Petrology of an Aplite Dyke from Iwaizumi, Northern Kitakami-mountainland

—With Special Reference to the Origin of the Diversity
of the Tanohata Granitic Mass—

by

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1. Introduction

The differentiation in dyke is a common subject in igneous petrology. In 1946 the author engaged in research for metamorphic petrology in the vicinity of Iwaizumi of northern Kitakami-mountainland. The present paper deals with the somewhat unusual differentiation observed in a small dyke of aplitic composition

Fig. 1 Geological route map showing the location of the aplite dyke. 1, chert; 2, limestone; 3, mainly psammite; 4, Otomo granodiorite.

occurring on the left bank of the Omoto River about 100 m west from the margin of the major granodioritic mass (Fig. 1). The general geology and metamorphic petrology of this district have been reported in another paper by the author (KANO 1957—1958).

As for the granitic intrusives of the district, an areal investigation including 8 chemical analyses of the granitic rocks has been performed by ISHII *et al* (1955). Independently of the former, SHIBATA *et al* (1956 and 1958) also have presented 13 chemical data on the granitic rocks of the same district. The present study owes much to those chemical data.

2. Nature of the Parent Granodioritic Rock of the Aplite

The aplite is a minor intrusive of a batholithic granitic mass which was called the Tanohata mass by ISHII *et al* (1955) (See Fig. 2). The Tanohata mass is a composite granitic mass consisting from several rock facies of different

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Fig. 2 Geological sketch map showing the distribution of the Otomo and the Moichi granodiorite masses, modified the original map after ISHII *et al*

granodiorite. These features are extremely manifested in the minor intrusives of aplitic composition. In Table 1 the data of the aplitic rocks of both types are arranged for comparison. Here it must be mentioned that the specimen (c) was collected from the central portion of an aplitic dyke occurring in the major granodioritic mass. The modal ratio Q : Pl : Or (32 : 40 : 28) of the rock may approximately correspond to that of the granitic restmagma which comes to 30 : 38 : 32 after J. H. L. VOGT (1931). Accordingly the specimen may be considered to represent an uncontaminated or juvenile residual of the original granodioritic magma.

Recently a score of chemical

kinds. Among them, the one which occupies the central to southern parts of the mass is called the Otomo granodiorite including the Haginari granodiorite. In the marginal parts of the mass, west and north of the Otomo granodiorite, another types of granodiorite develop. These are named *en bloc* the Moichi granodiorite. As ISHII *et al* have pointed out, it is worthy of special note that the Tanohata granitic mass is characterized by the remarkable diversity of rock facies.

The main facies of the Otomo granodiorite* is coarse-grained and leucocratic, essentially composed of quartz, plagioclase (An 20—30), orthoclase and biotite. Large euhedral crystal of biotite is a prominent feature of the rock. Hornblende appears rarely. The Moichi granodiorite** is medium-grained and less leucocratic, mainly composed of quartz, plagioclase (An 30—40), orthoclase, hornblende and biotite. The latter two minerals are present more plentiful than in the Otomo granodiorite. The modal difference between the two is shown in Table 1 and illustrated in Fig. 3.

In short the Otomo granodiorite is less calcic and less potashic (more sodic) than the Moichi

Fig. 3 Modal An : Ab : Or diagram showing the relations between the granodiorites and aplites listed in Table 1 as well as in Table 2.

* The specimens were collected from Shimo-Sarusawa, 2 km south of the village of Otomo.

** The specimens were collected from Uchinosawa, 4 km north of the town of Iwaizumi. Though my field observation has not covered the whole area of the Tanohata mass, the biotite-hornblende granodioritic rocks occurring at Uchinosawa may be regarded to belong to the Moichi facies.

Table 1 Modal compositions of standard specimens of the Otomo and the Moichi granodiorites

	Qz	Pl	Or	Bi	Mu	Ho	Others*	An%	An	: Ab	: Or
(a).....	33.2	54.0	8.4	4.2	—	0.1	0.1	28	24	63	13
(b).....	32.0	52.7	9.5	3.1	—	1.4	1.3	35	30	55	15
(c).....	31.6	39.4	27.8	1.2	—	—	—	8	5	54	41
(d).....	29.2	28.2	36.4	2.6	3.6	—	—	16	7	37	56

(a).....Main facies of the Otomo granodiorite.

(b)..... " of the Moichi granodiorite.

(c).....Aplitic facies of the Otomo granodiorite. (Loc. 2 in Fig. 1)

(d)..... " of the Moichi granodiorite.

* Sphene, epidote, magnetite, apatite etc.

Abbr.: Qz, quartz; Pl, plagioclase; Or, orthoclase; Bi, biotite; Mu, muscovite; Ho, hornblende.

Fig. 4 Variation diagrams of Al_2O_3 , CaO and total alkalis to SiO_2 contents of the Tanohata granitic rocks comparing with the average granitic rocks after DALY.

analyses of the Tanohata granites including the Miyako and the Yamada granites have been accomplished by ISHII *et al* (1955) as well as by SHIBATA *et al* (1956 and 1958).

According to these available chemical data, the Tanohata granites and the allied granites are characterized by being more silicic, more aluminous, more calcic and less alkalic than the average granites in the world after DALY (1933) (Fig. 4). The similar nature is commonly observed in most granitic rocks in Japan*. In the Tanohata granitic rocks, however, it needs particular attention that the variation of $\text{K}_2\text{O}/\text{Na}_2\text{O}$ ratio is extremely irregular notwithstanding the linear variation of total alkalis. Obviously the

* The average granite in Japan calculated by SUZUKI and NEMOTO (1935) shows essentially the same characteristics. But it must be noticed that the greater part of the chemical data used in their calculation consists of those on the Cretaceous granites, whereas the data on the granitic rocks from such districts as Ryôke, Sangun, Kitakami, Abukuma, etc. which have been considered as the central metamorphic zones of the Honsyu orogenic belt are very scanty. Therefore if a new calculation including the recent analyses of the granitic rocks from those districts were made, the above-mentioned nature of the Japanese granitic rocks will be more decidedly distinguished.

Fig. 5 Normative An:Ab:Or diagram of the Tanohata granitic rocks. The curves R and T indicate the general trends of variation of the Dando (or Ryôke) granodioritic intrusives and the Tanzawa trondhjemitic intrusives respectively. The small numericals suffixed the plotted circles represent SiO_2 percents of the analysed rocks.

Fig. 6 Normative Q:Ab:Or diagram of the Tanohata granitic rocks.

andalusite-two mica-oligoclase-quartz hornfels derived from pelitic sediment (Loc. 3). Though the latter hornfels occurs at the nearly immediate contact, andalusite is preserved stably, no sillimanite being present. In the metamorphic aureole related to the Moichi granodiorite, on the other hand, andalusite is always unstable or metastable and sillimanite occurs in its place.

There occur a number of aplite dykes in this vicinity, most of which are found in psammitic hornfels near the contact as well as in the marginal facies of the major granodiorite. None but the aplite under discussion intrudes into limestone.

The greater parts of limestone are composed of coarse-grained, saccharoidal

diversity of the Tanohata granitic rocks in question is mainly due to this variability of ratio $\text{K}_2\text{O}/\text{Na}_2\text{O}$.

For demonstrating the special feature of the Tanohata granitic rocks, a pair of triangle diagrams showing the ratios of An:Ab:Or (Fig. 5) as well as Q:Ab:Or (Fig. 6) were constructed from these data. As shown in these diagrams, the most of the Moichi granodiorites, though there is one exception, are characterized by comparatively high ratio of Or/Ab, whereas the ratios in the Otomo granodiorites are considerably lower than those of the former.

In this respect the Otomo granodiorites much resemble the quartz diorite-trondhjemitic series of Tanzawa-mountainland, while the Moichi granodiorites are closely like to the quartz diorite-granodiorite-granite series of Ryôke zone. The question why these different rock types coexist in the same district will present an important subject on the origin of the granites of the orogenic zones.

3. Metamorphism of the Adjacent Rocks

The aplite is intrusive into the foot wall of a limestone bed intercalated with chert bands. The narrow zone about 100 m in width between the limestone and the major granodiorite mass is occupied mainly by two mica-quartz hornfels of psammitic rock origin with a thin bed of

marble. But in some lenticular inclusions, diopside, clinozoisite or tremolite are often found. The assemblage of phlogopite-clinozoisite-diopside-calcite-quartz occurs from Loc. 4, 130 m west of the aplite. A metamorphosed siliceous nodule from Loc. 5 exhibits the assemblage of tremolite-calcite-quartz suggesting that the metamorphic facies of this district may correspond to the comparatively lower grade of the amphibolite facies.

Fig. 7 Sketch of the outcrop of the aplite dyke. ①—⑤ show the locations where the specimens were collected. 1, aplite; 2, limestone; 3, chert; 4, calcareous shale; 5, psammite.

As shown in the sketch of Fig. 7 the main portion of the wall rocks of the aplite consists of banded alternation of limestone and chert which, in turn, is underlaid by calcareous shale and psammite. Considerable amounts of wollastonite accompanying few diopside and vesuvianite occur at the boundary surfaces between the limestone and chert. Probably a large portion of silica spent to form wollastonite may have been supplied from the chert beds. The assemblage of vesuvianite-diopside-wollastonite corresponds to Class 10 of GOLDSCHMIDT. The calcareous shale underlying the alternation is altered to a dark green-coloured, massive hornfels composed of saalitic diopside and clouded andesine (An 32), accompanying subordinate amount of quartz. This assemblage represents

GOLDSCHMIDT's Class 7. The psammite hornfels from the lowest wall is simply composed of muscovite, biotite, and quartz.

4. Mineralogical and Textural Features of the Aplite Dyke

To examine the mineralogical and textural changes in the dyke, sets of specimens were collected (Fig. 7). In Table 2 are listed the mineral compositions*, An percents of plagioclase, modal feldspar ratios and "C" percents of plagioclase twinning measured for those specimens.

Table 2 Modal compositions of the central portions and the chilled margins of the aplite dyke

Qz	Pl	Micr	Bi	Mu	Di	Sph	Ga	An%	An : Ab : Or	"C"%
(1).....36.6	30.7	30.4	2.3	—	—	0.0	0.0	6	3 47 50	4
(2).....39.2	59.5	1.0	0.1	—	0.2	0.0	—	30	29 69 2	25
(3).....40.6	58.1	0.0	1.0	—	0.1	0.2	—	25	25 75 0	16
(4).....33.6	36.3	26.0	2.5	1.6	—	—	—	10	6 53 41	9
(5).....33.7	47.2	17.6	1.5	—	—	—	—	10	7 66 27	4

- (1).....Central portion of the upper part of the dyke intruding through the alternation of limestone and chert.
 (2).....Chilled margin of the same part as above.
 (3).....Chilled margin of the middle part of the dyke intruding through the calcareous shale.
 (4).....Central portion of the lower part of the dyke intruding through the psammite shale.
 (5).....Chilled margin of the same part as above.
 Abbr.: Qz, quartz; Pl, plagioclase; Micr, microcline; Bi, biotite; Mu, muscovite; Di, diopside; Sph, sphene; Ga, grossularite-garnet; "C"% , percent of plagioclase-twinning in Carlsbad law after GORAI's method.

* The measurements were carried by means of the point counter.

Apparently there are appreciable differences in composition between the central portions and the chilled margins of the dyke. It needs special notice that the difference is particularly distinct in *the upper part of the dyke intruding through the banded alternation of limestone and chert and its underlying calcareous shale*. The central portion is graphic, *pegmatitic* in texture, essentially consisting of plagioclase (weakly zoned albite, An 6 in composition), microcline-perthite and quartz. Few biotite appear in platy form, measuring upto 3 mm in length. Rutil, sphene and grossuralite-garnet occur sporadically. On the other hand the chilled margin is equi-granular, typically *aplitic* in texture, mainly made up of plenty of plagioclase and subordinate amount of quartz. The plagioclase is often cloudy, zoned ranging from An 25 to An 30. Comparing with the central portion, poverty in microcline is striking. Biotite is present but few. Unlike the biotite of the central portion, it occurs as a decoloured, partly chloritized small crystal, measuring 0.1–0.2 mm in length. Granular or sometimes elongated crystals of diopside and/or sphene occur in place of biotite.

In brief, the dominant feature of the compositional difference between the center and the margin may be characterized by the compensative exchange of plagioclase and microcline. With respect to the ratio An : Ab : Or, therefore, the marginal rock corresponds to quartz-diorite or basic trondhjemite, while the central one does to normal granite. Attention must also be paid to that the quantitative proportion of quartz to plagioclase plus microcline in the margin as well as in the center exceeds that in the juvenile aplite, c in Table 1, which shows approximately the eutectic ratio Q : Pl : Or.

To the contrary, in the lower part of the dyke intruding through the psammitic shale, the difference between the center and the margin is not so remarkable that there is no problem which needs further discussion. Both portions are aplitic in texture, composed of quartz, slightly zoned plagioclase (An 6–10) and microcline-perthite, containing small amounts of fresh biotite as well as muscovite. No lime-silicate mineral appears. Decrease of microcline in the chilled margin is less conspicuous than in the former case.

5. Discussion and Conclusion

Normally the process of fractional crystallization may be the most fundamental cause of the differentiation of any igneous body. So far as the modal feldspar ratio is concerned, its change passing from the chilled margin to the central portion shows a normal line of evolution. (See Fig. 3.) The central portions lie on the acidic ends of the lines whereas the marginal portions do on the basic ends of the lines. Nevertheless the phenomenon of differentiation observed in the part intruding through the banded alternation of limestone and chert or the calcareous shale is somewhat unusual and it seems inadequate to ascribe the principal cause of the differentiation to the normal fractional differentiation. As is illustrated in Fig. 3, the distance between the two differentiates, (1) and (2, 3), exceeds far beyond that between the major granodiorite (a) and its normal descendant (c). Such phenomenon should be regarded as another thing than those which are commonly observed in the cases due to simple crystallization differentiation.

On the other hand, the presence of lime-silicate minerals and the appreciable increase of An content of plagioclase in the chilled margin may indicate to

some degree the effects of assimilation of lime upon the aplite. It must be noted, however, that any desilication or syenitization of aplite characterizing the assimilation of limestone can not be observed in this case*. To the contrary, the amount of quartz appreciably increases in the chilled margin as well as in the central portion as compared with those in the normal aplites, e. g. (4) and (5) in Table 2 or (c) and (d) in Table 1. Apparently silicification or desyenitization has proceeded with the assimilation of lime.

In this respect, that the dyke intruded not into the part exclusively consisting of limestone but into the part composed of alternation of *limestone and chert* is much significant. It means that not only lime but also silica might be introduced from the wall rocks into the dyke. Then in the chilled margin, instead of forming alkali-mafics and feldspathoid, calcic plagioclase and non-alkalic lime-silicate minerals saturated in silica were formed and subsequently remaining free silica crystallized as quartz. The silica introduced may have played the following two rôles: the first is to counteract the desilication process which might be otherwise promoted by the assimilation of lime, the second is to proceed to silicification as well as desyenitization leading to relative decrease of alkalis, particularly of potash.

Thus a less alkalic, more calcic and more silicic facies was formed in the chilled margin. The feldspar ratio of the rock is essentially corresponding to the trondhjemitic or tonalitic facies of the Otomo granodiorite.

On the other hand, a large majority of potash entered into the residual solution to form relatively abundant microcline-perthite which intergrows graphically with quartz or albitic plagioclase. Thus, in the central portion of the dyke, a pegmatitic facies with comparatively high proportion of potash to soda finally consolidated. It is interesting that the modal ratio Or/Ab of the rock in question, (1) in Fig. 3, deviates from that of the uncontaminated aplite of the main granodiorite, c in Fig. 3, and approaches towards that of the most acidic differentiate of the Moichi granodiorite, d in Fig. 3.

In conclusion, the formation of the two contrasting products from the aplitic magma contaminated by lime and silica may suggest that the differentiation of a certain synthetic granite-magma** assimilating lime and silica, extensively but in different degrees, will lead to produce sets of rock types with variable ratios K_2O/Na_2O . Probably the origin of the diversity of the Tanohata granitic mass will be able to interpret in such manner. In this respect, it is significant that a part of the Tanohata granitic mass occurs cutting across the Akka limestone*** at its western margin and that the Kawaguchi facies which has

* As is well known, the assimilation process of limestone, in general, leads to resulting desilication or syenitization of granitic rock. According to my observation of the Fukuhara limestone from Ibaragi Prefecture which occurs enclosed in biotite-granite, the granite alters its composition successively towards the wall of the enclosed limestone in the following order: biotite-granite→hornblende-aegirine augite-granite→wollastonite bearing syenite-aplite→diopside-grossularite-wollastonite-skarn. The syenite-aplite occurring at the very contact is essentially composed of 82% microcline and 14% wollastonite. Quartz and plagioclase are very scanty, not exceeding 2%. That desilication as well as enrichment of potash happened is without doubt.

** The composition of the supposed original granitic or granodioritic magma may be considered to be intermediate between the Otomo and the Moichi granodiorite or to be close to that of the standard granite or granodiorite of DALY.

*** The Akka limestone is characterized by the inclusion of considerable amounts of siliceous bands or nodules and by accompanying beds of banded chert at its both walls.

been remarked by the particularly striking variability of composition (ISHII *et al* 1955) develops just there.

It must be remembered, however, that there is another point of view that the effect of assimilation upon any granitic magma may be merely local and restricted along the contact with the wall rocks. H. KOIDE (1958) who studied in detail the Dando granodioritic rocks is of the same opinion. Concerning the origin of the Dando granodioritic intrusives which resemble the Moichi granodiorite in many respects, he says that the subtraction of alkalis and alumina from the Dando granodioritic intrusives themselves during the palaeogenic period of granitic shell is the most fundamental cause, though he did not put forth the reason why the process happened there.

From the standpoint of anatexis, the granodioritic magma in question might be generated through the remelting of geosynclinal column rich in limy and siliceous sediments.

But further discussions as to whether the origin of the granitic magma may be syntectonic or anatectic are beyond the scope of the present subject. Whatever the origin may be, it must be noted, the process of differentiation would be essentially the same in either case.

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北部北上山地岩泉産のあるアプライト岩脈の成因

——とくに田野畑花崗岩体の多様性の起源に関連して——

加 納 博

(摘 要)

アプライト岩脈の急冷縁と中心部における組成の変化は一般によく知られている現象であるが、ここでは石灰岩とチャートの互層を貫いたアプライトに見られる、やや異常な分化現象について論じた。問題のアプライトは第7図のような産状を呈するもので、上半部で石灰岩・チャート互層および泥灰質岩を切り、下半

- 1 Micro-photograph of the central portion of the dyke, (1) in Fig. 7, intrusive into the banded alternation of limestone and chert, showing graphic, pegmatitic texture. Crossed nicols.
- 2 Microphotograph of the marginal portion of the dyke, (2) in Fig. 7. The rock is essentially composed of 39% quartz, 60% plagioclase (An 25—30), 1% microcline, with few diopside and sphene. Crossed nicols.
- 3 Microphotograph of the marginal portion of the dyke, (3) in Fig. 7. The rock is composed of 41% quartz, 58% plagioclase (An 24—27), 0.6% biotite, 0.3% diopside and 0.4% sphene. No microcline is present. Crossed nicols.
- 4 Micro-photograph of the central portion of the dyke intrusive into the psammitic hornfels, (4) in Fig. 7. The rock is normally aplitic in composition as well as in texture. Crossed nicols.

部で砂質粘板岩を切つている。この場合、下半部における急冷相⑤と中心相④との組成の差は、大した問題にならないが、上半部における分化はきわめて著しく、急冷相②と③ではカリ長石をほとんど欠き、斜長石 An 成分の高いトロニウム岩または石英閃緑岩相（ただし長石比に関して）を形成するのに対し、中心相では Or/Ab 比の異常に高い花崗岩相となつている。また全体を通じて石英が富化し、したがって相対的にはアルカリが減少していることもあわせて問題となる。

このアプライトの親岩体である田野畑花崗岩は、かねてから岩相変化の多様性の著しいことで注目されていた。この花崗岩は、本邦の他の花崗岩類と同様に、アルミナ、石灰およびノルム石英に富みアルカリに乏しい特性を示すものであるが、ここでとくに問題となるのは、アルカリの全量が比較的一定しているのに反し K_2O/Na_2O 比が非常に変化に富むこと、そしてそれが岩体の多様性に少なからず貢献していると考えられることである。

上述のアプライト岩脈に観察された分化現象は、小規模ではあるが、田野畑花崗岩体の多様性の一つの雛型を与えるものとみなされる。これから類推されることは、今ある種の花崗岩～花崗閃緑岩質マグマ——その組成は標準型花崗岩に近い、あるいは、岩体内部の対蹠的な岩相を代表する乙茂型と茂市型の間に近い——が、石灰と珪酸を広範にそして種々の程度に同化した場合を仮定するとき、その融合マグマから K_2O/Na_2O 比のきわめて不定な、しかも全体としてアルカリに乏しく、石灰、アルミナおよびノルム石英に富んだ各種の岩型を分化生成する可能性が十分にある、ということである。実際、田野畑花崗岩体の一部は、その西縁において安家石灰岩（珪質岩塊をかなり包有し、その上下盤には板状チャートを伴う）を切り、その部分に岩相変化のとくに著しい川口型花崗閃緑岩が発達していることは、この意味において重要であろう。