HOKKAIDO UNIVERSITY

Title	Petrological Significance of Large Anorthite Crystals Included in Some Pyroxene Andesites and Basalts in Japan
Author(s)	Ishikawa, Toshio
Citation	Journal of the Faculty of Science, Hokkaido University. Series 4, Geology and mineralogy, 7(4), 339-354
Issue Date	1951-03
Doc URL	http://hdl.handle.net/2115/35845
Type	bulletin (article)
File Information	7(4)_339-354.pdf

Instructions for use

Hokkaido University Collection of Scholarly and Academic Papers : HUSCAP

PETROLOGICAL SIGNIFICANCE OF LARGE ANORTHITE CRYSTALS INCLUDED IN SOME PYROXENE ANDESITES AND BASALTS IN JAPAN

By

Toshio ISHIKAWA

Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University. No. 397.

CONTENTS

1. Introduction and acknowledgement ········· 339
2. Distribution and occurrence of large anorthite crystals ··· 340
3. Characteristic properties of large anorthite crystals ········ 345
4. Relation of large anorthite crystals with common phenocrysts of plagioclase included in the same lava ········· 348
5. Some considerations on the genesis and petrological significance of large anorthite crystals ········· 348
References cited ········· 353
Plate

1. Introduction and acknowledgement

Crystal lapilli of anorthite ejected from Volcano Miyakejima on the occasion of the explosion in 1874 attracted one's interest as rare occurrence, and were studied crystallographically,[12] optically,[20][22][25][41] physically[13][22][24] and chemically.[23] Especially Kôzu[21] gave some considerations on it's genesis, after particular observations from various points. After the simillar large crystals of anorthite were found in volcanic rocks or as crystal lapilli, from Tônosawa,[13][44] Iwatesan,[34] Zaôsan,[34] Hedaohama,[38] Kôshinzan[45] and Mitaki,[27] crystal lapilli of anorthite were ejected also from Volcano Tarumai,[17][18][19][35] accompanied by the explosion in 1909.

In 1936, HARADA[5] summarized on anorthite found so far in Japan volcanic rocks, adding those from new localities with their crystallographical, optical and physical data measured by him. And he concluded that the formation of volcanic rocks including large anorthite crystals is due to mixing of two different magma just before effusion. HARADA's theory on the mechanism of formation is considered to be excellent to explain the difference of characteristic between large anorthite and common phenocrystic plagioclase included in the same lava.

The author[6] noticed in the course of petrological study on Volcano Tarumai, that the genesis of large anorthite has close relation with characteristic of magma from which its mother rock crystallized out. Though very common in north-east Japan, such large crystal of anorthite has been never found in other districts in Japan and may be rare in other countries. From its distribution and occurrence, large anorthite in question is considered to have important significance on the petrographical province, although it's genesis can not yet be clarified.

In publishing the present paper, the author wishes to express his cordial thanks to Dr. Z. HARADA, Professor of Hokkaidô University, who offered many specimens collected by him and gave valuable advice to the author, and to Dr. J. SUZUKI, Professor of Hokkaidô University, who has given kind advice and encouragement ever since the author was engaged in geological and petrological studies on volcanoes. Hearty gratitude should be offered to Mr. T. NEMOTO, Director of Hokkaidô Branch of Geological Survey, Mr. Y. KATSUI, assistant of Hokkaidô University, Mr. G. SHIBUYA and Mr. H. OSANAI, students of Hokkaidô University, who gave the author specimens collected by them. The author also wishes to express his grateful thanks to Dr. H. KUNO, assistant Professor of Tôkyô University, Mr. A. TAKABATAKE, member of Hokkaido They are of Geological Survey and Mr. T. KONTA, Lecturer of Yamagata University, who noticed to the author kindly new localities with geological data.

2. Distribution and occurrence of large anorthite crystals.

Localities of anorthite contained in volcanic rocks in Japan were already reported by HARADA[5] in 1936. Thereafter many new localities of simillar large anorthite crystals were found as follows. They are three localities in Ketoi Island and Volcano Shinshiru in Shinshiru Island, Kuril, by NEMOTO; Volcanoes Oakan and Fuppushi,[11] Akan volcanic district, by KATSUI; Fugoppe near Yoichi-machi by HARADA; Volcano Kuttara near Noboribetsu by R. FUKAYA and HARADA; Murorandake near Muroran by SHIBUYA; two localities on Volcano Kamabuse, Osoreyama volcanic group, by ÔTAKI[32] and the author; Torishima by TAKABATAKE. YAGI[47] also reported from somma lava of Volcano Usu, uplifted on the roof mountain of Shôwa Shinzan in the activity of 1943–1945. Konta found in pyroxene andesitic lavas from Koshikidake (1 cm in size), Gantoyama (2 cm) and Hayama (1.5 cm) in Miyagi-Yamagata district, all of which erupted perhaps in pleistocene, and in basaltic andesite flow intercalated in miocene formation at Innai Silver mine (1.7 cm). Kuno communicated to the author several occurrence as follows; in dyke at the southern end of Sukumogawa village, in somma wall lava to the south west of Yumotomachi and in lava at the north east of Ashinoyu,

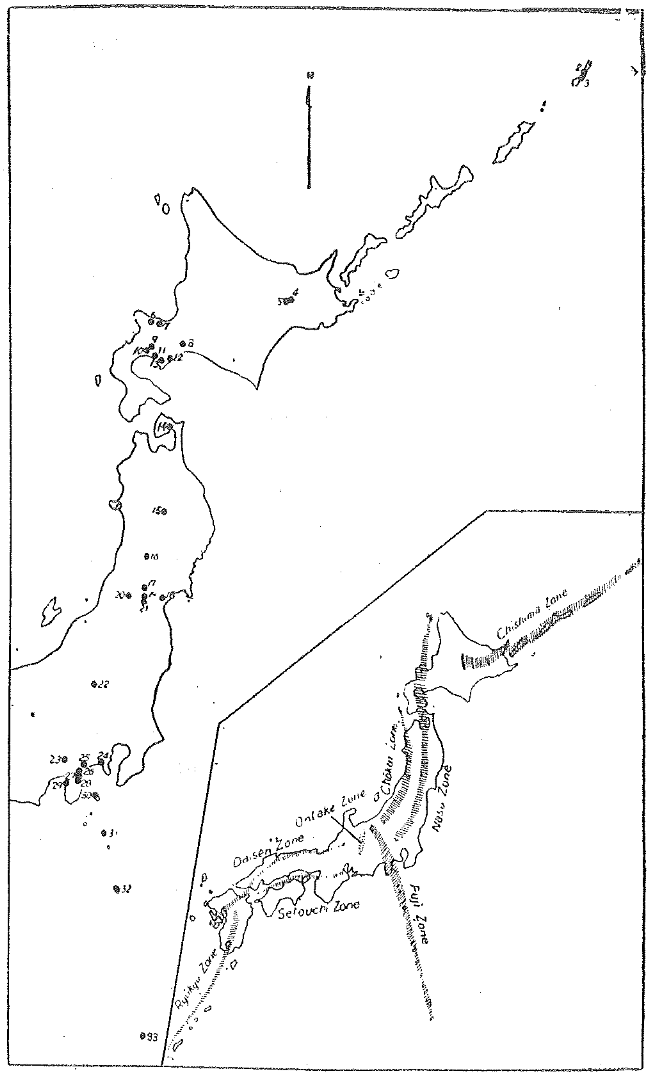


Figure 1. Distribution of localities of large anorthite crystals.

TABLE 1. List of localities of large anorthite crystals

1. Ketoi island (Minamizawa ; Fukazawa ; south west of Lake Ketoi).
2. Volcano Shinshirufuji, Shinshiru Island.
3. Volcano Midoriko, Shinshiru Island.
4. Volcano Oakan, Akan district, Hokkaidô.
5. Volcano Fuppushi, Akan district, Hokkaidô.
6. Fugoppe, Yoichi, Hokkaidô.
7. Otaru, Hokkaidô.
8. Volcano Tarumai, Hokkaidô.
9. West side of Lake Tôya, Hokkaidô.
10. Nukkibetsu, Toyoura, Hokkaidô.
11. Somma of Volcano Usu, Hokkaidô. (Nishimaruyama)
12. East foot of Volcano Kuttara, Hokkaidô.
13. Murorandake, Muroran, Hokkaidô.
14. Volcano Kamabuse, Osoreyama volcanic group, Aomori Prefecture. (Top part and east foot of the volcano).
15. Yakushidake, Volcano Iwate, Iwate Prefecture.
16. Innai Mine, Akita Prefecture.
17. Koshikidake, Yamagata Prefecture.
18. Mitaki, Sendai, Miyagi Prefecture.
19. Gantoyama, Yamagata Prefecture.
20. Hayama, Yamagata Prefecture.
21. Nyûdoyama, Volcano Zaô, Yamagata Prefecture.
22. Kôshinzan, Tochigi Prefecture.
23. Volcano Fuji, Shizuoka Prefecture.
24. Keshôzaka, Kamakura, Kanagawa Prefecture.
25. Volcano Hakone, Kanagawa Prefecture. (Tônosawa; south of Sukumogawa village; somma-wall to the south west of Yumoto-town; north east of Ashinoyu and several other places).
26. North of Jikkokutôge, Volcano Yugawara, Kanagawa Prefecture.
27. Nishikiura to the south of Atami, Shizuoka Prefecture. (Volcano Taga).
28. Volcano Usami, Shizuoka Prefecture. (North, South-west, and South of Usami).
29. Hedaohama, Takata, Shizuoka Prefecture.
30. Chigasaki, Volcano Ôshima, Idzu Islands.
31. Volcano Miyakezima, Idzu Islands.
32. Dôrinzawa, Volcano Hachijôzima, Idzu Islands.
33. Volcano Torishima, Idzu Islands.

in Volcano Hakone; in lapilli from Volcano Taga at Nishikiura to the south of Atami; in lava from Volcano Yugawara at the north of Jikkokutôge; from lavas at the north and south of Usami-machi and from tuff at the south-west of it, in Usami volcanic area. It is noteworthy that all known localities are distributed only in northeast Japan, ranging from Ketoi to Torishima. (Figure 1 and Table 1) Most of them are included in quarternary volcanic zones of so-called Chishima, Nasu and Fuji, though some belongs to the tertiary volcanic area along the above three volcanic zones.

Occurrence of large anorthite is classified as follows;

(1) Crystal lapilli. It is ejected as an isolated crystal at the moment of explosion and has been called also "crystal bomb" as special ejecta. Typical examples are known from Miyakejima and Tarumai. Those which are found mingling in lapilli bed or in tuff and agglomeratic tuff at present, may be primarily of this type of occurrence. (Figure 2) Crystal lapilli are often coated or attached with lava crusts, so they are considered to have escaped away from lava, with which anorthite has the close genetical relation.

Figure. 2. Anorthite crystals (Natural size).

The right is an anorthite crystal from tuff or agglomeratic tuff at the east foot of the volcano Kuttara. The left is one from agglomerate at Nukkibetsu, Toyoura, Hokkaidô. The latter is surrounded with the marginal zone of labradorite.

(2) Crystal included in lava. Most anorthite crystals are included in lava flow, bomb or lava block, which are petrographically two pyroxene andesite, olivine two pyroxene andesite, basalt or olivine basalt (Figure

Figure 3. Large anorthite included in olivine two pyroxene andesite from Nakaarakawa, at the east foot of Volcano Kamabuse, Aomori Prefecture. Common phenocryst of plagioclase is seen to the left of the photograph. (Natural size)

3). Large anorthite is generally associated with common phenocryst of more sodic plagioclase in the same lava.

(3) Crystal mingled in tuff or agglomeratic tuff. Some crystals of anorthite occur in tuff, agglomeratic tuff or agglomerate which are mostly petrographically pyroxene andesitic. Anorthite crystals from Otaru, Kuttara, Keshôzaka and south west of Usami belong to this type. Good crystals can be often collected from this type.

(4) Crystal found in placer. Examples of this type are reported from Minamizawa in Ketoi Island and Dôrinzawa in Hachijojima. Such occurrence is secondary, and may be derived from any of the abovestated three occurrence.

Generally speaking, such large anorthite are mostly related with pyroxene andesite, some with basalt. It is interesting also that they are ejected often followed by the explosion.

3. Characteristic properties of large anorthite crystals.

Crystallographical, optical, physical and chemical properties of large anorthite crystals were summarized by HARADA[5] in 1936, adding new data measured by him to descriptions already published by many researchers. The author observed most specimens from Hokkaidô and Aomori by the Universal stage, though those from Mitaki, Miyakezima and Tarumai were already examined delicately by the above method by NEMOTO[30] and WATANABE.[46] Maximum size, composition of the main part and the marginal zone, and inclusions in specimens from each locality are shown in Table 2. Characteristic properties of large anorthite are summarized as follows;

(1) Compositions of large crystals determined by Universal stage or calculated from chemical compositions, refractive indices and specific gravities are ranging from An_{85} to An_{99}, and mostly anorthite, rarely basic bytownite.

(2) Zonal structure is absent or very faint in general, although the narrow zone of far more sodic composition develops often at the margin of the crystal. (Plate, Figure 1) Even though the main part shows sometime faint zonal structure, difference of An content between each zone is not more than 4 per cent.[46]

(3) The marginal zone is generally narrow, though it is rarely wide so as to be divided into few zones. Composition of the marginal zone is ranging from An_{50} to An_{90} and generally far more sodic than the composition of the main part in each individual crystal. (see Table 2) Accordingly the abrupt change in An content or discontinuity of composition between both parts is noticed. When few zones develop near the margin, Composition of the inner zone of them is from An_{80} to An_{90}, and that of the outermost zone decreases abruptly to $An_{50} \sim An_{70}$, as far as can be determined by Universal stage.

(4) Polysynthetic twins after Albite and Pericline laws are most predominant, (Plate, Figure 2 & 4) though twinning of Carlsbad, Carlsbad-albite and Penetrated types are also often seen and rarely Manebach twin develops.

(5) Crystals are generally clear without minute dusty inclusions and free from decomposition under the microscope. Sometime the main zone of anorthite crystal is corroded at it's margin, and the zonal arrangement of minute inclusions develops along the boundary between the main part and the surrounding marginal rim of the crystal, as seen in the specimen from Nukkibetsu. (Figure 2, Left).

TABLE. 2 Occurrence and properties of large anorthite crystals

Localities	Occurrence or mother rocks	Maximum size (cm)	An% of the Main part	An % of the Marginal zone	Inclusions	An % of plagioclase in mother rocks	
						Phenocryst	ground-mass
Minamizawa, Ketoi Is.	Placer	3	88	± 80–73	Olivine		
SW of Lake Ketoi	Olivine two pyroxene andesite	1.5	99	±	"		
Shinshirufuji, Shinshiru Is.	"	2.5	88	±	"	70	
Midoriko, Shinshiru Is.	"	2	99	±		80	65
Oakandake, Akan[11]	"	1.8	96	+	Olivine	80–53	45
Fuppushidake, Akan[11]	"	1	96	—	Olivine	77–54	48
Fugoppe, Hokkaidô	Quartz bg. two pyroxene andesitic agglomerate (Tertiary)	1.7	97 ($\alpha=1.573$, $\beta=1.582$, $\gamma=1.587$)[37]	±	Olivine	80–57	50
Otaru, Hokkaidô[5][26]	Tuff (Tertiary)	1.5	93[5]				
Tarumai, Hokkaidô	Crystal lapilli, Two pyroxene andesite (Dome lava, bomb, black compact block)	2	96– (92～94)[46] 93.6 93	90– (50～60)[46] 75	Olivine	Dome 90–45, Bomb 66–43, Block 72–47,	65–50, 45, 42,
W. side of L. Tôya, Hokkaidô	Olivine two pyroxene andesite and it's agglomerate (Tertiary)	3	95	±		80,	68,
Nukkibetsu, Hokkaidô	Olivine bearing two pyroxene andesitic agglomerate (Tertiary)	3.5	94	88–71		79–54	69–53
Nishi-maruyama, Usu	Olivine two pyroxene andesite	2	96[33] 97	82	Olivine, augite	80	70
Shôwa-Shinzan, Usu[47]	Olivine two pyroxene andesite	10	89	+		68	

Kuttara, Hokkaidô	Tuff or agglomeratic Tuff	4.5	87~85	80-65	Olivine, rhombic pyroxene		
Murorandake, Hokkaidô	Two pyroxene andesite. (Tertiary)	1	98	65		80-65	65
Dome of Kamabuseyama	Two pyroxene basaltic andesite	1	95~94,[32] 99,	74	Olivine, rhombic pyroxene	75-70[32] 78,	65
East foot of Kamabuseyama	Olivine two pyroxene andesite	3	98~90[32]	±	Olivine	85-80[32]	
Yakushidake, Iwatesan[34]	Crystal in lapilli bed		Nm≒1.572[20]				
Mitaki, Sendai[29][30]	Andesitic basalt (Tertiary)	3	95	74.9	Pyroxene	92.9, 76.9,	68.2
Nyûdoyama, Zaôsan[34]	Two pyroxene andesite	1	1.572<Nm<1.582[20]				
Kôshinzan, Tochigi[44]	Pyroxene andesite	1.5	Anorthite				
Volcano Fuji[45]	Two pyroxene bg. olivine basalt	1	95			84,	74,
	Augite bg. olivine basalt		95			83,	78,
Keshôzaka, Kamakura[15]	Two pyroxene andesitic agglomerate and tuff	2	Anorthite				
Tônosawa, Hakone[13][20]	Andesite (dyke)	1	95				
Hedaohama, Shizuoka[38]	Olivine andesite	3	Anorthite				
Chigasaki, Ôshima[40]	Two pyroxene olivine anorthite basalt	2	95		Olivine	95	
Miyakejima	Crystal lapilli	5	96,[46] 95.4 94[12][22]	90-64[46]	Olivine	Lapilli 80[22]	
Dôrinzawa, Hachijôjima[4][5]	Placer	3	97				
Torishima[39]	Two pyroxene andesite	1	94			91	

(6) Inclusions of olivine are very common (Figure 3 and Plate, Figure 2), though pyroxenes are sometimes included in anorthite. Included olivine are often so large as phenocrysts in volcanic rock and rounded in shape, sometimes exhibiting zonal structure.

(7) Sometimes partings parallel to $(1\bar{1}0)$ and any other plane develop in alternating lamellae of polysynthetic twin after Albite or Pericline laws, as shown in specimens from Kamabuse (Plate, Figure 2) and Kuttara. (Plate, Figure 3)

(8) Crystal of anorthite is generally nearly idiomorphic, but sometimes invaded irregularly at the margin by the groundmass of the including lava. (Plate, Figure 4).

4. Relation of large anorthite crystals with common phenocrysts of plagioclase included in the same lava

Volcanic rocks which contain large anorthite are mostly pyroxene andesites and basalts as shown in Table 2. Common phenocrysts of plagioclase contained in the same lava show usually strong zonal structure, and their compositions are generally labradorite to bytownite. Though there is a remarkable gap in composition between large anorthite and common phenocrystic plagioclase in the same lava, composition of the former's marginal rim tends to approach to that of the latter's outermost zone, further to that of the groundmass plagioclase. Accordingly the marginal rim of anorthite and the outermost zone of phenocrystic plagioclase were precipitated in effusive stage perhaps from the same residual liquid. But the main parts of anorthite and phenocrystic plagioclase are considered to have crystallized out from the different melts under the different conditions. Anorthite without marginal rim is sometime seen in lava rapidly effused before it's reaction with the residual melt from which the groundmass of the mother lava solidified.

Olivine are often included in anorthite crystals, even though the mother volcanic rock lacks olivine. Olivine as inclusion is richer in Forsterite molecule than that contained as phenocryst in the same rock. These facts suggest also that large anorthite and phenocrystic plagioclase crystallized from different melts.

5. Some considerations on the genesis and petrological significance of large anorthite crystals

Kozu[22] considered on the genesis of the large crystal of anorthite ejected from Volcano Miyakejima, that it is due to rapid growth of anorthite in the melt rich in volatile substance and low in viscosity, rather than long duration of crystallization under the equilibrium state. If it takes long for plagioclase to crystallize out from magma, plagioclase may become richer in albite molecule and also pyroxene begin to crystallize. TSUBOI[40] stated in petrological study on Volcano Ôshima, that anorthite exhibiting very faint or no zonal structure was formed by slow cooling under the perfect equilibrium condition and movement of crystal in the magma matching with calcic plagioclase in density. HARADA[5] concluded excellently that such large crystals of anorthite were mixed into the magma from which common phenocrysts of plagioclase crystallized out, or violent mixing of two different magma occurred just before effusion. From remarkable difference of characteristics between large anorthite and phenocrystic plagioclase, also the author supports HARADA's consideration on the mechanism of formation.

It is interesting that such anorthite crystals are very common in northeast Japan which includes the Nasu, Fuji and Chishima volcanic zones and Tertiary volcanic area along the above zones, but they have been never found in other districts of Japan and perhaps in other countries. It is presumed that the formation of large anorthite has close relation with petrographical province or characteristic of magma in the above-stated volcanic areas. In the course of geological and petrological studies on Volcano Tarumai, the author[6] noticed that lavas from this volcano are relatively rich in Al_2O_3. In Niggli's value *al-alk* corresponding to *si*, calculated from chemical compositions, most of lavas from volcanoes belonging to the Nasu zone which includes Tarumai are higher

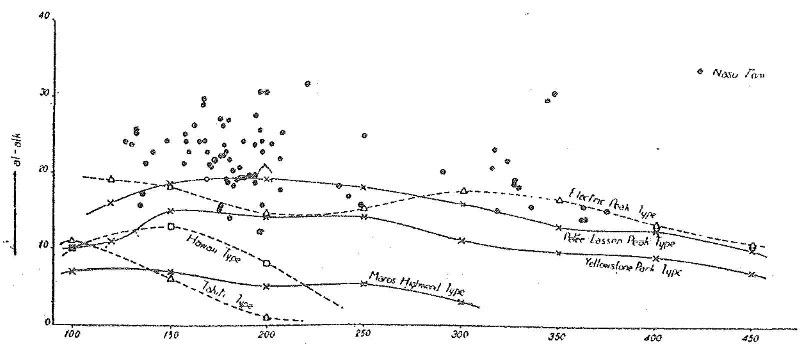


Figure 4. Niggli's value *al-alk* corresponding to *si*, calculated from chemical compositions of lavas from the Nasu volcanic zone.

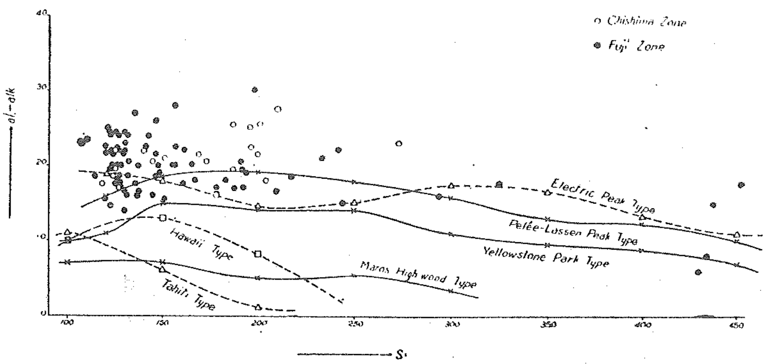


Figure 5. Niggli's value *al-alk* corresponding to *si*, calculated from chemical compositions of lavas from the Chishima and Fuji volcanic zones.

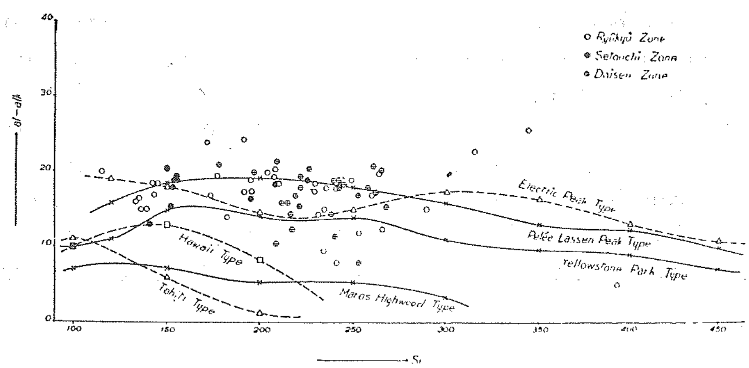


Figure 6. Niggli's value *al-alk* corresponding to *si*, calculated from chemical compositions of lavas from the Ryûkyû, Setouchi and Daisen volcanic zones.

than the curves drawn from the average values of the Pelée-Lassen Peak and Electric Peak types which are both higher than those of other provinces in the world[2] (Figure 4.) Also lavas from the Fuji and Chishima zones have, as a whole, relative high values in *al-alk* (Figure 5), while those from the Ryûkyu, Setouchi and Daisen zones show generally lower value in *al-alk* in comparison with the above three zones (Figure 6). Though

Tertiary volcanic area along the above three zones in northeast Japan, where large anorthites are often found, is not yet studied closely on it's chemical characteristic, andesitic basalt from Mitaki which includes large anorthite shows high value of *al-alk* 27, corresponding to *si* 125.

It is well known that in Japan volcanic rocks plagioclase is more basic and rhombic pyroxene is dominant in comparison with those from other countries in the world. Addition of Al_2O_3 to basaltic magma accelerates the formation of basic plagioclase.[1] Expence of CaO for anorthite molecule in plagioclase leads to the increase of rhombic pyroxene and decrease of lime pyroxene as augite and diopside.

Relative increase of Al_2O_3 in igneous rocks is considered to be due to magmatic assimilation of preexisting basal rocks rich in Al_2O_3 as clayey rocks. Geological tectonic by which contamination between magma and preexisting rocks is apt to take place, may prevail in the above-stated volcanic areas. At chance, abnormally strong addition of Al_2O_3 may happen by assimilation, partly in magma in such areas. Basaltic melt increases its viscosity with increase of SiO_2, Al_2O_3 or K_2O, while decreases with addition of CaO, MgO, FeO, Fe_2O_3, Na_2O, MnO or TiO_2.[9] Abnormally Al_2O_3-rich part may be maintained immiscible in magma for some time due to it's viscosity and other causes. It is imagined also that from such Al_2O_3-rich part in magma anorthite is ready to crystallize. Crystallization of plagioclase begins at constant temperature, no matter how much Al_2O_3 adds.[9] And An-rich plagioclase is greater in speed of crystallization than An-poor plagioclase.[10] Physical condition influenced by contamination may also aid the growth of large crystal, as clay mixed in salt water leads to the better growth of salt crystal physically.[16]

The formation of large anorthite without zonal structure is due to rapid growth of crystal according to Kôzu,[21] and slow cooling in equilibrium state according to Tsuboi.[40] The author considers that strong addition of Al_2O_3 to magma may introduce other condition in crystallization of minerals than normal course of crystallization from basaltic magma. Large crystals of minerals found often in metasomatic rocks give some suggestion to consider on the genesis of large anorthite in question. But the frequent occurrence of olivines included in anorthite crystals indicates that olivine crystallized surely earlier than anorthite, as seen normaly in basaltic magma. Sometime pyroxenes also are inculded in anorthite. Accordingly addition of Al_2O_3 continued strongly even after olivine or rarely pyroxenes began to crystallize, and special portion rich in Al_2O_3 was formed partly in magma. But what other minerals crystallized in the parallel association with anorthite from such portion, or whether any residual liquid remained in that portion just before mixing or not, the author can not answer.

From the general part of magma which may assimilate more or less preexisting basal rocks, olivine crystallizes at earliest stage, but it disappears or decreases by reaction with residual magma, and pyroxenes take place of it. Basic plagioclase and rhombic pyroxene may tend to increase, due often to some addition of Al_2O_3. After phenocrystic minerals were formed at the intratelluric stage, the general part of magma mixed with special portion from which anorthite crystallized, by violent upward movement of magma due to abrupt decrease of pressure. Or the general part of magma might have captured anorthite crystals as xenoliths. The narrow marginal rim of more sodic composition surrounding the main part of anorthite crystal was formed at the effusive stage, due to the reaction with residual magma. Viscosity of magma increasing with addition of SiO_2 and Al_2O_3 may be one of causes to lead often to violent explosion on the occasion of effusion of anorthite crystal lapilli and anorthite bearing lava.

Development of remarkable partings in some specimens of anorthite may be due to abrupt change in physical conditions such as temperature, pressure, viscosity and others, at the moment of violent mixing of two different portions. Or special condition under which large anorthite crystallized out from the melt formed by strong assimilation, may control types of twinning, and have any connection also with development of partings.[(8)]

Though there are many points remained undissolved on the genesis of large anorthite crystals, it is significant in petrology that large anorthite crystals are found only from pyroxene andesites and basalts in those areas, where volcanic rocks are generally relative rich in Al_2O_3 or high in *al-alk*.

References cited

(1) BOWEN, N. L.: J. Geol. 30, 513–570 (1922).
(2) BURRI, C. R.: Schweiz. Min. Petr. Mitt. 6, 115–199 (1926).
(3) HARADA, Z.: J. Geol. Soc. Japan 31, 357–364 (1924).
(4) " : Ibid. 40, 343–345 (1933).
(5) " : Bull. Volc. Soc. Japan 2, 330–349 (1936).
(6) ISHIKAWA, T.: J. Geol. Soc. Japan 53, 64 (1947).
(7) " : Ibid. 56, 272–273 (1950).
(8) KANO, H.: J. Jap. Assoc. Petr. Min. Econ. Geol. 34, 148 (1950).
(9) KANI, K.: J. Jap. Assoc. Petr. Min. Econ. Geol. 12, 80, 120 (1934).
(10) " : Ibid. 15, 3–6 (1936).
(11) KATSUI, Y.: Graduation Thesis, Hokkaidô Univ. 247 (1950).
(12) KIKUCHI, Y.: J. Coll. Sci. Tokyô Univ. 2, 31–49 (1888).
(13) " : J. Geogr. Tokyo, 2, 187 (1890).
(14) KINOSHITA, K. & KAWAI, K.: J. Geol. Soc. Japan, 30, 192 (1923).
(15) KOBAYASHI, M.: J. Geol. Assoc. Hiroshima (Hiroshima Chigaku Dôkôkaihô) 5, 17–19 (1934).
(16) KOIDE, H. & NAKAMURA, T.: Proc. Imp. Acad. Tôkyô, 19, 202–204 (1943).
(17) KÔZU, S.: Bull. Geol. Survey Japan, 15, 37–67 (1909).
(18) " : J. Geol. Soc. Japan, 17, 1–7, 49–56 (1910).
(19) " : Ibid. 17, 283–294 (1910).
(20) " : Sci. Rep. Tôhoku Univ. 2, 7–37 (1914).
(21) KÔZU, S., & KADOKURA, S.: The globe, (Chikyû) 7, 378–386 (1927).
(22) KÔZU, S.: Ibid. 7, 440–448 (1927).
(23) " : Ibid. 8, 247–264 (1928).
(24) KÔZU, S. & UEDA, J.: J. Jap. Assoc. Petr. Min. Econ. Geol. 5, 114–117 (1931).
(25) LEISEN, E.: Zs. Krist. 89, 53 (1934).
(26) MAKINO, K.: Beiträge zur Mineralogie von Japan, 5, 287–288 (1915).
(27) NAKAJIMA, K.: J. Geol. Soc. Japan, 15, 328–338 (1908).
(28) " : Beiträge zur Mineralogie von Japan, 4, 202–205 (1912).
(29) NEMOTO, T.: J. Jap. Assoc. Petr. Min. Econ. Geol. 3, 383–390, 4, 17–28 (1930).
(30) " : Ibid. 6, 74–80 (1931).
(31) ODA, R.: J. Geol. Soc. Japan, 19, 485–486 (1912).
(32) ÔTAKI, T.: Graduation Thesis, Hokkaidô Univ. 231 (1949).
(33) SASAKI, S.: Ibid. 33 (1935).
(34) SATÔ, D.: J. Geol. Soc. Japan, 10, 551–552 (1903).
(35) " : Bull. Geol. Survey, Japan, 14, 24 (1909).

(36) SUZUKI, J. & SHIMOTOMAI, T.: Bull. Volc. Soc. Japan, **1** (3) 38, (1933).

(37) SHÔDA, T.: J. Jap. Assoc. Petr. Min. Econ. Geol. **32**, 147–156 (1944).

(38) T. H.: J. Geol. Soc. Japan **3**, 248–249 (1896).

(39) TAKABATAKE, A.: Private communication.

(40) TSUBOI, S.: J. Coll. Sci. Tôkyô Univ. **43**, 108–112 (1920).

(41) " : Min. Mag. **20**, 118 (1923)

(42) " : Bull. Earthq. Res. Inst. **6**, 131–138 (1935).

(43) TSUYA, H.: Ibid. **13**, 645–650 (1935).

(44) WADA, T.: Trans. Seism. Soc. Japan **4**, 31–37 (1882).

(45) " : Japanese minerals, 226 (1904).

(46) WATANABE, S.: J. Jap. Assoc. Petr. Min. Geol. **7**, 18–20 (1932).

(47) YAGI, K.: Ibid. 38, 1–17 (1949).

Plate

Plate

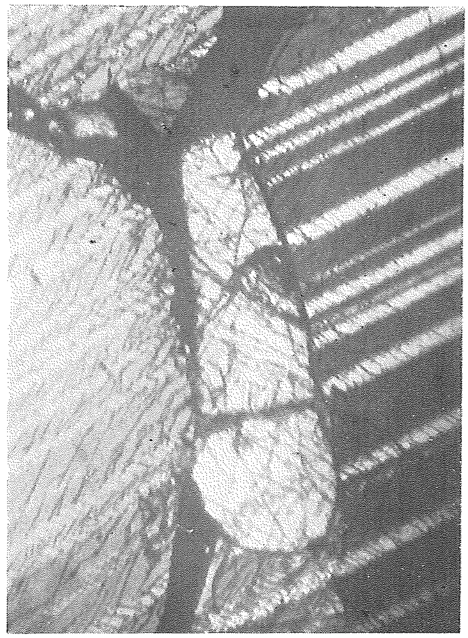
Figure 1. Photomicrograph of anorthite bearing black compact block (two pyroxene andesite) from Volcano Tarumai.
Large anorthite is surrounded with marginal rim of labradorite. Common phenocryst of plagioclase shows strong zonal structure. Crossed nicols. × 27.

Figure 2. Photomicrograph of large anorthite in olivine two pyroxene andesite at the east foot of Volcano Kamabuse. Partings develop in alternating lamellae of polysynthetic twin, and olivine is seen as inclusion. Crossed nicols. × 27.

Figure 3. Photomicrograph of large anorthite from agglomeratic tuff at the east foot of Volcano Kuttara. Partings develop only in some zones. One nicol. × 27.

Figure 4. Photomicrograph of large anorthite included in olivine two pyroxene andesite from Volcano Midoriko, Shinshiru Island. Margin of anorthite crystal which shows polysynthetic twin after. Albite law is invaded irregularly with the groundmass. Croossed nicols. × 27.

1



2

3

4

T. Ishikawa: Petrological Significance of Large Anorthite Crystals.