ORIGIN OF SCHIST CLASTS OF UPPER CRETACEOUS ONOGAWA GROUP, SOUTHWEST JAPAN*

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Abstract The Upper Cretaceous Onogawa Group in east Kyushu is a thick turbiditic sequence that contains large clasts of schist of unknown origin. Newly determined K-Ar ages of white micas from these schist clasts are concentrated in 199–182 Ma (Early Jurassic) and they clearly deny the previous belief that the schist clasts were derived from the Sanbagawa Belt. The first surface exposure of the Sanbagawa metamorphic rocks was recorded not by the Late Cretaceous Onogawa Group, but by the Middle Eocene (52–40 Ma) Kuma Group in west Shikoku. K-Ar ages around 199–182 Ma suggest that the schist clasts of the Onogawa Group were derived most probably from the high-P/T Sangun metamorphic rocks in the Inner Zone of Southwest Japan.

Introduction

The high-P/T metamorphic rocks of the Sanbagawa Belt in the Outer Zone of Southwest Japan are generally regarded as products of late Mesozoic subduction processes along the Asian continental margin. Radiometric and micropaleontological studies have provided age constraints for the Sanbagawa metamorphism; the pre-metamorphic materials contain Middle-Late Triassic (MATSUDA, 1978) and Late Jurassic sedimentary rocks (IWASAKI *et al.*, 1984) and the peak metamorphism was around 120–110 Ma *i.e.* Early Cretaceous (MINAMISHIN *et al.*, 1979). Uplift history after peak metamorphism has not been fully clarified, however, the cooling rate during uplift was recently estimated as 9–12°C/Ma in the oligoclase-biotite zone in central Shikoku (ITAYA & TAKASUGI, 1988).

The Upper Cretaceous Onogawa Group in east Kyushu is an unmetamorphosed thick sedimen-

tary succession which forms a synclinolium with an eastward plunging axis. It consists of coarse-grained terrigenous clastics (mostly turbidites) with conglomerates containing abundant clasts of schists (MATSUMOTO, 1936; TERAOKA, 1970). Because the Onogawa Group crops out widely around the southwestern edge of the Sanbagawa metamorphic rocks on the Saganoseki Peninsula (Fig. 1a), the schist clasts are generally regarded as having been derived from Sanbagawa Belt. The Late Cretaceous Onogawa Group clearly predates the Middle Eocene Kuma Group in west Shikoku, which is the oldest sediments lying unconformably over the Sanbagawa metamorphic rocks (NAGAI, 1972). Accordingly, sediments of the Onogawa Group have long been believed to record the first surface exposure of the Sanbagawa schists. Their consanguinity, however, has been highly suspect, because the Onogawa Group occurs in fault contact with the Sanbagawa schists, and it is not known to show any unconformable relationship with the latter, and also because there has been no systematic study of the metamorphic petrology of the schist clasts that allows comparison with the Sanbagawa schists.

This article describes the latest results of K-Ar dating of the problematic schist clasts of the Onogawa Group. These new data provide evidence which clearly conflicts with the hypothesis that these schist clasts were derived from the Sanba-

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Fig. 1. Geologic map around Usuki City and localities of dated samples.

a : Index map of the study area.

b : Geologic map around Usuki City compiled after TERAOKA (1970).

c : Localities of dated schist clasts of the Amabe Formation at Shitanoe, Usuki City.

gawa Belt, and suggest instead that they were probably derived from the Sangun Belt, an older high-P/T metamorphic belt in the Inner Zone of Southwest Japan.

Schist clasts and their mode of occurrence

Schist clasts are abundant in the Amabe Formation, the uppermost unit of the Onogawa Group (TERAOKA, 1970), which is distributed mainly in the Usuki City area, east Kyushu (Fig. 1a). The age of this formation is biostratigraphically constrained by the occurrence of Santonian (*ca.* 86–83 Ma), Late Cretaceous, molluscan fossils (TERAOKA, 1970).

In Shitanoe village, north of Usuki City (Fig. 1b), the A1 and A2 members of the Amabe Formation (TERAOKA, 1970) are exposed along a rocky

shore, where they display large clasts of schists up to 5 m in diameter. Large schist clasts occur as isolated blocks in bedded conglomeratic sandstones (Plate I). Conglomerates contain abundant subangular clasts of schists, mostly less than 10 cm in diameter (Plate II-1) and minor amounts of slate, sandstone, chert, hornfels, gneiss, and acidic to intermediate volcanic and plutonic rocks. The largest and most abundant schist clasts are pelites, with subordinate psammitic, basic and siliceous schists. For more details on the conglomerate and mode of occurrence of clasts, see the description by TERAOKA (1970).

Pelitic schists are usually well-foliated, and kink folds are common. Their parent rocks are mostly mudstone with scattered lenses and clasts of sandstone. Some of them also possess tiny

clasts of chert and greenstone less than 2 cm in diameter. White mica in the pelites is very fine-grained, aligned parallel to the schistosity and usually associated with carbonaceous material (Plate II-2). Basic schists are less foliated than pelitic ones, and in general are strongly weathered. However, white micas in these schists are fresh and aligned parallel to the schistosity under microscope. To date, mineral paragenesis and metamorphic evolution have not been evaluated in detail for these schist clasts.

K-Ar dating

White mica-bearing schist clasts collected from the A2 member of the Amabe Formation include four pelitic schists (Sh-1, -3, -4, -5,) and one basic schist (Sh-2); sample locations are shown in Fig. 1c. Pelitic schist of Sh-6 is from the A1 member of the Amabe Formation. Petrographic characteristics of these samples are briefly described as follows;

Sh-1 — Well-foliated pelitic schist derived from pebbly mudstone with fine clasts of sandstone, chert and greenstone. Rock fragments are completely recrystallized, but their outlines are clearly preserved. Constituent minerals are white mica, chlorite, albite, quartz and carbonaceous material. White mica, length-fast chlorite and carbonaceous material appear parallel to schistosity. The #200-250 mesh size fraction of white mica was dated. This sample was collected from the outcrop (Plate I-2) previously described and illustrated by MATSUMOTO (1936) in his fig. 5 and plate 47-1, and by TERAOKA (1970) in his fig. 26 and plate VII-2.

Sh-2 — Basic schist probably derived from basic hyaloclastite. It is composed of chlorite, white mica, albite, quartz, titanite, calcite and opaque minerals. Fine-grained white mica is abundant, and the #250-325 mesh size fraction was dated.

Sh-3 — Well-foliated pelitic schist composed of alternating 1-3 mm thick quartz-rich layers and those rich in white mica-carbonaceous material. The rock is completely recrystallized and its original sedimentary textures are rarely preserved, and is formed by elongated fine-grained quartz, carbonaceous material and minor albite (Plate II-2). White mica is abundant and the #145-200 mesh size fraction was dated.

Sh-4 — Fine-grained pelitic schist. Schistosity does not well develop. Constituent minerals are white mica, chlorite, albite, quartz and carbonaceous material. White mica is minor in amount and the #200-250 mesh size fraction was dated.

Sh-5 — Pelitic schist composed of alternating 2-3 mm thick layers of quartzo-feldspathic and white mica-carbonaceous material. Constituent minerals are white mica, chlorite, albite, quartz and carbonaceous material. White mica is abundant and the #145-200 and #200-250 mesh size fractions were dated. The outcrop is illustrated in Plate I-1.

Sh-6 — Pelitic schist composed mainly of elongated quartz, fine-grained white mica and carbonaceous material with minor amount of chlorite and albite. The #200-250 mesh size fraction was dated.

All of these pelitic schists lack garnet and biotite, and contain chlorite. This indicates that the metamorphic facies probably belongs to the greenschist facies or much lower one. Textural relations of white mica strongly suggest that all of them are of recrystallized origin (Plate II-2). There is no positive evidence of relict detrital origin of white micas.

Rock samples were crushed and sieved into the fractions #145-200, #200-250 or #250-325 according to the white mica grain size. The isodynamic magnetic separation method was used first to remove chlorite, albite and quartz grains. The white mica-dominated fraction was then treated with dilute HCl solution to remove chlorite occurring along the cleavage planes of white mica, and was washed repeatedly. Owing to the very fine grain size of the white mica, complete removal of carbonaceous material and quartz was not achieved, resulting in K contents lower than those of pure white mica. K-Ar dating was carried out in the laboratory of the Hiruzen Research Institute using the analytical procedure reported by NAGAO *et al.* (1984).

The K-Ar age data are shown in Table 1. The 9 ages range from 182 to 199 Ma, except for the younger ages of Sh-3 (153 and 165 Ma). Judging from the remarkable concentration of the ages between 182 and 199 Ma (Fig. 2A), most of the schist clasts of the non-metamorphosed Onogawa Group were probably derived from the same

Table 1. K-Ar ages of white micas from the schists clasts of the Onogawa Group.

sample no.	lab. no.	grain size (mesh)	K (wt.%)	rad. ⁴⁰ Ar (10 ⁻⁸ ccSTP/g)	non-rad. ⁴⁰ Ar(%)	K-Ar age (Ma)
Sh-1	S13-66	200-250	2.85±0.06	2187±21	1.4	187.7±3.9
-1*	S13-65	200-250	2.74±0.06	2237±22	1.0	199.0±4.2
Sh-2	S13-64	250-325	3.47±0.07	2677±26	1.9	188.6±4.0
Sh-3	S13-35	145-200	6.68±0.13	4139±44	8.8	153.0±3.3
-3*	S13-33	145-200	6.40±0.13	4287±44	6.2	164.9±3.5
Sh-4	S13-63	200-250	2.15±0.04	1593±15	3.3	181.5±3.8
Sh-5C	S13-27	145-200	4.27±0.09	3351±32	2.3	191.7±4.0
-5F	S13-34	200-250	3.21±0.06	2380±23	3.3	181.6±3.8
Sh-6	S13-62	200-250	2.41±0.05	1794±18	4.2	182.3±3.9

For Sh-1 and Sh-3, two fractions, *i.e.* less magnetic and more magnetic (with *), were dated. For Sh-5, two fractions, *i.e.* coarser (C) and finer (F), were dated.

provenance area characterized by metamorphism of 182–199 Ma age.

The younger K-Ar ages of the Sh-3 clast cannot be due to radiometric rejuvenation of older schists by local tectonic and/or thermal disturbance after deposition of the Onogawa Group, because the Sh-3 clast occurs not only in the same manner as but also very close to those of Sh-1, -2, -4, and -5 (Fig. 1c). The younger ages of the Sh-3 clast may indicate either derivation from a different source area or the existence of certain tectonic and/or thermal events in the provenance area prior to erosion.

Discussion

Newly obtained white mica K-Ar ages around 199–182 Ma (Early Jurassic according to the time scale of SNELLING, 1985) clearly indicate that the schist clasts of the Onogawa Group were not derived from the Sanbagawa metamorphic belt, because they predate not only the peak of the Sanbagawa metamorphism around 120–110 Ma (MINAMISHIN *et al.*, 1979), but also the pre-metamorphic sedimentary accumulation of the Sanbagawa rocks in latest Jurassic time (*ca.* 135 Ma) or later. For example, the Sanbagawa metamorphic rocks in the Saganoseki Peninsula north of the study area (Fig. 1b) were dated by the whole-rock K-Ar method as 91, 49, 95 Ma (UEDA *et*

al., 1977). These relations indicate that the Sanbagawa schists were probably never covered unconformably by the Onogawa Group, and that both units were secondarily juxtaposed through later tectonic processes like normal faulting as pointed out by TERAOKA (1970). Accordingly, there is no need to imagine the hypothetical “lost geologic segments at the Median Tectonic Line”, which were proposed by KOJIMA (1973) on the basis of the alleged “Sanbagawa schists clasts” contained in the Onogawa Group.

Under the circumstances, the oldest geological information on the surface exposure of the Sanbagawa metamorphic rocks was recorded not by the Onogawa Group but by the Middle Eocene (*ca.* 52–40 Ma) Kuma Group in west Shikoku, which unconformably covers the Sanbagawa schists (NAGAI, 1972) and contains abundant schist clasts of Sanbagawa origin (YOKOYAMA, 1987). Hence, it took approximately 60–80 Ma for the Sanbagawa metamorphic rocks to be uplifted from a deep-seated high-P/T metamorphic environment to the erosional surface of early Tertiary arc-trench gap in Southwest Japan.

The authors propose that the Sangun Belt in the Inner Zone of Southwest Japan (Fig. 1a) is the most favorable source of the schist clasts of the Onogawa Group as discussed below. According to NISHIMURA & SHIBATA (1987), the high-P/T Sangun

Fig. 2. K-Ar ages of white micas from the schists clasts of the Onogawa Group (A). They are compared with those of several metamorphic rocks in Southwest Japan (B: compiled from the references cited in the text). Chronological positions of the Amabe Formation of the Onogawa Group and the Kuma Group are also shown. Time scale is after SNELLING (1985).

metamorphic rocks are divided into three distinct groups on the basis of radiometric ages and lithologic character; *i.e.* metamorphic rocks of 200–160 Ma, those of 230–210 Ma and those of 305–208 Ma. The 199–182 Ma old schist clasts of the Onogawa Group, therefore, can be chronologically well compared with the metamorphic rocks of 200–160 Ma of the Sangun Belt (Fig. 2B). This understanding is concordant with paleocurrent data on the Amabe Formation indicating predominant sediment influx from the north (TERAOKA, 1970). In addition, sediment supply from the Inner Zone is supported by the occurrence of abundant clastics derived from the Ryoke Belt, *e.g.* acidic to intermediate volcanic and plutonic rocks, gneiss and hornfels (TERAOKA, 1970, 1977).

The 200–160 Ma old metamorphic rocks of the Sangun Belt are widely distributed in east Chugoku, but have not been found to crop out in north Kyushu and in the surroundings of the present

study area. The 200–160 Ma old schists might possibly once have cropped out near the Onogawa sedimentary basin, but have since been completely eroded away in the process feeding clastics to the Onogawa Group. Otherwise, their remnants may be represented by the 177–153 Ma old part of the high-P/T Nagasaki metamorphic rocks (NISHIMURA, 1985) and/or by some metamorphic rocks of enigmatic origin scattered in north-central Kyushu (KARAKIDA *et al.*, 1969).

Other metamorphic belts in Kyushu are not suitable sources for the schist clasts of the Amabe Formation (Fig. 2B), for reasons given below. Two of the metamorphic belts are too young to have been source rocks. The low-P/T Ryoke metamorphism clearly postdates 199–182 Ma, because the Ryoke metamorphism affected rocks yielding Late Jurassic (*ca.* 135 Ma) fossils (HAYASAKA *et al.*, 1983). The main part of the high-P/T Nagasaki metamorphic rocks with 90–60 Ma radiometric ages

(NISHIMURA, 1985) are also too young to correlate with the 199–182 Ma old schist clasts. On the other hand, the high-P/T metamorphic rocks in the Kurosegawa Zone (MARUYAMA *et al.*, 1984), distributed in the south of the Onogawa basin, are dated mostly too old to correlate with the 199–182 Ma schist clasts of the Amabe Formation, *i.e.* 240–208 Ma (MARUYAMA *et al.*, 1978), 384–344 Ma (UEDA *et al.*, 1980) and 445–402 Ma (MARUYAMA & UEDA, 1976). However, we cannot totally eliminate the possibility of the Kurosegawa origin of the schist clasts, because the youngest radiometric age of the Kurosegawa high-P/T rocks (208 Ma) is very close to those of the schist clasts, and also because some lower parts of the Onogawa Group might have received clastics possibly from the Kurosegawa Belt located immediately to the south of the Onogawa basin as suggested by TERAOKA (1970).

Summary

1. K-Ar ages of the schist clasts of the Upper Cretaceous Onogawa Group in east Kyushu range from 199 Ma to 182 Ma (Early Jurassic).
2. Newly obtained K-Ar ages clearly deny the Sanbagawa origin of those schist clasts.
3. The oldest sedimentary unit recording the surface exposure of the Sanbagawa metamorphic rocks is not the Upper Cretaceous Onogawa Group, but the Middle Eocene Kuma Group in west Shikoku. Thus the duration of uplift of the Sanbagawa metamorphic rocks is roughly estimated to be 60–80 Ma.
4. The schist clasts of the Onogawa Group were derived most probably from the high-P/T Sangun metamorphic rocks in the Inner Zone of Southwest Japan.

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** in Japanese

(地 名・地 層 名)

Amabe	海辺	Kuma	久万	Onogawa	大野川
Saganoseki	佐賀関	Shitanoe	下の江	Usuki	臼杵

(要 旨)

ISOZAKI, Y. and ITAYA, T., 1989: Origin of schist clasts of Upper Cretaceous Onogawa Group, Southwest Japan. *Jour. Geol. Soc. Japan*, **95**, 361-368. (磯崎行雄・板谷徹丸, 1989: 上部白亜系大野川層群産結晶片岩礫の起源. 地質雑, 95, 361-368.)

大分県臼杵市下の江海岸の上部白亜系大野川層群海辺層中には結晶片岩の巨礫が産し, 大野川層群が佐賀関半島の三波川結晶片岩に隣接して分布することから, これらの礫は従来三波川帯起源とみなされることが多かった. 今回これらの結晶片岩礫の白雲母 K-Ar 年代を測定した結果, その年代値が 182-199 Ma の範囲 (ジュラ紀古世) に集中することが判明した. 三波川変成作用のピークの年代は 110-120 Ma とされ, 明らかに大野川層群産の結晶片岩礫の K-Ar 年代より若い. したがって, 大野川層群産の結晶片岩礫を三波川帯由来とみなすことはできない. 西南日本内帯に分布する "三郡変成岩" の一部は, 約 160-200 Ma の年代をもち, 今回検討した礫と年代の上で最もよく対応することから, 大野川層群の礫の供給源であった可能性が強い.

Explanation of Plate

Plate I Mode of occurrence of schist clasts of the Upper Cretaceous Onogawa Group.

1. Pelitic schist clast at Loc. 5, Shitanoe coast.
Note chevron folds in the schist clast.

2. Pelitic schist clast at Loc. 1, Shitanoe coast.

1. Conglomerate with abundant pelitic schist pebbles, near Loc. 1, Shitanoe coast. The pen for scale is 13 cm long.

2. Photomicrograph of pelitic schist from Loc. 3, Shitanoe coast.
Plane-polarized light. Scale bar represents 0.1 mm. Light colored part :
white micas, dark colored part : carbonaceous materials, granular minerals :
albite and quartz.