Source Identification of Some Granitic Xenoliths in Volcanic Rocks

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Source Identification of Some Granitic Xenoliths* in Volcanic Rocks

By

Tôru TOMITA and Yoshifumi KARAKIDA

Introduction

So many occurrences of granitic xenoliths in volcanic rocks have repeatedly been reported in our country that it would be an exceedingly laborious work to make a complete list of literature concerning them. Such as the circumstances are, the sources of these granitic xenoliths have not yet been definitely determined because perhaps of an inevitable difficulty frequently met with in identifying by thin-section examination the essential minerals of xenoliths which were affected by lava heat with those of supposed source granite. In addition, according to our experience, in such a case as are found two or three kinds of granitic rocks among the basement complex, the usual microscopic examination scarcely provides reliable criteria upon which we are to make a choice of the source granite of xenoliths.

In this paper is presented a new method of identification in question. Under this method the habit of zircon crystals concentrated from both xenolithic and basement granites are compared with each other, the results having been practically satisfactory. Since the details of the rocks concerned have nothing to do with the subject of this paper, the descriptions of them are not given here.

Brief Sketch of Geology

Guided by previous geological reports and colleagues' information, one of us (Y. K.) visited several localities in Southwest Japan of granitic xenoliths in volcanic rocks (Table 1) to collect specimens for this work.

Table 2 shows the geological records of the volcanic rocks, their xenoliths, and the basement rocks dealt with in this paper. Age problem on these rocks will be discussed in another paper now in preparation.

Identifying Source Granite by Zircons

Classification of Zircons. This investigation is concerned with two aspects of the morphology of granite zircons: (1) combination of forms, or Tracht (NIGGLI, 1924, p. 641); (2) relative width of prismatic faces.

Our simple classification of the Tracht of zircons is as follows (Fig. 1):

* Received April 15, 1958

Table 1. Localities of Granitic Xenoliths Investigated, Southwest Japan

No.	Localities	References
1	Imayama, Fukuoka City, Fukuoka Pref., Kyushu	This paper
2	Mizukami — Itoshima Peninsula, 20 km west of Fukuoka City, Fukuoka Pref., Kyushu	This paper
3	Kubota — Itoshima Peninsula, 20 km west of Fukuoka City, Fukuoka Pref., Kyushu	This paper
4	Myoken-yama Hill, near Kurosaki, Yahata City, Fukuoka Pref., Kyushu	This paper
5	Tsurumi Volcano — west of Beppu City, Oita Pref., Kyushu	TOMITA et al. (1952); KASAMA (1953)
6	Yufu Volcano — west of Beppu City, Oita Pref., Kyushu	TOMITA et al. (1952); KASAMA (1953)
7	Ishigami-yama Hill, at the eastern foot of the Kimpo-zan Volcano, Kumamoto City, Kumamoto Pref., Kyushu	MORIYAMA (1948)
8	Eastern foot of the Sakurajima Volcano, Kagoshima Bay, Kyushu	K. YAMAGUCHI's oral communication
9	Shibuki — about 10 km northeast of Hagi City, Yamaguchi Pref., Chugoku	SUGI (1942)
10	Nanae — about 10 km northeast of Hagi City, Yamaguchi Pref., Chugoku	SUGI (1942)
11	Kashima islet, off Hojo Town, about 12 km north of Matsuyama City, Ehime Pref., Shikoku	TOYODA (1931)
12	Ruins of the Marugame Castle, Marugame City, Kagawa Pref., Shikoku	SATO (1936)
13	Washino-yama Hill, about 14 km east of Marugame City, Kagawa Pref., Shikoku	SATO (1936)
14	Ko-no-ura — west coast of the Mito Peninsula, southwest end of Shodo-shima I., Seto-uchi (Inland Sea of Japan), Southwest Japan	SATO (1932)
15	Gongen-saki — west coast of the Mito Peninsula, southwest end of Shodo-shima I., Seto-uchi (Inland Sea of Japan), Southwest Japan	SATO (1932)
16	South of Yoshino hamlet — west coast of the Mito Peninsula, southwest end of Shodo-shima I., Seto-uchi (Inland Sea of Japan), Southwest Japan	SATO (1932)

Group I. Crystals of one prism, either *a* (100) or *m* (110), with one or more pyramids:

Tracht S

Group II. Crystals of two prisms, both *a* (100) and *m* (110);

Sub-group IIA. Those having only one pyramid, either *p* (111) or *x* (311) or *u* (331):

Tracht D

Sub-group IIB. Those having both *p* (111) and *x* (311), with
or without any other pyramids:
Tracht C

On the other hand, zircons may also be classified according to the relative width of *a* (100) and *m* (110) as follows:

(1) Habitus[1] A: *a* only, or $a>2m$;

(2) Habitus M: *m* only, or $m>2a$;

(3) Habitus G: $2m>a>m$, or $2a>m>a$.

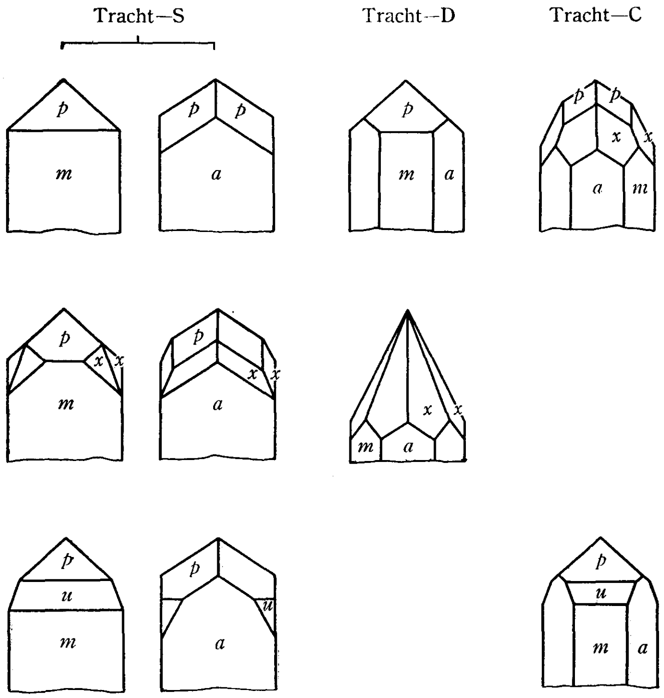

Fig. 1. Schematic classification of zircon Tracht.
a (100), *m* (110), *p* (111), *x* (311), *u* (331)

Tracht and Habitus Diagrams. After the Tracht type for each crystal of zircon crops from a single granite specimen is determined under the microscope,[2] the sum of the three Tracht types is calculated to 100 per cent to obtain a plotting point for a triangular diagram, or the Tracht diagram SCD. Thus any point on the SCD diagram represents the Tracht of the zircon concentrate, which consists of a mixture of the three end types, of a single granite. Such is also the case with the Habitus diagram AGM.

Source Identification of Granite Xenoliths. With the aid of these two diagrams

1) This term (NIGGLI, 1924, p. 641) is conveniently used here to designate the relative width of prismatic faces.

2) Two hundred to four hundred crystals are dealt with for each rock sample.

Table 2. Volcanic Rocks, Basement Rocks, and Xenoliths in the Volcanic Rocks

No.	Loc.	Volcanics	Basement	Xenoliths
1	Imayama	OB (plug)	Itoshima GD, coarse and schistose	Schistose GD, <30–40 cm; AP (rare)
2	Mizukami	OB (plug, 50–100 m in dia.)	Ditto	Coarse and schistose GD, disintegrated, <50 cm
3	Kubota			
4	Myoken-yama	OB (plug, 200 m in dia.)	Hirao GD, not fresh, with "dark inclusions"	Porous GrR, 7–8 cm; AP, 3–4 cm
5	Tsurumi	HA (lava)	Propylite; PA	Partially fused GD, <30 cm (usu. 2–4 cm), occas. drawn out; Fine Gr; Ap; Pg; CS (rare)
6	Yufu			
7	Ishigami-yama	HA (plug)	No exposure	GD, faintly schistose Gr, fine Gr, Pg, <15–20 cm; Slaty to phyllitic rocks, meta-db, greenschists, amphibolite, IGn, GnR, <20–30 cm
8	Sakurajima	PA (1st lava)	No exposure	Fused (vitrified) Gr
9	Shibuki	OB (lava)	Rhyolites; various QP; monzonite; biotite-Gr	Partially fused Gr, <10 cm; AP (rare)
10	Nanae	HA (lava)		Fragile Gr, rounded (<15 cm) and filmy (1 cm in thickness)
11	Kashima	Ol-bA (plug)	Matsuyama GD, decomposed	GrR, finely fragmental
12	Marugame	Ag–SA (dike)	Coarse biotite-Gr with fine D xenoliths; Fine two-mica-Gr, associated with GnR	Highly decomposed GrR, <30 cm
13	Washino-yama	Hy–HA (lava)	Hornblende-biotite-GD, coarse	Meta-Gb; D; medium–coarse schistose Gr; Aggregates of biotite and of garnet
14	Ko-no-ura	OB (large plug)	Mito GD, consisting of very coarse GD (schistose in part, with "dark inclusions"), GnR, leuco-Gr, and "hedenbergite-syenite"	Partially fused granodioritic rock (schistose) (<1 m or more)
15	Gongen-saki	OB (plug)		
16	Yoshino	Ol–Ag–AB (lava)		GD (schistose), Gb, D, IGn, CS, <30 cm

Abbreviation key. Ag–SA, augite-bearing sanukitic andesite; Ap, aplite; CS, crystalline schist; D, diorite; db, diabase; Gb, gabbro; GD, granodiorite; GnR, gneissose rock; Gr, granite; GrR, granitic rock; HA, hornblende-andesite; Hy–HA, hypersthene-hornblende-andesite; IGn, injection-gneiss; OB, olivine-basalt; Ol–Ag–AB, olivine-augite-andesitic basalt; Ol–bA, olivine-bearing bronzite-andesite; PA, pyroxene-andesite; Pg, pegmatite; QP, quartz-porphyry.

xenolith-zircons can be identified with those of basement granitic rocks, and when the zircon of the granite of the basement or in the neighbouring area is proved to be identical in habit with xenolith-zircon, the granite is considered to be the source granite of the xenolith.

Results

A. Xenoliths Derived from Exposed Granites

Imayama (Loc. 1), *Mizukami* (Loc. 2), and *Kubota* (Loc. 3). Xenolith-zircons from these localities (Pl. 7, Figs. 2, 4) are identical in Tracht (Tracht C$>$ 99%; the SCD diagram is omitted here), in Habitus (Figs. 2, 3), and in clearness with the Itoshima zircon[3)] (Pl. 7, Figs. 1, 3).

Myoken-yama (Loc. 4). Fig. 4 shows that the Myoken xenolith-zircons (Pl. 7, Fig. 6) and the zircons of the decomposed Hirao granodiorite (Pl. 7, Fig. 5) have identical habits.

Shibuki (Loc. 9) and *Nanae* (Loc. 10). Fig. 5 shows that the Shibuki xenolith-zircons (Pl. 8, Fig. 14) are closely identified with the zircons of the biotite-granite (Pl. 8, Fig. 13), a member of the basement. Of the two fragile granite xenoliths from Nanae, the filmy one is proved to be identical with the above-mentioned biotite-granite, while the identity of the other, which is of rounded form, is unknown (Fig. 5).

Marugame (Loc. 12). Highly decomposed they are, the xenoliths of granitic rock are divided megascopically into two types: one is coarse, and the other fine grained. Fig. 6 shows that the zircons of the coarse xenoliths (Pl. 9, Fig. 18) resemble those of the coarse biotite-granite (Pl. 9, Fig. 17) and that the zircons of the fine xenoliths (Pl. 9, Fig. 20) are identical with those of the two-mica-granite (Pl. 9, Fig. 19). The latter identification, moreover, is confirmed by the fact that both the

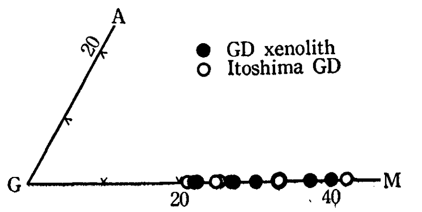

Fig. 2. Zircon Habitus diagram of Itoshima granodiorite and granodiorite xenoliths in Imayama olivine-basalt, Fukuoka City, Kyushu.

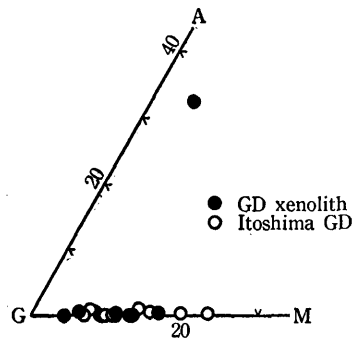

Fig. 3. Zircon Habitus diagram of Itoshima granodiorite and granodiorite xenoliths in Mizukami and Kubota olivine-basalts, west of Fukuoka City, Kyushu.

3) "Itoshima zircon" is short for the zircons of the Itoshima granodiorite.

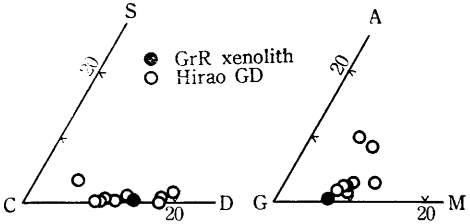

Fig. 4. Zircon Tracht and Habitus diagrams of Hirao granodiorite and a granitic xenolith in Myoken-yama olivine-basalt, near Kurosaki, Yahata City, Fukuoka.

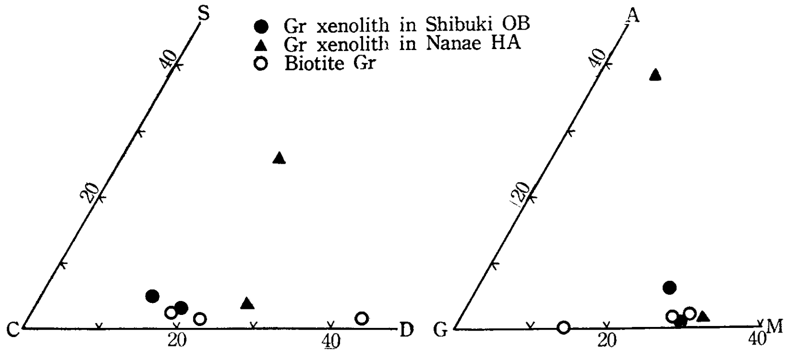

Fig. 5. Zircon Tracht and Habitus diagrams of biotite-granite and granite xenoliths in Shibuki olivine-basalt and Nanae hornblende-andesite, northeast of Hagi City, Yamaguchi Pref., Chugoku.

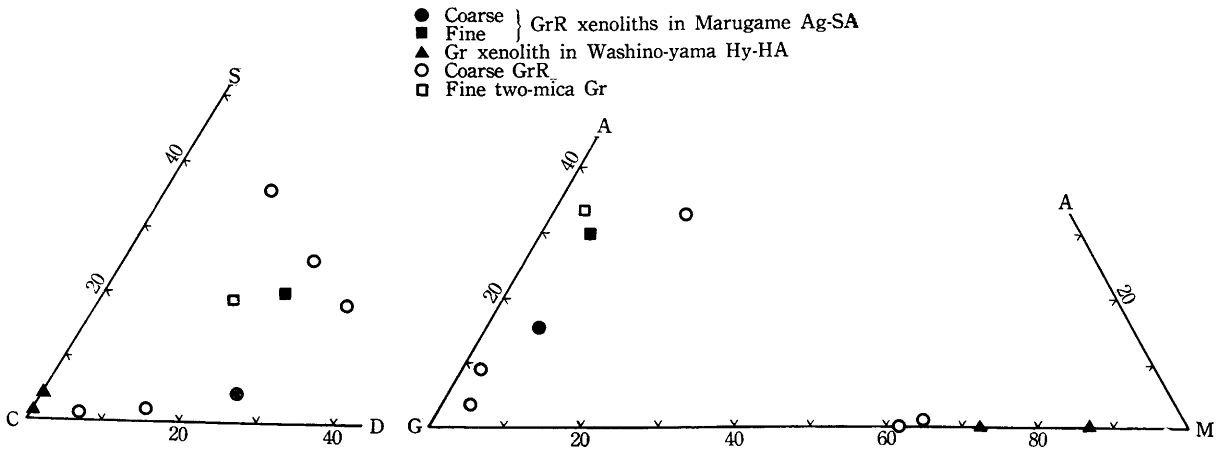

Fig. 6. Zircon Tracht and Habitus diagrams of coarse granitic rock and fine two-mica-granite and granitic xenoliths in Marugame augite-bearing sanukitic andesite and Washino-yama hypersthene-hornblende-andesite, in and near Marugame City, Ehime Pref., Shikoku.

fine xenolith and the two-mica-granite are relatively poor in zircon while relatively rich in monazite.

Ko-no-ura (Loc. 14), *Gongen-saki* (Loc. 15), and *Yoshino* (Loc. 16). Fig. 7 undoubtedly proves that the sources of the granitic xenoliths from these localities are the granodiorite and gneissose rock (Pl. 9, Figs. 21–24), members of the Mito granodiorite which consists of various rocks (Table 2).

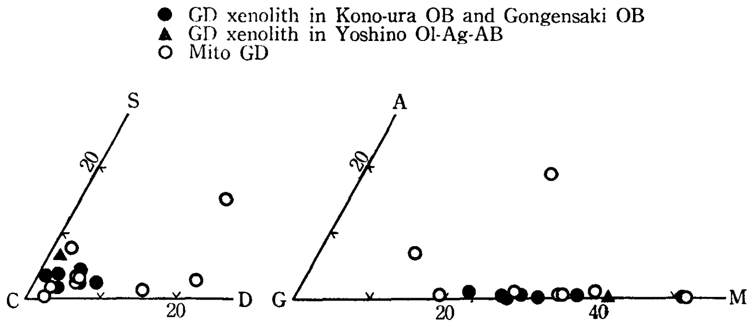

Fig. 7. Zircon Tracht and Habitus diagrams of Mito granodiorite and granodiorite xenoliths in Ko-no-ura and Gongen-saki olivine-basalts and Yoshino olivine-augite-andesitic basalt, Shodo-shima Island, Seto-uchi.

B. Xenoliths Derived from Buried Granites

Case–1. Localities where the basement granite is exposed

Kashima[4] (Loc. 11). Fig. 8 shows a slight difference both in Tracht and in Habitus between the xenolith-zircons (Pl. 8, Fig. 16) and the Matsuyama zircon (Pl. 8, Fig. 15), though much more data for the latter are necessary before a definite conclusion can be arrived at.

Washino-yama (Loc. 13). Highly schistose granite xenoliths yield zircons of somewhat characteristic habit (Fig. 6) which differs from that of the basement granodiorite[5] zircons.

Case–2. Localities where no basement granite is exposed

Tsurumi (Loc. 5) and *Yufu* (Loc. 6). Since there is no exposure of granitic rock in the basement, the xenolith-zircons from Tsurumi (Pl. 7, Fig. 8) and Yufu have been compared with the zircons of the Maruta granodiorite[6] (Pl. 7, Fig. 7), which is narrowly exposed beneath volcanics along the Maruta Valley, about 8 km north of the Yufu-dake Volcano. Between the xenolith-zircons and the Maruta zircon no difference in Tracht is distinguished (Tracht C>99%; the SCD diagram

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4) Specimens of the basement granodiorite and the xenolith from this locality were given by Mr. H. Toyoda.

5) Several specimens of the basement rocks were given by Mr. M. Yamada.

6) This rock, coarse to medium grained and schistose, encloses disk-like "dark inclusions," and, according to Kasama (1953), is a member of the Ryoke Metamorphic Zone.

is omitted here) and difference in Habitus is so slight as to be almost negligible (Fig. 9).

Ishigami-yama (Loc. 7). The Ishigami-yama hornblende-andesite belongs to the pre-Kimpo volcanics consisting chiefly of pyroxene-andesites (MORIYAMA, 1948). Although there is no exposure of the basement of these volcanics, many xenoliths of various rocks (Table 2) are observed at the Ishigami quarry. Fig. 10 shows that the xenolith-zircons (Pl. 8, Fig. 10) present an almost complete similarity in habit to the zircons of the Tamana granodiorite[7] (Pl. 8, Fig. 9), which is developed to the north to northeast of the Kimpo Volcano.

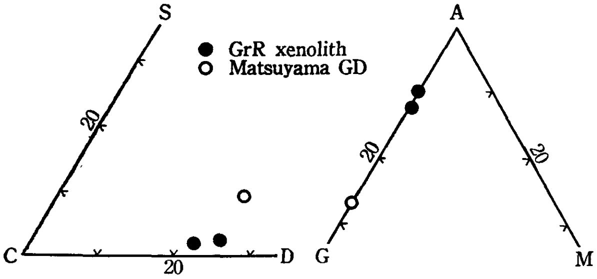

Fig. 8. Zircon Tracht and Habitus diagrams of Matsuyama granodiorite and granite xenoliths in Kashima olivine-bearing bronzite-andesite, Kashima islet, off Hojo Town, Ehime Pref., Shikoku.

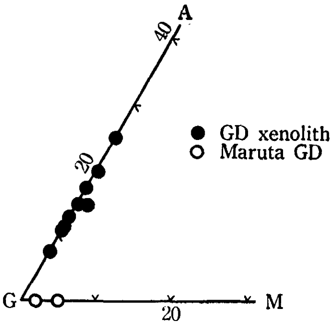

Fig. 9. Zircon Habitus diagram of Maruta granodiorite, about 8 km north of Yufu-dake Volcano, and granodiorite xenoliths in Tsurumi and Yufu hornblende-andesites, west of Beppu City, Oita Pref., Kyushu.

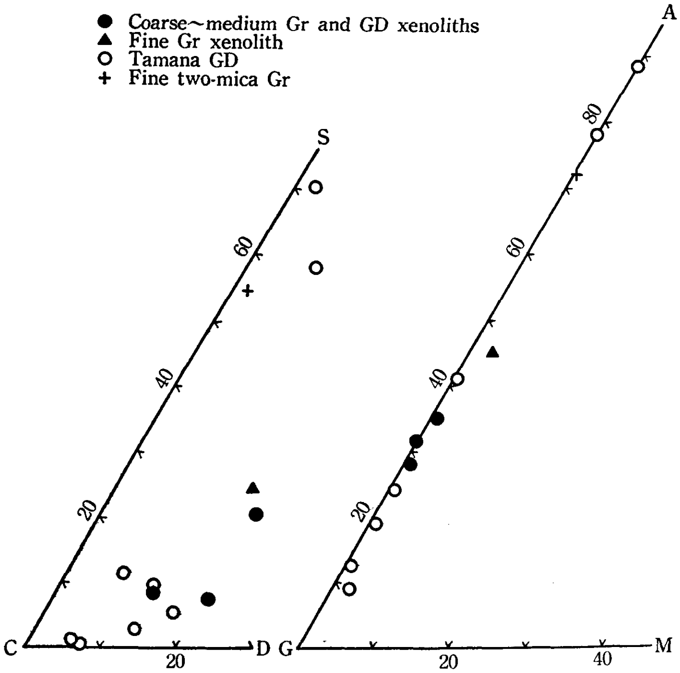

Fig. 10. Zircon Tracht and Habitus diagrams of Tamana granodiorite, fine two-mica-granite, and various granitic xenoliths in Ishigami-yama hornblende-andesite, Shimazaki, Kumamoto City, Kumamoto Pref., Kyushu.

7) Some of the examined specimens of this granodiorite were given by Mr. H. YAMAMOTO.

Sakurajima (Loc. 8). The source of the xenolith[8] from this locality cannot easily be inferred from geologic evidence, partly because there is no exposure of granite basement and partly because there are four granite-fields around the Sakurajima Volcano: (1) the Takakuma-yama fiield, about 15 km southeast, (2) the Osumi field, about 50 km southeast, (3) the Shibi-san field, about 50 km northwest, (4) the Satsuma field, about 25 km west-southwest, of the volcano. So far the Takakuma[9] and Osumi[10] zircons have been examined. Fig. 11 shows that the zircons of a biotite-granite (coarse) facies (Gr I) in the Takakuma-yama mass (Pl. 8, Fig. 11) closely resemble the xenolith-zircons (Pl. 8, Fig. 12).

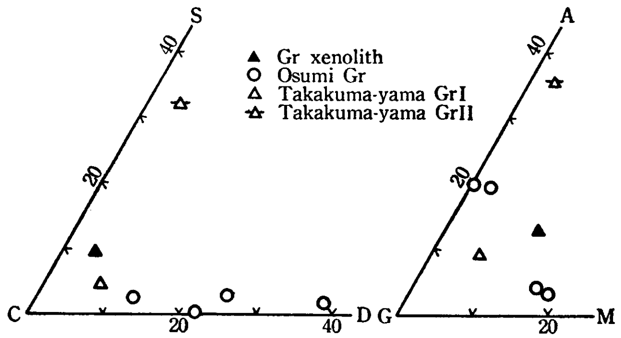

Fig. 11. Zircon Tracht and Habitus diagrams of Takakuma-yama and Osumi granites and a granite xenolith in the first pyroxene-andesite lava of Sakurajima Volcano, Kagoshima Bay, Kyushu.

Conclusions

A new method of determining the source of granitic xenoliths in volcanic rocks has been devised, the method being concerned with a comparison between the habits of zircons of the xenoliths and those of granitic rocks of the basement or neighbouring areas. Fourty-six granitic xenoliths from sixteen localities in Southwest Japan have been examined, and the main conclusions are:

1. Of the twenty-eight specimens of xenoliths from ten localities, twenty-six have closely identified with the basement granites. This indicates that the method presented here is a simple and exact one for our purpose.

2. This method, moreover, has been verified to be excessively useful, if not the best, in studying those xenoliths essential minerals of which are highly altered by lava heat.

3. Most, if not all, granites both at the earth-surface and at depths of a single batholith have zircons of very similar habits.

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8) Specimen of this xenolith was given by Dr. K. Yamaguchi.

9) Specimens of the Takakuma-yama granite were given by Mr. M. Miyahisa.

10) Specimens of the Osumi granite were given by Mr. M. Miyahisa and Mr. T. Arita.

4. All of the xenoliths from four localities where no basement granites are exposed have been identified with the granites of neighbouring areas.

5. It is interesting that the xenolith of fused granite in the first lava of the Sakurajima Volcano has been determined as the derivative of the Takakuma-yama granite, because it may be inferred that this small granite body, about 5 km across, exposed in Mesozoic sediments should be continued underground for a distance of at least 15 km to the base of the volcano.

Acknowledgments

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Plates 7-9

Plate 7

Explanation of Microphotographs of Granite Zircons
Plate 7 (× 50)

Fig. 1. Itoshima granodiorite (It-980), Imayama, Fukuoka City, Kyushu.

Fig. 2. Granodiorite xenolith (It-983m) in Imayama olivine-basalt plug. Loc. do.

Fig. 3. Itoshima granodiorite (It-571), Mizukami, Itoshima Peninsula, 20 km west of Fukuoka City, Kyushu.

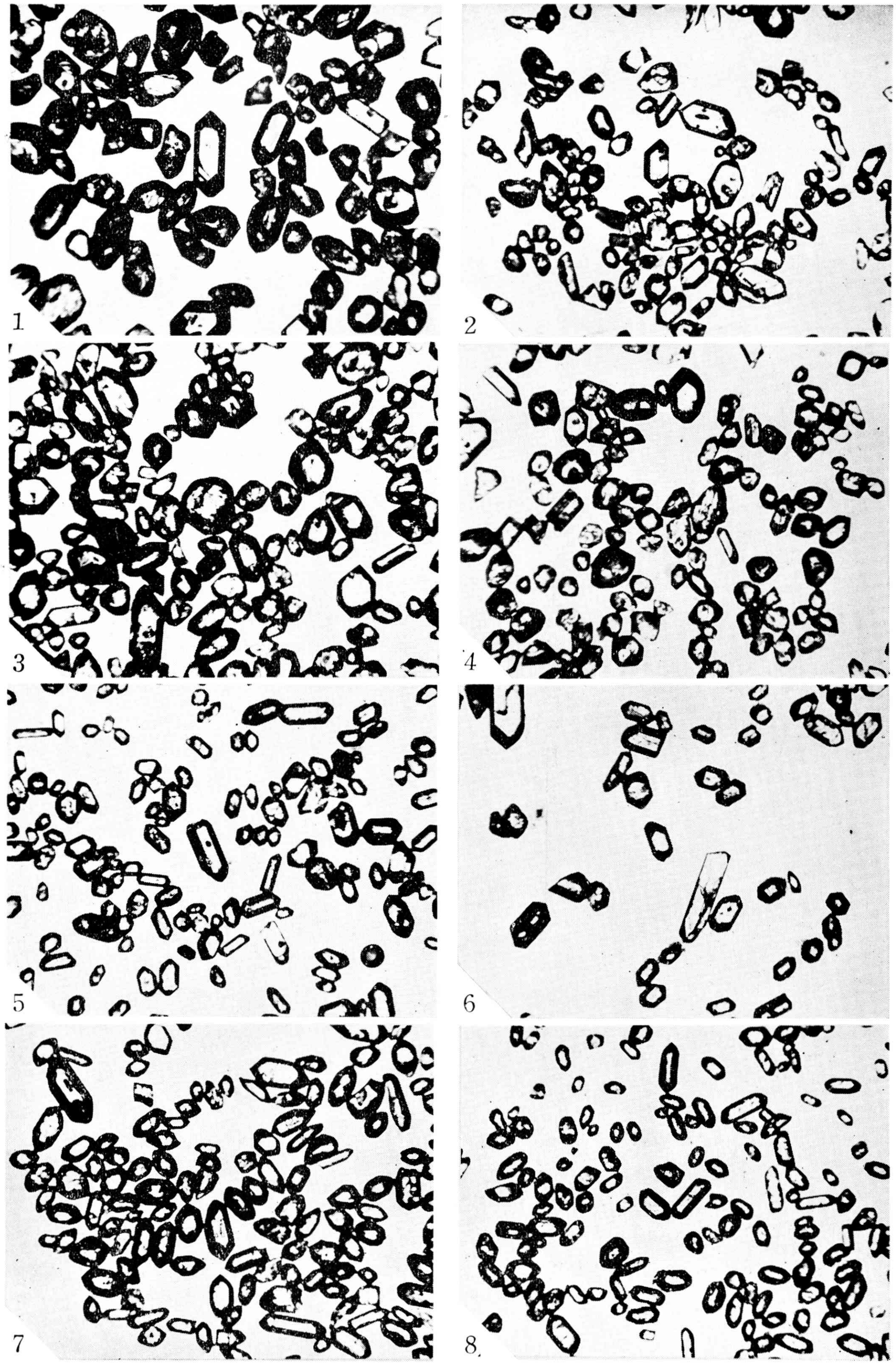
Fig. 4. Granodiorite xenolith (It-573) in Mizukami olivine-basalt plug. Loc. do.

Fig. 5. Hirao granodiorite (Yh-30), Fujita, Yahata City, Fukuoka Pref., Kyushu.

Fig. 6. Granite xenolith (Yh-26h) in Myoken-yama olivine-basalt plug. Myoken-yama, near Kurosaki, Yahata City, Fukuoka Pref., Kyushu.

Fig. 7. Maruta granodiorite (Bp-23), about 8 km north of Yufu-dake Volcano, Oita Pref., Kyushu.

Fig. 8. Granodiorite xenolith (Bp-8) in Tsurumi hornblende-andesite lava, west of Beppu City, Oita Pref., Kyushu.



TOMITA and KARAKIDA: Source Identification of Granite Xenoliths

Plate 8

Explanation of Microphotographs of Granite Zircons
Plate 8 (× 50)

Fig. 9. Tamana granodiorite (Tm-2), Shironoshita, Tamana City, Kumamoto Pref., Kyushu.

Fig. 10. Granodiorite xenolith (Km-28b) in Ishigami-yama hornblende-andesite plug, west of Kumamoto City, Kumamoto Pref., Kyushu.

Fig. 11. Takakuma-yama granite (M-6), about 15 km southeast of Sakurajima Volcano, Kagoshima Bay, Kyushu.

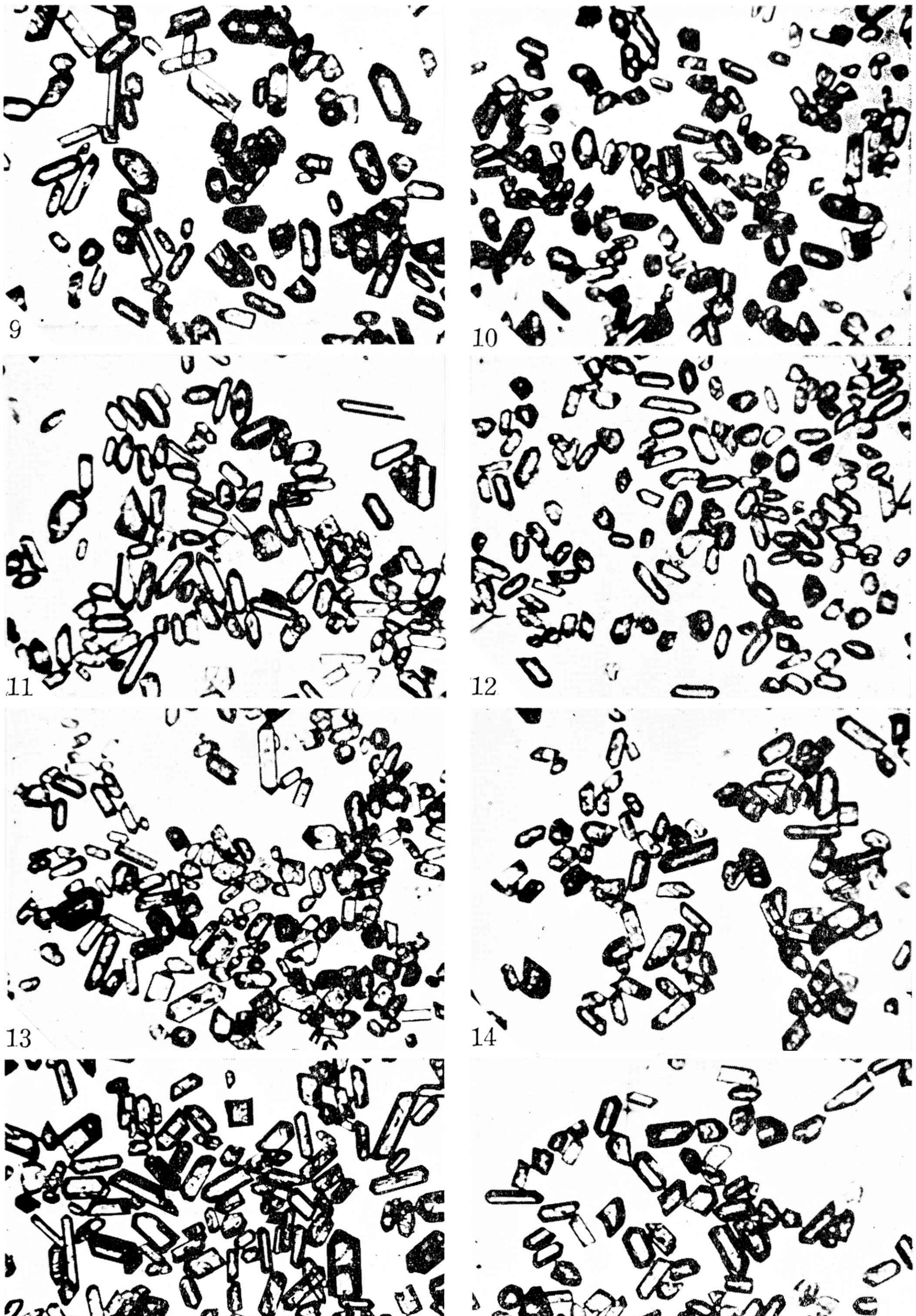
Fig. 12. Granite xenolith (Y) in the first pyroxene-andesite lava, eastern foot of Sakurajima Volcano.

Fig. 13. Biotite-granite (Ab-22), about 10 km northeast of Hagi City, Yamaguchi Pref., Chugoku.

Fig. 14. Granite xenolith (Ab-9a) in Shibuki olivine-basalt lava. Loc. do.

Fig. 15. Matsuyama granodiorite (T-3), Kashima islet, off Hojo Town, about 12 km north of Matsuyama City, Ehime Pref., Shikoku.

Fig. 16. Granite xenolith (T-1) in Kashima olivine-bearing bronzite-andesite plug. Loc. do.



TOMITA and KARAKIDA: Source Identification of Granite Xenoliths

Plate 9

Explanation of Microphotographs of Granite Zircons
Plate 9 (× 50)

Fig. 17. Coarse granitic rock (Mg-26), northeast foot of Hino-yama Hill, about 14 km east of Marugame City, Kagawa Pref., Shikoku.

Fig. 18. Granitic xenolith (Mg-la) in Marugame augite-bearing sanukitic andesite dike, ruins of the Marugame Castle, Marugame City, Kagawa Pref., Shikoku.

Fig. 19. Fine two-mica-granite (Mg-4). Loc. do.

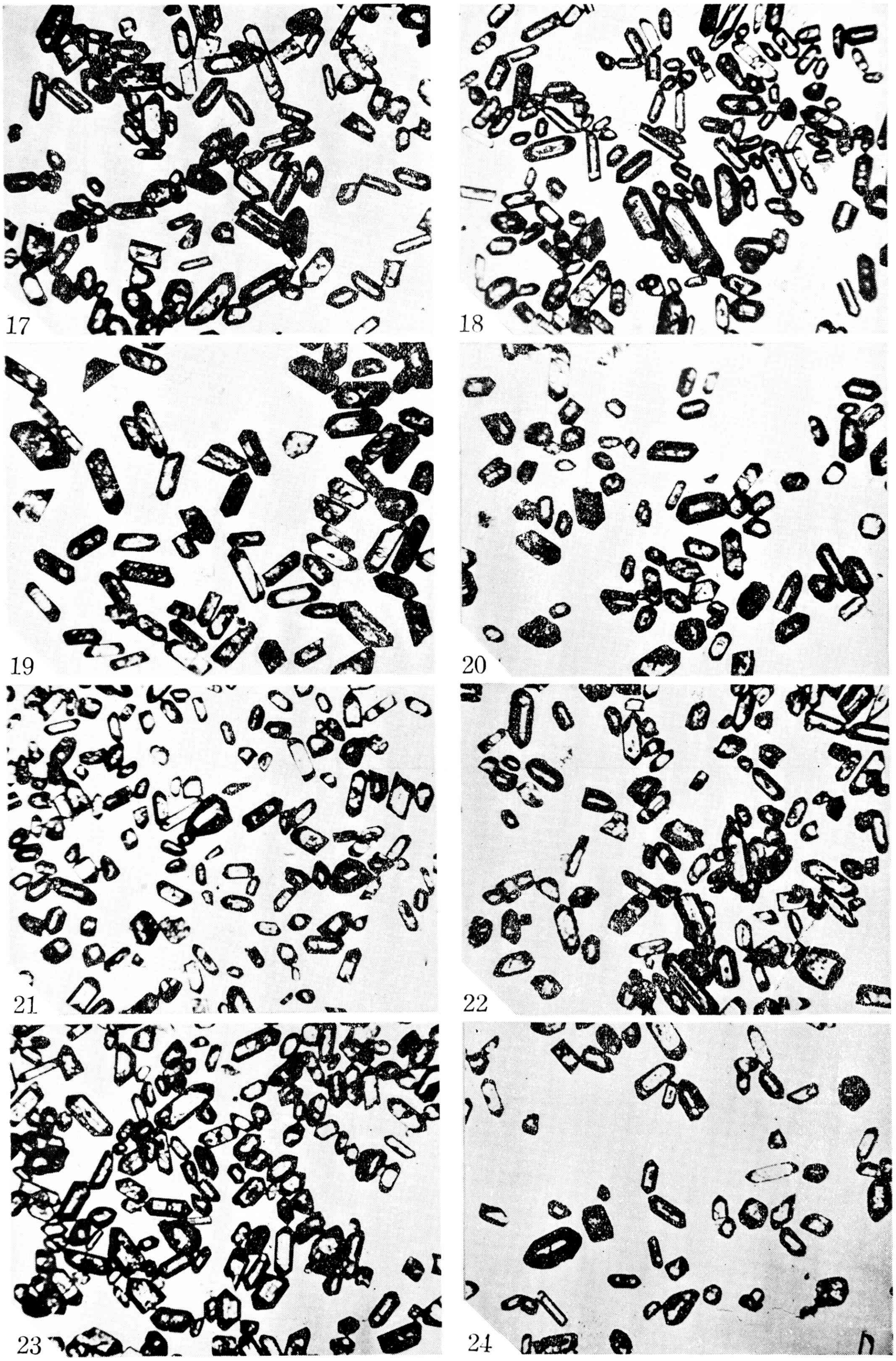
Fig. 20. Granitic xenolith (Mg-lb) in Marugame augite-bearing sanukitic andesite dike. Loc. do.

Fig. 21. Mito granodiorite (Sd-21), Ko-no-ura, west coast of the Mito Peninsula, southwest end of Shodo-shima Island, Seto-uchi (Inland Sea of Japan), Southwest Japan.

Fig. 22. Granodiorite xenolith (Sd-26a) in Ko-no-ura olivine-basalt plug. Loc. do.

Fig. 23. Mito granodiorite (Sd-31), Tanijiri, east coast of the Mito Peninsula, southwest end of Shodo-shima Island, Seto-uchi (Inland Sea of Japan), Southwest Japan.

Fig. 24. Granodiorite xenolith (Sd-17a) in Yoshino olivine-augite-andesitic basalt lava, south of Yoshino hamlet, west coast of the Mito Peninsula, southwest end of Shodo-shima Island, Seto-uchi (Inland Sea of Japan), Southwest Japan.



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