39. *Geological Investigations on the Zaō Volcanoes. III Byōbu Volcano.**

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Introduction

The western half of the South Zaō is represented by the Byōbu Volcano which includes Byōbu-dake (1817.1 m.), Sugiga-mine (1745.3 m.), Fubō-zan (1705.3 m.), Ushiro-eboshi-dake (1666 m.), Mae-eboshi-dake

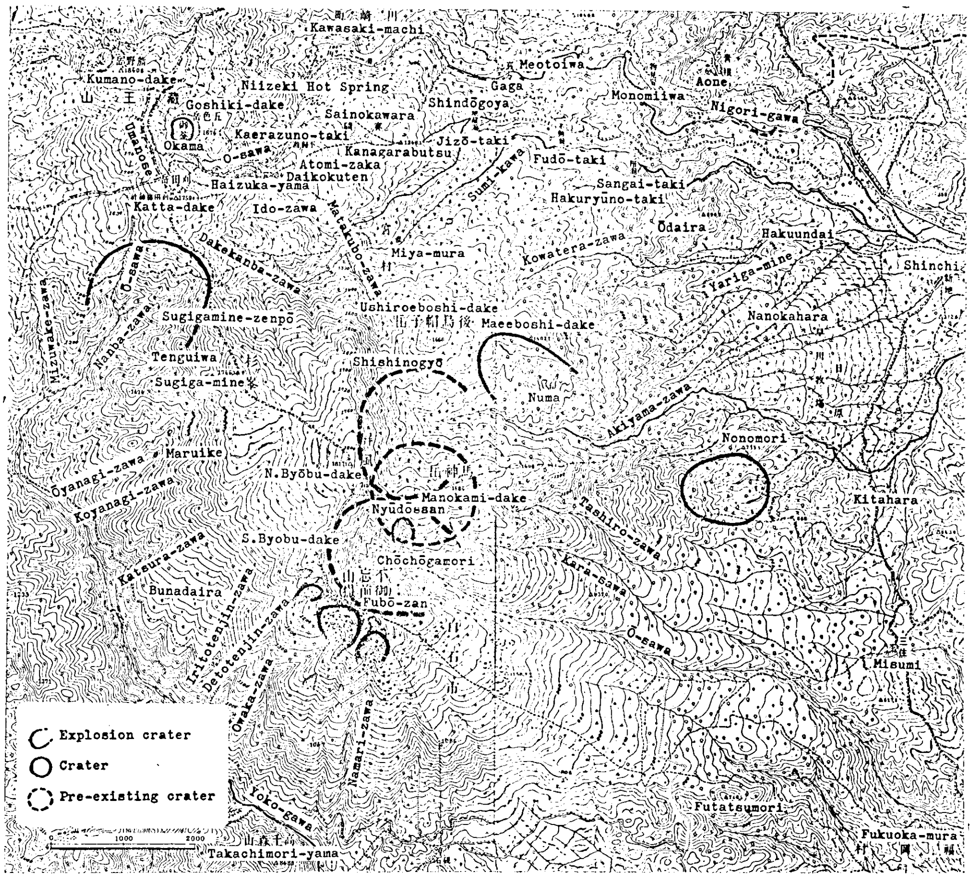

Fig. 1. Topographical map of the Byōbu Volcano and its vicinity.

* Communicated by N. Nasu.

(1402.1 m.), Nyūdō-san (1640 m.), Manokami-dake (1585 m.) and Nonomori (733.3 m.), and is separated from the North Zaō by the Sumi-kawa, and Nanba-zawa. This area is now dissected deeply along the Yoko-gawa, Sumi-kawa, Nigori-gawa and Akiyama-zawa as well as along their tributaries (Fig. 1). Moreover, it is thickly forested and almost unexplored when compared with other parts of the Zaō volcanoes. Most of its area is, therefore, not easily approached, but the first geological work was already carried out by A. Takada[1] more than 30 years ago. From that time, no further investigation had been intended until the writer's field work started in the autumn of 1947.

The results obtained in his field and laboratory works are summarized in this paper, excluding those of chemical investigations of lavas and ejecta which have not been finished.

Location

The Byōbu Volcano is situated at the northeastern corner of Katta-gun, Miyagi Prefecture. It is now accessible from Tōgatta, Kamasaki and Gaga respectively. These courses lead us to different parts of this volcano.

In the first case, Manokami-dake, Ushiro-eboshi-dake, Mae-eboshi-dake, Nonomori and Fubō-zan can be approached from Tōgatta. For the purpose of climbing up Fubō-zan, Byōbu-dake and Nyūdō-san as well as reaching the source of the Yoko-gawa, the course from Kama-saki is frequently selected. The summit of Sugiga-mine is, however, more easily attained from Gaga, crossing over Sainokawara, Haizuka-yama and Katta-dake.

Geological Features of the Byōbu Volcano

The lavas and ejecta of the Byōbu Volcano rests upon the eroded surface of base rocks composed of granite, aplite, pegmatite, plagio-liparite, felsitic rock, propylite, older andesite, basalt and Tertiary sediments. This geological feature is shown at the deeply dissected area where lavas and ejecta of Byōbu Volcano are highly cliffed (Fig. 2).

(1) Intrusives and extrusives prior to the first activity of the Byōbu Volcano:—Of these, biotite granite or hornblende-biotite granite is the most predominant rock covered by the Tertiary formation and

1) H. TAKADA, The Zaō Volcano, *M.S.*, 1922.

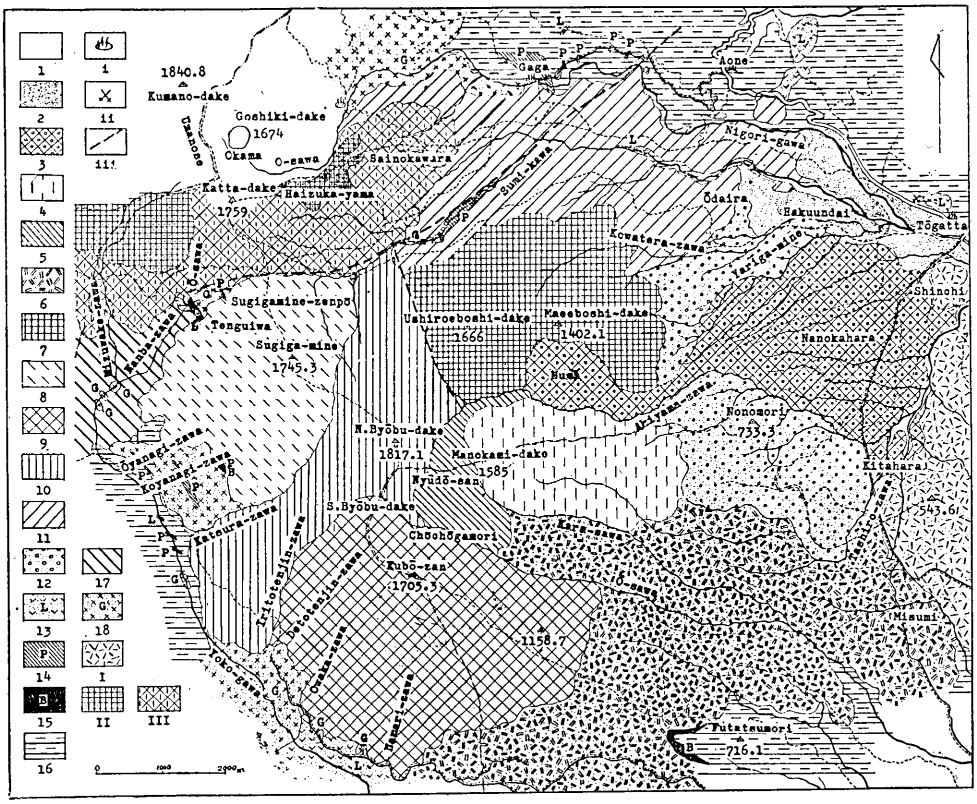

Fig. 2. Geological map of the Byōbu Volcano and its vicinity.

1. Recent fluviatile deposits, 2. Older fluviatile deposits, 3. Nanokahara mud flow, 4. Manokami-dake lava and agglomerate, 5. Nyūdō-san lava and agglomerate, 6. Kara-sawa mud flow covered partly by talus deposits, 7. Ushiro-eboshi-dake lava and ejecta, 8. Sugiga-mine lava and agglomerate, 9. Fubō-zan lava and ejecta, 10. Byōbu-dake lava, 11. Sumi-kawa lava and agglomerate, 12. Nonomori agglomerate, 13. Liparite, felsophyre and felsite, 14. Propylite, 15. Basalt, 16. Green tuff and shale (Upper Miocene), 17. Older andesite, 18. Granite or granodiorite, I. Matsu-kawa mud flow (Aoso Volcano), II. Kumano-dake lava and ejecta (Zaō Proper), III. Nanba-zawa lava and ejecta (Zaō Proper), i. Hot spring, ii. Mine abandoned, iii. Fault.

older or younger andesite, being cut by aplite, pegmatite, plagioliparite, felsitic rock, propylite and basalt. The granite here are sporadically exposed near Gaga and along the Sumi-kawa as well as along Yoko-gawa. The best exposure can be seen on the bottom of Yoko-gawa and its tributaries represented by the Ōyanagi-zawa, Koyanagi-zawa, Nanba-zawa, etc. The highest point is seen at the upper course of the Nanba-zawa more than 1300 meters above the sea-level. This fact undoubtedly suggests that the lavas and ejecta supplied from the Byōbu Volcano were not thickly accumulated.

So far as is known at present, biotite granite is found in high frequency as compared with hornblende-biotite granite. Occasionally, they indicate a striking textural variation from coarse to fine, passing into the schistose variety. Moreover, those of the Yoko-gawa are not infrequently represented by a coarse but leucocratic granite stained here and there by a color due to the abundance of hematite.

The occurrence of aplite and pegmatite is restricted to the area of granite. In this case, the former is found more frequently than the latter, being 50 cm. or thereabouts in its maximum width.

Small aplite dykes are commonly seen along the Nigori-gawa and Sumi-kawa. They are hornblende aplite and biotite aplite.

Plagioliparite is exposed at several places. It occurs as dyke or flow in Tertiary sediments. Remarkable exposures are to be seen near Aone and also along the Yoko-gawa. The former extends north-northeastwards from the bus road between Aone and Tōgatta beyond the Mae-kawa. It has such varying colors as grey, dark grey, brown, etc. and is characterized by the abundance of quartz and plagioclase phenocrysts embedded in the groundmass with a microgranitic texture. The rock is a hornblende plagioliparite in which phenocrystic hornblende shows a green color and is scarcely present in some specimens. Generally, this mineral alters to chlorite, preserving its original crystal form. The latter seems, on the other hand, to be underlain by granite at the southern foot of Fubō-zan. The plagioliparite here reveals a beautiful columnar joint which occasionally takes a horizontal position. It is a spherulitic liparite with a light greenish grey color due to chloritization.

Tertiary sediments are sometimes traversed by felsitic rocks, as is observed on the route between Gaga and Aone. The similar kind of rock is also found near Fudō-taki of the Sumi-kawa and at the lower course of the Namari-zawa running down southwards from near the summit of Fubō-zan. The felsitic rock is felsite or felsophyre with a light grey or light greenish grey color. The specimen obtained from the Namari-zawa is a felsophyre rich in phenocrystic plagioclase and grades into plagioliparite westwards.

A noticeable feature of base rocks is the abundance of propylite dykes, large or small, in the granitic mass and green tuff. The largest one is traceable more than 800 meters west-northwestwards from Gaga, being bordered by green tuff on the ridge behind Gaga. It is 400 meters or thereabouts in the widest part and is highly cliffed at its southeastern end, where the dyke is deeply cut down by the Nigori-gawa and is partly covered by olivine two-pyroxene andesite. Usually, the rock has a dark greenish grey or green color, although there is some varieties with a purplish shade.

The next prominent exposure extends from northeast to southwest at the upper course of the Sumi-kawa in contact with biotite granite and green tuff. It has a black color in fresh specimens, but a green color in weathering. Besides these, many minor dykes are distributed along the Yoko-gawa and its tributaries or elsewhere.

Although there are some differences in mineral composition and texture, the rock has a porphyritic texture and consists of such ingredients as andesine or labradorite, augite, magnetite, hematite, chlorite, sericite, zoisite, leucoxene, epidote, etc. Of these minerals, chlorite is usually abundant in the specimens with a green color and seems to have been derived from plagioclase, augite, olivine, etc. Epidote occurs, on the other hand, as veinlets or incrustations of druses. In the specimens collected from the dyke near Gaga, augite phenocrysts are still preserved in fresh condition, but some phenocrystic mineral resembling olivine entirely alters to chlorite and magnetite. It exhibits a diabasic mineral composition and texture.

Older andesite begins to be exposed at the western corner of the Byōbu Volcano and extends westwards beyond the boundary between Miyagi and Yamagata Prefectures. It is a lava flow underlain by biotite granite and overlain by green tuff. Its thickness is variable from place to place, the exposure being estimated to be about 1300 meters at the highest point.

The andesite under consideration is a compact and porphyritic rock with a dark grey or dark greenish grey color which passes into a grey or yellowish grey color in intensely decomposed specimens. Under the microscope, the rock is composed of labradorite, magnetite, chlorite, leucoxene, titanite and glass. Exclusive of plagioclase, it does not contain any other phenocrystic mineral with a fresh appearance. Most of ferromagnesian minerals and a part of plagioclase change into chlorite or other secondary minerals.

Olivine basalt older than lavas and ejecta of the Byōbu Volcano are found as dykes, large or small, along the Nanba-zawa, Sumi-kawa and Koyanagi-zawa as well as near Futatsumori. Of these exposures, dykes of the Nanba-zawa seem to extend from east to west in contact with biotite granite and older andesite. The specimens collected here have a black color and a coarse porphyritic texture due to the abundance of large plagioclase phenocrysts, 5 millimeters or more in the maximum diameter. Besides plagioclase, this type of basalt consists of olivine, augite and magnetite in fresh specimens, but usually changes to the rock with a greenish shade or grey color, resulting in the formation of such minerals as bowlingite, calcite, sericite and chlorite. These alteration products are derived from various phenocrystic minerals and the ingredients of the groundmass with an intergranular texture. Moreover, the rock has a tendency to break easily into small fragments in weathering. There are also many boulders of similar basalt on the bed of the Sumi-kawa where they are supposed to have been supplied from the dyke running across the granitic area.

The olivine basalts of the Koyanagi-zawa and near Futatsumori, on the other hand, have somewhat different features from those mentioned above. The former traverses biotite granite and is exposed about 1500 meters along the valley, whereas the latter is traceable more than 1000 meters from east to west and 700 meters or thereabouts from north to south in green tuff. They are finely porphyritic and compact rocks with a black color and contain plagioclase, olivine, augite, magnetite, apatite, bowlingite and chlorite. In some specimens, phenocrystic olivine is abundantly present in the intergranular groundmass.

(2) Tuff, conglomerate and shale beds:—The Byōbu Volcano is partly underlain by Tertiary sediments which are composed of tuff, conglomerate and shale. They are well exposed along the Yoko-gawa and its tributaries, Sumi-kawa, Nigori-gawa and Mae-kawa as well as in the surrounding district of this volcanic area. These sediments are occasionally traversed by plagioliparite, felsitic rock, propylite, basalt, etc. and rest upon biotite granite or hornblende-biotite granite of the Yoko-gawa, Nanba-zawa, Sumi-kawa and Nigori-gawa. It is noteworthy that the formation frequently has a basal conglomerate, as is shown in the vicinity of Gaga and at the upper course of the Nanba-zawa and Sumi-kawa. The basal conglomerate contains various kinds of pebbles represented by biotite granite, hornblende-biotite granite aplite, plagioliparite, felsitic rock, propylite, older andesite and shale. They are cemented with tuffaceous or sandy substances with a green or grey color different from place to place, and pebbles of older

andesite and shale are restricted to the specimens from the Nanba-zawa where the fragments of petrified woods are abundant in conglomerate. In such cases, the presence of granite pebbles supplied undoubtedly from this district suggests that granite had already been intruded prior to the sedimentation of the Tertiary formation under consideration.[2)]

Green tuff is sometimes associated with conglomerate with a gradual transition between them. It is generally mottled with a green color. The writer has discovered some fossils in green sandy tuff exposed on the trail near Fudō-taki of the Sumi-kawa. They are imperfectly preserved, but there are brachiopods which can be identified with *Terebratulina*.

Grey shale is distributed in close association with green tuff. The former, however, occurs in a small extent as compared with the latter, and its exposure is to be seen along the Nigori-gawa near Aone and the upper course of the Yoko-gawa.

The Tertiary formation mentioned above is much disturbed here and there. Hence, the green tuff bed near Aone and Gaga indicates a strike of N 50°–55°E to N 20°–70° W and a dip of 40°–60° SE or 25°W–40° SSW, whereas the shale bed of the Yoko-gawa has a strike of N–S and a dip of 30°–40° W. They are always poor in fossils, but have some lithological similarities to the Upper Miocene sediments of the neighbouring district.

(3) Lavas and ejecta from the Byōbu Volcanio:—The volcanic products including lavas and ejecta of the Byōbu Volcano are complicatedly overlapped, suggesting that there were repeated eruptions of this volcanic area. They are the Nonomori agglomerate, Sumi-kawa lava and agglomerate, Byōbu-dake lava, Fubō-zan lava and ejecta, Sugigamine lava and agglomerate, Ushiro-eboshi-dake lava and ejecta, Karasawa mud flow, Nyūdō-san lava and agglomerate, Manokami-dake lava and Nanokahara mud flow.

(i) Nonomori agglomerate:—The first eruption of the Byōbu Volcano seems to have taken place at the eastern periphery of this volcanic area where the large crater of Nonomori is found on the hilly land between the Akiyama-zawa and Tashiro-zawa. The agglomerate exposed here extends northwards up to Yariga-mine and Haku'undai, being overlain by the Nanokahara mud flow on its east and by the

2) T. ICHIMURA, H. MINATO & K. KANEHIRA, *Jour. Geol. Soc. Japan*, **56** (1950), 470.

Sumi-kawa lava and agglomerate, Ushiro-eboshi-dake lava and ejecta and Manokami-dake lava on its west respectively. It was undoubtedly erupted from the crater which was almost circularly hollowed at the southern foot of Nonomori (Fig. 3).

The best exposure can be seen along the middle course of the Akiyama-zawa, and it is composed of the angular fragments of two-pyroxene andesite or olivine-bearing two-pyroxene andesite, large or small, cemented with tuffaceous or sandy matrix.

(ii) Sumi-kawa lava (olivine-bearing two-pyroxene andesite or olivine two-pyroxene andesite) and agglomerate:—The Sumi-kawa lava and agglomerate are exposed at the northern part of the Byōbu Volcano dissected deeply by the Nigori-gawa, Sumi-kawa and Kowatera-zawa. Of these, the lava flow gently inclines northwards or northeastwards and is highly cliffed along the Nigori-gawa and Sumi-kawa (Figs. 4—5), where it is 150 meters or thereabouts in the thickest part and is characterized by the predominance of columnar joints (Fig. 6). Such exposures are traceable up to Kaerazuno-taki of the Nigori-gawa and the junction of the Matakubo-zawa and Sumi-kawa.

The agglomerate is, on the other hand, found only at the lower course of the Sumi-kawa. It is well exposed on the cliff near Fudō-taki and Sangai-taki, showing that it is the basal part of the thick lava flow mentioned above.

These volcanic products rest upon the eroded surface of the Nonomori agglomerate, biotite granite or hornblende-biotite granite or Tertiary sediments, but they partly disappear beneath such lavas and ejecta erupted later from the Byōbu Volcano and Zaō Proper, as is indicated by the Byōbu-dake lava, Ushiro-eboshi-dake lava and ejecta, Nanba-zawa lava and ejecta, etc.

The Sumi-kawa lava and agglomerate are supposed to have been supplied from the pre-existing crater which is now obscured by the eruption of the Manokami-dake lava and Nyūdō-san lava and agglomerate.

(iii) Byōbu-dake lava (olivine-bearing two-pyroxene andesite):—The eruption of the Byōbu-dake lava took place later than those of the Sumi-kawa lava and agglomerate, although it poured out from the same pre-existing crater. The lava flow extends down to the uppermost course of the Sumi-kawa northwards and to the Yoko-gawa southwestwards. It is bordered by the Sugiga-mine lava and agglomerate on the west, but is covered by the Ushiro-eboshi-dake lava and ejecta and Nyūdō-san lava and agglomerate on the east. The eastern side of

Byōbu-dake slopes steeply downwards and forms here a high cliff in contrast with its western gentle slope (Figs. 7–8). Such a topographic feature partly depends upon the inclination of the Byōbu-dake lava. The highest point of this lava is 1817.1 meters above the sea-level, and its thickest part is more than 400 meters. It is also known that the lava flow rests upon Tertiary sediments and biotite granite along the Yoko-gawa and Katsura-zawa.

(iv) Fubō-zan lava (olivine-bearing two-pyroxene andesite or olivine two-pyroxene andesite) and ejecta:—The southern end of the Byōbu Volcano is represented by Fubō-zan (Figs. 3, 9) which rises up to 1705.3 meters above the sea-level on the base rocks composed of biotite granite, felsophyre, olivine basalt and green tuff. The lava flows and ejecta exposed here are alternately bedded with an inclination of 20°–30° southwestwards, suggesting that they are supplied from the same source as that of the Byōbu-dake lava. Such features are confirmable on the narrow ridge extending northwestwards from the summit of this peak. It is also noteworthy that these alternate beds of lava flows and ejecta are repeatedly traversed by small basalt dykes on the cliff rising up from Chōchogamori.

(v) Sugiga-mine lava (olivine two-pyroxene andesite) and agglomerate:—The Byōbu-dake lava is covered by the Sugiga-mine lava and agglomerate which had a source on the western flank of Byōbu-dake. In this case, the lava flow, about 400 meters thick, was preceeded by the eruption of agglomerate, about 100 meters in thickness. It is well exposed on the western flank of Sugiga-mine in close association with agglomerate underlain by the Tertiary andesite and biotite granite of the Yoko-gawa and its tributaries. The relationship between lava and agglomerate can be seen at the upper course of the Ōyanagi-zawa, and the latter passes into the former upwards. The lava of this area is highly cliffed and shows a topographically characteristic feature. Such remarkable cliffs are sporadically traceable from Tengu-iwa to the upper course of the Koyanagi-zawa southwards. The northern end of these exposures are bordered by the Nanba-zawa lava of the Zaō Proper along the Nanba-zawa and Sumi-kawa.

(vi) Ushiro-eboshi-dake lava (two-pyroxene andesite) and ejecta:—As has already been explained, the Ushiro-eboshi-dake lava and ejecta partly cover the Sumi-kawa lava and agglomerate or Nonomori agglomerate, constructing here Ushiro-eboshi-dake and Mae-eboshi-dake at the northern end of the Byōbu Volcano. The former inclines 15°–20°

northeastwards on the eroded surface of the latter and is supposed to have been erupted from the crater which had similarly been the source of the Sumi-kawa lava and agglomerate. The alternation of these lava flows and ejecta, about 350 meters thick, may be well investigated by going up the Kowatera-zawa or traversing Ushiro-eboshi-dake from north to south. In this case, lava flows are usually predominant as compared with ejecta composed of agglomerate, lapilli and tuff.

(vii) Kara-sawa mud flow:—The gentle slope dissected by the Tashiro-zawa, Kara-sawa and Ō-sawa is widely covered by the Kara-sawa mud flow (Fig. 3) which seems to have poured out from the source which is supposed to have succesively supplied the Nyūdō-san lava and agglomerate. It flowed down eastwards and spreaded widely over the area including Misumi and the eastern foot of Fubō-zan, probably in contact with the Matsu-kawa mud flow of the Aoso Volcano[3] at its eastern end.

(viii) Nyūdō-san lava (two-pyroxene andesite) and agglomerate:—Nyūdō-san (Figs. 3, 10) is composed of lava and agglomerate erupted alternately from the pre-existing crater where it was borned as a central cone. The basal part of these volcanic products is agglomerate which is exposed along the uppermost course of the Akiyama-zawa and passes into lava flow intercalated by agglomerate upwards. They have mostly an inclination of 20°–30° to the south.

(ix) Manokami-dake lava (two-pyroxene andesite):—It extends from east to west and builds up Manokami-dake (Figs. 3, 10), being bordered by the Akiyama-zawa at the north and the Kara-sawa at the south. The best exposure of this lava is seen on the northern flank of Manokami-dake where the lava flow is deeply dissected and highly cliffed here and there by the Akiyama-zawa. It is considered to have poured out from the pre-existing crater after the eruption of the Nyūdō-san lava and agglomerate, since there are some evidences that the former rests upon the latter.

(x) Nanokahara mud flow:—The activities of Byōbu Volcano was closed with the eruption of the Nanokahara mud flow (Fig. 3). The source of this mud flow is the explosion crater of Numa just beneath the summit of Mae-eboshi-dake. The mud flow which rushed down from here to northeast through the narrow between the southern branch of Mae-eboshi-dake and eastern end of Manokami-dake, formed a large fan-shaped slope now called Nanokahara. Topographically, it

3) T. ICHIMURA, *Bull. Earthq. Res. Inst.*, **31** (1953), 134.

shows a characteristic feature easily distinguishable easily from its surrounding district.

(4) Quaternary fluviatile deposits :—Younger or older fluviatile deposits are seen along the present river course where they consist of clay, sand and gravel.

Structure of the Byōbu Volcano

The Byōbu Volcano consists of two homates. One of these includes the hilly land between the Akiyama-zawa and Tashiro-zawa where a large but shallow crater is still preserved, and Nonomori seems to have been formed on its peripheral part. The extension of this homate is distinctly shown by the panoramic view looking down from Ōmori-yama of the Aoso Volcano (Fig. 3).

Another one is a strato-homate associated with central cones and rises up to 1817.1 meters above the sea-level as the main part of the Byōbu Volcano, but it is now deformed and dissected to some extent. The large pre-existing crater here is obscured by the formation of central cones and the destruction of crater wall due to explosions. It is, however, not impossible to suppose the position of the crater from the direction of inclination of lavas and ejecta exposed on such peaks as Byōbu-dake, Fubō-zan, Ushiro-eboshi-dake, Mae-eboshi-dake, Nyūdō-san and Manokami-dake. This center of activity is located on the southern extension of the weak line which passes through those of the Zaō Proper and Ryū-zan Volcano.

The structure of the Byōbu Volcano is more complicated by the lavas and ejecta erupted from other sources. They are the lava and agglomerate of Sugiga-mine and the mud flow of Nanokahara and the Kara-sawa.

As has already been stated elsewhere, the volcano under consideration rises up on the foundation composed of the Tertiary formation, granite, aplite, plagioliparite, propylite, felsite, felsophyre, andesite and basalt. It is constructed by two-pyroxene andesite, olivine-bearing two-pyroxene andesite, olivine two-pyroxene andesite and various kinds of ejecta. Some of these volcanic products are alternately piled up, starting mostly with the eruption of agglomerate or tuff. Such a structure is commonly seen on Ushiro-eboshi-dake, Sugiga-mine, Fubō-zan and Nyūdō-san as well as along the lower course of the Sumi-kawa. In the last case, the thick lava flow extends northwards or northwestwards beyond the Sumi-kawa and even the Nigori-gawa at some places. Its exposure is highly cliffed and rests upon base rocks along these valleys (Fig. 5).

So far as is known at present, a part of this volcanic area seems to have been subjected to faulting. For example, the eastern cliff of Byōbu-dake, which is about 300 meters high and extends straightly from north to south, looks like a fault scarp (Fig. 8). Moreover, it is necessary to describe the trend of the Sumi-kawa and Nanba-zawa. They rise from a divide between Sugiga-mine and Katta-dake and run down to the opposite side, taking a course from southwest to northeast and from northeast to southwest respectively. The northeastern extension of this line almost agrees with the trend of the Mae-kawa, passing the vicinity of Monomi-iwa and Aone, whereas its opposite trend is traceable southwestwards to Kayadaira. It is also noticeable that various kinds of base rocks are frequently exposed on these two valleys which are parallel to the Hanoki-zawa dislocation line.

Crater

There are two craters in this volcanic area (Fig. 1). They are respectively found at its central part and eastern periphery. At present, the former disappears beneath two central cones surrounded partly by Byōbu-dake, Fubō-zan and Ushiro-eboshi-dake. The location of pre-existing crater is, however, inferable from the structure of this volcano, although the original topographical feature was largely destroyed later by explosions and dislocations.

The latter is, on the other hand, well preserved on the hilly lands between the Akiyama-zawa and Tashiro-zawa (Fig. 3). This crater had been overlooked until it was recently confirmed by the writer. Its diameter is 1200 meters from east to west, but 1000 meters from north to south. It has a crater wall, about 100 meters high from its bottom, and is opened in agglomerate. This is supposed to have been the earliest center of activity.

Explosion Craters

The Byōbu Volcano is characterized by the frequency of explosion craters, large or small, by which the present topographical feature of this volcano is considerably affected (Fig. 1). They are found in the area around the pre-existing crater. One of remarkable explosion craters is preserved at Numa, where the mud flow poured out at the last stage of activity and rushed down eastwards along the Akiyama-zawa (Fig. 3). The explosion crater here is semicircularly surrounded by a steep wall of about 100 meters high on the southern flank of Mae-eboshi-dake. It opens southwards, and its bottom is filled up with an accumulation of mud flow. The undulatory surface of this mud flow is thickly covered by a beautiful forest of beech and is adorned with many small swamps from which the name "Numa" was taken.

Besides this, another explosion crater seems to have been opened farther up the Akiyama-zawa. It was, however, subjected intensely to the subsequent erosion of the Akiyama-zawa and its tributaries, resulting in a remarkable modification of the original form.

There is also a similar explosion crater at the source of the Ō-sawa. It is situated behind Nyūdō-san and is semicircularly walled by Byōbu-dake and Fubō-zan, although its inner part is intricately dissected by the Ō-sawa with an undulation of Chōchogamori. The highest point of this wall is estimated to the about 400 meters above the bottom of the main valley.

In connection with it, several explosion craters are located on the southern flank of Fubō-zan. They are scattered here and there, some of these being found near the crest line between its summit and S. Byōbu-dake. Such explosion craters are represented by horse-shoe-shaped or semicircular hollows opened mostly southwards or southwestwards. The largest one is sccoped out downwards from near the summit of Fubō-zan and is surrounded by a wall composed of thickly accumulated lavas and agglomerates which incline about 30° southwards. It is the source of the Owaka-zawa, a tributary of the Yoko-gawa.

Moreover, the presence of a large explosion crater is noticed at the uppermost course of the Nanba-zawa, being situated between Katta-dake and Sugiga-mine. It has a diameter of about 1500 meters from northwest to southeast. This crater seems to have exploded southwestwards, and a part of its wall shows an alteration due to solfataric action. It is about 300 meters high above its bottom, where granite and Tertiary sediments are exposed. A small explosion crater is also known on the southern flank of Nyūdō-san.

Central Cones

Two central cones rise up in the pre-existing crater obscured by the eruption of their lavas and ejecta. These central cones are Nyūdō-san and Manokami-dake (Fig. 10). They stand side by side with a trend from east to west, showing that the eruptions took place in succesion. The lava flow and agglomerate of Nyūdō-san partly disappear beneath the Manokami-dake lava. This fact evidently suggests that Nyūdō-san is older than Manokami-dake. Their structures can be examined by going up along the Akiyama-zawa, Kara-sawa and Tashiro-zawa as well as along their tributaries. One remarkable feature is the existence of a horse-shoe-shaped hollow on the southern flank of Nyūdō-san. It looks like an explosion crater, being partly surrounded by a wall on which lava and agglomerate are well exposed with an inclination of about 30° southwards. Both central cones are strikingly dissected along the Akiyama-zawa, where they are highly cliffed here and there, but thickly forested. In this case, the agglomerate of Nyūdō-san exposed near the bottom of the Akiyama-zawa passes into a lava flow upwards. The similar order of eruption is indicated by volcanic products of Manokami-dake.

Possible Source of the Sugiga-mine Lava and Agglomerate

There is no evidence that the Sugiga-mine lava and agglomerate were erupted from the pre-existing crater beneath Nyūdō-san and Manokami-dake. These volcanic products begin to be exposed on the western flank of Byōbu-dake and spread extensively down to the Yoko-gawa, Sumi-kawa and their tributaries. The highest point rises up as a large dome called Sugiga-mine which is now eroded deeply by such several tributaries of the Yoko-gawa as the Nanba-zawa, Ōyanagi-zawa, Koyanagi-zawa and others on its western flank. The present summit is partly fringed by swampy terraces and is free of any crater-like hollow. It is, however, not unreasonable to say from the distribution and inclination of lava and agglomerate exposed here that they were supplied from a source somewhere near the summit.

Mineral Composition of Lavas and Ejecta

(1) *Andesite fragments of the Nonomori agglomerate*:—Angular or subangular fragments of two-pyroxene andesite or olivine-bearing two-pyroxene andesite are abundantly contained in the Nonomori agglomerate, being cemented by a tuffaceous matrix in which they are found without any regular arrangement. The writer collected many specimens of these fragments from various parts of this agglomerate, particularly along the Akiyama-zawa and also on the hilly land between the Tashiro-zawa and Akiyama-zawa where it is extensively exposed. Although these andesite fragments indicate somewhat different features from place to place, most of them are compact and remarkably porphyritic. They have a dark grey or black color and assume a grey or reddish

brown color by alteration.

The specimens examined under the microscope are mainly composed of plagioclase, augite, hypersthene and magnetite with a minor or almost negligible amount of hornblende, olivine, biotite, quartz, apatite, tridymite, chlorite, pyrite, goethite and limonite. The last four minerals are secondary products.

The most predominant mineral is plagioclase. Its phenocryst takes a rectangular or tabular form and belongs to labradonite or bytownite with a composition of An_{60-76}. In this case, the crystal is generally euhedral or subhedral, and the largest one is 3 mm.-4 mm. long or across. It has a fresh appearance and is well zoned. The phenocryst is sometimes turbid along the periphery or at the inner part of crystals. Such a feature is seen in the specimens obtained along the trail traversing the hilly land mentioned above from northwest to southeast. Some of it encloses augite or magnetite crystals and is characterized by a worm-eaten structure. It is also noteworthy that phenocrystic plagioclase is occasionally altered to chlorite along its crack or cleavage.

Minute lath-shaped or rectangular plagioclase is an important ingredient of the groundmass, showing a fluidal arrangement in some cases. It is commonly 0.03 mm.-0.25 mm. in length and is represented by labradorite.

Augite occurs as phenocrysts, granular aggregates and ingredients in the groundmass. In these cases, phenocrystic augite is often twinned on (100) or (101) and has a subhedral or anhedral form, being 2.55 mm. long and 1.02 mm. across in its largest crystal. The extinction angle, $Z \wedge c$, is 39°-40°. When it is found in association with hypersthene, the latter is fringed by the former. There are also zoned crystals in which the inner part has a large extinction angle as compared with the periphery. The phenocrystic augite generally encloses magnetite. The augite crystal of the groundmass is abundantly present with magnetite, hypersthene and minute lath-shaped plagioclase. It takes a prismatic or granular form which is 0.01 mm.-0.13 mm. in length or diameter.

The phenocrystic hypersthene usually shows a frequency slightly higher than augite. It has a long or stout prismatic habit, being 4.15 mm. long and 1.53 mm. across in the largest crystal. Of these, the long prismatic crystal is occasionally euhedral. It contains magnetite and is partly chloritized along cracks. Hypersthene is also a remarkable ingredient in the groundmass of a certain specimen. In such a case, it is mostly represented by a long prismatic crystal 0.05 mm.–0.15 mm. long.

Table I. Compositions and optical characters of plagiocalse, augite and hypersthene phenocrysts of the andesite fragments in Nonomori agglomerate (Measured by F. Hori).

	No. 1 (T.I. 47102502)	No. 2 (T.I. 47102801)	No. 3 (T.I. 47102805)
Plagioclase	$\alpha=1.559\pm0.003$ $\gamma=1.575\pm0.003$ An_{60-71}*	$\alpha=1.562\pm0.003$ $\gamma=1.577\pm0.003$ An_{63-76}*	$\alpha=1.564\pm003$ $\gamma=1.577\pm0.003$ An_{67-76}*
Augite	$\beta=1.683\pm0.003$ $(+)2V=53°$ $Wo_{44}En_{46}Fs_{10}$**	$\beta=1.692\pm0.003$ $(+)2V=47°$ $Wo_{39}En_{43}Fs_{18}$**	$\beta=1.685\pm0.003$ $(+)2V=54°$ $Wo_{45}En_{44}Fs_{11}$**
Hypersthene	$\gamma=1.713\pm0.003$ $(-)2V=58°$ $Mg=63\%$***	$\gamma=1.710\pm0.003$ $(-)2V=60°$ $Mg=65\%$***	$\gamma=1.711\pm0.003$ $(-)2V=58°$ $Mg=63\%$***

* After F. Chayes's chart [Am. Min. Bowen Volume, (1952) 95].
** After H.H. Hess's chart [Am. Min., 34 (1949) 634].
*** After H. Kuno's chart [Am. Min., 39 (1954) 40].

No. 1. = Andesite fragment in the Nonomori agglomerate exposed along the Akiyama-zawa.
No. 2. = 〃 〃 exposed on Yariga-mine
No. 3. = 〃 〃 exposed near Hakuundai.

A noticeable feature of andesitic fragments is the abundance of magnetite as an enclosure in other minerals and in the groundmass of some specimens. The octahedral or granular crystals of this mineral is sometimes more than 1.20 mm. in its diameter, but is usually 0.01–0.04 mm. across.

The occurrence of olivine phenocrysts is restricted to the specimens obtained at the bottom of the Tashiro-zawa and on the hill between the Tashiro-zawa and Akiyama-zawa as well as from Haku'undai. It is a rare ingredient in these specimens and takes an unhedral form, 1.1 mm. in its maximum diameter.

Subhedral or anhedral hornblende is seen in the xenoliths of several specimens. It is long prismatic and has a fresh appearance, being characterized by such a pleochroic scheme as light yellow (X), light brown (Y) and yellowish brown (Z). The absorption is $Z>Y>X$, and the largest crystal is 1.22 mm. long and 0.4 mm. across. The mineral shows a small extinction angle, $Z\wedge c$, of 18° or thereabouts. Some of it twins on (100) and contains minute magnetite grains.

Biotite and apatite seldom occur in the groundmass. The former is strongly pleochroic from dark brown (Y and Z) to yellow (X), whereas the latter has a dark brown color due to decomposition in the inner part of prismatic crystals. The maximum length is 0.48 mm.

Tridymite fills up the interstices of the ingredient minerals in the groundmass. Quartz is, on the other hand, a xenocryst supplied from base rocks and is subjected to the magmatic corrosion. This mineral is scarcely found in the fragment of olivine-bearing two-pyroxene andesite. Pyrite is richly present in a specimen from the Akiyama-zawa. It traverses the rock as veinlets or irregular networks. Chlorite, goethite and limonite are the decomposition products due to weathering.

The groundmass reveals a pilotaxitic texture, consisting of plagioclase, augite, hypersthene, biotite, tridymite, magnetite and apatite. Besides these, some specimens contain gabbroic, noritic or basaltic inclusions composed of plagioclase, augite, hypersthene, hornblende and magnetite.

(2) *Sumi-kawa lava and agglomerate*:—The Sumi-kawa lava and andesite fragments of its agglomerate have similar feature and mineral composition, being almost composed of olivine-bearing two-pyroxene andesite or olivine two-pyroxene andesite with or without a glassy groundmass.

They are usually hard and compact rocks with a black or dark grey color and remarkable porphyritic texture. These andesites are, however, scoriaceous at the bottom of lava flows which are found in contact with base rocks, as is indicated along the Nigori-gawa, particularly on the cliff opposite to the Gaga Hot Spring. Moreover, one of characteristic features to these andesite lavas is the occurrence of a pitchstone with a porphyritic texture and black color. It is exposed along the trail between Ōdaira and Hakuryūno-taki.

The specimens collected by the writer consists of plagioclase, augite, hypersthene, olivine, hornblende, magnetite, quartz, tridymite, apatite, biotite, chlorite, bowlingite and brown glass.

The most important ingredient is plagioclase which occurs mostly as euhedral or subhedral crystals, 3.91 mm. long and 1.39 mm. across in the largest crystal. These crystals are commonly well zoned and frequently turbid. Such a turbid part is formed by a cloudy aggregate of unknown substance, and it is present at the periphery or inner portion of crystals, being surrounded by clear zones free of enclosures. The phenocrystic plagioclase is also characterized by the predominance of worm-eaten structure and includes such ingredients as augite, hypersthene, magnetite and irregular patches of brown glass. The indices of refraction measured on (010) suggest that this plagioclase ranges from labradorite to bytownorthite with a composition of An_{58-81}. The plagioclase of the groundmass is represented by minute lath-shaped or rectangular crystals, 0.01 mm.-0.25 mm. long. It is labradorite.

Augite and hypersthene are very common minerals in all specimens, although the proportion between them varies in different localities. Of these minerals, the phenocrystic augite generally takes a subhedral form with a stout prismatic habit, whereas the phenocrystic hypersthene is mostly euhedral or subhedral and occurs as a long prismatic crystal. They are sometimes associated together, which shows that hypersthene is always fringed by a minute aggregate of augite. Both kinds of minerals commonly include magnetite, but rarely glass and plagioclase. Some of the crystals are also marked by the presence of a worm-eaten structure as in the case of plagioclase.

The augite crystal is 3.48 mm. long and 1.78 mm. across in the largest one and twins on (100) or (101), forming frequently a polysynthetic twin in cross section. It is also noteworthy that there are minute aggregates of granular augite around the skeletal crystal of magnetite. The extinction angle, $Z \wedge c$, is 38°-41°, and it gradually decreases inwards in zoned crystals.

The phenocrystic hypersthene is found as well-defined crystals as compared with augite, the largest one being 2.72 mm. long and 0.71 mm. across. It is partly chloritized.

In the groundmass, augite is a predominant ingredient, but hypersthene occurs in less amount. They are prismatic or granular, and most of these are 0.02 mm.-0.08 mm. in length or diameter.

The compositions and optical characters of phenocrystic plagioclase, augite and hypersthene are summarized in the following table (Table II).

The occurrence of olivine is restricted only to the phenocryst. The high frequency of this mineral is known in the specimens collected from the area including the Niizeki Hot Spring, Kanagarabutsu, Shindōgoya, Sangai-taki and Aone. It is, however, mostly found in a small amount. The crystal is generally anhedral or subhedral, being occasionally surrounded by minute aggregates of augite, hypersthene, magnetite and plagioclase. It is 4.91 mm. across in the largest crystal and includes magnetite. In alteration, such a phenocrystic olivine passes into bowlingite along its periphery and crack. Chlorite is, furthermore, its decomposition product.

All thin sections contain magnetite in varying amounts. It occurs as an enclosure of phenocrystic minerals or a main ingredient of the groundmass. The crystal with an octahedral, granular or skeletal form is 1.75 mm. across in the largest one, but commonly ranges between 0.01 mm. and 0.08 mm. in dismeter.

Quartz is a xenocryst supplied from granites or other quartz-bearing rocks. The crystal is subjected to magmatic corrosion and has a subangular or rounded form, 1.5 mm. in its maximum diameter. Exclusive of some examples shown by several specimens, quarts is a rare ingredient.

Apatite is contained only in three specimens obtained from the lower course of the Sumi-kawa and the uppermost course of the Nigori-gawa. It takes a long prismatic form, 0.17 mm.–0.34 mm. in length. Its inner part has a grey or dark brown color due to decomposition and is closely striated. Biotite, hornblende and tridymite are also minor ingredients. Of these, biotite takes an irregular flaky form, but this mineral is absent in most specimens. Hornblende is represented by a brown variety with a subhedral form, showing such a pleochroic scheme as X=light yellow, Y=yellowish brown, Z=dark brown and an extinction angle, $Z \wedge c$, of 15°–17°. Tridymite is seen in several specimens and fills up the interspaces of various ingredients of the groundmass. The brown glass is, on the other hand, noticed frequently in the phenocrystic plagioclase and hypersthene as well as in the groundmass.

The groundmass consists of plagioclase, augite, hypersthene, magnetite, apatite, biotite, tridymite, quartz and brown glass. In this case, there are many specimens with a pilotaxitic groundmass which is quite similar to the Tōmori-yama lava of the Aoso Volcano.[4] The specimens collected from the lower part of the Sumi-kawa lava are mottled by the frequent occurrence of leucocratic parts due to decomposition. When the groundmass has a hyalopilitic texture, the brown glass is contained in varying amounts. The extreme case rich in the brown glass is pitchstone with swarms of microlites.

Besides various ingredients mentioned above, the occurrence of xenoliths, large or small, is known in almost all specimens. They are gabbroic, noritic or basaltic rocks formed by the confused aggregates

4) T. ICHIMURA, *op. cit.*, (1953), 140-142.

Table II. Compositions and optical characters of plagioclase, augite, and hypersthene phenocrysts in Sumi-kawa lava (Measured by F. Hori)*

	No. 1 (T.I. 47101401)	No. 2 (T.I. 47101406)	No. 3 (T.I. 47101902)
Plagioclase	$\alpha=1.560\pm0.003$ $\gamma=1.574\pm0.003$ An_{61-70}	$\alpha=1.559\pm0.003$ $\gamma=1.574\pm0.003$ An_{60-70}	$\alpha=1.561\pm0.003$ $\gamma=1.579\pm0.003$ An_{62-81}
Augite	$\beta=1.688\pm0.003$ $(+)2V=48°$ $Wo_{40}En_{44}Fs_{16}$	$\beta=1.685\pm0.003$ $(+)2V=47°$ $Wo_{39}En_{48}Fs_{13}$	$\beta=1.690\pm0.003$ $(+)2V=49°$ $Wo_{41}En_{43}Fs_{16}$
Hypersthene	$\gamma=1.705\pm0.003$ $(-)2V=63°$ $Mg=68\%$	$\gamma=1.715\pm0.003$ $(-)2V=56°$ $Mg=61\%$	$\gamma=1.707\pm0.003$ $(-)2V=63°$ $Mg=68\%$
	No. 4 (T.I. 47101909)	No. 5 (T.I. 47102104)	No. 6 (T.I. 47110402)
Plagioclase	$\alpha=1.560\pm0.003$ $\gamma=1.573\pm0.003$ An_{61-69}	$\alpha=1.560\pm0.003$ $\gamma=1.574\pm0.003$ An_{61-72}	$\alpha=1.557\pm0.003$ $\gamma=1.574\pm0.003$ An_{58-70}
Augite	$\beta=1.688\pm0.003$ $(+)2V=49°$ $Wo_{41}En_{44}Fs_{15}$	$\beta=1.683\pm0.003$ $(+)2V=50°$ $Wo_{41}En_{47}Fs_{12}$	$\beta=1.694\pm0.003$ $(+)2V=45°$ $Wo_{37}En_{42}Fs_{21}$
Hypersthene	$\gamma=1.702\pm003$ $(-)2V=65°$ $Mg=70\%$	$\gamma=1.710\pm0.003$ $(-)2V=58°$ $Mg=63\%$	$\gamma=1.710\pm0.003$ $(-)2V=59°$ $Mg=64\%$

*To confirm An, WoEnFs ratio and Mg% the charts devised by F. Chayes, H.H. Hess and H. Kuno were respectively used.

No. 1. = The Sumi-kawa lava from near Jizō-taki.
No. 2. = 〃 from the cliff opposite to the Gaga Hot Spring.
No. 3. = 〃 from the road cutting, about 700 m. from Gaga.
No. 4. = 〃 from near Aone.
No. 5. = 〃 from the upper course of the Nigori-gawa where it rests directly upon the eroded surface of granite.
No. 6. = 〃 from the cutting of bus road near Aone.

of plagioclase, augite, hypersthene, olivine, magnetite and brown glass.

(3) *Byōbu-dake lava*:—The lava flow of Byōbu-dake is exposed on its eastern cliff and western flank as well as at the area dissected deeply by the Owaka-zawa, Katsura-zawa and the uppermost course of the Sumi-kawa. The specimens collected by the writer has a remarkable porphyritic texture and dark grey color. Some of these are finely porous, whereas the others are very compact, both passing into one

Table II. (continued.)

	No. 7 (T.I. 48092009)	No. 8 (T.I. 48092010)	No. 9 (T.I. 48092101)
Plagioclase	$\alpha=1.560\pm0.003$ $\gamma=1.574\pm0.003$ An_{61-70}	$\alpha=1.558\pm0.003$ $\gamma=1.574\pm0.003$ An_{59-70}	$\alpha=1.562\pm0.003$ $\gamma=1.577\pm0.003$ An_{63-76}
Augite	$\beta=1.690\pm0.003$ $(+)2V=47°$ $Wo_{39}En_{44}Fs_{17}$	$\beta=1.688\pm0.003$ $(+)2V=52°$ $Wo_{42}En_{43}Fs_{15}$	$\beta=1.693\pm0.003$ $(+)2V=46°$ $Wo_{38}En_{42}Fs_{20}$
Hypersthene	$\gamma=1.713\pm0.003$ $(-)2V=56°$ Mg=61%	$\gamma=1.709\pm0.003$ $(-)2V=58°$ Mg=63%	$\gamma=1.711\pm0.003$ $(-)2V=61°$ Mg=66%

	No. 10 (T.I. 48100705)
Plagioclase	$\alpha=1.561\pm0.003$ $\gamma=1.576\pm0.003$ An_{62-75}
Augite	$\beta=1.685\pm0.003$ $(+)2V=48°$ $Wo_{40}En_{47}Fs_{13}$
Hypersthene	$\gamma=1.711\pm0.003$ $(-)2V=58°$ Mg=63%

No. 7. = The Sumi-kawa lava from the cliff, situated about 1500 meters northwest from Kanagarabutsu.
No. 8. = 〃 from the northwestern part of Sainokawara.
No. 9. = 〃 from the bottom of the Sanzuno-kawa near Kanagarabutsu.
No. 10. = 〃 from the lower course of the Sumi-kawa.

another. They are sometimes similar to the Sumi-kawa lava.

The microscope reveals that the Byōbu-dake lava is composed of plagioclase, augite, hypersthene, olivine, magnetite, hematite, apatite and brown glass. Of these, the amount of the phenocrystic olivine varies from place to place, and there are some specimens quite devoid of this mineral. The occurrence of brown glass is an exceptional case, whereas apatite is a negligible ingredient and is mostly absent.

Plagioclase is the most important mineral which occurs as a phenocryst or an ingredient of the groundmass. The phenocrystic plagioclase belongs to labratownite with a composition ranging from An_{61} to An_{69}. The crystal is commonly euhedral or subhedral, taking a tabular or rectangular form. It is generally well zoned and frequently turbid. The worm-eaten structure is also one of noticeable features in this phenocrystic plagioclase, the largest crystal being 2.88 mm. long and 1.28 mm. across. In such a case, augite, hypersthene and brown glass are sometimes found as enclosures.

The plagioclase of the groundmass has a lath-shaped or rectangular form, 0.02 mm.–0.2 mm. long and indicates a fluidal arrangement around phenocrystic minerals.

Similarly, augite and hypersthene are predominant ingredients as phenocrysts and components in the groundmass. They are found in varying proportion, the former being frequently present abundantly as compared with the latter in some sections.

In all specimens, the phenocrystic augite takes a subhedral or anhedral form, 2.12 mm. long and 0.68 mm. across in the largest crystal. It twins on (100) or (101), and its extinction angle, $Z \wedge c$, is 39°–41°. When this mineral occurs together with hypersthene, the latter is always surrounded by the former. A glomeroporphyritic texture is also formed by the granular aggregate of minute augite crystals associated with magnetite and brown glass. Most of the phenocrystic hypersthene have a long prismatic habit, and the largest crystal is 1.6 mm. long and 1.02 mm. across. The crystal is usually euhedral or subhedral. It contains magnetite as in the case of the phenocrystic augite. In the groundmass, augite is more abundant than hypersthene, and its short or long prismatic crystal is 0.02 mm.–0.1 mm. in length.

Table III. Compositions and optical characters of plagioclase, augite and hypersthene phenocrysts in Byōbu-dake lava from the summit of Byōbu-dake (Measured by F. Hori).

	(T.I. 49082309)
Plagioclase	$\alpha=1.560\pm0.003$, $\gamma=1.573\pm0.003$ An_{61-69}*
Augite	$\beta=1.692\pm0.003$ $(+)2V=49°$ $Wo_{40}En_{42}Fs_{18}$**
Hypersthene	$\gamma=1.703\pm0.003$ $(-)2V=60°$ Mg = 65%***

* After F. Chayes's chart.
** After H.H. Hess's chart.
*** After H. Kuno's chart.

Olivine is richly present as a phenocryst in the specimen collected from near the summit of Byōbu-dake, but it is almost or entirely absent in some thin sections obtained from the lava which is exposed on its western flank. This mineral is always anhedral and has a longer diameter of 0.4 mm.–1.2 mm. It encloses magnetite, being frequently surrounded by the aggregate of hypersthene crystals.

Magnetite takes an octahedral or irregular form. It is mostly 0.01 mm.–0.08 mm. across, although some crystals are 0.4 mm. or more in diameter. In this case, the former is scattered in the groundmass, whereas the latter is generally contained in phenocrystic ingredients, xenoliths and aggregates of augite crystals.

Of such negligible ingredients as apatite and hematite, the former has a subhedral prismatic form, 0.24 mm. long in the largest crystal. The inner part is characterized by a dark brown color due to decomposition. The occurrence of brown glass is known in the specimens from the summit or western flank of Byōbu-dake, filling up the interstices of other ingredients of the groundmass.

The groundmass has a pilotaxitic or hyalopilitic texture and consists of plagioclase, augite, hypersthene, magnetite, hematite, apatite and brown glass. The xenolith is a gabbroic or basaltic rock composed of plagioclase, augite, hypersthene, magnetite and olivine.

(4) *Fubō-zan lava and ejecta*:—The Fubō-zan lava is intercalated with various kinds of ejecta, being traversed by some basaltic dykes. It is mostly characterized by the abundance of plagioclase phenocrysts which are partly composed of big bytownorthite crystals. The writer has also collected intensely magnetic specimens from near the summit. They are, however, found only to a small extent.

The andesite here, including lava flows and fragments in ejecta, is compact or porous and has a dark color. They take on a reddish color in oxidized specimens. Under the microscope, the lava flows and fragments of ejecta consist of plagioclase, augite, hypersthene, olivine, magnetite, tridymite, bowlingite and brown glass; but the amount of such ingredients as olivine, tridymite and brown glass is quite variable even in the same lava flow. Commonly, there is a tendency of the andesite with big bytownorthite phenocrysts to be rich in olivine crystals as compared with other kinds of andesite largely exposed here on Fubō-zan.

The predominance of phenocrystic plagioclase gives a remarkable poprhyritic texture to the Fubō-zan lava. Such a phenocrystic plagioclase is occasionally represented by bytownorthite with a composition of An_{80-82}, and it is frequently 1 cm. across, assuming mostly an euhedral or subhedral form. In the groundmass, plagioclase is more acidic and belongs to bytownite or labradorite. It occurs as a lath-shaped or rectangular crystal, mostly 0.02 mm.-0.2 mm. in its longer diameter. Some of it shows a fluidal arrangement around the phenocrystic plagioclase, giving a pilotaxitic or hyalopilitic texture to the groundmass.

Augite is a very common ingredient in the groundmass, whereas the occurrence of its phenocrystic crystal is rather scarce in most specimens. Specimens devoid of phenocrystic augite are also known. Moreover, it is worthnoting that there are many examples of this mineral associated closely with hypersthene. In such a case, the former is always fringed by the latter. The subhedral or anhedral phenocryst occasionally twins on (100) or (101), and the largest one is 2.38 mm. long and 1.03 mm. across. The crystal reveals an extinction angle, $Z \wedge c$, of 39°-40°. and contains magnetite. In the groundmass, augite is usually found as a minute prismatic crystal, 0.02 mm.-0.08 mm. in length.

Hypersthene indicates, on the other hand, a high frequency as compared with augite. Its long prismatic crystal has a euhedral or subhedral form and is 1.29 mm. long in the largest one. Besides phenocryst, it occurs as an ingredient of the groundmass. Its phenocryst encloses magnetite.

Table IV. Compositions and optical characters of plagioclase, augite and hypersthene phenocrysts in Fubō-zan lava (Measured by F. Hori).

	No. 1 (49082610)	No. 2 (51071804)
Plagioclase	$\alpha=1.564\pm0.003$, $\gamma=1.580\pm0.003$ An_{67-82}*	$\alpha=1.560\pm0.003$, $\gamma=1.579\pm0.003$ An_{61-81}*
Augite		$\beta=1.692\pm0.003$ $(+)2V=490$ $Wo_{40}En_{42}Fs_{18}$**
Hypersthene	$\gamma=1.704\pm0.003$ $(-)2V=65°$ $Mg=70\%$***	$\gamma=1.704\pm0.003$ $(-)2V=64°$ $Mg=69\%$***

* After F. Chayes's chart.
** After H.H. Hess's chart.
*** After H. Kuno's chart.
No. 1.=The Fubō-zan lava from the southern flank of Fubō-zan.
No. 2.= 〃 from the southern foot of Fubō-zan.

Olivine is found as a phenocrystic ingredient. It is commonly present in a small amount, but there are some specimens rich in this mineral. It is represented by a subhedral or anhedral crystal, and the largest one is 1.84 mm. across. Such olivine phenocryst are frequenty surrounded by minute augite crystals and contain magnetite, passing into bowlingite along its crack and periphery.

Tridymite and biotite are rarely seen in the groundmass. The presence of brown glass is restricted to a small extent. It is exceedingly abundant in scoriaceous ejecta.

The groundmass is composed of plagioclase, augite, hypersthene, magnetite, tridymite, biotite and brown glass. In most thin sections, it has a pilotaxitic or hyalopilitic texture, but the groundmass with an orthophyric texture is also seen. The xenolith is mostly absent. It consists of plagioclase, augite, hypersthene and magnetite.

(5) *Sugiga-mine lava and agglomerate*:—Most of the Sugiga-mine lava and andesite fragments of its agglomerate are not so remarkably porphyritic as compared with the Byobu-dake lava exposed largely at the adjacent area. They have a dark grey or black color in fresh specimens, but take on a grey color after subjected to weathering. Such specimens were collected from various parts of lava flow and agglomerate, and the thin sections examined by the writer are composed of plagioclase, augite, hypersthene, olivine, magnetite, brown glass, tridymite and chlorite.

In these thin sections, plagioclase phenocrysts are found as euhedral or subhedral crystal which are frequently well zoned. Some of the phenocrysts indicate a very clear appearance without any inclusion or turbid part, but there are many crystals characterized by a worm-eaten structure, which consists of irregularly outlined pores filled up with such substances as brown glass or other ingredients of the groundmass. These pores are arranged with their longer axes parallel to the elongated direction of the crystals. The phenocryst ranges from labratownite to bytownite with a composition of An_{63-71}, and the largest one is 3.62 mm. long and 1.87 mm. across in thin sections. The plagioclase is also a very important ingredient in the groundmass. It occurs as a lath-shaped or rectangular crystal, 0.02 mm.–0.2 mm. long, showing occasionally a fiuidal structure.

Subhedral or anhedral augite phenocrysts are usually more abundant than those of hypersthene, although there are some specimens in which the latter exceeds the former in its amount. The crystal takes a stout or long prismatic form, twinning frequently on (100) or (101) or (201). In the last case, the penetration twin is formed. It is sometimes found in close association with hypersthene. In such a case, the long prismatic hypersthene has a narrow fringe of augite. The largest crystal is 3.31 mm. long and 1.19 mm. across. The extinction angle, $Z \wedge c$, is 38°-41°. When the crystal is zoned, the extinction angle gradually decreases outwards. Moreover, the phenocrystic augite encloses magnetite and plagioclase, being partly invaded by the groundmass. The minute augite crystals of the groundmass have a prismatic or granular form and are abundantly found together with lath-shaped plagioclase. Most of these are 0.01 mm.-0.05 mm. in length or diameter.

The occurrence of hypersthene is mostly known as phenocryst. This mineral shows an euhedral or subhedral and long or stout prismatic form, 1.7 mm. long and 1.19 mm. across in the largest crystal. Most of hypersthene phenocrysts contain magnetite as enclosure.

Table V. Composition and optical characters of plagioclase, augite and hypersthene phenocrysts in Sugiga-mine lava from the summit of Sugiga-mine (Measured by F. Hori).

	(T.I. 48092503)
Plagioclase	$\alpha=1.562\pm0.003$, $\gamma=1.575\pm0.003$ An_{63-71}*
Augite	$\beta=1.688\pm0.003$ $(+)2V=50°$ $Wo_{41}En_{44}Fs_{15}$**
Hypersthene	$\gamma=1.703\pm0.003$ $(-)2V=64°$ Mg = 69%***

* After F. Chayes's chart.
** After H.H. Hess's chart.
*** After H. Kuno's chart.

Olivive is seen in almost all thin sections, but it is commonly present as a subordinate ingredient as compared with other colored minerals. It is found only as a phenocryst and takes generally an anhedral form except in several cases in which euhedral or subhedral crystals are observed. In the well-defined and largest crystal, it is

1.31 mm. long and 0.51 mm. across. The mineral encloses minute magnetite crystals and passes into bowlingite or some chloritic substance along its periphery or crack, being sometimes corroded by the groundmass and being also surrounded by a granular aggregate of augite.

One of characteristic features indicated by this lava and andesite fragments of agglomerate is the abundance of magnetite in the groundmass. The magnetite under consideration is octahedral or granular or skeletal in its form. It is mostly 0.01 mm.-0.03 mm. in diameter except the skeletal crystals which are 0.85 mm. across in the largest one. Some of these skeletal crystals aggregate together with granular augite to form small rounded dots.

Brown glass on the other hand, is seen only in two specimens collected by the writer on the northern branch and southern flank of Sugiga-mine. It fills up the interstices of other ingredients. Besides it, a minor amount of tridymite is present in the groundmass of the lava exposed on the western cliff near the summit of Sugiga-mine.

The groundmass exhibits a pilotaxitic or hyalopilitic texture and consists of such minerals as plagioclase, augite, hypersthene, magnetite, tridymite and brown glass. Gabbroic or noritic xenolith is noticed in several specimens. It is commonly represented by a coarse or fine aggregate of plagioclase, augite, hypersthene and magnetite. In xenolith, olivine is not an important ingredient, and its occurrence is restricted to the specimen from the southern flank of Sugiga-mine.

(6) *Ushiro-eboshi-dake lava and ejecta*:—The Ushiro-eboshi-dake lava is repeatedly intercalated by agglomerate, pumiceous bed and other ejecta. Although lava has somewhat different features from place to place, it is mostly represented by a compact and porphyritic rock with a dark grey or black color in fresh specimens, but a grey or reddish color in those subjected to weathering.

The agglomerate is composed of such andesite fragments as mentioned above and sandy or tuffaceous matrix. In these cases, most specimens collected by the writer are represented by olivine-free andesite different from the underlying Sumi-kawa lava in various points.

The lava flows and andesite fragments under consideration consist of plagioclase, augite, hypersthene, olivine, magnetite, apatite, quartz, biotite, tridymite, bowlingite, chlorite and brown glass. Of these ingredients, the phenocrystic plagioclase belongs to labradorite or bytownorthite with a composition of An_{59-80}. Generally, it takes an euhedral or subhedral form, being 3.5 mm. long and 2.72 mm. across in the largest crystal. Some of plagioclase phenocrysts are well zoned and turbid. There are also many crystals with a worm-eaten structure formed by the invasion of brown glass or other ingredients of the groundmass, Moreover, such phenocrysts frequently enclose minute crystals of augite, hypersthene and magnetite. More acidic plagioclase occurs as an ingredient of the groundmass where lath-shaped or rectangular crystals, 0.03 mm.–0.17 mm. long, are abundant, showing the fluidal arrangement in some specimens.

The augite phenocryst mostly reveals a high frequency as compared with hypersthene. Subhedral or anhedral phenocrysts of this mineral frequently twin on (101) or (100) and have an extinction angle, $Z \wedge c$, of 38°–41°. The largest crystal examined in the thin section is 1.78 mm. long and 0.68 mm. across. In the groundmass, augite crystals are prismatic or irregular, being commonly 0.02 mm.–0.2 mm. in length or diameter. Sometimes they aggregate together with skeletal crystals of magnetite. Hypersthene is also an important colored mineral, but it is scarcely seen in the groundmass. Most of this mineral have an euhedral or subhedral form and a long prismatic habit.

Table VI. Compositions and optical characters of plagioclase, augite and hypersthene phenocrysts in Ushiro-eboshi-dake lava from the summit of Ushiro-eboshi-dake (Measured by F. Hori).

	(T.I. 49082205)
Plagioclase	$\alpha=1.558\pm0.003$, $\gamma=1.578\pm0.003$ $An_{59-8)}$*
Augite	$\beta=1.694\pm0.003$ $(+)2V=50°$ $Wo_{41}En_{39}Fs_{20}$**
Hypersthene	$\gamma=1.709\pm0.003$ $(-)2V=60°$ Mg% = 65***

* After F. Chayes's chart.
** After H.H. Hess's chart.
*** After H. Kuno's chart.

The occurrence of olivine is an exceptional case for the Ushiro-eboshi-dake lava and andesite fragments in agglomerate. It is contained in the specimens obtained on the summit of Ushiro-eboshi-dake and its northwestern foot as well as from near Tengu-iwa of Mae-eboshi-dake. Even the largest phenocryst is 1.04 mm. long and 0.68 mm. across in thin sections and euhedral crystals are absent. Bowlingite is formed from this mineral along its crack and peripheral part.

Magnetite is the commonest ingredient in the groundmass. Minute octahedral or irregular crystals, commonly 0.01 mm.–0.08 mm. across, are most abundant, although there are some crystals attaining to a diameter of 1 mm. or thereabouts. Magnetite is occasionally enclosed by such minerals as plagioclase, augite, hypersthene and olivine.

Quartz is only found as a xenocryst which was probably supplied from granitic rocks. It has a rounded form due to the magmatic corrosion, and the largest grain is 1.54 mm. across. Apatite is rarely present in the specimen collected from the southeastern flank of Ushiro-eboshi-dake. It is a long prismatic crystal, 0.39 mm. in length, and its inner part has a brownish grey color resulting from decomposition. Tridymite fills up the irregular interstices of minute ingredients in the groundmass, and biotite is an unimportant mineral in xenoliths. Chlorite is, on the other hand, a secondary mineral and partly replaces the phenocrystic plagioclase.

Besides various ingredients mentioned above, the occurrence of brown glass is known in the phenocrystic plagioclase and also in the groundmass of the specimen from Tengu-iwa. In the latter case, it occupies the main part of the groundmass, and a hyalopilitic texture is formed.

The groundmass is composed of plagioclase, augite, hypersthene, magnetite, apatite, tridymite and brown glass. It has mostly a pilotaxitic texture. The groundmass of some specimens are intensely decomposed, and it is not clear whether the groundmass has a pilotaxitic or hyalopilitic texture. Moreover, leucoratic spots, rounded or irregular, are abundantly seen, as is indicated by the decomposed groundmass of the Sumi-kawa lava and Byōbu-dake lava. Xenolith is an aggregate of plagioclase, augite, hypersthene and magnetite with a minor amount of biotite flake. It has a gabbroic, noritic or basaltic character and is commonly found in all specimens.

(7) *Andesite fragments of the Kara-sawa mud flow*:—So far as is known at present, there are two kinds of andesite fragments in the Kara-sawa mud flow. They are two-pyroxene andesite and olivine-bearing two-pyroxene andesite, being composed of plagioclase, augite, hypersthene; magnetite and tridymite with or without olivine pheno-

crysts. Of these, the olivine-free andesite is more extensively distributed, and its groundmass has a fine pilotaxitic texture. A similar type of andesite is frequently seen in the Ushiro-eboshi-dake lava. Olivine-bearing andesite is, however, found to a small extent and seems mostly to have been supplied from the Fubō-zan lava.

In such two kinds of andesite fragments, the phenocrystic plagioclase, euhedral or subhedral, is 2.89 mm. long and 1.86 mm. across in the largest crystal. It is always characterized by the frequent presence of a worm-eaten structure, being occasionally turbid and well zoned. The crystal includes augite and magnetite. When the phenocrystic augite reveals a worm-eaten structure, the cavities are filled up by brown glass or other ingredients. Minute lath-shaped plagioclase, mostly 0.02 mm.–0.08 mm. in length, is abundant in the groundmass of olivne-free andesite, whereas the rectangular form, 0.02 mm.–0.2 mm. long, is very common in olivine-bearing variety, giving an orthophyric texture to its groundmass.

In thin sections, the phenocrystic augite is generally 2.38 mm. long and 1.13 mm. across in the largest crystal. Its frequency is commonly higher than the phenocrystic hypersthene. It twins on (100) or (101), and the extinction angle, $Z \wedge c$, is 40°. Hypersthene has a long prismatic habit, and the largest crystal is 1.07 mm. long and 0.59 mm. across. These two minerals contain magnetite, and are sometimes associated together. In this case, hypersthene is fringed by a narrow zone of augite. Minute augite crystals, stout prismatic or irregular in form, are abundant in the groundmass. They are 0.03 mm.–0.08 mm. in longer diameter.

Octahedral or ill-defined magnetite crystals are one of important ingredients in the groundmass, where they are mostly 0.01 mm.–0.08 mm. across, although there are large skeletal crystals, the largest one being 1.36 mm. across in the andesite fragments obtained near Misumi. The occurrence of anhedral olivine crystals is known in several specimens. It is 1.1 mm. long in the largest phenocryst and partly or wholly passes into bowlingite. The groundmass consists of plagioclase, augite, magnetite and tridymite, but noritic xenoliths are almost absent.

(8) *Nyūdō-san lava and agglomerate*:—All the specimens collected by the writer on Nyūdō-san are two-pyroxene andesite. They are compact and porous rocks with a dark grey or black color and porphyritic texture. Some of these specimens are characterized by the frequent occurrence of large plagioclase phenocrysts and xenoliths of plagioliparite.

The former is seen in those obtained on the summit or western flank, whereas the latter is commonly observed in the andesite fragments of agglomerate exposed on the ridge extending south-southeastwards from the summit. The andesite fragments of agglomerate, which constructs the bottom of volcanic products here, are, however, free of such xenoliths and are frequently alunitized to some extent.

The microscopical examination of thin sections shows that they contain plagioclase, augite, hypersthene, magnetite, tridymite, bowlingite and chlorite.

Of these ingredients, phenocrystic plagioclase takes an euhedral or subhedral form, 4.65 mm. long and 1.6 mm. across in the largest one. It is labratownite or bytownite with a composition of An_{63-76}. Sometimes, the crystal looks clear without any inclusions and turbid portion, but it has occasionally a worm-eaten structure due to the invasion of the groundmass. In the latter case, some of phenocrysts enclose minute crystals of augite, hypersthene and magnetite, being frequently subjected sporadically to chloritization. Zoned phenocrysts are also seen commonly in these specimens. Lath-shaped plagioclase crystals, mostly 0.03 mm.–0.08 mm. long, are found abundantly in the groundmass, where they partly reveal a fluidal arrangement.

The augite phenocryst is generally found in high or nearly same frequency as compared with that of hypersthene and occurs as a subhedral or anhedral crystal. It twins on (100) or (101) and contains magnetite and hypersthene crystals. Some of augite crystals indicate a zonal structure with hypersthene. Its largest phenocryst is 3.8 mm. long and 1.76 mm. across. The extinction angle, $Z \wedge c$, is 40°–41°, and the crystal encloses magnetite grains. It is, however, worthnoting that the phenocrystic augite is almost absent in the specimens obtained on the ridge branching south-southeastwards from the summit.

Hypersthene is generally found as phenocryst, but is a scarce ingredient in the groundmass. It has a long or stout prismatic habit, and the largest crystal measured by the writer is 2.35 mm. long and 0.51 mm. across. The crystal includes magnetite and is occasionally altered to bowlingite along its periphery and crack.

Magnetite is always an important mineral in the groundmass, where it occurs as an octahedral or ill-defined crystal, commonly 0.005 mm.–0.08 mm. in diameter, although there are some large skeletal crystals, 0.3 mm.–0.5 mm. across. Tridymite is, on the other hand, a rare ingredient in the groundmass, and it is found filling up the interspaces

Table VII. Compositions and optical characters of plagioclase, augite, hypersthene phenocrysts in Nyūdō-san lava from the western flank of Nyūdō-san (Measured by F. Hori).

	(T.I. 49082310)
Plagioclase	$\alpha=1.562\pm0.003$, $\gamma=1.577\pm0.003$ An_{63-76}*
Augite	$\beta=1.694\pm0.003$ $(+)2V=50°$ $Wo_{41}En_{39}Fs_{20}$
Hypersthene	$\gamma=1.709\pm0.003$ $(-)2V=61°$ Mg=66%***

* After F. Chayes's chart.
** After H.H. Hess's chart.
*** After H. Kuno's chart.

of other minerals. The groundmass has a pilotaxitic texture and consists of plagioclase, augite, hypersthene, magnetite and tridymite. Usually, it contains gabbroic or noritic xenoliths and also some fragments of plagioliparite.

(9) *Manokami-dake lava*:—The lava and andesite fragments collected from agglomerate have a dark grey color, when they are fresh, but takes on a grey color in the process of weathering and a reddish color when reheated. These rocks are finely porphyritic and frequently contain xenoliths. Some of the lava and agglomerate are intensely subjected to the solfataric action, by which they are kaolinized and opalized, being widely pyritized. Such an alteration can be seen along the Akiyama-zawa.

Microscopically, the mineral components of the writer's specimens are represented by plagioclase, augite, hypersthene, olivine, hornblende, magnetite, apatite, brown glass, bowlingite, calcite and chlorite. In such a case, it is worthnoting that the occurrence of olivine is restricted only to the specimens obtained on the southern flank of Manokami-dake.

Of these, the phenocrystic plagioclase is labratownite or bytownite with a composition of An_{63-74}. The euhedral or subhedral crystal of this mineral is occasionally invaded by the groundmass and shows a characteristic worm-eaten structure. The largest crystal is 4.33 mm.

long and 2.8 mm. across. It contains augite and magnetite in frequent association with brown glass and chlorite, being sometimes turbid and well zoned. Besides these, minute lath-shaped or rectangular plagioclase, mostly 0.02 mm.-0.2 mm. long, is abundantly present in the groundmass where it reveals a fluidal arrangement.

Augite and hypersthene are found in varying amount, the former being more abundant than the latter or *vice versa.* In almost all specimens, the phenocrystic hypersthene occurs as a well defined crystal as compared with the phenocrystic augite. When these minerals are associated together, the latter is always fringed by the former. In the writer's specimens, the phenocrystic augite is 1.84 mm. long and 0.8 mm. across in the largest one, and its extinction angle, $Z \wedge c$, is 38°-41°. The crystal has a tendency to be twinned on (100) or (101), and a polysynthetic twinning is seen in some thin sections. It encloses plagioclase and magnetite. In the former case, an ophitic texture is formed occasionally between them. The groundmass contains many small crystals of the stout prismatic or granular augite, 0.02 mm.-0.2 mm. in length or diameter. The alteration product of augite are bowlingite and calcite, but the latter is very rare in its occurrence. The phenocrystic hypersthene is generally characterized by a long prismatic habit. The largest crystal of this mineral is 1.39 mm. long and 0.33 mm. across. Frequently, it contains plagioclase, augite and magnetite. The alteration to bowlingite and hematite is known in the specimens subjected to oxidation.

Table VIII. Compositions and optical characters of phenocrystic plagioclase, augite and hypersthene in Manokami-dake lava from the eastern foot of Manokami-dake (Measured by F. Hori).

	(T.I. 47102603)
Plagioclase	$\alpha = 1.562 \pm 0.003$, $\gamma = 1.575 \pm 0.003$ An_{63-74}
Augite	$\beta = 1.685 \pm 0.003$ $(+)2V = 57°$ $Wo_{42}En_{46}Fs_{12}$**
Hypersthene	$\gamma = 1.711 \pm 0.003$ $(-)2V = 57°$ Mg = 62%***

* After F. Chayes's chart.
** After H.H. Hess's chart.
*** After H. Kuno's chart.

The occurrence of the phenocrystic olivine is noticed in the specimen collected at the uppermost course of the Tashiro-zawa which starts on the southern flank of Manokami-dake. The anhedral crystal of this mineral passes into bowlingite at its periphery as well as along its crack. Magnetite is, on the other hand, the most predominant ingredient in the groundmass of all specimens. It takes an octahedral or granular or skeletal form, usually 0.01 mm.–0.08 mm. in diameter, but 0.5 mm. across in the largest skeletal crystal. Apatite and hornblende are very scanty minerals in the writer's specimens. They are found only in the specimen from the uppermost course of the Tashiro-zawa. Of these two minerals, apatite has a long prismatic form, 0.12 mm. or more in length, being more or less decomposed, whereas hornblende, 0,24 mm. long in the largest crystal, is closely associated with augite and hypersthene in parallel intergrowth and reveals the following pleochroic scheme. X=light yellow, Y=brownish yellow and Z=yellowish brown.

The groundmass is composed of plagioclase, augite, hypersthene, magnetite and apatite. It has a pilotaxitic or hyalopilitic texture which is often obscured by the formation of leucocratic dots due to decomposition. Noritic, gabbroic and basaltic xenoliths are sporadically found in the groundmass, being composed of plagioclase, augite, hypersthene and magnetite.

(10) *Andesite fragments of the Nanokahara mud flow*:—Andesite fragments of this mud flow were supplied from the Ushiro-eboshi-dake lava, because the mud flow here erupted from the explosion crater of Numa surrounded by a semi-circular wall of the Ushiro-eboshi-dake lava. All of these andesite fragments are, therefore, two-pyroxene andesite with a dark grey or black color and remarkably porphyritic texture. They are composed of plagioclase, augite, hypersthene, magnetite and apatite imbedded in the groundmass with a pilotaxitic texture. Various characters of such ingredients are almost same as those of the Ushiro-eboshi-dake lava. In the specimens collected by the writer, the largest phenocrystic plagioclase is 4.67 mm. long and 2.35 mm. across. As in the case of the Ushiro-eboshi-dake lava, most of these are characterized by a worm-eaten structure.

As to augite and hypersthene phenocrysts, there is no remarkable feature different from those of the Ushiro-eboshi-dake lava, the former being more abundant than the latter. Apatite is a very rare ingredient, 0.2 mm. long in the largest crystal. It has a dark brown color in its inner part and is somewhat rounded. Subjected to weathering, the groundmass yields a leucocratic dots by which its pilotaxitic texture is obscured.

History of Igneous Activities

The extensive distribution of lavas and ejecta suggests that there was once an important active center in the Byōbu volcanic area. The activity here seems to have taken place at different sources in concert with other area of the Zaō Volcanoes. It is supposed to have been repeated several times, resulting in the formation of such remarkable peaks as Byōbu-dake, Fubō-zan, Ushiro-eboshi-dake, Sugiga-mine, Nyūdō-san and Manokami-dake.

The forerunner of these repeated activities is represented by the eruption of the Nonomori agglomerate which had its source at the southeastern corner of this volcanic area. It spreaded over the eroded surface of base rocks composed of the Tertiary formation and various kinds of extrusives. The eruption of the Nonomori agglomerate was followed by those of the Sumi-kawa lava and agglomerate which were abundantly supplied from the center opened newly at the west of the former source. This crater was deformed and obscured later by erosion, explosion and faulting as well as by the formation of central cones, although it is believed to have been a big crater in the beginning.

The Sumi-kawa lava poured out successively after the eruption of its agglomerate, running down northwards beyond the area now dissected by the Sumi-kawa and Nigori-gawa where the Tertiary formation, granite (granodiorite) and other intrusives or extrusives are well exposed.

In the next activity, the Byōbu-dake lava also poured forth through this crater and covered older volcanic products or base rocks. This was followed by other eruptions from the same crater, as is indicated by lavas and ejecta accumulated thickly on Fubō-zan and Ushiro-eboshi-dake. There is, however, no evidence to confirm the relationship between them. The same may be said of the Sugiga-mine lava and agglomerate ejected from the source situated on the western flank of Byōbu-dake.

After these repeated activities, explosion craters which opened between Fubō-zan and Ushiro-eboshi-dake poured out the Kara-sawa mud flow down to Misumi and its surrounding area. As a result of the eruption subsequent to this activity, two central cones such as

Nyūdō-san and Manokami-dake were successively formed within the pre-existing crater.

The activity of the Byōbu Volcano moved from here to Numa at its final stage. It is indicated by the explosion which happened on the southern flank of Mae-eboshi-dake and also by the ejection of the Nanokahara mud flow which extended northeastwards presenting a very characteristic topographical feature.

At the Byōbu volcanic area, even the last activity mentioned above is of the pre-histric time, and it is one of the noteworthy points which differ from the Zaō Proper where the activity is still expected.

Summary

(i) The South Zaō is constructed by such two volcanoes as Byōbu and Aoso. Of these, the Byobu Volcano occupies the western half of this area and includes Nonomori, Byōbu-dake, Fubō-zan, Ushiro-eboshi-dake, Mae-eboshi-dake, Sugiga-mine, Nyūdō-zan, and Manokami-dake, rising to 1817.3 meters above the sea-level at the highest point. They are now deeply dissected and thickly forested as compared with the Zaō Proper.

(ii) The Byōbu Volcano rests upon the eroded surface of such base rocks as Upper Miocene sediments, granite and other intrusives or extrusives. It is built up of various volcanic products represented by the Nonomori agglomerate, Sumi-kawa lava and agglomerate, Byōbu-dake lava, Fubō-zan lava and ejecta, Sugiga-mine lava and agglomerate, Ushiro-eboshi-dake lava and ejecta, Kara-sawa mud flow, Nyūdō-san lava and agglomerate, Manokami-dake lava and Nanokahara mud flow.

(iii) The largest source of these lavas and ejecta is the pre-existing crater or explosion crater which opened at the central part of this volcanic area. It is now surrounded by Byōbu-dake, Fubō-zan and Ushiro-eboshi-dake, but is partly deformed and obscured by the explosion and erosion as well as by the formation of the central cones. Other craters and explosion craters ejected the Nonomori agglomerate, Sugiga-mine lava and agglomerate and Nanokahara mud flow. The most characteristic explosion crater is preserved on the southern flank of Mae-eboshi-dake.

(iv) The beginning of activities repeated here is shown by the eruption of the Nonomori agglomerate, which was followed by the eruption of the Sumi-kawa lava and agglomerate. The latter is the biggest eruption of the Byōbu Volcano, and a large amount of lava

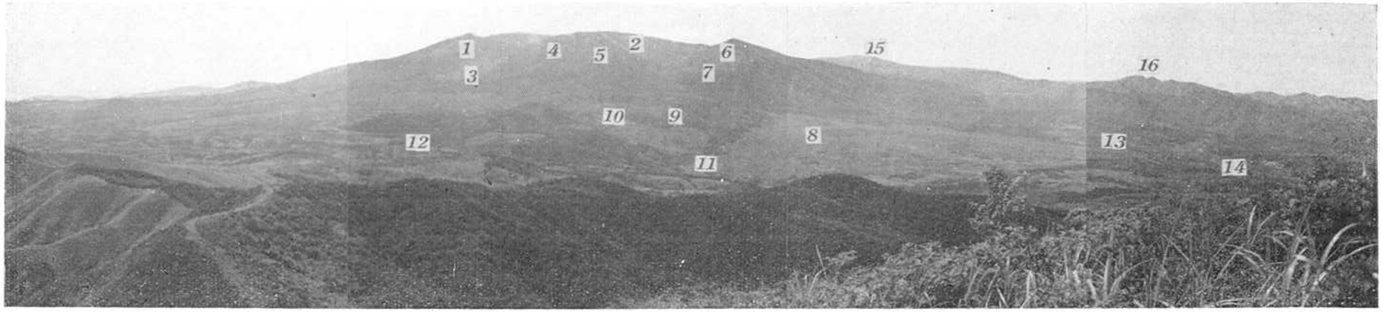

Fig. 3. The Byōbu Volcano viewed from Ōmori-yama of the Aoso Volcano.

1=Fubō-zan, 2=Byōbu-dake, 3=Kara-sawa mud flow, 4=Nyūdō-san, 5=Manokami-dake, 6=Ushiro-eboshi-dake, 7=Numa, 8=Nanokahara mud flow, 9=Nonomori, 10=Crater, 11=The Akiyama-zawa, 12=The Tashiro-zawa, 13=The Sumi-kawa, 14=The Nigori-gawa, 15=Kumano-dake, 16=Gando-yama.

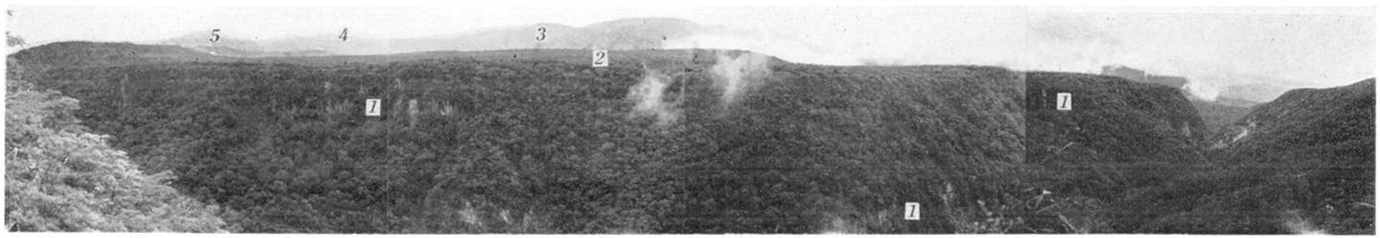

Fig. 4. The Sumi-kawa lava exposed along the Sumi-kawa.

1=Sumi-kawa lava, 2=Nanba-zawa lava underlain by Sumi-kawa lava, 3=Kumano-dake, 4=Goshiki-dake, 5=Katta-dake.

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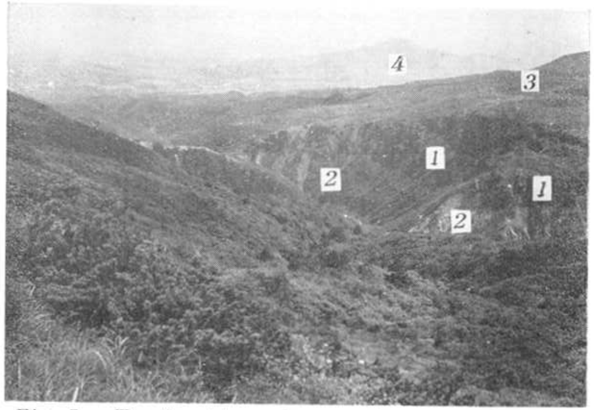

Fig. 5. The Sumi-kawa lava resting upon the eroded surface of granite. 1=Sumi-kawa lava, 2=Granite, 3=Sainokawara, 4=Aoso Volcano.

Fig. 6 Columnar joints of the Sumi-kawa lava at the bottom of the Sumi-kawa.

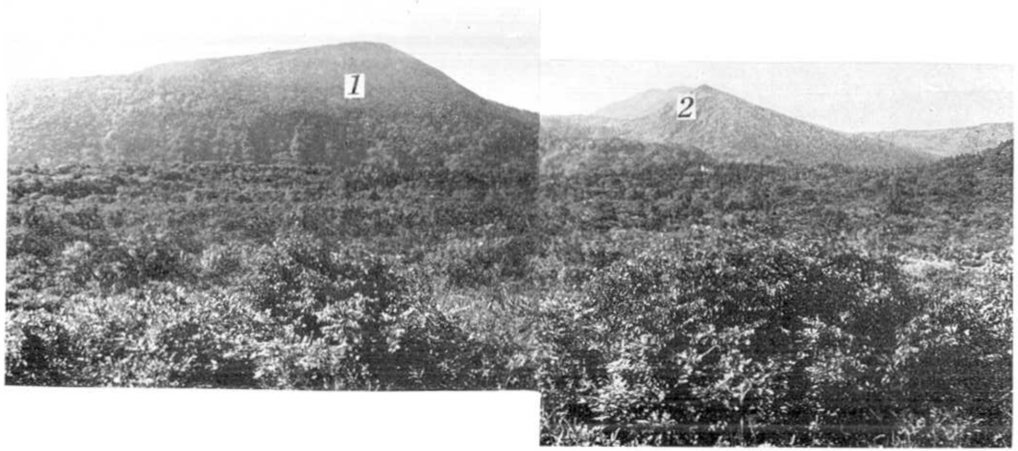

Fig. 7. Byōbu-dake and Ushiro-eboshi-dake viewed from Sainokawara.
1=Ushiro-eboshi-dake,
2=Byōbu-dake.
The eastern side of Byōbu-dake slopes steeply downward and forms here a sharp cliff in contrast with its western gentle slope.

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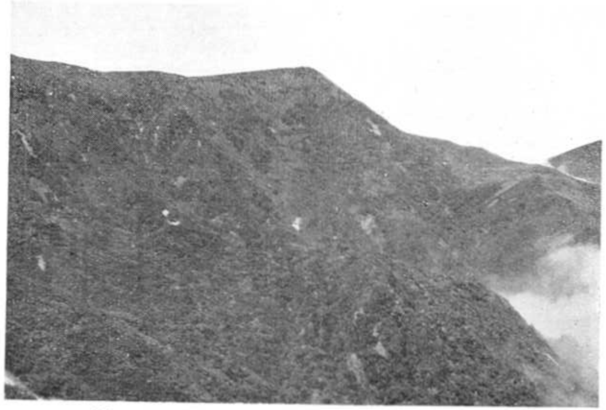

Fig. 8. The eastern cliff of Byōbu-dake looking like a faultscarp.

Fig. 9. Fubō-zan viewed from near the summit of N. Byōbu-dake.

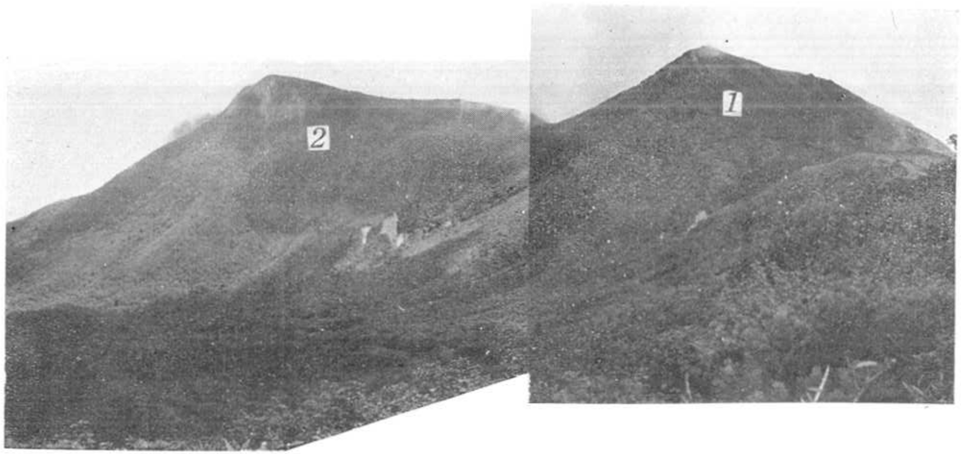

Fig. 10. Nyūdō-san and Manokami-dake, two central cones of the Byōbu Volcano. 1 = Nyūdō-san, 2 = Manokami-dake.

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flowed down northwards beyond the Nigori-gawa and Sumi-kawa at that time. Such activities had happened several times until the Nanokahara mud flow poured out finally from the explosion crater near Numa, but there has been no activity in the historic time.

(v) Two central cones were succesively formed within the pre-existing crater or explosion crater mentioned above. These cones were formed at the last stage of several activities, being composed of two-pyroxene andesite and its agglomerate. They are characterized by the absence of such dacite as is exposed on the central cones of the neighbouring volcano.

(vi) The geological age of the first eruption here may be the Pleistocene. It is inferred from the fact that the lavas and ejecta of the Byōbu and Aoso Volcanoes erupted together, and the oldest mud flow of the latter is unconformably underlain by alternate beds of clay, sand and gravel assigned to Pleistocene.

In conclusion, the writer wishes to offer his hearty thanks to Dr. N. Nasu and Dr. H. Tsuya who helped him to continue his work even after he had been transferred from the Earthquake Research Institute of Tokyo University to Yamagata University. The writer's sincere thanks are also due to Mr. F. Hori for his co-operation in the petrographical investigations of lavas and ejecta obtained from this volcano. A part of this investigation was carried out with the aid of the Education Ministry Grant for Natural Science.

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39. 蔵王火山の地質学的研究 (第 3 報)

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遠刈田温泉に近い青麻火山の西方に，大きく根を張る屏風火山は，屏風岳，不忘岳，杉ケ峰，後烏帽子岳，前烏帽子岳，入道山，馬神岳，ノノ森などよりなり，蔵王火山群の重要なる部分を占めるものである．この火山は，花崗岩（花崗閃緑岩），新第三系，これ等を貫き，或は被覆する各種火成岩を基盤として，その侵蝕面上に盛上り，火山体を構成する多量の橄欖石複輝石安山岩，含橄欖石複輝石安山岩，複輝石安山岩，砕屑岩は，極めて複雑なる分布を見せている．現在不忘山，屏風岳，後烏帽子岳により包囲され，入道山，馬神岳の両中央火口丘が存在する地域は，屏風火山活動の主要な中心と考えられ，又これに接近してノノ森噴火口，沼爆裂火口，その他からも，熔岩，集塊岩，泥流などが噴出しているのを見ることが出来る．この火山地域の活動は，ノノ森噴火口の生成に始まり，七日原泥流の噴出を以て，終りを告げたものと見做し得可く，青麻火山や蔵王火山群の他の火山と相呼応し，恐らく第四紀に入つてから活動が開始されたものと想像される．ただしこの火山では，青麻火山と同じ様に，有史以後の活動が知られていない．