BULLETIN OF THE EARTHQUAKE
RESEARCH INSTITUTE
Vol. 40 (1962), pp. 523-531

24. *Orbicular Rock from Asahi-dake, Yamagata Prefecture.**

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(Read April 24th, 1962.—Received April 24th, 1962.)

Introduction

The granitic area of Asahi-dade is deeply dissected and highly cliffed along the uppermost course of the Ara-kawa, as can be seen at the source of this river where main peaks are represented by Ōasahi-dake (1870.3 m.), Nishi-asahi-dake (1813.7 m.), Sode-asahi-dake (1665.1 m.) and Hiraiwa-yama (1609 m.). In August of 1956, when the writer spent several days here to prospect uranium minerals, his students, S. Sutō and K. Sugai, found some boulders of orbicular rock on the river-bed of the Ara-kawa running down southwestwards at the eastern foot of Sode-asahi-dake. As far as is known at present, these boulders are distributed to a small extent, suggesting that they were supplied from the eastern flank of Sode-asahi-dake which rises up very steeply on the boundary between Yamagata Prefecture and Niigata Prefecture. It is, however, impossible to approach this place, since there are many large cliffs here and there. Thus, the specimens of orbicular rock could not be collected from its outcrop. Mineralogical and chemical investigations were, therefore, carried out only on the fragments gathered from the boulders mentioned above.

Form and Structure

The rock under consideration contains heavily crowded orbicules in the matrix of a dark grey color due to the abundance of ferromagnesian minerals. These orbicules are mostly found as rounded polyhedrons, something like ill-shaped ellipsoids which have their long and short axes ranging from 4.5 cm. × 3.5 cm. to 9 cm. × 7.5 cm. They are composed of a nucleus and its concentric shells. In this case, the former is 6 cm. × 5 cm. in the long and short axes of the largest one, and the latter reveals a thickness of 0.3 cm. — 1.5 cm. As can be noticed in each of such orbicules, the nucleus is always the coarse aggregate of feldspar

* Communicated by H. TSUYA.

with a small amount of ferromagnesian minerals, whereas the rim consists of concentric zones rich or poor in biotite which are alternately arranged, the outermost part being generally surrounded by a thin zone, 1 mm.—2 mm. thick, almost free of ferromagnesian minerals.

The size and form of such orbicules are much affected by those of the nucleus. The same may be said of the thickness of concentric shells. Hence, the large orbicules have thick concentric shells composed of several zones, but the small ones show a very simple structure.

Mineral Composition of Matrix ond Orbicules

(1) Matrix: It is a compact and hard rock of a dark color and dioritic appearance. Under the microscope, the rock is composed of quartz, plagioclase, biotite, hornblende, allanite, apatite, zircon, leucoxene, titanite, epidote, chlorite, limonite and sericite, suggesting that it has some similarity to the quartz diorite exposed largely on Nishi-asahi-dake[1].

Of these, quartz has an irregular form and is present in small quantity, filling up the interstices of other minerals and revealing a mosaic or interdented structure. This mineral is always characterized by a remarkable strain shadow, predominance of cracks and high frequency of liquid inclusions. Sometimes, it includes apatite, biotite, hornblende and plagioclase.

Plagioclase is one of the important mineral ingredients. It is andesine and occurs as subhedral or anhedral crystals which are rarely zoned and intensely sericitized. Its enclosures are apatite and magnetite.

Biotite and hornblende are main ferromagnesian minerals. The former is not infrequently enclosed by the latter when they are closely associated, forming some intricate texture between them. Biotite is found as flaky crystals occasionally twisted, and it is partly or wholly chloritized with the formation of leucoxene and titanite. Such enclosures as apatite, magnetite and zircon are commonly to be seen. Hornblende is subhedral or anhedral in its crystal form and has a fresh appearance. Some of it is twinned on (110), and there are sporadically opacitized crystals. Exclusive of biotite, the enclosures are restricted only to magnetite and zircon.

Among accessory minerals, the prismatic or needle-shaped apatite is most noticeable, being generally enclosed in plagioclase. It has a

1) T. OGURA, *Bull. Yamagata Univ.* (*Nat. Sc.*), **4** (1957), 208.

Table 1. Essential mineral ingredients of matrix.

Quartz	Andesine-labradorite	Biotite	Hornblende
Diameter= 0.06 mm.– 0.2 mm.	Mostly 0.2mm.–0.6mm. in larger diameter. α=1.546 (min.) γ=1.560 (max.) An_{35-46}	Max. diameter (on base)=1.8 mm γ=1.650± X=light yellow, $Y=Z$=dark brown.	7 mm. long and 1.5 mm across in the largest crystal. Mostly, 0.3 mm.– 4 mm. in length. γ =1.657 α =1.678 $\gamma-\alpha$=0.021 $Z \wedge c$=22° X =light yellow. Y =yellowish green. Z =green $Z>Y>X$

length of 0.94 mm. in the largest crystal.

Magnetite takes an octahedral or irregular form and is mostly contained in hornblende crystals. The largest one is 2 mm. in diameter.

Zircon appears in minute prismatic crystals, 0.13 mm. long and 0.06 mm. across in the largest one. It is very low in frequency. In the same way, allanite is a mineral of rare occurrence.

Leucoxene and titanite are alteration products due to the chloritization of biotite and appear in anhedral crystals along the cleavage of chloritized biotite, whereas the scaly sericite derived from plagioclase produces a confused aggregate. Besides them, there are epidote and limonite contained in a negligible amount.

(2) Orbicules: As has already been described, the orbicules under consideration are composed of two parts, nucleus and concentric shells characterised by a radiate structure.

(i) Nucleus: It is a whitish and coarse-grained rock consisting of plagioclase, quartz, biotite, apatite, magnetite, zircon, titanite, leucoxene, chlorite, epidote and calcite.

Under the microscope, plagioclase is extremely abundant as compared with others, and the nucleus is almost entirely composed of this mineral. It is labradorite which is mostly represented by subhedral or anhedral crystals. Some of these crystals are intricately twinned and partly sericitized. The largest crystal is estimated to be 13.2 mm. long and 3.4 mm. across.

Quartz is also a common mineral in the nucleus. It has an irregular form and mosaic or interdented structure, filling up the interstices of plagioclase crystals. In this case, the wavy extinction is always very remarkable. Moreover, the crystal is generally rich in cracks and liquid inclusions.

Besides these, a noticeable mineral is biotite. This mineral is frequently chloritized and uniformly distributed throughout the nucleus.

Table 2. Essential mineral ingredients of the nucleus.

Quartz	Plagioclase	Biotite
Diameter=0.01 mm.−7 mm.	Mostly, 4 mm.−7 mm. in larger diageter.	Max. diameter (on base) =2 mm.
	γ=1.555	γ=1.643±
	α=1.562	X=light brownish yellow.
	An_{50}	$Y=Z$=dark brown.

The prismatic or needle-shaped apatite is contained in minor quantity. Its crystal is 0.32 mm. in the maximum length. Similarly, magnetite and zircon are present to a negligible degree. Epidote and titanite are, on the other hand, found occasionally in high frequency. They take an irregular form, the larger diameter being 0.93 mm. in the former and 1.27 mm. in the latter. Some of this titanite is an alteration product derived from the chloritized biotite which forms a confused aggregate together with leucoxene. In connection with these, chlorite is a secondary mineral of frequent occurrence. Sericite forms the aggregate of minute flaky crystals in plagioclase and is also found in association with biotite.

(ii) Concentric shells: The concentric shells of orbicules are composed of whitish or dark zones which are formed by a gradual increase or decrease of biotite. These two kinds of zone are alternately arranged and reveal no sharp boundary between them, although they are sometimes repeated several times in large orbicules. In such a case, the outermost shell is almost or entirely free of biotite, whereas the innermost one is always rich in this mineral.

The mineral composition is nearly the same as that of the nucleus already mentioned, excluding the occurrence of allanite and hornblende in some zone.

In each zone, plagioclase is the most abundant mineral, ranging from andesine to labradorite and being characterized by the change of basicity which increases towards the inner zone. Frequently, the crystal is twinned in an intricate manner. Some of it is indistinctly zoned and intensely sericitized.

Quartz fills up the interstices of plagioclase crystals as is shown in the nucleus. It is also a noteworthy mineral ingredient throughout all zones. The remarkable wavy extinction, liquid inclusions and cracks are similarly to be seen in most thin sections. Apatite is its common enclosure.

Biotite plays an important role to form a zonal structure in shells. The mineral occurs as six-sided plates or flaky crystals and has a tendency to increase its indices of refraction in the inner zone. It is partly chloritized.

Table 3. Essential mineral ingredients of concentric shells.

Quartz	Plagioclase	Biotite
Diameter = 0.02 mm.–2.3 mm.	Mostly, 0.25 mm.–2 mm. in larger diameter. 4.35 mm. long and 1.53 mm. in the largest one. γ =1.547–1.554 α =1.555–1.561 $\gamma-\alpha$=0.008–0.007 An_{36-50} Enclosure = apatite	Max. diameter (on base) =1.84 mm. γ =1.643–1.652 X=light brownish yellow. $Y=Z$=dark brown. Enclosures = apatite and magnetite.

Hornblende is, on the other hand, present to a negligible degree at the outermost part of concentric shells. This mineral, however, increases remarkably in the matrix. It is a green hornblende and pleochroic from light yellow (X) to yellowish green (Y) or green (Z). The crystal is mostly subhedral or anhedral.

Apatite is the commonest accessory mineral, taking a long or short prismatic form. In the case of needle-shaped crystals, the largest one is 0.5 mm. long. The mineral is generally enclosed in quartz or plagioclase. Magnetite is octahedral or skeletal, its largest crystal being 0.5 mm. in its greatest diameter. It occurs in a minor quantity. The stout prismatic or rounded zircon is almost negligible in frequency. In the same way, allnite is a mineral of rare occurrence with a strong absorption changing from dark brown (X) to dark reddish brown (Z).

In addition to these, the occurrence of the anhedral epidote and titanite is known in all thin sections. In these cases, the former is a alteration product due to the decomposition of such a ferromagnesian mineral as biotite. The latter is also contained mostly in the chloritized biotite, forming a confused aggregate together with leucoxene and suggesting that they are similarly decomposition products. Sericite is abundant in plagioclase and is occasionally associated with biotite subjected to chloritization.

Chemical Composition

There are two available data for the chemical composition of orbicules. They are shown in Table 4.

Table 4. Chemical composition of an orbicule.

Weight %			Norm		
	I	II		I	II
SiO_2	55.08	61.80	Q	7.02	12.78
Al_2O_3	23.17	22.57	Or	8.89	7.23
Fe_2O_3	1.05	0.58	Ab	38.78	40.35
FeO	2.06	0.68	An	36.14	36.14
MgO	1.28	0.52	C	0.71	0.10
CaO	7.30	7.32	Fs	2.51	0.53
Na_2O	4.59	4.78	En	3.20	1.30
K_2O	1.51	1.20	Il	0.61	0.30
H_2O+	0.72	0.26	Mt	1.39	0.70
H_2O-	0.30	0.35			
TiO_2	0.35	0.16			
P_2O_5	tr.	—			
MnO	tr.	—			
Total	100.45	100.24			

I = Concentric shells. II = Nucleus.
Analyst, T. T. Yen. (Taiwan National University)

As can be seen in this table, the nucleus is more acidic than its concentric shells, both of them being characterized by a high percentage of Al_2O_3 as compared with that of SiO_2. The abnormal features are also indicated by the normative albite and anorthite. The rooks with such chemical compositions are almost unknown in those of magmatic origin. They are, however, found commonly in gneissose rocks metamorphosed from sediments.

Origin of the Orbicular Rock

So far as is known at present, there are at least eleven localities of orbicular rocks in Japan. They are represented by those of Otakasawa[2], Minedera-san[3], Kenashi-yama[4], Nikenya[5], Aonohara-mura[6], Sanage-yama[7], Amo[8], Marugami-jima[9], Yashiro-jima[10], Ainoura[11] and Kamisho-mura[12]. In these cases, the host rocks of orbicules are granite, quartz diorite, diorite and norite.

As has already been stated, the orbicules contained in quartz diorite of Asahi-dake are always composed of nucleus and concentric shells with a radiate structure, some of them having the external appearance of the orbicular esbolite of the Amō mine[13]. In the writer's specimens, they are quite free of such xenolithic nuclei as is indicated by those of orbicular granite of Minedera-san first found by the writer and K. Iwasaki[14] many years ago. There is, therefore, no exact evidence to determine the original rocks from which the orbicules under consideration were derived, although the chemical composition suggests that they were probably formed from fragmental sediments that had fallen into the granitic magma.

As to the alteration of xenolithic rocks immersed in the granitic magma, the writer has observed many good examples at Wushiphi in Formosa[15] where amphibolite and gneiss are well exposed. The gneiss of this place contains various fragments of amphibolite, large and small. When they are subjected to alteration, biotite begins to appear in the xenolithic amphibolite and increases its frequency with the simultaneous decrease of hornblende. Thus, the original amphibolite becomes first biotite schist. These fragments of biotite schist are next surrounded

2) D. SATŌ, *Dept. Home Affairs, Preservation Nat. Monuments, Japan*, (1926), 18-19.

3) K. K. IWASAKI, *Jour. Geol. Soc. Tokyo*, **22** (1915) 372, 388-390., B. YOSIKI, *Jour. Japan Assoc. Min. Petrol. & Econ. Geol.*, **10** (1933), 151-157.

4) H. TAKEUCHI, *Jour. Japan. Assoc. Min. Petrol. & Econ. Geol.*, **22** (1935), 75-105. 211-222.

5) T. SHIKAMA & Y. SHIMAOKA, *Jour. Geol. Japan*, **58** (1952), 154.

6) K. MIKAMI, *Jour. Geol. Soc. Japan*, **58** (1952), 516.

7) Y. KAWANO, *Jour. Japan. Assoc. Min. Petrol. & Econ. Geol.*, **20** (1938), 12-25. 60-70.

8) K. ISHIOKA, *Jour. Earth Sc., Nagoya Univ.*, **1** (1953), 85-95, 97-106.

9) H. SATŌ, *Jour. Geogr. (Tokyo)*, **42** (1939), 236-237.

10) Y. WATANABE, Ms. *from Hiroshima Univ.*, (1951).

11) T. AKAGI, Explanatory Text of the Ogi Sheet, *Imp. Geol. Surv. Japan*, (1935). T. FUTAGAMI, Our Minerals, **6** (1937), 10-13.

12) K. KINOSHITA, *Jour. Geogr. (Tokyo)*, **41** (1929), 122.

13) K. ISHIOKA, *op. cit.*, 85-95.

14) K. IWASAKI, *op. cit.*, 372, 388-390.

15) T. ICHIMURA, *Taiwan Tigakukizi*, **8** (1942), 4-5.

and traversed by a leucocratic material which consists of quartz, plagioclase and a small amount of biotite. At the final stage, every part of biotite schist changes into the leucocratic mass with a rounded form, being sharply or indistinctly bordered against its host rock.

The same process of alteration may be observed in the formation of orbicules contained abundantly in quartz diorite of Asahi-dake. The products of interaction here are likely to have diffused outwards, resulting in the formation of feldspathic nucleus and alternate zones rich or poor in biotite as well as the radiate structure through them.

Summary

i) Quartz diorite containing heavily crowded orbicules were found at the uppermost course of the Ara-kawa where Ōasahi-dake, Nishi-asahi-dake and Sode-asahi-dake are highly cliffed.

ii) The orbicules of this rock have a spherical or ellipsoidal form, consisting of nucleus and concentric shells with a radiate structure. In such cases, the nucleus is feldspathic and poor in biotite, whereas the concentric shells are represented by biotite-rich or poor zones alternately arranged. The mineral ingredients of the leucocratic part are quartz, labradorite or andesine, biotite, apatite, magnetite, zircon, titanite, leucoxene, epidote and calcite. In the dark zone, biotite is abundantly present, but almost or entirely free of green hornblende which is a common mineral in the host rock. It is also noticed that plagioclase of orbicules is more basic in nucleus.

iii) Chemically speaking, the nucleus and concentric shell of orbicules are abnormally high in Al_2O_3 when compared with the percentage of SiO_2. In this case, the former is more acidic than the latter.

iv) The chemical composition suggests that the orbicules were derived from xenolithic sediments subjected to granitization. At the final stage of alteration, the diffusion of material seems to have taken place outwards in the products of interaction. Probably, it formed the feldspathic nucleus and concentric shells as well as the radiate structure.

Acknowledgments

The writer wishes to express his sincene thanks to Professor H. Tsuya, Mr. T. Watanabe and Professor T. T. Yen who facilitated his work. He is also deeply indepted to Mr. K. Sugai and Mr. S. Suto for

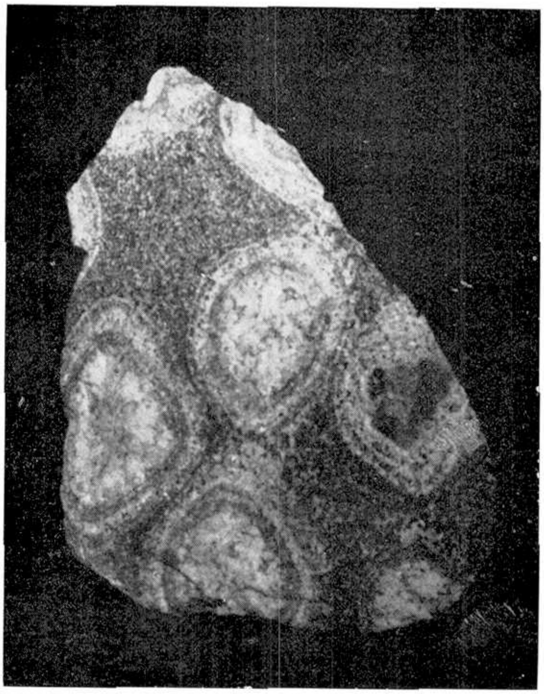

Fig. 1. Orbicules in the host rock. 1/3.

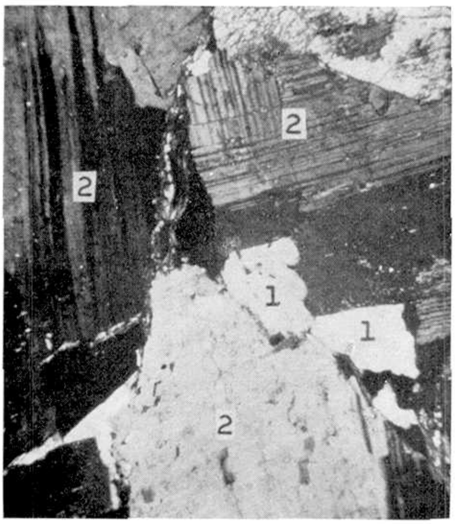

Fig. 2. Nucleus. 1=Quartz, 2=Labradorite. ×100.

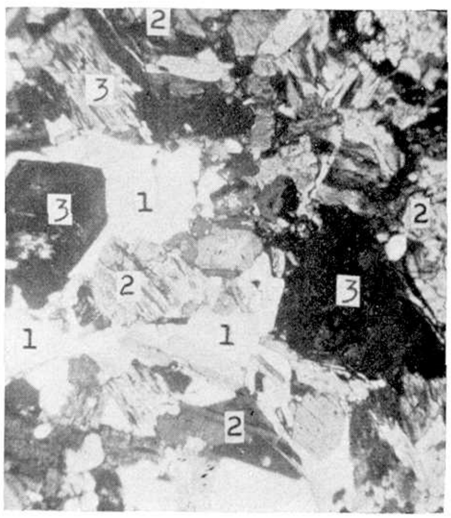

Fig. 3. Biotite-rich zone of concentric shells. 1=Quartz, 2=Andesine, 3=Biotite. ×100.

the collection of several specimens. Thanks are also due to Miss M. Suzuki for her co-operation in his petrographical investigations of the orbicular rock.

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24. 朝日岳産の球状岩

市村　　毅

山形・新潟県境の大朝日岳，西朝日岳，袖朝日岳などによつて囲まれた荒川の奥地には，石英閃緑岩を母体として，球状岩が産する．それは袖朝日岳東腹の大きな断崖上に露出するものであり，今日では，その断崖を登ることはできないが，そこから転落したものが，荒川最上流の河床に数多く見出される．

球状岩は，母体をなす石英閃緑岩とその中に密集する大小の球状体からなり，これらの球状体は，優白色長石質の核とこれをとり巻く優白色および暗色の交互帯とに区別できるばかりでなく，いずれの球状体にも，放射状構造が認められる．この場合，優白色部は，石英，中性長石，曹灰長石，黒雲母，燐灰石，磁鉄鉱，ジルコン，榍石，白チタン石，緑簾石および方解石を含み，黒雲母が多量になると，暗色部へ変つて行く，ただし，球状体には，その縁の部分でも，母体に多い角閃石を殆んど，あるいは全然含有しない．

化学的に見ると，球状体の核も，そのまわりの交互帯も，SiO_2 の割合に比し，Al_2O_3 が異常的に多く，これが元来岩漿から導かれたものでなく，堆積岩の花崗岩化作用によつて生じた片麻岩に該当することを示し，核は交互帯よりも酸性である．球状体の生成については，花崗岩漿に落ち込んだ堆積岩の岩片が，周囲から岩漿の影響を受けて内容に変化を起し，最後に前記のような化学成分を有する球状体化したものと思われる．またその際，球状体の内部から外側へと一部混合物質の移動，滲透が起り，交互帯が核のまわりに生じるようになつたと見做され，放射状構造も，このとき作られたものと考えられる．