicating their origin of mixture of the two end-members. Sr and Rb content of the katazonal granitoids of the migmatite zone are very close to that of hornfels (Fig. 7).

K/Rb ratio is highest in gabbroids (average 411, n=5 excluding dike, Table 6). Most of the other rocks including granitoids, gneisses and even shale hornfels of wall rocks have narrow range around 250, but sandstone hornfels is depleted in Rb and its K/Rb ratio is about 345. Ca/Sr ratio is highest in gabbroids (average 282, n=5 excluding dike) and is lowest in sedimentary rocks (average 48, n=4). The ratio of granitoids and gneisses fall between these two values but is more close to that of the sedimentary rocks.

Rb/Sr ratio decreases generally as the magmatic differentiation advanced. This is especially remarkable in the case of ilmenite-series granitic magmas (ISHIHARA and TERASHIMA, 1977a). The ratio of the studied granitoids is highest in the Nissho body (~9.9), which is followed by the Tomuraushi (~5.3), Otchube, Okushibetsu and Uttsu (~1.3), and the Oshirabetsu granitoids are poorly differentiated (~0.55). Katazonal granitoids of Saruru river are the most primitive one (~0.22).

Lateral Variation across the Nissho Pluton

As mentioned previously, granitoids of the Nissho pluton vary in texture and composi-

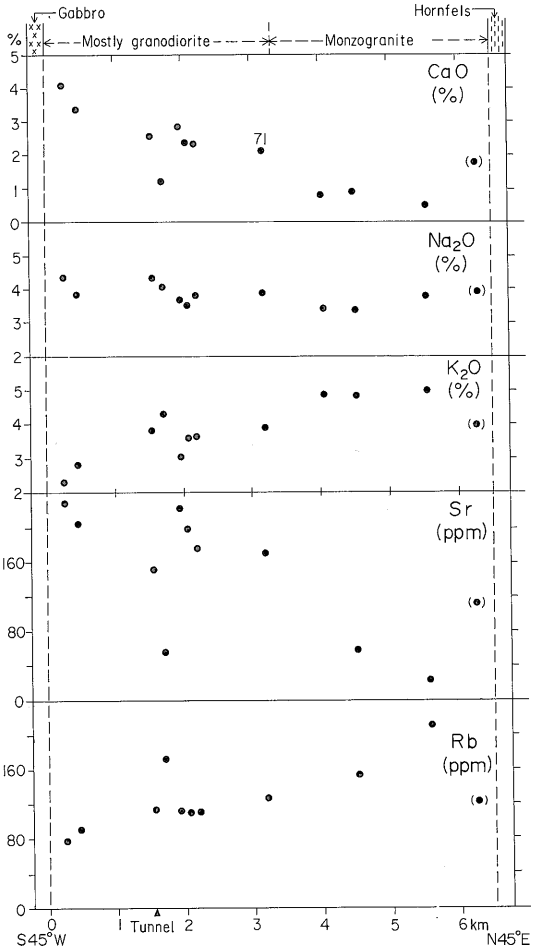

Fig. 9 E-W variation of selected components across the Nissho granitic comple. The samples 74HK80 and 81 are in parenthesis, because they belong to different intrusive phase from the main phase rocks.

tion in an E-W direction. The granitoids are often foliated and calcic in the western part (Fig. 8), while they are massive and felsic in the eastern part.

Figure 9 illustrates content variation of CaO, Na_2O and K_2O across the main part of the Nissho body diagonal to the foliation. CaO decreases steadily and K_2O increase northeastward. Sr is similarly decreases and Rb increases toward the same direction.

The general felsic characteristics toward the eastern side of the Nissho granitic complex are similar to vertical change in the Ohkue granitic complex of the Outer Zone of Southwest Japan (Fig. 10), which was interpreted as typical example of fossiled zoned magma chamber existed in Miocene time (TAKAHASHI, 1980). In the Nissho body migmatites occur at the western margin, and thus calcic western part appears to be originally a deeper part of the body. Moreover, foliated granitoids and gneisses do not show protoclastic texture but wavy extinction on quartz and biotite in some degrees. Thus, the stress effect is weak and the foliation is considered to have been formed by not NW-SE shearing but load pressure and gravity settling of the rock-forming minerals. Based on this interpretation, we could turn the body back about 90° to the northwest, to reconstruct the original position, because of nearly vertical dip of the foliation. What we see across at present would imply the vertical change of some 10 km of the upper most part of the island-arc crust at the time of intrusion.

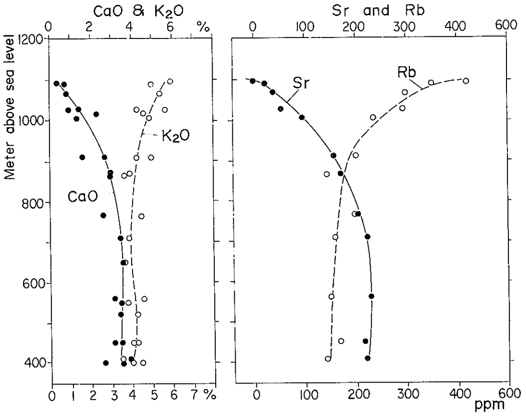

Fig. 10 Vertical variation of selected components across the Ohkue granitic complex, Kyushu (ISHIHARA and TERASHIMA, unpublished data).

Discussions

Magma Genesis

In our earlier work of sulfur isotope analyses (SASAKI and ISHIHARA, 1979), we

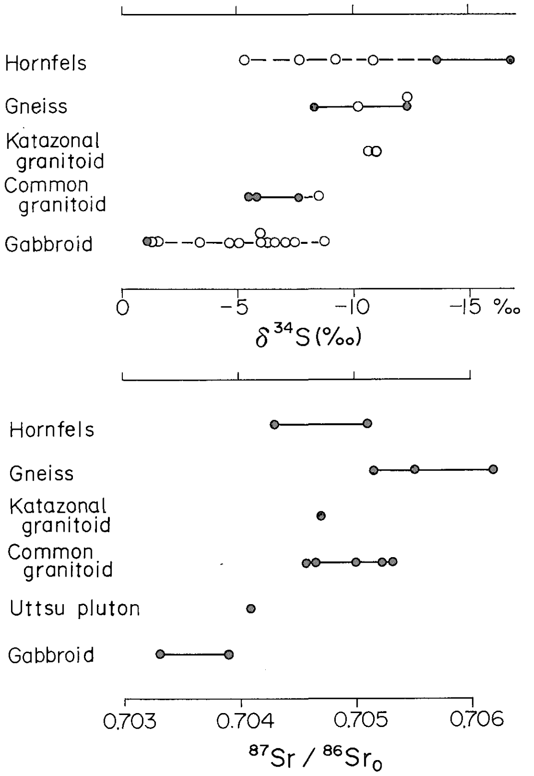

Fig. 11 $\delta^{34}S$ of rock sulfur and initial strontium ratio of plutonic rocks of central Hokkaido. Open circle of the sulfur data is taken from TAKAHASHI and SASAKI (1983). The strontium data from SHIBATA and ISHIHARA (1979a, b) and Tables 2 to 5. Common granitoids include Miocene granitoids of the northern and southern group plutons and Oligocene granitoids.

have pointed out that a significant contribution of sedimentary sulfur for the genesis of granitoids of central Hokkaido. Figure 11 summarizes the previous data which clearly indicate a gradual decreasing tendency of $\delta^{34}S$ of the rock sulfur from the gabbroids and granitoids to gneisses and sedimentary rocks.

TAKAHASHI and SASAKI (1983) studied in detail gabbroids and related Ni-bearing pyrrhotite-graphite deposits which occur near the Oshirabetsu pluton in the southernmost part. They found only toloctolite has $\delta^{34}S$ value ($-1.6\sim-1.7$ ‰) close to that of our freshest gabbro (74HK64, -1.1 ‰), and $\delta^{34}S$ of the rock sulfur decreases as the gabbroid magma differentiate to diorite (down to -8.7 ‰). They considered the negative values resulted from the mixing of biogenic sulfur from the sedimentary wall rocks to gabbroid magmas in each differentiation stage, and estimated more than 50% of sulfur was introduced from the wall rocks in assuming the initial gabbroid magma of -1 ‰ and the sedimentary sulfur of -9 ‰

$\delta^{34}S$ values of gneisses and katazonal granitoids are within the range of hornfels and sedimentary wall rocks. Thus all sulfur of the gneisses and granitoids are considered to have derived from the sedimentary rocks. $\delta^{34}S$ values of the other, common granitoids are similar to those of the differentiated gabbroids of TAKAHASHI and SASAKI (1983), so that similar mixing ratio to that of the gabbroids is applicable for the granitic magma. Slightly negative value for the 74HK64 gabbro indicates that sulfur is mobile and sedimentary sulfur is incorperated even in rocks whose silicate minerals are fresh.

Data of initial $^{87}Sr/^{86}Sr$ ratio (SHIBATA and ISHIHARA, 1979b) are also summarized with some additional data in Figure 11. The lowest value is obtained from the gabbroids and the next one from the intermediate-series granite of the Uttsu pluton. In assuming the freshest 74HK64 gabbro (0.7033) originated in the upper mantle, slightly higher values for diorite of the gabbroid member (0.7039) and the Uttsu granite (0.7041) imply the original magmas assimilated only small amount of crustal materials.

Common ilmenite-series granitoids have the ratios of 0.7046–0.7053, which are higher than those of the gabbroids. Thus the granitoids were much more effected by the crustal materials than the Uttsu granitoids. The range of the ilmenite-series granitoids is similar to that of the hornfelses of the Hidaka Supergroup (0.7043–0.7051), which are mostly from the Nakanogawa Group of KONTANI (1980), and is lower than that of the gneisses (0.7051–0.7062), whose original

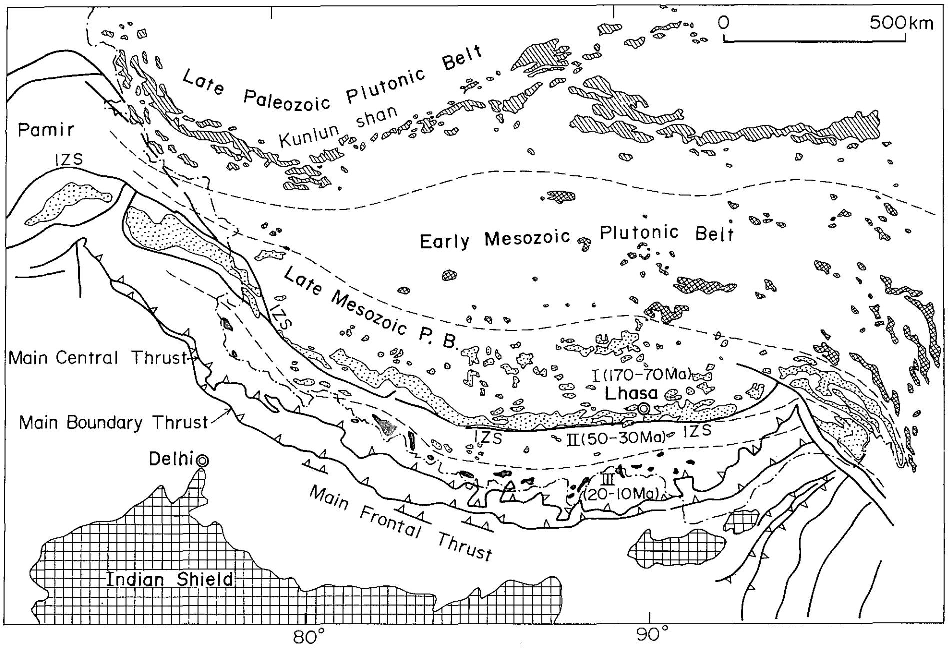

Fig. 12 Main plutonic belts across the Himalaya-Kunlun region. I, Late Mesozoic Trans-Himalaya plutonic belt; II, Paleogene Tibetan Himalaya plutonic belt; III Neogene High Himalaya Plutonic belt. IZS, Indus-Zangbo suture zone where ophiolites occur. Compiled from Tu *et al.* (1982), Dietrich and Gansser (1981) and Gansser (1964).

rocks are possibly different from the rocks of the Nakanogawa Group. These general low values of initial $^{87}Sr/^{86}Sr$ ratio over all the rock types are characteristics of the Hidaka belt, indicating the absence of older continental crust rich in rubidium prior to the granitic magmatism and even before the sedimentation of the Hidaka Supergroup. Clastics of the Hidaka Supergroup in the southern part of the Hidaka terrane, *i.e.*, the Nakanogawa Group, are considered to have derived from a tectonic and volcanic terrane mainly occupied by felsic to intermediate volcanic rcoks and sedimentary rocks by modal analyses of the sandstones (Kontani, 1980). Our limited chemical data suggest the source rocks composed of low-K volcanic rocks, which could have formed an inmatured island arc in then-existed oceanic envirnment.

Most of the other chemical components are also associated among the hornfelses, gneisses and granitoids. Strontium and rubidium contents of calcic phases of the granitoids, for example, fall between those of the gneisses and gabbroids, though more akin to the gneisses, then follow fractionation trend of these components in granitic magmas (Fig. 7).

Chemistry of the granitoids is very much related in another respect to that of the surrounding gneisses and hornfels. Average contents of strontium and rubidum, for example, vary areally as follows (see also Table 6):

The chemical similarity of the granitoids to the surrounding crustal materials suggests that the granitic magmas were very much affected by the rocks whereby the magmas intruded. However, the magmas may not have been formed directly by partial melting of the wall rocks, instead initiated by mantle-derived primary magma of either gabbroic or tonalitic composition and assimilated more than 50 percent of the wall rocks.

Rock type	Nissho area		Saruru area	
	Sr (ppm)	Rb (ppm)	Sr (ppm)	Rb (ppm)
Hornfels	347	100	482	62
Gneisses	168	117	330	75
Granitoids	138	129	237	100

Table 7 Comparison of selected chemical components between the two regions: Hokkaido and Himalaya.

		Himalaya	Hokkaido
Neogene granitoids	SiO_2 (%)	72.6	72.2
	Fe_2O_3/FeO	0.56	0.22
	Na_2O/K_2O	0.86	0.97
Paleogene granitoids	SiO_2 (%)	72.4	71.2
	Fe_2O_3/FeO	0.70	0.33
	Na_2O/K_2O	0.98	1.19
Late Mesozoic granitoids	SiO_2 (%)	65.7	Not present
	Fe_2O_3/FeO	0.89	
	Na_2O/K_2O	1.02	

The Himalayan data are average values given by Tu *et al.* (1982). Neogene data of Hokkaido are the average of granites of the Nissho body (Table 3). Paleogene data of Hokkaido are the average of the Uttsu and Monbetsu stocks (see Table 2).

Comparison with the Himalayan Region

In the most famous collision region across the Himalaya-Qingzang plateau, there occur five plutonic belts from north to south of the late Paleozoic, early Mesozoic, late Mesozoic, Paleogene and Neogene ages (Fig. 12). Plutonic rocks of the southern half appear to be products of a series of granitic activity that occurred by northward subduction and by the final collision of the Indian plate against the Eurasian plate during Eocene time (Tu *et al.*, 1982; HONEGGER *et al.*, 1982; HUANG *et al.*, 1984).

The late Mesozoic, Trans-Himalayan plutonic belt is constituted by large composite batholiths of gabbroic to granitic composition with low strontium initial ratios (0.7047-0.7057) that belong to both magnetite series and ilmenite series (ISHIHARA, 1985) but I type (IIZUMI, 1983). They may be mantle-derived (DIETRICH and GANSSER, 1981) but partly anatectic (SCHÄRER *et al.*, 1984). The Paleogene Tibetan Himalaya plutonic belt is composed of fault-controlled small plutons of foliated two-mica granite, intruded into weakly metamorphosed, Paleozoic and Masozoic clastics (Tu *et al.*, 1982). The Neogene, High Himalaya granitoids consist of two-mica granite and tourmaline-muscovite granite of ilmenite series and S type, and are characterized by very high initial $^{87}Sr/^{86}Sr$ ratios (more than 0.77, DIETRICH and GANSSER, 1981), and intruded into metamorphic rocks of Precambrian to Mesozoic ages (Tu *et al.*, 1982).

The studied granitoids of central Hokkaido correspond to the Paleogene and Neogene granitoids of the Tibetan Himalaya and the High Himalaya. There are similar tendencies in the two regions that the granitoids become older in age and sodic and more oxidized in chemistry away from the core zone of the magmatic belts (Table 7), indicating an eastward subduction for the Hokkaido rocks, at least in the northern half, which proves the HORIKOSHI's (1972) initial proposal of eastward subduction to be valid. Yet this subduction must have been local and inactive, because of the limited amount of the magmatism.

Difference between two regions are very low ratios of Fe_2O_2/FeO in Hokkaido and very high ratios on the initial $^{87}Sr/^{86}Sr$ in the Himalayas. These differences imply that the intruded sedimentary rocks of Hokkaido have had a high carbon content, an extreme case of which is represented by graphite ore deposit at Oshirabetsu, and that older basement rich in rubidium did not exist before the sedimentary rocks deposited. The Himalayan granitoids, on the other hand, originated in older sialic crust (sediments and granitoids, DIETRICH and GANSSER, 1982), which had had S type characteristics already and higher Fe_2O_3/FeO ratio than the Hokkaido rocks.

Concluding Remarks

Granitic activities of central Hokkaido are considered to have occurred in inmatured island arcs associated with gabbroic activity during Eocene time onward. Mantle-derived primary magmas of probably tonalitic composition were successive to the gabbroic activity and assimilated a large amount of sedimentary rocks of the then-existing continental crust. The sedimentary rocks had originally I-type characteristics and may have contained abundantly carbonaceous materials, hence I-type ilmenite-series granitoids and graphite ore deposit were formed.

The studied results provides some constraints to the interpretation on the tectonic development of Hokkaido Island. Lateral variation of alkali content and ferric/ferrous ratio in the northern group plutons indicate eastward subduction or fracture zones related to the granitic magmatism. Chemical variation of the Nissho granitoids in the southern group plutons constrains the age of the thrusting and tilting of the southern Hidaka belt later than their whole rock Rb-Sr age of 17 Ma. What we can see there at present may be Miocene section of the upper part of the continental crust.

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北海道中央部の新生代花崗岩類—衝突帯深成活動の一例

石原舜三・寺島　滋

要　旨

北海道中軸帯には南北に伸長する花崗岩体が散在し，始新世—中新世の年代を示す．これらは産状から南北2群に分けられる．北部では小岩体が日高累層群の堆積岩類に貫入するもので，主に花崗閃緑岩と花崗岩からなり，文象花崗岩を伴い，電気石化を被る．これらはチタン鉄鉱系（うっつ岳岩体のみ中間系）マグマが浅所に貫入固結したものである．南部岩体群は規模が大きいが，変成岩帯と密接な狭いゾーンに分布する．西側は主に花崗閃緑岩質でミグマタイト，片麻岩などを夾み，これらと斑糲岩に貫入する．東側は主に花崗岩で一部に文象花崗岩を含み，日高層群（主に中の川層群）の堆積岩類に貫入し，これらにホルンフェルス化を及ぼしている．南部岩体群は全てチタン鉄鉱系岩体から構成される．

岩石帯磁率は一般に 10^{-5} emu/g で，低い．うっつ系岩体では 10^{4} emu/g の岩石がややまとまって現れる．前者の値の岩石ではチタン鉄鉱，磁硫鉄鉱，(黄銅鉱)などが一般的な不透明鉱物であり，後者では磁鉄鉱が出現する．斑糲岩ではチタン鉄鉱が多いことがあり(0.8%)，ミグマタイトや一部の花崗岩では磁硫鉄鉱が著しく多い．中軸帯花崗岩類は一般に硫黄に富んでいる．岩石の Fe_2O_3/FeO 比は不透明鉱物組合せから推定されるように，一般に低い値を示すが，その中で比較的酸化的なもの(うっつ系)，中間的なもの(北部岩体，中新世)，還元的なもの(日勝)とがある．

中軸帯の花崗岩類は西南日本外帯のものと，構造的位置，岩質，鉱物組合せ，主成分元素などで似るが，微量成分元素で異なり，Cl, F, Li, Rb, Pb, Sn, Be, As などに乏しい性格を持つ．始新世花崗岩類は Na_2O に富む傾向があり，Sr, Pb に乏しい．これらは Sr–Rb 図で斑糲岩と似た分布傾向を示す．一方，日高層群の堆積岩は砂岩，頁岩共に Sr に富んでいる．一般のチタン鉄鉱系花崗岩類は両者の中間的な値を持つ．

最大規模の日勝岩体では東西変化がみられ，西部は変成岩類を夾有する片状トナル岩，花崗閃緑岩が主体で，東方に漸次珪長質成分が増加し，最東部では Rb/Sr 比が著しく増加し，最も分化が進んでいる．この性質は西南日本外帯で一般的な岩体中の上下変化である(例，大崩山)．日勝岩体の変成岩や花崗岩類の片状構造を荷重圧によるものと考え，その方向を用いて岩体の復元を試みると，現在の露頭は西側が持上げられて約90度転位し，形成当時の上部大陸地殻断面を約10 km に亘って示していることになる．この転位は北海道西部と東部の2つの島弧の衝突によって生じたと考えることが合理的であり，日勝岩体の全岩 Rb–Sr 年代から推察してその最大転位の時期は 17 Ma 以降であったものと思われる．

岩石の S 同位体比は S の大部分が日高層群の堆積岩源であることを示している．Sr 同位体比も同様な傾向を示す．日高層群の堆積岩類は著しく低い Sr 初生値を有しており，その後背地には古い，あるいは Rb に富む大陸地殻は存在しない，大洋の島弧的環境が推定される．同位体，主微量成分共に，貫入の場の岩石の再溶融よりも，トナル岩質の初生マグマが地殻物質を大量に同化し，花崗岩質マグマを生成した存在量変化を示す．

著名な衝突帯であるヒマラヤ山塊の新生代花崗岩類と比較すると，北海道では時代，Fe_2O_3/FeO，Na_2O/K_2O 比が東方へ，ヒマラヤではこれらが北方へ増加する共通の広域的性格が認められる．この事実は衝突以前のマグマ活動が沈込み帯に関係したとすれば，北海道では東方に傾斜する沈込み帯が存在した可能性を暗示する．一方，相違点としては，Sr 初生値がヒマラヤで極めて高い，Fe_2O_3/FeO 比が北海道で著しく低い点などが顕著である．これらの原因は両地域の異なる基盤の性質に求められ，前者はヒマラヤ地域でみられる先カンブリア時代の花崗岩類で代表される様に古い珪長質基盤の存在に起因するものと考えられる．他方，後者の原因は北海道の古—中生代堆積岩類が地殻起源の C に富んで

いることに由来するものと思われ，それがチタン鉄鉱系花崗岩類を生んだのみならず，その濃集によって音調津グラファイト鉱床を生成するなどの異常な現象を生じたものと考えられる.

（受付：1985年5月7日；受理：1985年10月28日）

Appendix: List of the samples collectecd by this study.

Sample No.	Sample Description	Magnetic Susceptibility	
		(a)	(b)
Otchube			
74HK06	Medium, hornblende-bearing biotite granite, lots of small xenolith	58	25
74HK07	Medium, biotite granite, pyrrhotite contained	81	34
74HK08	Medium-coarse, biotite granite	41	22
74HK09	Fine, hornblende-biotite granodiorite	51	20
74HK10	Fine, biotite granite	25	20
74HK11	Crushed and recrystallized biotite granite, with green biotite veinlet	25	n.d.
Furreppu			
74HK12	Fine, biotite granite (river float)	17	12
74HK13	Very fine, biotite granite (river float)	5	12
74HK14	Fine, tourmaline-spotted, muscovite-bearing syeno-granite, granophyric (river float)	4	10
Uttsu (Eocene)			
74HK15	Fine, pyrrhotite-bearing biotite-hornblende granodiorite, altered	50	10
74HK16	Fine, hornblende-bearing biotite granite	14	14
74HK17	Very fine, pyrrhotite-bearing hornblende quartz diorite, "mafic inclusion" (river float)	52	15
74HK18	Medium, Hornblende-bearing biotite granite, altered (river float)	38	10
74HK19	Fine, granophyric hornblende-biotite granite, altered (river float)	18	12
74HK20	Tourmaline-sericite-quartz stockworked granite, altered (river float)	31	n.d.
74HK21	Very fine, hornblende-biotite granite	335	118
74HK22	Fine, orthopyroxene quartz diorite porphyry (river float)	2200	555
74HK23	Very fine, sphene-bearing hornblende granophyre (river float)	673	176
Monbetsu (Eocene)			
74HK24	Fine, biotite granite, granophyric and altered (calcite microveinlet)	52	19
74HK25	Very fine, biotite granite (sericite-calcite microveinlet)	n.d.	22
Ichinohashi			
74HK26	Medium, hornblende-biotite granodiorite	26	10
74HK27	Medium, clinopyroxene-hornblende-biotite quartz diorite	101	21
74HK28	Fine, hornblende-bearing biotite granite	27	12
Okushibetsu			
74HK29	Fine, biotite granite, moderately altered (sericite and clays)	23	18
74HK30	Fine, biotite granite, altered (calcite microveinlet, sericite, chlorite)	20	13
74HK31	Same as the above	19	11
Shikaribetsu-Ososhu			
No.1	Altered biotite granite	n.d.	6
Karikachi			
74HK32	Medium, hornblende-biotite granodiorite, crushed and altered (ser.chl)	40	n.d.
74HK33	Same as the above	30	8
74HK34	Fine, hornblende gabbro, "mafic inclusion" (float)	48	9
74HK35	Fine, hornblende-bearing biotite granite, altered (sericite)	405	117
74HK36	Fine-medium, biotite granite, granophyric and altered (sericite)	78	23
Nissho (from west to east)			
74HK42	Medium-coarse, garnet-bearing biotite gneiss, hetrogeneous and N50°W-75°S gneissosity	46	13
74HK76	Fine-medium, hornblende-biotite gneiss, slightly porphyritic	46	6
74HK77	Same as the above	26	7
74HK78	Fine, hornblende-biotite gneiss, homogeneous	30	12
74HK41	Fine-medium, clinopyroxene-hornblende-biotite tonalite	41	18
74HK79	Fine-medium, clinopyroxene-hornblende-bearing biotite granodiorite, equigranular	33	11
74HK43	Very fine, biotite aplitic granite, 20 cm wide dike in gneiss	13	3
74HK75	Fine, hornblende-bearing biotite granite	26	6
74HK44	Fine, hornblende-biotite granodiorite, slightly porphyritic and N60°W-85°S foliation	38	10
74HK74	Medium-coarse, cordierite-garnet xenolith-bearing biotite granite, N30°W-80°S foliation	59	14

Appendix: Continued

Sample No.	Sample Description	Magnetic Susceptibility (a)	(b)
74HK73	Medium, hornblende-bearing biotite granite, leucocratic	13	4
74HK72	Fine, hornblende-biotite granite, irregular sheet-like pool	22	8
74HK40	Fine, biotite granite, porphyritic	34	16
74HK71	Fine, biotite granite, slightly porphyritic	14	8
74HK37	Fine, biotite granite, granophyric	14	8
74HK39	Fine, biotite granite, slightly porphyritic	9	5
74HK45	Fine, biotite granite	7	7
74HK50	Fine, biotite-hornblende granodiorite (hybrid), foliated & pyrrhotite	48	17
74HK38	Medium, biotite granite, slightly porphyritic	12	10
74HK80	Very coarse, bornblende-bearing biotite granite, porphyritic	14	8
74HK81	Same as the above	12	8
Southern Part			
74HK51	Fine-medium, hornblende-bearing biotite granite (float)	15	5
74HK52	Fine-medium, biotite granite, granophyric (float)	16	7
74HK53	Same as the above, aplitic (float)	11	5
74HK46	Very fine, muscovite-bearing biotite hornfels, originally shale	30	11
Tomuraushi (gabbroids)			
74HK47	Very fine, clinopyroxene-bearing biotite-hornblende quartz diorite(float)	64	12
74HK48	Fine, biotite-bearing hornblende quartz diorite	45	11
74HK56	Fine-medium, biotite-hornblende quartz diorite dike, 20 m wide	65	19
74HK61	Fine, biotite-bearing hornblende quartz diorite	68	16
74HK64	Fine, clinopyroxene-hornblende gabbro	88	23
74HK65	Coarse, hornblende diorite	54	13
Tomuraushi (gneissose granitoids body)			
74HK54	Medium, garnet-bearing biotite gneiss	80	27
74HK55	Fine, muscovite-bearing biotite gneiss	88	22
74HK62	Very fine, biotite gneiss alternated with 74HK63	24	12
74HK57	Fine, hornblende-biotite granite, dike? (float)	13	10
74HK59	Very coarse, biotite tonalite, gneissosed (float)	46	15
74HK60	Very coarse, biotite granodiorite, gneissosed	19	10
74HK63	Coarse, biotite tonalite, gneissosed	53	17
Totabetsu			
74HK66	Very fine, biotite-bearing hornblende tonalite, "mafic inclusion"	28	8
74HK67	Medium, biotite-bearing hornblende granodiorite, matrix of 74HK66	13	6
74HK68	Coarse, biotite-hornblende granodiorite, matrix of gabbroids	39	12
74HK69	Fine, hornblende-biotite granite, altered (chlorite, epidote, sphene)	8	5
74HK70	Fine, hornblende-bearing biotite granite (float)	401	117
Oshirabetsu (Oligocene)			
74HK82	Fine-medium, biotite granodiorite, altered (sericite, epidote, chlorite)	32	7
74HK83	Fine, biotite granodiorite, weakly latered (sericite)	34	17
74HK84	Medium, hornblende-bearing biotite granodiorite	34	8
74HK85	Medium-coarse, hornblende-bearing biotite granite	48	13
Saruru Migmatite Zone (Oligocene)			
74HK86	Fine, biotite gneiss-hybrid	43	10
74HK87	Fine-medium, biotite gneiss, granitic, pyrrhotite	37	13
74HK88	Same as the above, much pyrrhotite	128	21
74HK89	Fine, muscovite-bearing biotite gneiss, pyrrhotite	66	21
74HK90	Medium-coarse, biotite tonalite, equigranular, less than 3 m in gneisses	34	8
74HK91A	Very fine, biotite gneiss (A and B, variation within hand specimen)	44	11
B	Medium, biotite gneiss, much pyrrhotite		34
74HK92	Coarse, cordierite(pinite)-biotite gneiss, some quartz pools	124	22
74HK93	Medium, biotite gneiss, pyrrhotite, 10 cm wide band between 74HK94 & 95	57	13
A	Fine, biotite gneiss, gneissic part of 50 cm granitic layer (B, C)	97	28
74HK94B	Medium, biotite granite, K-feldspar-rich part of the granitic layer	41	14
C	Medium, biotite tonalite, equigranular; main part of the granitic layer	n.d.	22
74HK95	Medium, biotite tonalite, homogeneous-equigranular; 1.5 m wide layer underneath 74HK93 and 74HK94 granitic layer	53	15

Magnetic susceptibility (a): Measured by Geoinstruments ky TH-1 on collected samples. Average of three measurements and expressed by SI unit ($\times 10^{-5}$). (b): Measured by Bison Model 3101A on powdered sample by H. KANAYA, GSJ. C.G.S. unit (emu/g$\times 10^{-6}$). n.d., not determined.