Finding of 192 Ma granitic cobbles from the Cape Shiretoko area, eastern Hokkaido, Japan

YOSHIHIKO GOTO*, NOBUO GOUCHI** and TETSUMARU ITAYA***

**Uryu Experimental Forest, Faculty of Agriculture, Hokkaido University, Tokuda, Nayoro, Hokkaido, 096, Japan*

***Shiretoko Museum, 12-3 Shari-cho, Hokkaido, 099-41, Japan*

****Hiruzen Research Institute, Okayama University of Science, 1-1 Ridai-cho, Okayama, 700, Japan*

Cobbles of granitic rocks were found from the seashore of the Cape Shiretoko area, eastern Hokkaido, Japan. They exhibit rounded to subrounded shape, and are 5 to 20 cm in length. The petrography, major element chemistry and K-Ar ages are presented to clarify the origin of the granitic cobbles.

The cobbles are composed of adamellite, granodiorite and quartz monzonite. Most of them show a hypidiomorphic texture, and some granodiorite and quartz monzonite have a mylonitic texture. Obtained K-Ar ages are 191.8 ± 4.5 Ma for biotite in adamellite, 114.6 ± 2.5 Ma for K-feldspar in mylonitized granodiorite and 124.2 ± 2.7 Ma for muscovite in mylonitized quartz monzonite. The granitic cobbles found at Cape Shiretoko are similar in age and petrography to the granitic rocks dredged from the Sea of Okhotsk. This fact may indicate that the granitic cobbles were derived from the granitic rocks forming the continental crust in the Okhotsk region.

I. Introduction

The Shiretoko Peninsula is situated in eastern Hokkaido, Japan. The peninsula is underlain chiefly by Tertiary to Recent volcanic and sedimentary rocks.

The authors found Jurassic to early Cretaceous granite cobbles on the seashore of Cape Shiretoko, although neither plutonic nor metamorphic basement rocks have been reported from this peninsula. This paper describes the petrography, major element chemistry and K-Ar mineral ages of these granitic rocks to elucidate their geological significance.

II. Geological outline of the Shiretoko Peninsula and occurrences of the granite cobbles

The Shiretoko Peninsula is located in the southwestern part of the Kurile arc (Fig. 1).

Tertiary volcanic and sedimentary rocks are basement rocks and are overlain by Quaternary subaerial volcanoes forming a straight volcanic chain along the peninsula (Kadokura, 1916; Sugimoto, 1960).

The Cape Shiretoko area is underlain by the Aidomari Formation, Shiretokomisaki Formation, Shiretokodake Lavas, and Terrace deposits (Fig. 1). The detailed geology of the area has been reported by Goto and Gouchi (1991). The Aidomari Formation is composed of altered massive andesite lavas and is overlain by the Shiretokomisaki Formation. The Shiretokomisaki Formation, having wide distribution along the seashore, is mainly composed of andesitic hyaloclastites. One of the volcanic necks which fed the hyaloclastites is located nearby at Akaiwa where it protrudes from the sea (Fig. 1, Goto and Gouchi, 1991). The volcanic rocks from this formation are 1.7 ± 0.1 Ma

Fig. 1. Geologic map of the Cape Shiretoko Area. Solid circles show the sample locations of the granitic cobbles. Open triangle shows the location of the volcanic neck called Akaiwa. The shaded area in the inset map indicates the distribution of the Tokoro and Nemuro belts. ASR, the Academy of Sciences Rise. IOR, the Institute of Oceanology Rise.

and 0.9 ± 0.2 Ma in K-Ar age (Goto *et al.*, 1990). The Shiretokodake Lavas consist of Quaternary subaerial andesite lavas which cover the Shiretokomisaki Formation. Coastal terraces are well developed along Cape Shiretoko.

The granitic cobbles studied in this paper were found in alluvial deposits along the seashore from Cape Shiretoko to Akaiwa. The alluvial deposits are mainly composed of cobbles of andesite lava of 2–20 cm across. The andesitic rocks of the alluvial deposits are similar in petrographical features to the volcanic rocks of the Shiretokomisaki Formation and Shiretokodake Lavas. The granitic cobbles exhibit rounded to subrounded shape and are 5 to 20 cm in length. They are present less than 1% of the alluvial deposits in modal abundance. No outcrop for these granitic rocks has been found in this area up to the present. The

granitic-cobbles may originally be xenoliths from the neck at Akaiwa, or less likely, they may have been transported by drift ice from the continent across the sea of Okhotsk. They were only found from the seashore on the Pacific Sea side of the Shiretoko Peninsula and were never found from the Okhotsk Sea side. This fact may eliminate the possibility of transportation of granitic cobbles by drift ice.

III. Petrography and major element chemistry of the granitic cobbles

The granitic cobbles are adamellite, granodiorite and quartz monzonite in modal compositions (Fig. 3, Table 1), and mostly show a hypidiomorphic texture. Some granodiorite and quartz monzonite have a mylonitic texture. The petrography of representative granitic cobbles is described as follows.

Fig. 2a. Photograph of hornblende-biotite adamellite (Sample No. T-1).

b. Protomicrograph of hornblende-biotite adamellite (Sample No. T-1). Qz, quartz; Pl, plagioclase; Kf, K-feldspar; Bi, biotite.

c. Photograph of mylonitized quartz monzonite (Sample No. T-2).

d. Photomicrograph of mylonitized quartz monzonite (Sample No. T-2). Qz, quartz; Pl, plagioclase; Ms, muscovite.

Note that the porphyroclastic plagioclase and fine grained quartz make a fluidal texture. Muscovite has well developed kinkbands.

(1) Hornblende-biotite adamellite (Sample No. T-1, Figs. 2a and 2b): The hornblende-biotite adamellite with hypidiomorphic texture is constituted by plagioclase, quartz, K-feldspar, biotite, hornblende and opaque minerals, all of which are 1-4 mm in size, and accessory sphene and zircon. Plagioclase is euhedral to subhedral, and quartz and K-feldspar are anhedral. K-feldspar, showing perthite texture with sodic lamellae, is slightly turbid in the interior owing to alteration. Subhedral to anhedral biotite often contains opaque minerals. Light green hornblende occurs as subhedral crystals.

(2) Hornblende granodiorite (Sample No. T-11): The hornblende granodiorite with hypidiomorphic texture contains plagioclase,

quartz, K-feldspar, hornblende and opaque minerals, all of which are 1-3 mm in size, and accessory sphene and zircon. Plagioclase and light green hornblende are euhedral to subhedral, and quartz and K-feldspar with perthite texture are anhedral. Opaque minerals are observed in hornblende.

(3) Cordierite-bearing biotite adamellite (Sample No. T-7): The cordierite-bearing biotite adamellite with hypidiomorphic texture has plagioclase, quartz, K-feldspar, biotite, opaque minerals and a small amount of cordierite, all of which are 1-3 mm in size, and accessory sphene and zircon. Plagioclase and biotite are euhedral. Quartz and K-feldspar with perthite texture are anhedral and occur in the interstices. Cordierite occurs as granular

Fig. 3. Modal compositions of granitic rocks plotted on a quartz-plagioclase-K-feldspar triangular diagram.

Classification of the granitic rocks, GR, granite, AD, adamellite, GD, granodiorite, QSY, quartz syenite, QMZ, quartz monzonite, QMD, quartz monzodiorite.

Symbols, 1-5, Granitic rocks from Cape Shiretoko, 1, Hornblende-biotite adamellite/granodiorite, 2, Hornblende granodiorite, 3, Cordierite-bearing biotite adamellite, biotite adamellite, 4, Mylonitized quartz monzonite, 5, Mylonitized granodiorite, 6, Dredged granitic rocks from the Northern Academy of Sciences Rise and the Northern Institute of Oceanology Rise in the Sea of Okhotsk (Burk and Gnibidenko, 1977).

crystal and is generally converted into pinite.

(4) Mylonitized quartz monzonite (Sample No. T-2, Figs. 2c and 2d): The mylonitized quartz monzonite exhibits a porphyroclastic texture. It is composed of porphyroclasts of plagioclase, K-feldspar and garnet(1%), all of which are 0.5-2 mm in size, and recrystallized fine grained quartz, muscovite, biotite, epidote, chlorite and opaque minerals. The recrystallized quartz, muscovite, biotite and epidote show subparallel arrangements, and the recrystallized quartz and muscovite have kink bands.

Major element analyses of the granitic rocks were done by XRF at Hokkaido University (Philips PW 1404), following the analytical procedures of Tsuchiya *et al.* (1989). The

analysed rocks range in SiO_2 from 63 to 71 wt.% (Table 1). Most of the rocks have $\text{Al}_2\text{O}_3/(\text{CaO}+\text{Na}_2\text{O}+\text{K}_2\text{O})$ ratios (molecular proportions) lower than 1.1, indicating that they belong to the I-type granites defined by Chappell and White (1974). The cordierite-bearing biotite adamellite (T-7) and biotite adamellite (T-15) have the ratios higher than 1.1, indicating S-type granites.

IV. K-Ar age determination

Three K-Ar mineral ages were determined for the granitic rocks from the Cape Shiretoko area. The rock samples were hornblende-biotite adamellite with hypidiomorphic texture (Sample No. T-1), mylonitized granodiorite (Sample No. T-9) and mylonitized quartz mon-

Table 1. Whole rock compositions and modal compositions (vol. %) of the granitic rocks from the Cape Shiretoko area

Sample No.	T-1	T-3	T-7	T-15	T-11	T-2	T-9
SiO ₂	69.67	67.44	68.55	67.62	63.35	67.67	70.74
TiO ₂	0.53	0.57	0.64	0.61	0.60	0.33	0.16
Al ₂ O ₃	14.31	15.18	15.48	15.80	15.44	16.23	16.35
Fe ₂ O ₃ *	4.07	4.73	4.74	4.10	5.50	3.67	1.14
MnO	0.06	0.08	0.07	0.06	0.07	0.10	0.01
MgO	1.47	2.02	2.31	2.03	2.68	0.94	0.27
CaO	2.71	4.22	1.71	2.08	4.44	4.19	1.31
Na ₂ O	3.40	3.17	3.39	3.79	3.68	4.40	6.16
K ₂ O	3.81	2.83	3.68	3.96	4.13	1.94	3.35
P ₂ O ₅	0.11	0.09	0.14	0.30	0.23	0.19	0.05
Total	100.14	100.33	100.71	100.35	100.12	99.66	99.54
A/CNK	0.98	0.95	1.22	1.11	0.83	0.96	1.01
Quartz	29.9	35.1	32.7	34.0	18.8	31.0	15.5
Plagioclase	37.9	30.5	33.7	33.1	42.6	48.9	48.8
K-feldspar	23.9	13.1	19.1	19.1	20.7	6.7	26.4
Hornblende	1.3	7.1	0.0	0.0	14.5	0.0	0.0
Biotite	6.2	12.2	13.9	13.7	0.0	1.0	1.2
Muscovite	0.0	0.0	0.0	0.0	0.0	3.1	8.0
Opaque	0.6	1.9	0.1	0.1	2.4	0.5	0.0
Others	0.2	0.1	0.5	0.0	1.0	8.8	2.1

Total iron is reported as Fe₂O₃*. A/CNK, Al₂O₃/(CaO+Na₂O+K₂O) (molecular proportion).

T-1, Hornblende-biotite adamellite, T-3, Hornblende-biotite adamellite, T-7, Cordierite-bearing biotite adamellite, T-15, Biotite adamellite, T-11, Hornblende granodiorite, T-2, Mylonitized quartz monzonite, T-9, Mylonitized granodiorite.

Table 2. K-Ar mineral ages of the granitic rocks from the Cape Shiretoko area

Sample No.	Locality	Rock type (mineral)	K (wt%)	Rad. argon40 (10 ⁻⁸ ccSTP/g)	K-Ar age (Ma)	Non Rad. Ar(%)
T-1	44° 19' 37" N	Adamellite	6.784	5280±76	190.2±4.4	5.2
	145° 20' 36" E	(biotite)	±0.316	5375±79	193.4±4.6	6.0
(average)					191.8±4.5	
T-2	44° 19' 31" N	Mylonite	7.530	3757±37	124.2±2.7	3.4
	145° 20' 36" E	(muscovite)	±0.151			
T-9	44° 19' 44" N	Mylonite	5.037	2313±23	114.6±2.5	4.6
	145° 20' 36" E	(K-feldspar)	±0.101			

zonite (Sample No. T-2). K-Ar age determinations were done for separated minerals, a subhedral to anhedral biotite (T-1), a porphyroclastic K-feldspar (T-9) of the mylonite, and a recrystallized muscovite (T-2) which shows

subparallel arrangements with fine grained recrystallized quartz (Fig. 2d). K was determined by flame photometry (Nagao *et al.*, 1984). ⁴⁰Ar was analyzed by the isotope dilution method with ³⁸Ar as a tracer using the

mass spectrometer of Okayama University of Science (Nagao and Itaya, 1988; Itaya *et al.*, 1991). K-Ar age was calculated using the physical constants $\lambda_0 = 0.581 \times 10^{-10}/\text{y}$, $\lambda_\beta = 4.962 \times 10^{-10}/\text{y}$, $^{40}\text{K}/\text{K} = 0.0001167$ (Steiger and Jäger 1977). The results of K-Ar dating are shown in Table 2.

V. Discussion

The hornblende-biotite adamellite (T-1) is 191.8 ± 4.5 Ma in age, indicating Early Jurassic age. This rock sample has an igneous texture, and show no alteration of biotite. Therefore, this age is regarded as the cooling age of the adamellite. The mylonitized granodiorite (T-9) and mylonitized quartz monzonite (T-2) are 124.2 ± 2.7 Ma and 114.6 ± 2.5 Ma in age, respectively, indicating Early Cretaceous. The ages of T-9 and T-2 may show the mylonitization stage of the rocks.

Early Jurassic granitic rocks have not been reported from eastern Hokkaido up to the present, although Tertiary and Cretaceous plutonic rocks are distributed along the central axial zone of Hokkaido and in southwest Hokkaido. The plutonic rocks along the central axial zone of Hokkaido are from 43 to 10 Ma in age (Maeda *et al.*, 1986), and those in southwest Hokkaido are 75 to 133 Ma in age (Tsuchiya *et al.*, 1986).

The Mesozoic basement of the eastern Hokkaido is distributed in the Tokoro belt and Nemuro belt (Fig. 1). The metamorphism of the Tokoro belt took place in Late Cretaceous, and igneous activity of the Nemuro belt occurred from Late Cretaceous to Early Eocene (Kiminami, 1983; Kiminami *et al.*, 1985), suggesting that the 192 Ma granitic rocks from Cape Shiretoko significantly predate the metamorphism and igneous activity of the Tokoro and Nemuro belt.

Many granitic and metamorphic rocks have been reported in dredged samples from the

Sea of Okhotsk (Gnibidenko and Ilyev, 1976; Burk and Gnibidenko, 1977; Geodekyan, 1977; Sergeyev and Krasny, 1987). The K-Ar ages of the granitic rocks are from 73 to 209 Ma. They are composed mainly of granodiorite (Fig. 3) and commonly show an igneous texture. Mylonitized granodiorites are also reported. These facts indicate that the granitic rocks of Cape Shiretoko are very similar in age and petrography to the dredged samples from the Sea of Okhotsk.

Regional seismic prospecting data suggest that the area in and around the sea of Okhotsk is underlain by the continental crust consisting of granitic rocks (*e.g.* Tuyezov, 1971; Moskvina *et al.*, 1983). Granitic rocks may be a constituent of the crust underneath Cape Shiretoko. It may be possible that the Plio-Pleistocene volcanic rocks in this area, such as those exposing at the Akaiwa volcanic neck, have included granitic xenoliths derived from the continental crust. To clarify the origin of the granitic cobbles reported in this study, it is necessary to find an outcrop of granitic rocks and to do a systematic study on them from geochemical and geochronological standpoints. Further work is planned on the granitic rocks dredged from the floor of sea of Okhotsk and from Cape Shiretoko, and on the xenolithic materials of crust origin in the Akaiwa volcanic neck.

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北海道東部、知床半島から発見された 192 Ma の花崗岩質岩

後藤 芳彦・合地 信生・板谷 徹丸

北海道の東部、知床半島の知床岬海岸において、花崗岩類の礫を見いだした。これらは径 5~20 cm の円礫~亜円礫をなす。これらの花崗岩礫の岩石学的記載、主成分全岩化学分析、K-Ar 法による年代測定を行った。知床岬の花崗岩礫は、アダムロ岩、花崗閃緑岩および石英モンゾニ岩からなる。これらの多くは半自形粒状組織を呈するが、石英モンゾニ岩と花崗閃緑岩の一部は圧碎組織を呈する。アダムロ岩中の黒雲母は 191.8 ± 4.5 Ma、圧碎花崗閃緑岩中のカリ長石は 114.6 ± 2.5 Ma、圧碎石英モンゾニ岩中の白雲母は 124.2 ± 2.7 Ma の K-Ar 年代を示した。知床岬の花崗岩礫の岩石学的性質と K-Ar 年代は、オホーツク海からドレッジされた花崗岩類に似ており、それらはオホーツク海域の大陸地殻を構成する花崗岩類の一部である可能性が高い。