Bulletin of the Earthquake
Research Institute
Vol. 41 (1963), pp. 391-402

26. *Some Geological Considerations on the Ha-yama Volcano.*

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(Read April 24th, 1962.—Received March 12, 1963.)

Introduction

The Ha-yama Volcano forms a dissected cone at the opposite side of Kaminoyama. It is composed of andesite lavas and ejecta which rest mostly upon the undulatory surface of the Dorobu formation accumulated under the lacustrine environment and assigned recently by S. Minakawa[1] to the late Miocene period. Such are well exposed here and there, suggesting that there may be some connection between them. The eruption of this volcano took place within the area now occupied by the Dorobu formation, and it was hitherto supposed by some geologists to have already ceased before the Pleistocene period.

The writer had an opportunity to spend several days here during his geological works covering the northern half of the Zaō Volcanoes. At that time these problems were examined by him from various points of view.

General Features of Topography and Geology

The Ha-yama Volcano is situated at the eastern periphery of the Kaminoyama Basin. It is a small isolated volcano composed of two main peaks called Ha-yama and Sankichi-yama, rising up to 687.4 m. above sea-level at the highest point and projecting out on to the plain irrigated by the Miya-kawa, Zaō-gawa and Namai-gawa (Figs. 2, 3).

Geologically speaking, the area under consideration consists of the Dorobu formation, plagiorhyolite, andesite, agglomerate and Quaternary fluviatile or talus deposits (Fig. 1).

(1) Extrusive prior to the deposition of the Dorobu formation: The lava flows and ejecta erupted from here are underlain by the Dorobu formation and plagiorhyolite. Among them, plagiorhyolite is

* Communicated by H. Tsuya.

1) S. Minakawa, *Bull. Yamagata Univ.* (Nat. Sc.), **4** (1959), 562.

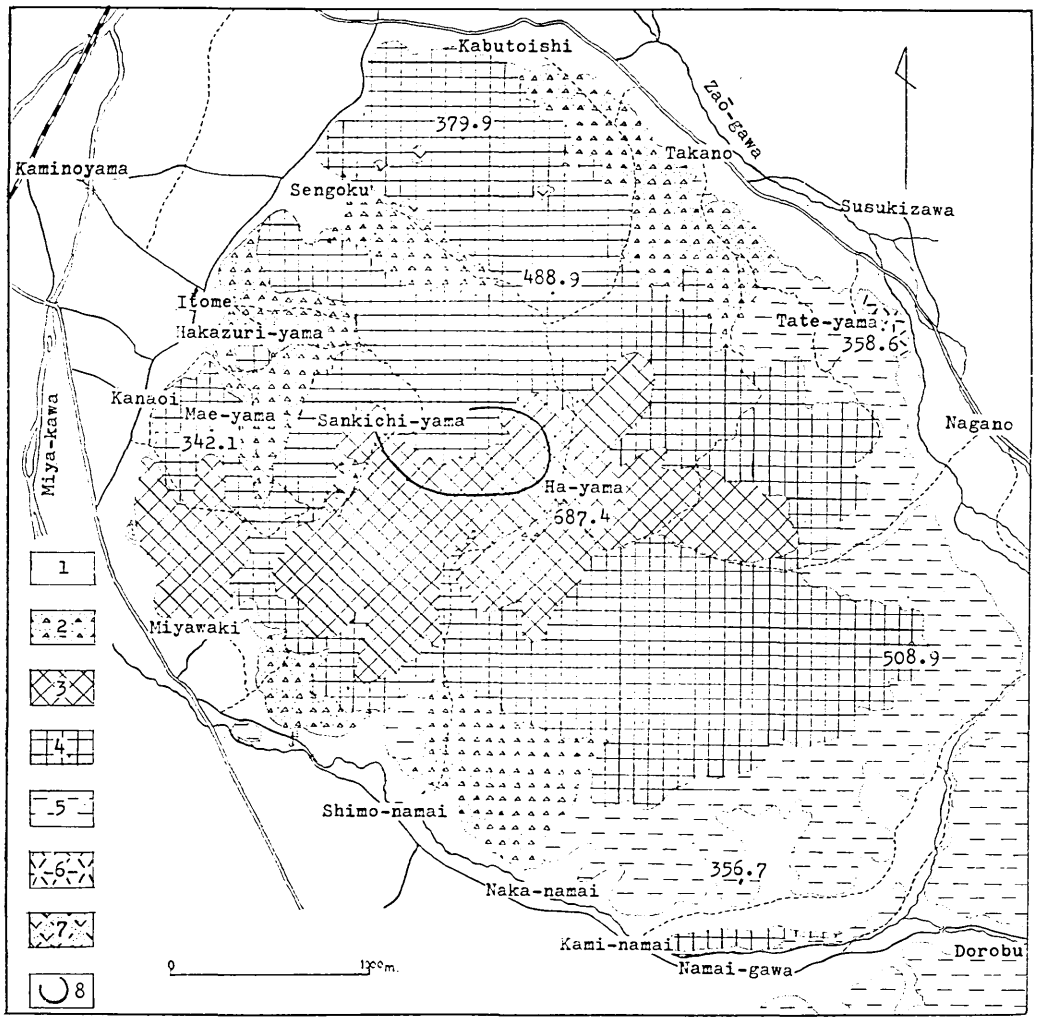

Fig. 1. Geological Map of the Ha-yama Volcano.
1. Quaternary fluviatile deposits, 2. Talus deposits, 3. Ha-yama lava and agglomerate, 4. Sengoku lava, 5. Dorobu formation, 6. Andesite lava intercalated between tuffaceous beds of the Dorobu formation, 7. Plagiorhyolite, 8. Explosion crater.

exposed at Sengoku and other places to a small extent without showing any relationship to the Dorobu formation. The rock has a grey color and consists of quartz, plagioclase, biotite, magnetite etc.

(2) Dorobu formation: This formation is to be seen along the Zaō-gawa, Namai-gawa and their tributaries as well as at the south-eastern foot of the volcano. It is 280(±)m. in thickness, and the

best exposures can be investigated at Dorobu and the vicinity. The formation here is commonly composed of tuff and sandy tuff or other tuffaceous sediments, whereas its middle horizon is represented by alternate beds of mudstone, siltstone and tuff well stratified. It is also noteworthy that the lowest part of the Dorobu formation is sometimes intercalated with andesite flows. Minakawa[2] has found some plant fossils in the beds of the middle horizon. They are cf. *Acer diabolicum* Blume, *Carpinus* Blume, *Juglans* sp. and *Tilia protojaponica* Endo. Thus, the formation seems to be of the Kitaura horizon. In these cases, some of tuffaceous sediments (Fig. 5) contain abundant gravels or breccias of biotite granodiorite, hornblende biotite granodiorite, older andesite, propylite, plagiorhyolite, tuff and pumice. According to Aoki's investigation[3], the tuffaceous sediments of the Dorobu formation are composed of augite, biotite, garnet, hornblende, hypersthene, ilmenite, magnetite, microcline, orthoclase, plagioclase, quartz and zircon as well as of minute fragments of granodorite, plagiorhyolite, andesite, propylite, pumice, shale and tuff. Of these minerals, augite and hypersthene are found in high frequency.

Beside them, the lava flows mentioned above are two-pyroxene andesite.

(3) Lavas and ejecta erupted from Ha-yama Volcano: There are at least two different types of lava. They are the Sengoku lava and Ha-yama lava. The latter is occasionally characterized by the occurrence of agglomerate at its bottom. Such lavas and ejecta are likely to have erupted from the pre-existing crater broken subsequently by the formation of the explosion crater. These volcanic products are respectively exposed on the Dorobu formation and plagiorhyolite, being partly covered by talus deposits and surrounded by the Quaternary fluviatile sediments.

(i) Sengoku lava: This is the oldest lava of this volcano and spreads widely as compared with the Ha-yama lava and agglomerate. Its eastern half rests directly on the surface of the Dorobu formation, whereas the western end disappears suddenly beneath recent fluviatile deposits as in the case of the Ha-yama lava and agglomerate.

The thickness of the lava flow is variable from place to place, being 200 m. or thereabouts on the eastern or southern flank, where the joint structure is sometimes quite remarkable and where talus deposits due

2) S. MINAKAWA, op. cit., 562, 566.

3) K. AOKI, *Bull. Yamagata Univ.* (Nat. Sc.), **5** (1961), 396-399.

to the landslide are to be seen at the area between Naka-namai and Shimo-namai.

(ii) Ha-yama lava and agglomerate: The upper part of the volcano is built up of a different type of lava and its agglomerate which extend westwards down to Miya-waki. Of these, the agglomerate is found at the bottom of the lava flow exposed on the cliff between Kanaoi and Miyawaki. It contains abundant fragments of two-pyroxene andesite, large or small, in the tuffaceous matrix.

Good exposures of the lava flow can be seen on the cliff of Sankichi-yama and also on the ridge branching south-westwards from the summit of Ha-yama where the lava flow is highly cliffed and characterized by the predominance of the joint structure. In such cases, the lava flow falls down here and there, forming a thick accumulation of its fragments at the foot of these cliffs. The lava and agglormerate are likely to have erupted from the pre-existing crater, and they are estimated to be 150 m. or thereabouts at the thickest part. The relationship between this lava and the underlying Sengoku lava can be examined at the old quarry opened on the western flank of Sankichi-yama. The latter is directly overlain by the former and has a reddish color due to reheating.

(4) Quaternary sediments: They are younger or older fluviatile and talus deposits.

(i) Fluviatile deposits: Older fluviatile deposits are sporadically preserved on the terraces along the Namai-gawa. The most characteristic one is to be seen at the uppermost course of this river. Younger fluviatile deposits are, on the other hand, distributed widely along the present rivers and their tributaries.

All of these deposits are composed of gravel, sand and clay.

(ii) Talus deposits: Thin or thick talus deposits due to the collapse of jointed andesite flows or the landslide are to be seen here and there at the foot or on the flank of this volcano, being composed of angular fragments or blocks supplied from the Sengoku lava or the Ha-yama lava. Some of these are found to a large extent on the gently-sloped area behind Takano, Itome, Naka-namai and Shimo-namai where the deposits are underlain by the Sengoku lava or Dorobu formation. Topographically, they have a characteristic feature distinguishable from other parts of the volcano. There are also two remarkable talus deposits formed of the fragments from the cliff of the Ha-yama lava exposed on the southern flank of Sankichi-yama (Fig. 4) and Ha-yama.

Structure of the Ha-yama Volcano

The Ha-yama Volcano is a homate with a big explosion crater opened northwest-wards. The lavas and ejecta erupted probably from the pre-existing crater are remarkably dissected at present, forming Ha-yama (687.4 m.) and Sankichi-yama near or on the margin of the explosion crater. The volcanic products thus erupted incline gently in all directions, and those of the western half are traceable down to the eastern periphery of the Kaminoyama Basin. The structure of this volcano can be investigated along several valleys where lava flows are sucessively exposed on the Dorobu formation, and there is no complicated feature between them.

Pre-existing Crater and Explosion Crater

The old crater is now obscured by the subsequent formation of the explosion crater. It is supposed to have been located in the hollow between Ha-yama and Sankichi-yama. The explosion crater was formed here at the final stage of activities and opened north-westwards. It is about 500 m. in diameter, and 200 m. or thereabouts in its present depth, the bottom being buried with andesite fragments which crumbled down from the surrounding wall.

Mineral Composition of Lavas and Ejecta

(1) Sengoku lava: It is a porous or non-porous two-pyroxene andesite which has a black color in fresh specimens, but a dark grey or grey color when decomposed, passing into a reddish variety at some places where the lava is supposed to have been subjected to reheating. The rock is composed of plagioclase, augite, hypersthene, magnetite, quartz, tridymite, chlorite and brown glass (Fig. 6).

Of these, the phenocrystic plagioclase ranges from labradorite to bytownite with a composition of An_{50-82}. The crystal is commonly euhedral or subhedral and takes a rectangular or tabular form, 6.03 mm. long and 4.13 mm. across in the largest one. It is well zoned, being sometimes turbid near its periphery or at its central part. Frequently, the large phenocryst reveals a worm-eaten structure due to the invasion of the groundmass and brown glass which are found as irregular patches arranged in parallel with crystal outline. Small lath-shaped or rectangular plagioclase is abundantly present in the groundmass. It is

labradorite, generally 0.02 mm.—0.35 mm. long and shows a fluidal structure.

Augite is also one of important ingredients as phenocryst and in the groundmass. The phenocrystic augite occurs in higher or lower frequency as compared with the phenocrystic hypersthene. The crystal form is commonly subhedral or anhedral, the largest one being 3.91 mm. long and 1.61 mm. across. The extinction angle, $Z \wedge c$, is usually 42°, but increases slightly outwards in zoned crystals. Almost all of the crystals are twinned on (100) or (101) and enclose magnetite. Some of these are corroded by the groundmass. The augite crystals of the groundmass have a prismatic or rounded form, 0.02—0.08 mm. in length or diameter.

Table 1. Composition and optical characters of plagioclase, augite and hypersthene phenocrysts. (measured by F. Hori)

	(T. I. 58110905)
Plagioclase	α=1.555 (n_1 min.) γ=1.582 (n_1 max.) An_{50-82}
Augite	α=1.684 β=1.690 γ=1.710 (+)2 V=49° $Ca_{41}Fe_{16}Mg_{43}$
Hypersthene	γ=1.710 (−)2 V=57° Fe %=37

The specimen was obtained on Hakazuri-yama near Itome.

Hypersthene is always phenocrystic and takes mostly a long prismatic habit. The largest crystal is 2.89 mm. long and 0.93 mm. across. When this mineral and augite are closely associated, the former is fringed by the latter. The crystal includes magnetite with a skeletal form, 1.02 mm. in the maximum diameter.

Quartz is a xenocryst probably supplied from the granitic rock or rhyolite which is largely distributed in this district. The mineral is of rare occurrence and has a rounded form due to the magmatic corrosion. The largest piece is 1.66 mm. in diameter.

Similarly, tridymite and chlorite are scarcely present. The former fills up the interstices of other ingredients in the groundmass, whereas the latter is an alteration product of the phenocrystic plagioclase.

One of the characteristic features of the Sengoku lava is the remarkable abundance of brown glass. Thus, some of the writer's specimens look like a glassy andesite. On weathering, such a glass

changes into a dark brown substance of an unknown character.

Moreover, the occurrence of basaltic xenoliths is known in some specimens. It produces an intergranular aggregrate of plagioclase, augite, hypersthene, magnetite and brown glass.

The groundmass has a hyalopilitic texture formed of labradorite, augite, magnetite and brown glass.

(2) Ha-yama lava and andesite fragments of associated agglomerate: In this case, the lava passes into agglomerate downwards, as is shown on the cliff behind Kanaoi. These rocks are ordinarily represented by a porphyritic and porous or non-porous two-pyroxene andesite with a black color in fresh specimens. They have several mineral ingredients similar to those of the Sengoku lava, although there is some marked difference in the texture of the groundmass (Fig. 7).

The most predominant mineral is plagioclase, in which the phenocryst takes a rectangular or tabular form, mostly euhedral or subhedral, being 4.64 mm. long and 1.32 mm. across in the largest crystal. It is labradorite—bytownite, An_{55-82} in composition. Some of them are invaded by the groundmass and brown glass, forming a worm-eaten structure as in the case of the Sengoku lava. The crystal is distinctly zoned and encloses augite and magnetite. There is also a turbid zone which is not infrequently fringed by a narrow clear rim. The minute lath-shaped or rectangular plagioclase of the groundmass is more acidic than the phenocryst. Such crystals produce a fine aggregate together with augite, magnetite and brown glass. Most of the crystals are 0.01 mm.—0.08 mm. in length.

Augite occurs as the phenocryst and in the groundmass. In the former case, it has a subhedral or anhedral form, 2.46 mm. long and 0.93 mm. across in the largest crystal. The phenocryst twins on (100) or (101), showing an extinction angle, $Z \wedge c$, of $42° \pm$. In the groundmass, the minute prismatic or granular augite is abundantly contained. Its length or diameter is 0.01 mm.—0.08 mm.

Hypersthene is phenocrystic. It has commonly a long prismatic habit and an euhedral or subhedral form. In the largest crystal, it is 3.06 mm. long and 1.7 mm. across. Sometimes it is fringed by augite. As is indicated by the phenocrystic augite, there are frequently corroded crystals. Magnetite is its enclosure.

The octahedral or granular magnetie is a very remarkable ingredient in the groundmass where it is 0.01 mm.—0.08 mm. in diameter. The phenocrystic magnetite is generally octahedral or skelectal, but

occasionally takes a rounded form. The maximum diameter is 0.5 mm.

On the contrary, corroded quartz crystal is rarely contained in the specimens obtained on the summit of Sankichi-yama and the pass between Miyawaki and Itome or elsewhere. It is a xenocryst captured from some acidic intrusive.

Table 2. Composition and optical characters of plagioclase, augite and hypersthene phenocrysts. (measured by F. Hori)

	No. 1 (T. I. 57051907)	No. 2 (T. I. 58112208)
Plagioclase	α=1.577 (n_1 min.) γ=1.579 (n_2 max.) An_{55-80}	α=1.560 (n_1 min.) γ=1.582 (n_2 max.) An_{60-82}
Augite	α=1.688 β=1.696 γ=1.791 (+)2 V=50° $Ca_{41}Fe_{21}Mg_{38}$	α=1.682 β=1.692 γ=1.715 (+)2 V=50° $Ca_{42}Fe_{17}Mg_{41}$
Hypersthene	γ=1.708 (−)2 V=58° Fe %=36	γ=1.705 (−)2 V=63° Fe %=32

No. 1=The Ha-yama lava collected on the ridge between Ha-yama and Sankichi-yama.

No. 2=The Ha-yama lava collected on the flank 400 m. north-east from the summit of Ha-yama.

The interstices of the minerals mentioned above are always filled by brown glass which is a characteristic ingredient of this type of lava. Besides these, basaltic or gabbroic xenolith consisting of plagioclase, augite, hypersthene, magnetite and brown glass is present in almost all of the thin sections.

The groundmass is a fine aggregate of plagioclase, augite and magnetite intermixed with brown glass. It has a hyalopilitic texture.

(3) Lava erupted during the deposition of the Dorobu formation: This is a different type of two-pyroxene andesite, although the rock is composed of plagioclase, augite, hypersthene, magnetite and brown glass (Fig. 8). Under the microscope, the mineralogical and optical

characters of plagioclase are quite similar to the Sengoku lava and Ha-yama lava. Its phenocryst is labradorite—bytownite (An_{55-77}) with a worm-eaten structure and turbid zone. The phenocrystic augite is found in low frequency as compared with hypersthene. The latter is not frequently fringed by the former.

Magnetite is abundantly found mostly as an ingredient in the groundmass. All of the minerals mentioned above occur together with brown glass which is not so predominant as in the lavas erupted from the Ha-yama Volcano. Moreover, this older lava is distinguishable from other lavas by the texture of the groundmass.

Table 3. Composition and optical characteristics of plagioclase, augite and hypersthene phenocrysts. (measured by F. Hori)

	(T. I. 58112201)
Plagioclase	$\alpha=1.557$ (n_1 min.) $\gamma=1.577$ (n_2 max.) An_{55-77}
Augite	$\alpha=1.690$ $\beta=1.696$ $\gamma=1.717$ $(+)2V=46°$ $Ca_{38}Fe_{22}Mg_{40}$
Hypersthene	$\gamma=1.710$ $(-)2V=56°$ Fe %=38

The specimen was collected on a cliff of the Zaō-gawa near Tate-yama.

Chemical Composition

For the purpose of chemical investigations, four types of specimens were selected from various kinds of lava exposed on the Ha-yama Volcano. All of these are two-pyroxene andesite rich in brown glass and the same mineral ingredients, although there is some textural difference in the groundmass between them.

The chemical composition of this table suggests that the Ha-yama lava and Sengoku lava are slightly acidic when compared with the lava intercalated between the tuffaceous beds of the Dorobu formation, as is indicated by the weight percentage of silica and the value of the normative quartz. Thus, the former seems to be also distinguishable chemically from the latter which poured out during the deposition of the Dorobu formation. In the same way, the Ha-yama lava is also more acidic than the Sengoku lava.

Table 4. Chemical Composion and Norm.

	(I) (52080201)	(II) (57051910)	(III) (58111608)	(IV) (58110201)
SiO_2	61.02	60.21	62.08	59.94
Al_2O_3	15.41	16.82	15.24	15.87
Fe_2O_3	3.69	3.56	3.78	4.01
FeO	3.46	3.71	3.26	3.56
MgO	3.08	2.95	3.48	3.12
CaO	5.83	6.10	5.37	5.74
Na_2O	3.48	2.98	3.07	3.25
K_2O	2.12	1.87	1.68	2.46
H_2O+	0.79	0.79	1.09	0.83
H_2O-	0.62	0.24	0.55	0.74
TiO_2	0.64	0.55	0.74	0.59
P_2O_5	0.17	0.18	0.21	0.20
MnO	0.14	0.12	0.15	0.17
Total	100.45	100.08	100.69	100.48
		Norm		
Q	16.44	18.78	21.00	14.82
Il	1.21	1.06	1.37	0.91
Mt	5.34	5.57	5.57	6.26
Ap	0.34	0.34	0.34	0.34
Or	12.79	11.12	10.01	14.46
Ab	29.34	25.15	26.20	28.30
An	20.02	26.97	22.52	21.13
Wo	3.36	1.04	1.62	2.78
En	7.70	7.40	8.70	8.80
Fs	2.38	3.30	1.82	5.94

(I)=Sengoku lava from Sengoku.

(II)=Ha-yama lava from the slope about 400 m. west of the summit of Ha-yama.

(III)=Ha-yama lava from the end of the ridge branching south-eastwards from the summit of Ha-yama.

(IV)=The lava intercalated between the tuffaceous beds of the Dorobu formation exposed near Tate-yama.

History of Volcanic Activities

The Dorobu formation contains some plant fossils from which it is supposed to be of the late Miocene period. This formation is composed of tuffaceous sediments and thin lava flows, suggesting that there was a volcanic activity here at that time. The Ha-yama Volcano rests mostly

upon the undulatery surface of this formation, and its eruption took place repeatedly within the area where the Dorobu formation had accumulated under the lacustrine environment.

It is now impossible to determine the position of the volcanic center from where the materials of the Dorobu formation were supplied. There is, however, the possibility that it existed somewhere near that of the Ha-yama Volcano.

Lavas and ejecta of the Ha-yama Volcano erupted successively from the crater which had been opened between Sankichi-yama and Ha-yama. In the beginning, the Sengoku lava poured out and spread largely on the eroded surface of plagiorhyolite and the Dorobu formasion. It was then followed by the eruption of the Ha-yama lava and agglomerate. In the latter case, the bottom of the lava partly passes into agglomerate. Such volcanic activities as mentioned above resulted finally in the formation of an explosion crater which is opened north-westwards and is fairly dissected at present. The Ha-yama Volcano, however, preserves its original form to some degree.

So far as is known at present, this volcano seems to have been erupted on the eroded surface of the Dorobu formation which had been subjected to the folding and faulting probably occurring in the Pliocene period. It is, therefore, more reasonable to say that the Ha-yama Volcano was active in the Quaternary and had no direct connection with the volcanism indicated by the deposition of the Dorobu formation.

Summary

(i) The Ha-yama Volcano rises up to 687.4 m. above sea-level at the opposite side of Kaminoyama, resting upon the upper Miocene sediments called the Dorobu formation and plagioryholite which were disturbed and eroded to some degree.

(ii) The volcano is formed of lavas and ejecta. One of these is the Sengoku lava, while the other is the Ha-yama lava and agglomerate, both being represented by two-pyroxene andesite rich in brown glass. They were erupted from the crater now broken by the subsequent explosion and opened north-westwards.

(iii) The Sengoku lava first poured out and covered largely the undulatory surface of bases rocks composed of the Dorobu formation and plagiorhyolite. It was then followed by the eruption of the Ha-yama lava and agglomerate from the same crater. In this case, the

lava flow passes locally into agglomerate at its base.

(iv) These lavas are different in the texture of the groundmass and also in the chemical character. In the latter case, the Ha-yama lava seems to be more acidic when compared with the Sengoku lava.

(v) The Ha-yama Volcano was born at the area where the Dorobu formation had accumulated under the lacustrine environment. It was active in the Quaternary. The formation of the volcano has, therefore, no direct connection with the deposition of the Dorobu formation which consists of tuffaceous sediments intercalated by lava flows and suggests that there was also a volcanism during its deposition.

Acknowledgments

The writer wishes to express his appreciation to Professor H. Tsuya and Mr. T. Watanabe as well as to Dr. F. Hori and Mr. T. Tōkairin who facilitated the writer's laboratory work.

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26. 葉山火山の地質学的考察

市　村　　毅

上山盆地の東縁，すなわち上山の対い側に孤立する葉山火山は，上部中新統と見做される泥部層やこれよりも古い斜長石流紋岩からなる基盤岩の侵蝕面上に座し，その最高点は，海抜 687.4 m. に達する．

この火山からは，仙石熔岩と葉山熔岩・集塊岩とを相次いで噴出し，後者の場合には，集塊岩が先駆をなしている．それ等の最も厚いところは，それぞれ約 200 m., 150 m. を算する．いずれも飴色ガラスの多い複輝石安山岩からなり，両者は，石基の組織の差と，古いものの方がやや酸性なることによつて区別される．

今日葉山火山には，葉山と三吉山との二つの峰があり，その間が爆裂火口になっているが，火山の原形の甚だしい変化が見られない．もつとも以前熔岩や砕屑物を噴出した火口は，この爆裂火口が出来たために破壊され，旧態が分らない．

火山の基盤をなす泥部層は，小湖水に堆積した凝灰質の物質や複輝石安山岩の薄い熔岩流その他からなるけれども，葉山火山の活動との間に，直接関係があつたとは思われない．又葉山火山の噴出物が変動を受けた泥部層の侵蝕面を被い，しかも火山の形態が保存されている点から見ると，それは，第四紀に入つてから生じたものであろう．

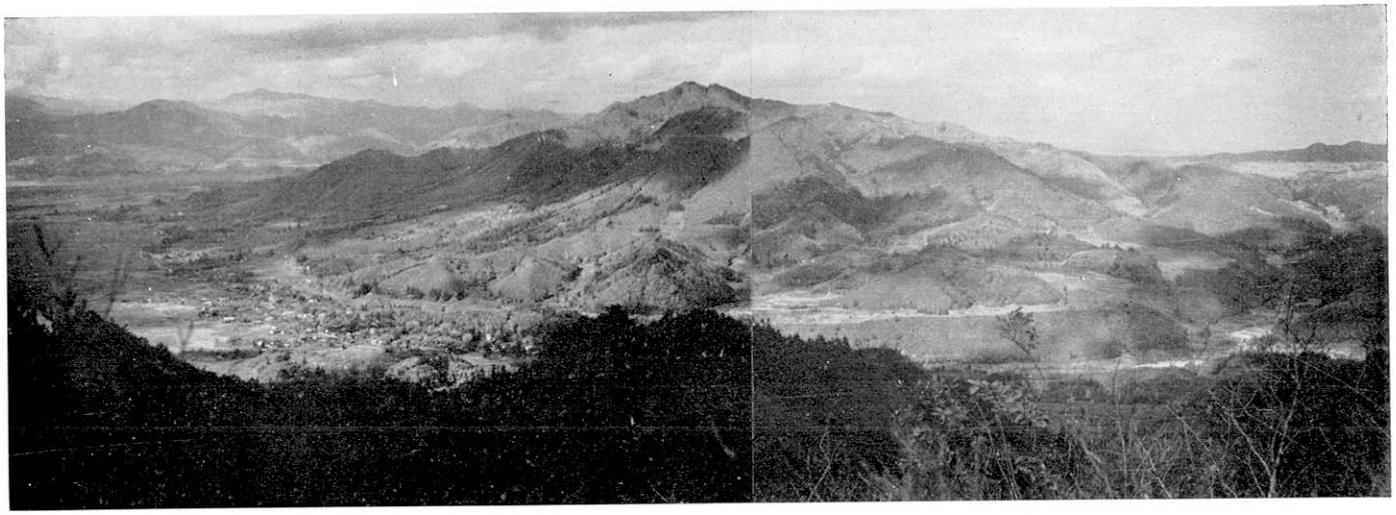

Fig. 2. The Ha-yama Volcano viewed from near the summit of Takahata-yama.

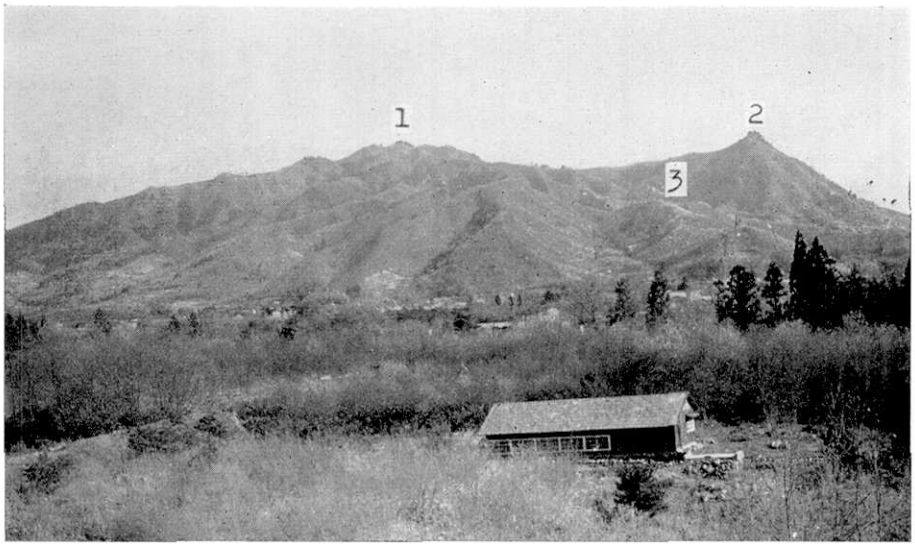

Fig. 3. The Ha-yama Volcano viewed from near the entrance of Kaminoyama.
1=Ha-yama (the summit of the Ha-yama Volcano), 2=Sankichi-yama, 3=Explosion crater.

Fig. 4. The talus deposits on the southern flank of Sankichi-yama.

Fig. 5. Tuffaceous rock of the Dorobu formation.
1=Plagioclase, 2=Quartz. (Kaminamai) ×100.

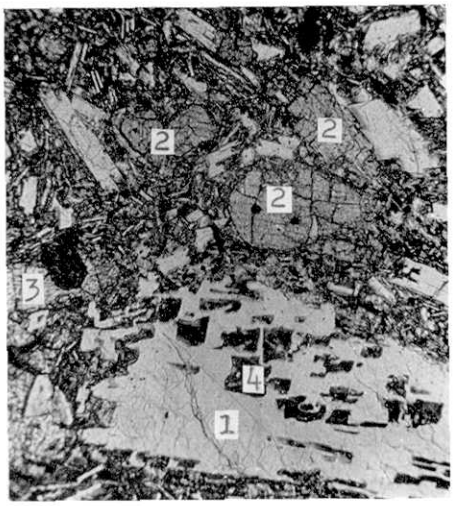

Fig. 6. Sengoku lava.
1=Plagioclase invaded by brown glass, 2=Augite, 3=Hypersthene, 4=Brown glass. The groundmass is rich in brown glass. (Sengoku) ×100.

Fig. 7. The Ha-yama lava.
1=Plagioclase, 2=Augite, 3=Hypersthene. (The summit of Ha-yama. Brown glass is abundantly present in the groundmass. ×100.

Fig. 8. Andesite lava intercalated between tuffaceous beds of the Dorobu formation.
1=Plagioclase, 2=Augite, 3=Hypersthene. (The cliff near Tate-yama) ×100.