GABBROIC BRECCIA (OLISTOSTROME) IN THE MIKABU GREEN STONE BELT OF THE EASTERN SHIKOKU

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Abstract In the Mikabu Green Stone Belt of southwestern part of Japanese Islands, gabbroic breccia (olistostrome) occur along the boundary between the Green Stone Belt and the Chichibu Zone (the zone of the weakly metamorphosed Paleozoic-Triassic formations).

Short descriptions of the olistostrome formation are given. The gabbro blocks (olistolith) have been derived from the gabbro layer which is assumed to be the basement rocks of the pillow lava formations and correspond to the rocks of the past oceanic crust.

Introduction

In the Mikabu Green Stone Belt of southwestern part of Japanese Islands, a suit of green stones occur along the rather narrow belt (Fig.1). The green stone complex in this Belt is composed of basic extrusives (pillow lava and hyaloclastite), diabasic dykes, along with gabbroic rocks, ultramafic and ultrabasic rocks of cumulative origin (Table 1). All of the gabbroic rocks have been previously believed to be igneous origin (intrusives), but recently it was found that the majority of gabbroic rocks should be sedimentary origin and are assigned to be the component of the olistostrome. Therefore, there are two kinds of gabbroic rocks in the Green Stone Belt, the one is cumulative origin and the other is sedimentary origin. On the handspecimens, the discrimination of the both types of gabbro is often rather difficult, but it could be made by their mineral composition, the texture under the microscope and the mode of occurrence in the field.

The gravity-sliding deposit (olistostrome) has been hitherto not reported in the Japanese green stone belts. Such deposits would be produced by the tectonic movement which is

accompanied by uplift or thrust up of the part of the crust (ELTER & TREVISAN, 1973; ABBATE *et al.*, 1970). In this connection, the finding of the gabbroic breccia in the green stone belt of the eastern part of Shikoku will be significant with relation to the tectonism of the green stone complex.

Geological setting

The Green Stone Belt of the eastern part of Shikoku is approximately 2—3 km in width and is situated at the boundary between the Sanbagawa and Chichibu Zone (Fig. 2). The Belt is separated from the Sanbagawa Zone to the north and from the Chichibu Zone to the south by the faults respectively.

The Green Stone Belt is composed of three tectonic slices and each tectonic slice is bounded by the thrust faults (Fig. 3). The geological age difference of the individual slice is not known, but the sequence of the igneous activities of the green stone complex is inferred by the field investigations and the petrographical point of view (IWASAKI, 1978) (Table 1).

The tectonic slices of middle zone (Unit I) are considered to be in the uppermost stratigraphic horizon and is thought to be composed of the tholeiitic basalt of upper pillow lava formation.

The tectonic slice of northern zone (Unit II) represents lower pillow lava formation

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Fig. 1. Greenstone belts of the eastern part of Shikoku.

- I. Zone of the Izumi Group (upper Mesozoic, mainly Cretaceous).
- S. Sanbagawa Belt (crystalline schists of glaucophane and green schist facies).
- C. Chichibu Belt (mainly middle and upper Paleozoic along with Triassic, weakly metamorphosed).
- M. Shimanto Belt (upper Mesozoic and Paleogene).
Green Stone Complex of the Mikabu Belt.
 - 1. Meta-hyaloclastite, pillow-breccia and pillow-lava (Unit I).
 - 2. Meta-hyaloclastite with diabase dykes, ultramafic and ultrabasic rocks of cumulative origin (Unit II).
 - 3. Gabbroic breccia (olistostrome) (Unit III).
 - 4. Basic schists in the Sanbagawa Belt.
 - 5. Basic volcanics in the Chichibu Belt.

and contains a lot of cumulative intrusives and diabase dykes. The cumulative intrusives and dykes intrude into the lower pillow lava with chilled contact and correspond respectively to the small-scale magma-pools and feeder channels of the upper pillow lava.

Thus, the two stages of submarine lava eruptions are recognized in the Mikabu Green Stone Belt.

The tectonic slice of southern zone (Unit

III) is composed of gabbroic rocks, gabbroic-breccia, -sand stone and -shale. Sometimes, a kind of submarine sliding deposits occur in this slice. Unit III, as a whole, is correspond to the olistostrome deposit.

Gabbroic breccia (olistostrome)

The lavas and intrusives of the Unit I and II are collectively a series of volcanism, on the other hand, gabbroic rocks of the

Fig. 2. Geological map of the Kamiyama-Sanagochi area, eastern part of Shikoku. The field occurrence of the gabbroic breccia (olistostrome) is shown.

1. Upper pillow lava (Unit I) Meta-hyaloclastite.
2. Lower pillow lava (Unit II) Meta-hyaloclastite accompanying with diabase dykes and cumulative intrusives.
3. Gabbro breccia-olistostrome (Unit III)
 - 3a. Gabbro blocks (olistoliths)
 - 3b. Matrix sediments of the olistostrome (Gabbroic-sandstone and -shale).
 - 3c. Submarine sliding deposits.
4. Sediments of the Chichibu Zone (Permian-Triassic).
5. Pelitic schists of the Sanbagawa Zone.

Unit III are thought to be the product of a different igneous activity comparing with the above volcanism, although the both igneous rocks belong to the tholeiitic affinity, the volcanic rocks of the Unit I and II have a trend of alkaline rock chemistry. The composition of relic clinopyroxene are somewhat different each other. In the gabbroic

blocks of the Unit III (olistostrome), the relic clinopyroxene is sometimes inverted pigeonite and Al_2O_3 content is around 2%, TiO_2 does not exceed 0.5% and is always associated with brown hornblende. On the other hand, the relic clinopyroxenes in the lavas and intrusives of the Unit I and II have the hourglass structure and contain around

Fig. 3. Cross section through the green stone complex of the eastern part of Shikoku. The ornaments are same as the Fig. 2. The structural trend lines within the Units I and II are determined by the measured bedding plane of the hyaloclastite. In Units I and II, some diabase dykes and cumulative intrusives are shown.

4% of Al_2O_3 , 3—6% of TiO_2 and are not always associated with brown hornblende (Table 2).

The gabbroic rocks within the Unit III (olistostrome) occur as blocks, cobbles and pebbles in the sediments of gabbroic composition. The size of the blocks sometimes exceeds several hundred meters in diameter and somewhat irregular in their shape. The irregularity may result from the coherence of the individual blocks. A kind of flow structure which was produced by the linear arrangement of the relic lath-shaped plagioclase crystals is observed in the blocks. The trend direction in the flow structure is oblique to the boundary of the blocks.

No chilled margin is observed in the outer rim of the block, and most of the boundaries between the blocks and the surrounding sediments are faults.

Rarely the survived boundary between the gabbroic block and the surrounding sediments can be observed. One of them is as follows; the outer margin of the block has an appearance of the coherence of small cobbles (several tens cm in diameter) with a little quantities of sedimentary matrix.

Then, the quantities of matrix gradually increase and the size of the cobbles become smaller (Fig. 4).

Most of the surrounding sediments are the alternation of sandstone and shale (Fig. 5), and the graded bedding is observed in them frequently. The sediments are composed of the angular fragments of detrital clinopyroxene and plagioclase along with some quartz grains.

Although most of the green stones in the Mikabu Belt do not contain potash mica, the sediments commonly contain sericitic muscovite and sometimes calcite. This means the addition of the ordinary pelitic materials to the gabbroic components. Because the main constituent minerals are clinopyroxene and plagioclase, and the rocks are green in colour, when the rocks are coarse grained, the distinction between the real igneous

Table 1. Sequence of the igneous activities in the Mikabu Belt.

Stages of activities	Green stones	Relic minerals	Metamorphic minerals
1st Basement of pillow lava	Hb-cpx gabbro, Plagiogranite	hornblende, clinopyroxene, pigeonite pseudomorph	pumpellyite, soda-amphibole
2nd Lower pillow lava	Hyaloclastite	clinopyroxene	pumpellyite, grossularite
3rd Intrusive facies of upper pillow lava (cumulate)	Hb-cpx gabbro, Hb-pyroxenite, Pyroxenite, Ultrabasic rocks	hornblende, clinopyroxene, olivine	pumpellyite, epidote, soda-amphibole, serpentine
3rd Feeder of upper pillow lava	Diabase dykes	clinopyroxene	epidote, soda-amphibole
3rd Upper pillow lava	Hyaloclastite, Pillow lava	clinopyroxene	pumpellyite, grossularite, riebeckite

All of the green rocks except ultrabasics contain actinolite, chlorite, albite and quartz as the metamorphic minerals.

Table 2. Chemical analyses of the clinopyroxene from the gabbroic block in Unit III (olistostrome) comparing with the minerals from the pillow lavas of Unit I and II.

	I	II	III	IV	
SiO ₂	48.13	51.3	52.85	52.09	I : The feather crystal in the ground-mass of the lava of Unit I.
Al ₂ O ₃	5.88	3.65	1.75	2.40	II : The phenocryst of the lava of Unit II.
TiO ₂	1.98	0.8	0.25	0.33	III : From the gabbroic block of Unit III.
FeO*	12.41	6.35	9.0	8.46	IV : Detrital clinopyroxene grain from the gabbroic sandstone of Unit III.
MnO	0.46	0.15	0.25	0.19	
MgO	11.64	16.8	16.4	17.60	
CaO	17.93	19.35	19.1	18.14	
Na ₂ O	1.00	0.25	0.25	0.15	
	99.43	98.65	99.85	99.36	Feo* : Total Fe as FeO.

Fig. 4. A hand specimen of the gabbroic breccia. The specimen came from near the huge gabbroic block. The distance from the block is approximately 100 m.

Fig. 5. An outcrop of the alternation of gabbroic-sandstone and -shale.

gabbro (gabbro blocks -olistoliths) and the gabbroic sandstone (matrix of the olistostrome) is usually difficult in the outcrop. However, the discrimination is possible under the

microscope (Fig. 6). The matrix sediments are sometimes conglomeratic, and the pebbles of basaltic lavas, red radiolarian chert and red shale are found along with abundant gabbroic pebbles. Sometimes, the amounts of red shale increase and the sediments gradually change into the strata of red shale. In the matrix sediments, all of the huge blocks are gabbro, the other kinds of rocks occur exclusively as small pebbles.

The submarine sliding deposits occur also in the matrix of the olistostrome. They are the alternation of red shale and green gabbroic sandstone, the appearance is chaotic mixture of green and red seams with complicately folding appearance. No acidic igneous rocks crop out in the Mikabu Belt of the eastern part of Shikoku, however, the pebbles of plagiogranite are found in the matrix sediments. The plagiogranite contains clinopyroxene, albite and quartz along with hornblende sometimes. The typical graphic texture of albite and quartz is observed in the rock (COLEMAN & PETERMAN, 1975).

Some considerations on the gabbroic breccia

The same gabbroic breccias (olistostrome) are also found in the other several localities within the Mikabu Belt. For example, in the Osugi area of central Shikoku and in the Okuki area of western Shikoku the same rocks occur in the same geological situations. In the Okuki area, the gabbroic breccia (olistostrome) has been hitherto erroneously

Fig. 6. The texture of the gabbroic rocks under the microscope.

- a) The texture of the gabbroic block (Olistolith).
The linear arrangement of the lath-shaped crystals of plagioclase could be visible.
- b) The texture of the coarse-grained gabbroic sandstone.
The difference between the both rocks are clear under the microscope, but their appearances are similar in the handspecimens.

referred to as a kind of layered gabbro, because the rock looks like the alternation of fine-grained and coarse-grained gabbro.

The similar gabbroic breccias have been reported in the Ligurian Apennine (GIANELLI & PRICCI, 1974) and in the several ophiolite area of the world. The rocks of the Ligurian Apennine has been explained as the erosion of the oceanic rise of Jurassic age.

The mode of emplacement of the gabbroic breccia in the Mikabu Belt is not certain at moment. However, it will be clear from the occurrence that the gabbroic breccia has been formed by the gravity sliding of gabbroic layer, and the gabbroic blocks slide into the gabbroic sediments which have the turbidite character.

The gabbroic layer would be composed of tholeiitic gabbro with small amount of plagiogranite and probably would be covered by lava and red radiolarian chert.

We can not find anywhere the continuous basement layer in the Mikabu Belt at present, but the pillow lava of Unit I and II are thought to be erupted on the gabbroic layer which corresponds to the past oceanic crust. This assumption is based on the chemistry of the pillow lavas (SUGISAKI *et al.*, 1972; TANAKA, 1977) and also based on the field occurrence.

Fig. 7. A texture of the gabbroic shale under the microscope.

A kind of the oolitic texture is visible in this specimen.

As shown in the Fig. 7, gabbroic sandstone has sometimes a kind of oolitic structure which is characteristic of shallow water sedimentation. It will be assumed that the uplift of the green stone belt has reached the level of the sea surface in the end of the Paleozoic age.

If the assumption is correct, the gabbroic blocks in the Unit III (olistostrome) will give the oldest age in the green stone complex. The determination of the age is not yet done. The metamorphic grade of the blocks and

the surrounding sediments is almost same, and we can not yet find the trace of oceanic metamorphism in the block. Though the diabasic dykes commonly carry the clinopyroxene phenocrysts, plagioclase phenocrysts are very rare and no hornblende phenocrysts are observed. In spite of this observation on the phenocrysts, a lot of intrusive bodies of hornblendites or clinopyroxene-hornblendites occurs in the lower pillow lava. It is not certain whether the hornblende is the metamorphic mineral or mineral which has crystallized from the basaltic liquid.

The two kinds of information, namely age determination and the detailed analyses of metamorphic mineral paragenesis will throw the light on the problems.

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四国東部みかぶ緑色岩帯のはんれい岩質角礫岩（オリストストローム）

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(要 旨)

四国東部みかぶ緑色岩帯に、秩父帯（上部古生代—三疊紀の弱変成層の帯）と緑色岩帯の境界にそってはんれい岩質角礫岩（オリストストローム）を産する。

このオリストストローム層の簡単な記載をした。オリ

ストリスとしてのはんれい岩塊は、はんれい岩層由来であり、そのはんれい岩層は枕状溶岩の基盤で、かつての海洋地殻を構成していた岩石に対応すると考えられる。