20. 自動水準式振動計

地震研究所 {金井 清 / 田中貞二

0.2 秒位よりも長い周期の振子をもつ換振器は，水準を保たねばならない．従つて，普通の換振器では，試錐孔，河海底，細長い構造物上，狭い場所などでの使用は容易でない．

最近，このような場所で，地震観測，振動測定をしなければならない事情にせまられて，次の原理によつて，自動的に振子の台の水準を出す換振器を試作した．即ち，

(i) 換振器用振子取付け台をもつ枠を，単振子とする．

(ii) 換振器を測定場所に据えてから，単振子を包むパラフィンを電熱器で熔かす．そうすると，枠の振子は減衰自由振動をした後，安定な位置で静止する．

(iii) 枠の振子が安定な位置で静止した状態では，換振器振子取付け台の水準が得られる．

(iv) 取付け台の水準が得られたら，枠を包むパラフィンを熔かしていた電熱器の電流を切る．

(v) このパラフィンが固まると，測定可能になるわけである．

100 mm 試錐孔底用と水底用の 2 種類の換振器を試作した．換振器を据えてから測定できるまでの時間は，10～15 分である．

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21. Geological Considerations on Plagioliparite and Associated Extrusives Exposed in the Tendō-Yamagata-Kaminoyama District, Yamagata Prefecture.*

By Takeshi ICHIMURA,

Yamagata University.

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Introduction

The frequent occurrence of plagioliparite and associated extrusives is one of the remarkable geological features on the mountainous or hilly land adjacent to the Yamagata Basin. These extrusives are mostly found as dykes and lava flows in the area where Neogene sediments and granitic rocks are well exposed.

They are characterized by succesive extrusions due to repeated igneous activities which took place during or after the sedimentation of green tuff formation and played an important rôle in the formation of metallic or non-metallic mineral deposits. Moreover, the frequency of such extrusives seems to be a key point in making clear the relation between the green tuff formation of the Tendō-Yamagata-Kaminoyama district and that of the adjacent area. There are, therefore, many problem on the geology of these rocks which need to be investigated in detail. The same may be said of their lithological characters and mineral compositions, since they have almost been neglected without any examination.

Since 1956, the writer's field and laboratory work has been done for the purpose of studying them, with the co-operations of his student, Masa Suzuki. The results thus obtained are summarized in this paper.

Distribution

Plagioliparite and associated extrusives are well exposed on the mountainous or hilly land interposed between the Yamagata Basin and Backbone Range as well as between this basin and the Mogami-gawa (Fig. 1). Exclusive of plagioliparite (plagiorhyolite)[1], these various kinds

* Communicated by H. Tsuya.

1) I. KATŌ, *Sc. Rep. Tōhoku Univ.*, [iii] **5** (1955), 72.

of extrusives are represented by perlite, trachytic andesite, dacite and andesite. Among them, plagioliparite and trachytic andesite are found in high frequency as compared with others. In this case, the occurrence of dacite is restricted to the eastern district, whereas perlite is present in the western area.

So far as is known at present, the northern distribution of plagioliparite in this district is sporadically traceable up to the area including Suishō-zan, Uzawa-yama, Amayobi-yama, Maizuru-yama near Tendō, the Ōishi-zawa and the ridge between the Iwano-sawa and the Zaimoku-zawa where it is closely associated with green tuff. The frequent occurrence of such a plagioliparite is similarly noticed in the area beyond the Tachiya-gawa. Thus, it can not infrequently be seen at the western side of the Omoshiro Volcanoes which is deeply dissected by such tributaries of the Tachiya-gawa as the Momiji-gawa, Ichino-sawa, Nino-sawa, Bunpeki-zawa, Tashiro-zawa and Magata-zawa. This area is mostly composed of tuffaceous sediments and granitic rocks covered partly by lavas and ejecta of the Omoshiro Volcanoes. Going westwards, however, the geological feature is somewhat different, since plagioliparite and trachytic andesite here are repeatedly exposed in an intricate manner, some of them being underlain or intercalated by Miocene sediments. Such exposures are observable at many places such as those shown by Ōmori-yama, Sanpō'oka, Tamagairi, Shimo-higashiyama, Kirihata, Ōoka-yama and Aono. They extend further south down to the Mamigasaki-gawa, passing through Fukazawa-fudō, Yanbe and Sakazuki-yama. Besides these, plagioliparite and trachytic andesite occasionally cut green tuff and its underlying granodiorite along the uppermost course of the Takase-gawa, but some of them rest upon the green tuff of the ridge behind Namekawa and Niiyama.

At the opposite side of Sakazuki-yama, there are plagioliparite of Chitose-yama and Saruoka-yama as well as dacite of Togami-yama and Iwanami underlain by green tuff beds. It is also noteworthy that small but repeated exposures of plagioliparite are seen in the granitic mass which forms the foundation of the Gando Volcano. Most of these are distributed at Sekizawa, Namekawa, Kami-hōzawa, Shimō-hōzawa, the upper course of the Mamigasaki-gawa, the Happō-zawa, etc., although the occurrence of plagioliparite is partly obscured by overlying lavas and ejecta of the Ryūzan Volcano and Gando Volcano.

It again appears largely in the area of green tuff watered by the Namai-gawa, Shōbu-gawa and Kayadaira-gawa, as is indicated by those

Fig. 1. Map showing the distribution of plagioliparite and associated extrusives in the Tendō-Yamagata-Kaminoyama district. 1=Plagioliparite, 2=Perlite, 3=Trachytic andesite, 4=Dacite, 5=Andesite.

of Sarukuramori-yama, Takahata-yama, Nomioka-yama, Furuyashiki and Kayadaira. Moreover, plagioliparite occurs in close connection with the extrusion of perlite, trachytic andesite and andesite at the southwestern side of the Yamagata Basin. They are generally associated with green tuff and construct the main parts of Togami-yama of Monden and its southern hills, Ōmori-yama, Matsumori-yama, small hills situated at the south of Urushibō, Takatori-yama, the southern side of Shiro-yama behind Hasedō, Kakumaba, Yamauchi, Sugarita, Umegataira-yama, Futatsumori-yama, Daihira-yama and Kyōzuka-yama or others near Kaminoyama. In the same way, plagioliparite is an important extrusive of the adjacent Yoshino district, but it is characterized by the absence of banded plagioliparite or perlite in this case.

Topographical Features

Since plagioliparite and associated extrusives are widely distributed in this district, the topographical features here are largely affected by the exposures of these rocks except the granitic area where plagioliparite and trachytic andesite are usually found as dykes, large or small. When their lava flows are, on the other hand, exposed together with Miocene sediments, the former is easily distinguishable topographically from the latter. In this case, most of these have a steep slope as compared with the surrounding area composed of tuff and other sediments. Such a topography is generally seen on the hilly or mountainous land including Yamadera, Ōmori-yama (365.6 m.) near Yamadera, Sanpō'oka, Tamagairi, Shimo-higashiyama, Nakazato, Ōoka-yama (401 m.), Yanbe, Sōzuki, Sakazuki-yama (270 m.), Chitose-yama (472 m.), Saruoka-yama (558 m.), Togami-yama (311.4 m.) near Iwanami, Nomioka-yama (592.4 m.), Takahata-yama, Sarukuramori-yama (873 m.), Togami-yama (402.2 m.) near Moden, Ōmori-yama (606.5 m.) near Urushibō, Umegataira-yama (639.5 m.), Futatsumori-yama (562.4 m.), Daihira-yama (714.4 m.), Kyōzuka-yama and others.

It is also worthy to notice that there are cone-shaped hills or small peaks here and there, being constructed by lava flows composed of plagioliparite, trachytic andesite and dacite. They are represented by Ōmori-yama (plagioliparite and trachytic andesite) near Yamadera, Togami-yama (dacite) near Iwanami, Togami-yama (trachytic andesite) near Monden, etc. which may be mistaken for small volcanoes at a glance (Figs. 2, 5). These conical masses rise up to a height of 311.4 m.–472 m. above the sea-level and are mainly underlain by green tuff. They are probably erosion remnants of folded lava flows, because almost all of them are seen in the area where the Miocene sediments are traversed by syncline axes running north-northeastwards. So far as is observed at present, it is inferable that many cracks or joints concentrating upwards but radiating downwards were formed by the tension or compression due to the syclinal fold and the pitching of fold-axes. The present topography under consideration may, therefore, be supposed to depend on this geological structure by which the subsequent erosion was much favored to build up an isolated cone.

Modes of Occurrence

There are, at least, four different modes of occurrence of plagioliparite and associated extrusives, namely (1) dykes in granitic rocks, (2) dykes in Miocene sediments, (3) lava flows resting upon the eroded surface of granitic rocks and (4) lava flows poured out during the deposition of Miocene sediments.

(1) Dykes in granitic rocks:—Most of these rocks are seen along the cutting of the Senzan Railway Line, the Mamigasaki-gawa and such tributaries of Tachiya-gawa as Momiji-gawa, Bunpeki-zawa and Takase-gawa. It is noteworthy that almost all of them are composed of plagioliparite with some exceptions of trachytic andesite traversing the granitic rocks exposed at the upper course of the Mamigasaki-gawa and along the Hanoki-zawa. Among them, the dykes of plagioliparite are generally 5–20 m. wide, but they are sometimes 60–100 m. in width, as is indicated along the Bunpeki-zawa. Some of these are found in association with propylite dikes along the Mamigasaki-gawa and its tributaries, both taking frequently a trend of N–S or NE–SW.

(2) Dykes in Miocene sediments:—As compared with those in granitic rocks, they appear in low frequency along the Matsutome-zawa, the upper course of the Akakura-zawa, the Sasaya Highway between Namekawa and Niiyama, etc., where plagioliparite was injected into green tuff of the Hōzawa Formation[2]. The similar mode of occurrence is shown by a trachytic andesite cutting the green tuff on the route between Shōbu and the Fubira Mine.

(3) Lava flows resting upon the eroded surface of grantic rocks:—

2) The Hōzawa Formation is composed of green tuff, brecciated tuff and conglomeratic tuff exposed mainly on the ridge behind Hōzawa. Stratigraphically, it corresponds to the lower part of the Kaneyama Formation or the Yoshino Formation.

This type of occurrence is only seen at the upper course of the Takasegawa, the opposite side of Bōbara and on the ridge between Niiyama and Hōzawa. In these cases, the extrusive is represented by plagioliparite and trachytic andesite.

(4) Lava flows poured out during the deposition of Miocene sediments:—There are many lava flows in association with the Sugarita Formation[3], the Yamadera Formation[4] and the upper part of the Yoshino Formation[5]. They were repeatedly erupted during the deposition of the formations composed of green tuff, conglomeratic tuff, brecciated tuff, shale, siltstone and sandstone. Some of them, therefore, interfinger with Miocene sediments and pass laterally into one another. Moreover, it is noticed that the same lava flow overlies occasionally granitic rocks on one hand but green tuff on the other.

So far as has been investigated on Maizuru-yama and its southern hills, plagioliparite is overlain by green tuff and hard shale which grade into the trachytic andesite upwards. The similar feature can be observed on the hills to the south of Nukitsu. In connection with them, a large exposure of plagioliparite flow is known in the area including Uzawa-yama, Jagaramogara and Kami-nukitsu and seems to be traceable southwards down to the Ōishi-zawa where it is found in contact with the brecciated tuff bordered by a fault, indicating that the former is supposed to have been thrown down against the latter.

At the south of the Tachiya-gawa, an extensive area of lava flows represented by plagioliparite and trachytic andesite is distributed in close association with tuffaceous sediments and shale beds. One of them is to be seen along the Magata-zawa or the Tashiro-zawa and overlies tuff beds or granitic rocks. The rock exposed here is plagioliparite with a high frequency of joint structure. In this case, a small isolated hill called Ōmori-yama situated between the Tachiya-gawa and the Senzan Railway Line is constructed of trachytic andesite and plagioliparite intercalated by tuff and shale. The same can be said of the area including Sanpō'oka, Tamagairi and Shimo-higashiyama, where the occurrence of tuff and shale beds is known at the lowest part of the thick lava

3) The Sugarita Formation corresponds to the Kusanagi Formation of the Shinjō Basin.

4) The Yamadera Formation is supposed to include the Kusanagi Formation and the uppermost horizon of the Kaneyama Formation. Hence, its lower part may be correlated with the Nishikurosawa Formation of the Akita Prefecture.

5) The name of the Yoshino Formation was first given by Y. Funayama, and it was also used by Minakawa in his paper [S. MINAKAWA, *Bull. Yamagata Univ.* (*Nat. Sc.*), **4** (1957), 244.], but there may be some difference between them.

flow composed of a trachytic andesite. Such a geological feature is confirmed near the hill behind the temple of Sanpō'oka and on the hill-side close to Shimo-higashiyama. The sediments of these places are brecciated tuff and black shale on the hill of Sanpō'oka, but black shale only in the vicinity of Shimo-higashiyama. In the latter case, trachytic andesite interfingers with shale bed in which *Propaemusium tateiwai*, *Sagarites* sp. and small fragments of echinoid are abundantly contained.

The lava flow mentioned above were probably displaced downwards by a fault against the alternate beds of shale and tuff near Shimo-higashiyama.

The plagioliparite and trachytic andesite with the same mode of occurrence extend further west or south, namely from here to the eastern margin of the Yamagata Basin, the Mamigasaki-gawa and the upper course of the Takase-gawa (Fig. 4). They are sometimes composed only of trachytic andesite. As is shown at several places, such as Nakazato, Kiridome, Fukazawa-fudō, Yanbe, Sōzuki and Namekawa or elsewhere, they are frequently underlain and inserted by tuff and shale beds which are sometimes characterized by the presence of *Propaemusium* and *Sagarites*, being more than 300 m. in the thickest part. It is furthermore confirmed that there are some remnants of tuffaceous or shaly sediments on the hill of trachytic andesite between Nakazato and Ōoka-yama. The plagioliparite and trachytic andesite here are likely to have successively or simultaneously been extruded, and some of these pass laterally or vertically into one another.

In the same way, plagioliparite of Chitose-yama and Saruoka-yama rests upon the green tuff beds, and its lava flow is estimated to be 300 m. or thereabouts in thickness. The same mode of occurrence may be said to be true of the dacite flow extending from Togami-yama to Iwanami and Kami-sakurada. Such an occurrence is equally indicated by the plagioliparite flows of Nomioka-yama, Takahata-yama, Sarukuramori-yama and Kayadaira, where the lava flows overlie the alternate beds of brecciated tuff, conglomeratic tuff, hard shale, sandstone, etc. Of these, the plagioliparite of Nomioka-yama contains occasionally many fragments of black shale. It seems to have a synclinal structure and the maximum thickness of about 300 m. The rock extends further south beyond the Miya-kawa and Kayadaira-gawa, resting on green tuff beds and being highly cliffed here and there. Its exposure is found in a possible connection with several dykes of plagioliparite and trachytic andesite which can be seen along the route between Shōbu and the Fubira Mine.

Very complicated modes of occurrence are revealed by plagioliparite, perlite, trachytic andesite and common andesite exposed repeatedly on the hilly land including Murakizawa, Nishi-yamagata, Motozawa, Yamamoto and Kaminoyama, The most remarkable extrusive of this area is plagioliparite associated frequently with perlite (Fig. 3), trachytic andesite and common andesite. The stratigraphical relationship between them is not exactly determined, but they are likely to be inserted in the Sugarita Formation and the upper horizon of the Yoshino Formation, as is suggested by many examples of Hōhōiwa, Mujinamori, Yamamoto, Matsumori-yama, Futatsumori-yama, Daihira-yama and Kyōzuka-yama near Kaminoyama. Minakawa[6] believes that plagioliparite begins to appear at the uppermost part of the Yoshino Formation. He also confirmed the occurrence of two plagioliparite flows in the Sugarita Formation distributed at such type localiteis as the tributaries of the Motozawa-gawa situated to the south of Sugarita and on the route between Sugarita and Kaminoyama or Sugarita and Uchiyama. Besides them, a noticeable geological feature here is the frequency of bentonite deposits in green tuff beds which are sometimes associated with the lava flows of banded plagioliparite. These deposits can be examined at Kakumaba and Motoyashiki as well as along the bus road between Yuta and Sugarita, but it is still uncertain whether there are stratigraphical connections between them. Plagioliparite and perlite are mostly found together, showing a gradual transition from one to another. Such a tendency is well investigated along the cutting near Matsumori-yama. The similar occurrence is known on a small hill rising at the south of Urushibō and the bottom of the valley behind Umegataira-yama or others. They extend north-northeastwards, although some complicated structure is revealed in the area including Takatori-yama, Nitazawa, Uchiyama and Umegataira-yama where plagioliparite, perlite and trachytic andesite are found together with andesite. In this case, the ocurrence of several andesite flows is known on the route which passes through Takatori-yama and Sugarita.

The trachytic andesite of Togami-yama and its neighbourhood is, however, isolated from the exposures of banded plagioliparite and perlite mentioned above, but it seems to have a close relationship to the extrusion of trachytic andesite exposed largely on the hills between the Tachiya-gawa and the Mamigasaki-gawa.

6) S. MINAKAWA, *Bull. Yamagata Univ.* (*Nat. Sc.*), **4** (1957), 245.

As can be inferred from the facts already stated, it is very worth noting that the accurrence of lava flows of plagioliparite, perlite, trachytic andesite, dacite and andesite is always confined to the lower half of the Yamadera Formation, the upper or lower horizon of the Sugarita Formation and the upper-most part of the Yoshino Formation. They are, on the other hand, absent at the uppermost horizon of the Yamadera Formation with some fossil brachiopods such as *Terebratalia pacifica*, *Terebratalia tenuis* and *Terebratulina crossei*[7].

Lithological Characters

Plagioliparite and its associated extrusives are classified as follow, viz., biotite plagioliparite, hornblende biotite plagioliparite, hornblende plagioliparite, biotite perlite, hornblende perlite, trachytic andesite, two-pyroxene hornblende dacite and two-pyroxene andesite.

(1) Plagioliparite:—Biotite plagioliparite is predominantly exposed as compared with other extrusives, being composed of two varieties with or without a banded structure. The occurrence of non-banded variety is well known along the Kuratsu-gawa, Tachiya-gawa, Takase-gawa, Mamigasaki-gawa and their tributaries. It is also seen in the area which includes Chitose-yama, Saruoka-yama, Nomioka-yama, Takahata-yama, Sarukuramori-yama, Kaneyama, Ōmizusawa-yama, Kakumaba, Takatori-yama near Kubote and others, where columnar or platy joints are seen at many places.

It is compact and hard rock with a porphyritic texture due to the presence of quartz, plagioclase, biotite and hornblende phenocrysts, having a dark grey color in fresh specimens and a grey color when decomposed. Some of it is characterized by the frequency of large phenocrystic quartz. Such a kind of rock is commonly to be observed on the hill behind Kirihata and at the opposite side of Bōbara beyond the Mamigasaki-gawa as well as along the Hanokizawa and near Kaminukitsu. Sometimes, the specimens are rich in small quartz phenocrysts, but they are almost free of them in other cases, as is indicated by the examples which can be observed at the entrance of the Nino-sawa traversed by the Senzan Railway Line or elsewhere. Besides these, there is silicified and partly kaolinized plagioliparite on Chitose-yama, where

7) The Similar fossil brachiopods are also contained in the tuffaceous sandstone exposed along the valley between Takatori-yama and Ōmori-yama. This uppermost horizon of the Sugarita Formation is, however, not free of the lava flows composed of plagioliparite and andesite.

the clay deposite are now being used for the porcelain industry of Hirashimizu. Moreover, the occurrence of brecciated plagioliparite is known at the southern foot of Nomioka-yama. It contains many fragments of granodiorite, propylite and black shale.

When non-banded biotite plagioliparite takes a dyke-form, the rock is frequently impregnated by pyrite and is stained by iron oxicides. In another case, it is thinly incrusted with thulite and dendrite, which are occasionally noticed on the cutting of a road opened recently at the southern side of the Tachiya-gawa.

Banded biotite plagioliparite is, on the other hand, a common extrusive at the southwestern part of this district, its occurrence being always restricted to the area of the Sugarita Formation and the upper horizon of the Yoshino Formation. The good exposures are known on Matsumori-yama, Shiro-yama near Hasedō, Umegataira-yama, Daihira-yama, Futatsumori-yama and Kyōzuka-yama as well as at Kakumaba, Uchiyama, Mujinamori and Motoyashiki. Among them, the most remarkable examples are represented by those of Daihira-yama, Futatsumori-yama, Kyōzuka-yama and the ridge along the Motozawa-gawa. In these cases, biotite plagioliparite of Daihira-yama and Futatsumori-yama pass frequently into hornblende-bearing variety.

The rock has a light reddish brown or grey color and reveals distinctly or indistinctly a banded structure in all cases, passing into the ordinary biotite plagioliparite and biotite perlite. When such a plagioliparite shows a remarkable banded structure and is subjected to weathering, it resembles frequently stratified sediments and breaks easily into platy fragments as is the case of Motoyashiki or elsewhere. The columnar joint is almost absent except that of Kyōzuka-yama. Generally, it is a hard rock which is sometimes represented by a porous type whose cavities are occasionally filled up by chalcedony. An example of brecciated biotite plagioliparite is also observable along the bus road near Motoyashiki, and the specimens encrusted with thulite or psilomelane are obtained from the valley behind Umegataira-yama.

Hornblende plagioliparite is found in a small extent as compared with biotite plagioliparite. It is exposed on the ridge extending northeastwards along the Ōishi-zawa near Yamadera, Daihira-yama, Futatsumori-yama and at the entrance of the valley between Suge and Kuromori of Yamamoto. In such cases, the first one has a grey color and contains large quartz phenocrysts and hard shale fragments, whereas the last three are compact and light reddish brown or light grey rocks.

Plagioliparite consists of quartz, orthoclase, plagioclase, biotite, hornblende, augite, magnetite, ilmenite, zircon, apatite, hypersthene, chlorite, pyrite, sericite, limonite, kaolinite, goethite and leucoxene (Fig. 6). The frequency of these minerals reveals a wide range of variation in the different specimens, and the rock is commonly rich in phenocrystic minerals.

Among them, the commonest ingredient is quartz which is found as a phenocryst and a component in the groundmass. Sometimes, its phenocrysts are abundantly present as compared with those of plagioclase, taking a rounded or angular form and being occasionally corroded by the groundmass. The occurrence of well-defined bipyramidal crystal, 4–5 mm. in diameter, is known in the specimen from the Hanoki-zawa and the cutting of truck road between Akayama and Kaneyama-tōge where it is obtained in dyke traversing granodiorite or green tuff. Most of it contain liquid inclusions and minute crystals of magnetite, zircon and chlorite.

Moreover, it is surrounded by a narrow fringe of plagioclase, quartz and sericite as well as of chalcedony and limonite. When such a fringe is composed of plagioclase and quartz, it constructs a spherulitic aggregate or micrographic intergrowth. The phenocrystic quartz ranges mostly from 0.5 mm. to 1.5 mm. in diameter. In the groundmass, this mineral occurs as very small grains with an irregular or rounded form and is intermixed with ill-defined orthoclase and plagioclase crystals.

Plagioclase is also an important ingredient. The phenocrystic plagioclase is very frequently to be seen in the writer's specimens except those obtained from the upper course of the Mamigasaki-gawa and the hill situated at the south of Nukizu-numa. It is oligoclase or andesine with a composition of An_{14-42} and has a rectangular tabular form, 3.48 mm. long and 1.36 mm. across in the largest crystal. Such phenocrysts are usually euhedral or subhedral and almost free of the zonal structure or turbid zone. The crystals are occasionally invaded by the groundmass and are surrounded by a fringe composed of minute quartz and plagioclase grains. They are often subjected to sericitization or kaolinization and to zeolitization in other cases. The plagioclase of the groundmass is oligoclase and is generally represented by ill-defined crystals. In some cases, however, lath-shaped crystals, 0.08 mm.–0.2 mm. long, are also found together.

The occurrence of biotite and hornblende is restricted to a small extent when compared with that of quartz or plagioclase. So far as is known at present, these two minerals are recognized only as phenocrysts in thin sections and are sometimes contained together in the same specimens. In these cases, biotite takes a tabular form, 1.98 mm. in the maximum diameter of its base and 0.57 mm. in the maximum thickness. It is strongly pleochroic from light brown to light yellow (X) to dark yellowish brown (Y or Z), and some of it encloses magnetite crystals. The index of refraction (γ) is 1.674–1.686, but 1.681–1.683 in banded varieties. This mineral is frequently seen in the specimens collected from the northwestern branch of Takatori-yama, Daihira-yama, Futatsu-mori-yama and the trails between Sumiga-hashi and Tozawa-bashi of the Takase-gawa as well as between Uchiyama and Marumori.

The frequency of hornblende is lower than biotite, and the crystal has a prismatic habit, being characterized by the following pleochroic scheme, viz., X=light yellow, Y=yellowish green or brown, Z=green or dark greenish brown. The absorption is $Z>Y>X$. The indices of refraction are as follows; N_1=1.665–1.669, N_2=1.679–1.682 on (110). The largest one is 0.97 mm. long and 0.34 mm. across. The extinction angle, $Z \wedge c$, is 17°–18°. When it has a zonal structure, its outer part reveals a smaller extinction angle.

Augite is a rare ingredient with a stout prismatic habit and can be seen in the specimens from the eastern hill-side of the Yamadera Highway and the Ōishi-zawa or elsewhere. It is 0.62 mm. long and 0.25 mm. across in the largest crystal, passing partly into bowlingite. Its extinction angle, $Z \wedge c$, is 40°(±). Besides the example mentioned above, the writer observed some chloritized augite with original crystal forms in the specimens from the Ōishi-zawa.

Magnetite has an octahedral or skeletal form and is scarcely present in almost all specimens. Its crystal is generally very small, and even the largest one does not go beyond 0.05 mm. in diameter.

One of minor ingredients is a pink or colorless zircon which is sometimes overlooked in thin sections. The writer extracted this mineral from crushed specimens by using Thoulet solution (Fig. 13). These two kinds of zircon are contained together, but the colorless variety is mostly absent.

In many specimens, there are several types of crystal characterized by simple or complicated combinations of (100), (111); (110), (111); (110), (111), (311), etc. The commonest form is, however, a combination of (100) and (111) or (110) and (111). They are composed of long or short prismatic crystals, the former being occasionally corroded to a crub-like form with an irregular outline. Such crystals are commonly rich in microlites which have unknown characters. In general, the frequency of zircon crystals seems to be high in the specimens from dykes and lava flows except those of banded plagioliparite. It is, however, noticed that this mineral is almost or entirely absent in some specimens obtained from the western hill of Narasawa, the upper course of the Takase-gawa, the lowermost course of the Happō-zawa and at both the sides of the Motozawa-gawa 500 m. or more east-northeastwards from the bus station of Kakumaba as well as on the ridge between Takatori-yama and Kyōzuka-yama or elsewhere.

Apatite and hypersthene are always negligible minerals. The former is usually colorless, but obtains a brown color when decomposed. The crystal is 0.17 mm. long and 0.03 mm. across in the largest one and occurs in the specimens from the Ōishi-zawa and Chitose-yama. The latter was examined only on the minute crystals extracted from crushed specimens as in the case of zircon. The largest prismatic crystals thus separated are 0.26 mm. or thereabouts in length and are strongly pleochroic from yellow (X) to brownish yellow (Y) or greyish green (Z). This mineral is rarely found in the specimens collected on the hill situated at the south of Nukitsu-numa and the railway cutting between Yamadera and Takase as well as at the junction of the To-zawa and its tributary. Similarly, ilmenite shows very low frequency and is examined only in several specimens. Minute crystals of magnetite are scattered in the groundmass. In this case, it has an octahedral or irregular form which is less than 0.15 mm. in diameter.

Chalcedony or agate(?) fill up generally small cavities in the groundmass and constructs a fringe around plagioclase phenocrysts, affording a characteristic feature to this rock under the microscope. Chlorite is an unimportant alteration product derived from biotite or other ferromagnesian minerals. Some of it is intermixed with quartz and plagioclase in the groundmass. When biotite is chloritized, leucoxene is commonly formed together.

The scaly or flaky sericite is also noteworthy mineral in altered specimens, replacing plagioclase phenocrysts and feldspathic parts of the groundmass. It is 0.2 mm. in the maximum diameter and is extremely abundant, when associated with pyrite which has generally a cubic form and is 0.6 mm. across in the largest crystal.

Moreover, irregular spots or veinlets of limonite are always predominant in the decomposed groundmass, where some of them occur together with chlorite and surround quartz or plagioclase phenocrysts.

Partly, they are supposed to have been derived from pyrite and pass into goethite with a transition stage between them.

The groundmass is constructed by quartz, orthoclase, oligoclase, magnetite, zircon, apatite, hypersthene and several alteration products. It is characterized by a microgranitic texture and reveals frequently a a spherulitic structure. The granular aggregate of quartz, orthoclase and oligoclase is, however, complicated occasionally by the frequent occurrence of small lath-shaped oligoclase crystals. Such a groundmass is entirely free of glassy substance except the case of brecciated varieties from the Ōishi-zawa.

(2) Perlite:—Biotite perlite passes mostly into banded biotite plagioliparite, as is indicated by the exposures on the cutting of truck road opened at the southern foot of Matsumori-yama, Shiro-yama behind Hasedo, two isolated hills about 200 m. southeast of Urushibō, Hōhō-iwa and its vicinity (Fig. 3) as well as on the trail behind Umegataira-yama and others. It has a black color and glassy luster, but obtains a greenish grey or grey or white color in decomposition. The soil derived from this rock exhibits commonly a grey or dark grey color. Among them, those of Matsumori-yama and two small hills near Urushibo as well as of Hōhō-iwa and Sugarita are largely exposed, being partly represented by a porphyritic variety which contains plagioclase and biotite phenocrysts.

At the southern foot of Matsumori-yama, perlite is sometimes rich in irregular cavities with or without the filling substance composed of chalcedony. Besides it, some banded structure is to be seen on the cutting of the hill between Yuta and Urushibō, where it is characterized by the presence of hard brown streaks with quartz phenocrysts and spherulites. There is also a large area where hornblende perlite is well exposed along the valley entering southwestwards from Niōtō-bashi of Kakumaba.

Exclusive of glassy substance, perlite contains quartz, plagioclase, biotite and hornblende in association with magnetite, ilmenite, chalcedony, agate(?), zircon, allanite and hypersthene. They are remarkably increased and decreased in different specimens, and the phenocrystic minerals are restricted to quartz, plagioclase, biotite and hornblende.

Even quartz is changeable in its frequency and is wholly absent in some cases. As is indicated by plagioliparite, the quartz phenocryst is not infrequently affected by the magmatic corrosion and is irregularly invaded by the groundmass. Some of the crystals are remarkably rounded, whereas others are subangular or angular, the largest phenocryst being 2 mm. in diameter. In the chalcedonic part, it is surrounded by a narrow zone of chalcedony and agate(?). Besides these, the sharp hexagonal section is rarely seen. Magnetite, zircon and biotite are included in some of these crystals.

Plagioclase is euhedral or subhedral and occurs in less frequency. It ranges from albite to oligoclase which vary from An_{10} to An_{19} in its composition and reveals a fresh appearance. The crystal is occasionally zoned and includes apatite, magnetite and biotite, being invaded by calcite vein and brown glass.

As a phenocrystic mineral, the platy biotite is less abundant. It lacks in the specimens from the cutting of the truck road between Yuta and Urushibō as well as from that of Shinden. The mineral is pleochroic from yellow (X) to dark brown (Y and Z), and the index of refraction (γ) is 1.683. Its remarkable occurrence is known in the perlite exposed at Hōhō-iwa and near Niōtō-bashi of Kakumaba. In the former case, it is complicatedly branched at the end of crystal which is 1.53 mm. in the maximum length.

Hornblende occurs in the specimens collected from the valley entering southwestwards from Niōtō-bashi. This mineral is occasionally contained strikingly together with biotite. It has a green color and such a pleochroic scheme as light yellow (X), yellowish green (Y) and green (Z). The extinction angle, $Z\wedge c$, is 17°, and the largest crystal is 0.8 mm. long and 0.22 mm. across.

Magnetite has an octahedral or irregular form and is scattered as a single crystal or aggregate. It is 0.2 mm. even in the largest crystal and occurs in a minor amount except the specimen from Shiro-yama near Hasedō. Ilmenite is almost absent, but is noticeably present in the perlite flows cropping out on the cutting near Shinden and traversing the trail situated about 1 km. west of the Hinokizawa-yama.

Allanite is a rare mineral which is found as stout prismatic crystals in the specimens from the southern flank or Futatsumori-yama. In this case, its well-defined crystal is strongly pheochroic from dark brown (X) to dark reddish brown (Y) or light brown (Z).

Pink zircon is a negligible ingredient and takes a stout or long prismatic habit. Chalcedony and agate(?) are associated together in the perlite flow on the cutting of the truck road between Yuta and Urushibō. The perlite here is partly rich in druses filled up with chalcedony and agate(?). The similar feature can be seen in the perlite flow of

Shinden. Moreover, hypersthene has the same frequency as zircon and is so scarce as to be overlooked in thin sections.

The most important feature of this rock is the predominance of the perlitic structure (Figs. 7–8), and it is noteworthy that the perlite exposed on the cutting mentioned above is filled with the swarms of trichites (Fig. 8) or microlites. The latter is also contained in the specimen of Shinden.

(3) Trachytic andesite:—The rock is very commonly exposed in the area between the Tachiya-gawa and Mamigasaki-gawa as well as at Jagaramogara of Nukitsu. In the southwestern district adjacent to the Yamagata Basin, however, it is almost absent except those of Togami-yama, Takatori-yama near Matsumori-yama, Ōmori-yama behind Urushibō and Kyōzuka-yama. The exposures of these localities are somewhat different from place to place in their lithological characters, constructing some columnar joints here and there on the cutting of the Senzan Railway Line between Tateyama and Yamadera as well as along the Mamigasaki-gawa near Sakazuki-yama and on Kyōzuka-yama or elsewhere.

Trachytic andesite reveals a gradual transition to plagioliparite. It is mostly porphyritic in texture, and its appearance resembles common andesite to some extent in fresh specimens. There are also nonporphyritic or slightly porphyritic varieties looking like tuff or shale in alteration, as can be examined on the ridge behind Shimo-higashiyama. The rock mentioned above is black grey in fresh specimens, but gets generally a grey or greyish white color when decomposed. When disseminated pyrite crystals are present, it is stained by brown oxidation products.

The mineral components are plagioclase, orthoclase, quartz, biotite, magnetite, zircon, apatite, hypersthene, chlorite, sericite, goethite, limonite, calcite, and leucoxene (Figs. 9, 10). In this case, the phenocrystic mineral is restricted to a rectangular or lath-shaped plagioclase which is represented by oligoclase or andesine with a composition of An_{16-47}. The amount of the phenocrystic plagioclase varies at different places, and there are some specimens quite devoid of it. The crystal is commonly euhedral or subhedral and lacks frequently the zonal structure, being 3.4 mm. long and 2.38 mm. in the largest one. Generally, it has a fresh appearance, but is occasionally sericitized and chloritized. Moreover, some of this mineral is kaolinized and limonitized. The enclosures are magnetite and apatite.

In the groundmass, plagioclase occurs as irregular of lath-shaped crystals, being intermixed with quartz grains and other minor ingredients. The frequency of these two types of crystal is variable in the writer's specimens. The minute lath-shaped crystals are extremely abundant in the specimens from Yanbe, Sakazuki-yama and Togami-yama near Monden. They are represented by oligoclase showing a fluidal arrangement, and most of them are 0.08 mm.–0.17 mm. in length. The rock rich in such oligoclase crystals is believed to be exposed very widely on the hills extending from the Tachiya-gawa to the Mamigasaki-gawa.

Quartz is found only in the groundmass together with orthoclase and plagioclase, but is entirely absent in the specimens mentioned above. It is hardly distinguishable from feldspar. Orthoclase is quite free of phenocryst. It is sometimes a common ingredient in the groundmass where it is not infrequently sericitized. In the same way, magnetite, ilmenite, biotite, zircon, hornblende, apatite, hypersthene are contained in the groundmass, although they are always low in frequency as compared with other ingredients.

Among them, magnetite is the most noticeable mineral with an octahedral habit or irregular form. In general, its diameter is less than 0.02 mm., and even the largest skeleton crystal is estimated to be 0.85 mm. in longer diameter. The frequent occurrence of ilmenite is known only in the specimens from the eastern or southern foot of small hill (283.1 m.) south to Togami-yama, This mineral is characterized by a hexagonal tabular form and jet-black color. The occurrence of minute biotite flakes is restricted to the rock characterized by the fluidal arrangement of oligoclase laths. They are pleochroic from light yellow (X) to dark yellowish brown (Y, Z) and chlorite is supposed to have derived from them.

Zircon is, on the other hand, a scanty ingredient which has a color and crystal form resembling those of plagioliparite. It is negligible or absent in most specimens. Hypersthene and hornblende are also present scarcely in the writer's specimens. The former is noticed in the specimens from the area including Nakazato, Ōoka-yama and Sanpō'oka, being generally indicated by well-defined prismatic crystals, whereas the latter is to be seen in those collected from Motoyashiki and the northern foot of Ōmori-yama near Urushibō. In these cases, hornblende has a subhedral form and green color. It is pleochroic from light yellow (X) to yellowish green (Y) or green (Z), and its maximum length is 0.74 mm.

Besides them, sericite and calcite are derived from ferro-magnesian minerals and feldspars together with limonite and leucoxene.

The groundmass of this rock consists of above-mentioned ingredients of which oligoclase and quartz are predominant as in the case of plagio-liparite. The texture is mostly microgranitic, but obtains some trachytic texture when quartz and orthoclase are gradually replaced by the swarms of lath-shaped oligoclase.

(4) Dacite:—As has already been stated, two-pyroxene hornblende dacite spreads over the area including Togami-yama, Onigoe, Iwanami and Sakurada at the northwestern end of the Ryū-zan Volcano. Some good exposures can be seen on the cutting near the bus station and the adjacent stream bed, exhibiting an indistinct joint structure. The fresh specimen has a black color and compact groundmass in which corroded quartz phenocrysts, 2–4 mm. across are embedded together with phenocrystic plagioclase, hornblende, augite and hypersthene.

The microscopical examination shows that this rock contains quartz, plagioclase, augite, hypersthene, hornblende, magnetite, tridymite, chrorite, limonite and glass (Fig. 11). They are found as phenocrysts and ingredients in the groundmass.

The phenocrystic plagioclase ranges from andesine to labradorite with a composition of An_{47-60}, and the indices of refraction are higher in the specimens from Togami-yama. The crystal is mostly euhedral or subhedral, indicating a rectangular or tabular form and a distinct zonal structure. It has generally a clear appearance, but is sometimes turbid to various extents. In the latter case, such a turbid part is always fringed by a narrow clear zone without any enclosure. Some of it is characterized by the invasion of the groundmass or brown glass and results in the formation of a worm-eaten structure. The largest one is 5.44 mm. long and 3.06 mm. across. Lath-shaped crystals, 0.08 mm.–0.25 mm. in length, are very abundantly present in the groundmass where they are characterized by a fluidal arrangement.

Quartz reveals a low frequency as compared with that of plagioclase and has a round or angular form. It contains liquid inclusions and magnetite crystals, some of it being subjected to the magmatic corrosion. The phenocrystic augite, subhedral or anhedral, occurs in a smaller amount. It is sometimes lower than hypersthene in its frequency and lacks entirely in the dacite exposed on the hill beyond Kamisakurada. Occasionally, the crystal twins on (100), and its extinction angle, $Z \wedge c$, 40°(±). When it is zoned together with hypersthene, the latter is always surrounded by the former. The occurrence of hypersthene is almost restricted to phenocryst. It can be seen in the specimens from the western foot of Togami-yama and its southern hill behind Kami-sakurada, but is unknown in those of Iwanami. This euhedral or sub-hedral mineral has a long prismatic habit and includes some magnetite crystals. The largest crystal is 1.44 mm. long and 0.25 mm. across.

Green hornblende is a common ingredient with a long prismatic habit. It is strongly pleochroic from light yellow (X) to yellowish green (Y) or green (Z). The absorption is $X<Y<Z$. The largest crystal is 1.19 mm. long and 0.3 mm. across, and the extinction angle, $Z \wedge c$, is 17°. The periphery of crystal is frequently opacitized, and its inner part passes into the confused aggregate of magnetite and augite.

Magnetite is an important ingredient in the groundmass where it is represented by an octahedral or irregular crystal and has a diameter less than 0.08 mm. The crystal with a phenocrystic size is, however, 0.42 mm. in the maximum diameter. Besides these, glass is a remark-able ingredinet in the specimens from Iwanami, whereas tridymite is present only in the dacite of the hill behind Kami-sakurada. Moreover, chlorite and limonite are decomposition products altered from ferro-magnesian minerals.

The groundmass is mainly composed of lath-shaped plagioclase, au-gite, and magnetite together with quartz, hypersthene, tridymite and glass. It has a fluidal structure or micrograniticic textutre, being char-acterized by the presence of gabbroic xenoliths rich in plagioclase, au-gite, hypersthene and magnetite..

(5) Andesite:—Several exposures of two-pyroxene andesite are found along the trail between the entrance of the Taiko-zawa near Su-garita and Uchiyama as well as between Nitazawa and Takatori-yama. They are characterized by the frequency of joints intersecting at right angle. It is a porphyritic and compact rock with a black or dark grey color in the specimens undecomposed.

The rock is made up of plagioclase, augite, hypersthene, magnetite, apatite and calcite (Fig. 12). Phenocrystic plagioclase has a tabular or rectangular habit and is euhedral or subhedral, being noticed with a fresh appearance and the absence of turbid zones. The indices of re-fraction suggest that this phenocryst ranges from labradorite to bytow-nite with a composition of An_{62-78}.

The crystal is sometimes free of the zonal structure, but it is well zoned in other cases. Some of it is invaded by the groundmass, and a worm-eaten structure is thus formed. Its enclosures are magnetite or augite, and the largest crystal is 2.18 mm. long and 1.28 mm. across.

In the groundmass, lath-shaped or rectangular plagioclase is a main ingredient, and it is generally 0.05 mm–0.3 mm. in length.

The phenocrystic augite is always low in its frequency. The subhedral or anhedral crystal of this mineral is 1.24 mm. long and 0.51 mm. across in the largest one. Magnetite is enclosed in such a crystal. Moreover, long or stout prismatic crystal, 0.02 mm–0.08 mm. in length, is, on the other hand, predominant in the groundmass.

Similarly, the long prismatic hypersthene is a scanty phenocryst which is occasionally surrounded by the aggregate of minute augite crystals. Magnetite has an octahedral or ill-defined form, 0.02 mm.–0.05 mm. in its general diameter and 0.35 mm. across in the maximum case. Calcite is a secondary mineral filling up the interstices of other ingredients and is abundantly found in the decomposed part.

The groundmass reveals a pilotaxitic texture, consisting of plagioclase, augite and magnetite as well as hypersthene, and interstitial calcite.

Frequency of Zircon and Its Geological Significance

Zircon reveals a remarkable varirtion of its frequency in plagioliparite and associated extrusives of this district. It is generally found abundantly in plagioliparite as compared with perlite, but seems to be almost or entirely absent in trachytic andesite, dacite and andesite Such a tendency was confirmed by extracting mechanically zircon crystals from the above-mentioned extrusives. For this purpose, 109 specimens of these rocks were crushed, and zircon crystals were carefully separated from each eight grams of crushed specimens by using Thoulet solution. The crystals thus obtained were crystallographically examined and classified into several types of combination. They are separately counted for each specimen to compare their frequency one to another, including ill-defined crystals which are strikingly contained in some specimens.

So far as is known in well-defined crystals, such types of combination as (100), (111); (110), (111) and (110), (111), (311) are more predominant than others. Among them the first two are most abundant in the specimens collected from the dykes of plagioliparite, whereas the last one seems to be present very commonly in the lava flows of the same rock which has no banded structure.

Plagioliparite shows generally a similar but high frequency of zircon crystals in most dykes and lava flows, although there are some exceptional cases which are nearly or wholly free of them. From the facts mentioned above, it is inferred that there is sometimes a difference of crystal habits of this mineral but no remarkable increase or decrease of its frequency between the dykes and lava flows of plagioliparite.

Zircon is also found frequently in perlite. Mostly, it occurs as a combination of (100) and (111) or ill-defined form. The same type of combination and others are also to be seen in trachytic andesite, but they are generally absent as is indicated by dacite and two-pyroxene andesite.

In short, its frequency is likely to depend upon the presence or absence of phenocrystic quartz, augite and hypersthene as well as of glass. If the rock contains quartz or abundant glass and is free of phenocrystic augite and hypersthene, zircon is a common accessory mineral as in the case of plagioliparite and perlite. It is, however, always absent, when phenocrystic augite and hypersthene are found together and these ferromagnesian minerals coexist with phenocrystic quartz and glass. The former is two-pyroxene andesite, and the latter is two-pyroxene hornblende dacite. Similarly, the frequency of zircon is influenced by the absence of the phenocrystic quartz, augite and hypersthene, showing that this mineral is usually lacking in trachytic andesite.

Some Considerations on Volcanic Activities

As has already been stated, the Neogene plagioliparite and associated extrusives are largely found in the Tendō-Yamagata-Kaminoyama district. They are supposed to have been extruded closely one upon the other. In these cases, some of them filled up the fissures of granitic rocks and Neogene sediments, whereas the others poured out as lava flows during the deposition of the Neogene formation.

According to the results of Minakawa's investigation[8], the occurrence of such extrusives seems to be repeated up to the upper horizon of the Hongō Formation at the north of the Sagae-gawa, but it is restricted only to the Sugarita Formation and Yamadera Formation as well as to the upper part of the Yoshino Formation in this district.

So far as is known at present, the first eruption of plagioliparite and associated extrusives is supposed to have taken place during the

8) S. MINAKAWA, *op. cit.*, 235–236.

sedimentation of the lower half of the Yamadera Formation or the upper part of the Yoshino Formation, because there is none of them at the lower horizon of the latter formation. Since that time, the extrusion of these rocks was repeated, and its evidences can be seen even at the upper half of the Sugarita Formation exposed in the southwestern area. Moreover, it happened in co-operation with the violent exprosions which resulted in the deposition of tuffaceous substance to a large extent. The frequency of such volcanic activities are shown by the alternation of lava flows and various kinds of tuff, being characterized by some intricate transitions between them from place to place.

The abundance of tuffaceous or pumiceous substance is the most noticeable feature in the Neogene sediments of this mountainous or hilly land, and it is exceedingly remarkable in the Sugarita Formation, Yamadera Formation and Yoshino Formation which are always associated closely with several kinds of extrusive. Of these, the lower half of the Yoshino Formation is usually accompanied by the dykes or lava flows of andesite, propylite and basalt. It is, therefore, distinguishable from the upper part of the Yoshino Formation, Yamadera Formation and Sugarita Formation associated with acidic or intermediate extrusives.

The influence of volcanic activities is, however, obscure in the Ōisawa Formation and Mizusawa Formation equivalent respectively to the Yoshino Formation and Sugarita Formation. Hence, it seems to have been restricted to the eastern or southwestern area where tuffaceous sediments were extensively accumulated. These types of volcanic activities may partly have a close relationship to those taken place during the deposition of the upper half of the Kaneyama Formation around the Shinjō Basin.

At to the volcanic centers, there is no evidence to confirm them, although pyroclastics and lavas are inferred to have been supplied from many places and some of their origin may be attributed to the submarine eruption. In the area now covered thickly by green tuff or

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9) The green tuff of the Yoshino Formation is frequently intercalated by hard shale or black shale at its upper horizon corresponding to a part of the Nishi-kurosawa Formation or the Onnagawa Formation. The same may be said of the Yamadera Formation. The formation rich in hard shale or black shale is widely exposed in the area including Maizuru-yama, Shimo-higashiyama, Kirihata and Ainohara at the north and Kokuzō-san, Suge, Ryū-zawa, etc. at the south. Some of its black shale are characterized by the frequent occurrence of animal or plant fossils. They are *Dentalium* cf. *yokoyamai* MAKIYAMA, *Linthia* sp., *Propaemusium tateiwai* KANEHARA, *Sagarites* sp., *Sardinia* sp., echinoid spines, fish scales, pectoral fins of pisces and plant fossils (gen. and sp. indet.).

other sediments and lava flows, it is very difficult to find out the position of sources from where volcanic products were abundantly supplied. The possible sources may, however, be suggested by the distribution of lava flows which are abnormally thickened and extensively exposed, as is shown by the exposures of Ōoka-yama and its southern extension as well as of Nomioka-yama, Kyōzuka-yama and Daihira-yama or elsewhere.

Besides these, other volcanic centers are supposable to have been located close to the Backbone Range, since many dykes of plagioliparite here traverse granitic masses and Neogene sediments. Some fissures now filled up with dykes may have once been the passages of lava flows.

Importance of Plagioliparite and Associated Extrusives as Sources of Neogene Sediments

Neogene sediments are largely exposed in this district and adjoining areas, where they extend from the Yoshino Formation or Ōisawa Formation up to the Aterazawa Formation intercalated with lignite beds. These formations are composed of various sediments represented mainly by tuff, hard shale, black shale, tuffaceous or pumiceous sandstone, non-tuffaceous sandstone and conglomerate, etc. Among them, tuff and tuffaceous sediments are very predominent, although they pass laterally or vertically into argillaceous rocks. It is also noteworthy that tuff, tuffaceous or pumiceous sandstone, non-tuffaceous sandstone and conglomerate contain generally remarkable amounts of fragments or pebbles consisting of plagioliparite and associated extrusives as well as of minerals derived from them.

As can be inferred from the geological evidences obtained by the writer, the area occupied by the green tuff formations and its base rocks seems to have partly been upheaved one after another during the sedimentation of overlying formations, resulting in a contemporaneous erosion. Several kinds of extrusives including plagioliparite and others may, therefore, be supposed to have been eroded together with green tuff and supplied the material to the younger formations. Besides fragments or pebbles of these rocks, it can be said that a part of such minerals as orthoclase, quartz, plagioclase, green or brown hornblende, biotite, augite, hypersthene, magnetite, pink zircon, etc. were probably supplied from the same sources.

Relationship between the Frequency of Volcanic Activity and the Formation of Metallic Mineral Deposits

The frequent occurrence of metallic mineral deposits is known at the eastern part of this district where granodiorite, plagioliparite, trachytic andesite, dacite, propylite and green tuff are largely exposed. These deposits are represented by quartz veins, networks and impregnations characterized by the predominance of chalcopyrite with or without bornite, covelline, chalcocite, zincblende, galena, pyrite, baryte, gold and silver. Among them, the Chiyonosawa Mine is situated on the northern or northeastern foot of Uzawa-yama (Tendō-machi), whereas the Takase Mine, Ōkubo Mine and Hōzawa Mine (Yamagata-shi) are respectively found near Nakazato and on the northern flank of Minami-omoshiro-yama as well as along several tributaries of the Mamigasaki-gawa. There are also some mines at the southeastern corner of Kaminoyama-shi. They are the Akayama Mine, Fubira Mine, Azuma Mine, Kaneyama Mine, Tōhō Mine, Ōminami Mine and Mikami Mine. The mines mentioned above are now stopped to be worked except the Akayama Mine, Ōminami and Tōhō Mine as well as the Takase Mine reopened recently along the Takase-gawa. The deposits of these mines were formed in granodiorite [Chiyonosawa Mine, Hōzawa Mine (Himesawa deposit), Fubira Mine, Azuma Mine and Ōminami Mine], trachytic andesite (Takase Mine, Akayama Mine, Kukeji Mine and Mikami Mine), propylite (Tōhō Mine and Ōminami Mine), green tuff [Hōzawa Mine (Ōshiozawa, Koshiozawa, Gandozawa and Murakizawa deposits)] and at the contact betweeen granodiorite and green tuff [Hōzawa Mine (Niiyama and Zazanosawa deposits)].

As has already been described, plagioliparite and trachytic andesite are the commonest extrusives on the hilly land or mountainous area including a part of the Backbone Range between Yamagata and Miyagi Prefectures. They are well exposed here and there as dykes or lava flows in the localities where metallic mineral deposits are distributed, and some of them are intensely subjected to the hydrothermal alteration in the mining area. Moreover, plagioliparite is always to be seen even in the vicinity of the deposits which fill up the fissures of propylite or granodiorite in the Tōhō Mine, Fubira Mine, Ōsaka Mine and Ōminami Mine. The same can be said of the veins formed at the contact between green tuff and granodiorite of the Hōzawa Mine.

From such geological features, it is inferable that the volcanic activities connected closely with the repeated extrusions of plagioliparite resulted in the formation of many metallic mineral deposits. The occurrence of plagioliparite and its relationship to the genesis of deposits are, therefore, quite identical with those of the adjacent districts represented by the northern corner of Miyauchi-machi (Kumano Mine, Shuzan Mine, Yoshino Mine, Minamizawa Mine, etc.) and the northern half of Takahata-machi (Futaezaka Mine, Takagami Mine, Kanahara Mine, Monju Mine, etc.).

Summary

(i) Plagioliparite and associated extrusives are widely distributed on the mountainous or hilly land including Tendō-machi, Yamagata-shi and Kaminoyama-shi where granitic rocks and Neogene sediments are extensively exposed.

(ii) Topographically speaking, the area composed of those extrusives has some remarkable features different from others and is characterized by the frequency of small peaks or hills with a conical form.

(iii) They are represented by biotite plagioliparite, hornblende biotite plagioliparite, biotite perlite, hornblende perlite, trachytic andesite, two-pyroxene hornblende dacite and two-pyroxene andesite. Most of them are found as lava flows, although there are various dykes of plagioliparite and trachytic andesite filling up the fissures of granodiorite and green tuff.

(iv) Among them, plagioliparite, perlite and trachytic andesite have a close connection and pass into one another. Moreover, they reveal some similarities between them concerning plagioclase no matter whether it occurs as a phenocryst or ingredient of the groundmass. The plagioclase is always albite, oligoclase and andesine.

(v) To confirm the relationship between zircon and different mother rocks, this mineral was crystallographically and optically examined in connection with its frequency. It has a pink color and several crystal forms represented by the combinations of (100), (111); (110), (111); (100), (111), (311); (100), (110), (311), (331); (100), (110), (311); (100), (101), (311) and (100), (110), (111). Of these, the combinations of (100), (111); (110), (111) and (100), (111), (311) are more commonly present than other types. So far as is known at present, the first two indicate the highest frequency in the specimens of plagioliparite obtained from many dykes, whereas the last one seems to be noticed frequently in the lava

flows of the same rock free of a banded structure.

On the whole, zircon is strikingly contained in the specimens of plagioliparite except those from lava flows with a banded structure, but decreases its frequency in perlite and is almost or entirely absent in trachytic andesite. It lacks absolutely in the case of dacite and andesite.

(vi) During the sedimentation of the Sugarita Formation and the upper half of the Yoshino Formation, the volcanic activity took place repeatedly, and these extrusive rocks were successively erupted, being accompanied by violent explosions which resulted in the deposition of such a tuffaceous sediment as green tuff.

(vii) Plagioliparite is an important rock in the area characterized by the abundance of metallic mineral deposits. It is not only distributed here, but in its neighbouring districts, where it is always sericitized intensely and is sometimes subjected to pyritization in the vicinity of deposits. These deposits are, therefore, supposable to owe their formation to repeated eruptions of plagioliparite.

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21. 山形県天童・山形・上ノ山地方の斜長石石英粗面岩及びその関係岩類に関する地質学的考察

山形大学 市 村 毅

本地域には斜長石石英粗面岩とこれに伴う真珠岩，粗面岩様安山岩，石英安山岩，安山岩とが広い範囲に亘り露出する．これ等の中，斜長石石英粗面岩，真珠岩，粗面岩様安山岩の間には，しばしば漸移的関係があり，共に曹長石，灰曹長石，叉は中性長石を斑晶として含む点に特徴が認められる．一方でかかる各種の火成岩が示す火成活動は，緑色凝灰岩の広大なる堆積を来たさせたものであり，緑色凝灰岩層中に著しく介在するそれ等の熔岩流は，緑色凝灰岩の層位的区分に役立つ様に考えられる．叉斜長石石英粗面岩と粗面岩様安山岩とは，山形市とこれに近接する地域とに多い多種多様の金属鉱床と共に見出され，これ等の間に生因上密接なる関係があることを示している．

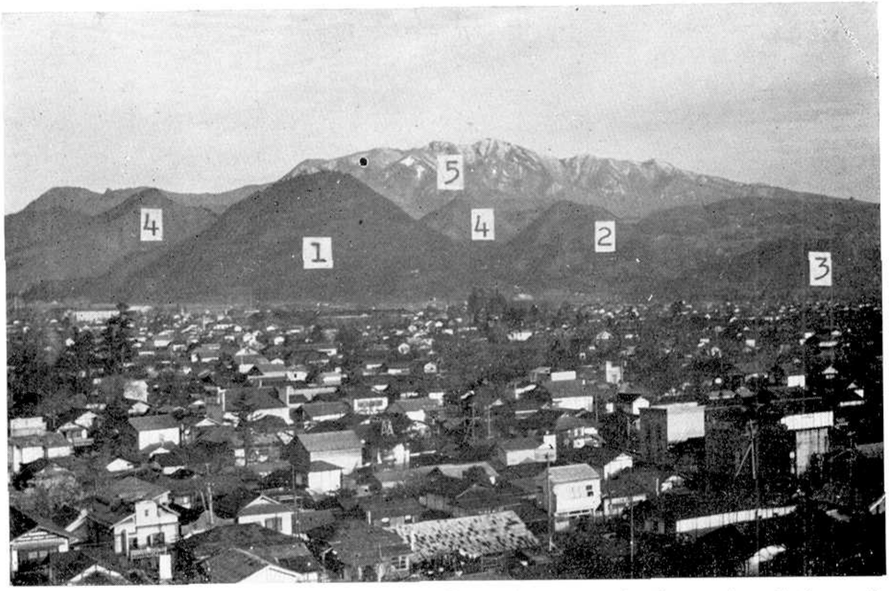

Fig. 2. Chitose-yama, Saruoka-yama, Togami-yama and others viewed from the roof of Marukyū in Yamagata City. 1=Chitose-yama (plagioliparite), 2=Saruoka-yama (plagioliparite), 3=Togami-yama (dacite), 4=Other hills composed of plagioliparite, 5=Ryūzan.

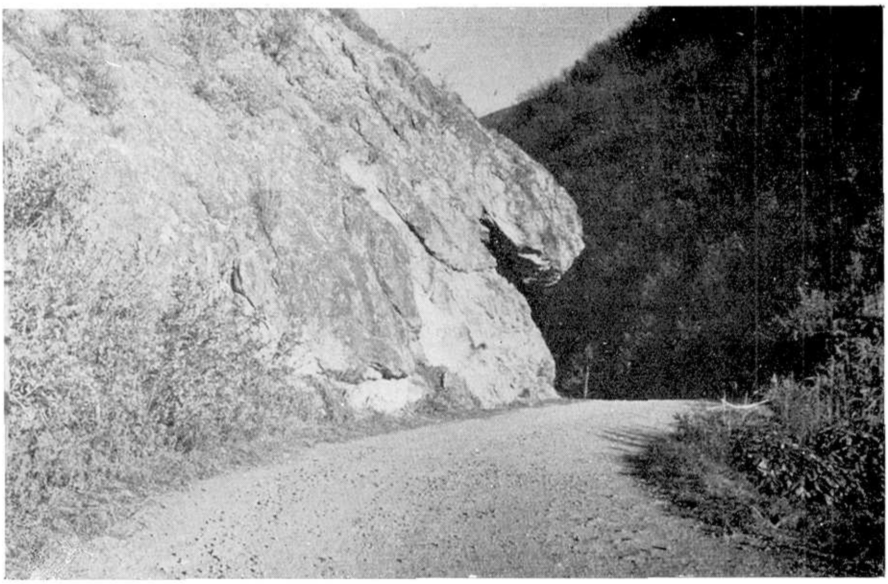

Fig. 3. Perlite exposed along the bus road between Iwanoshita and Sugarita.

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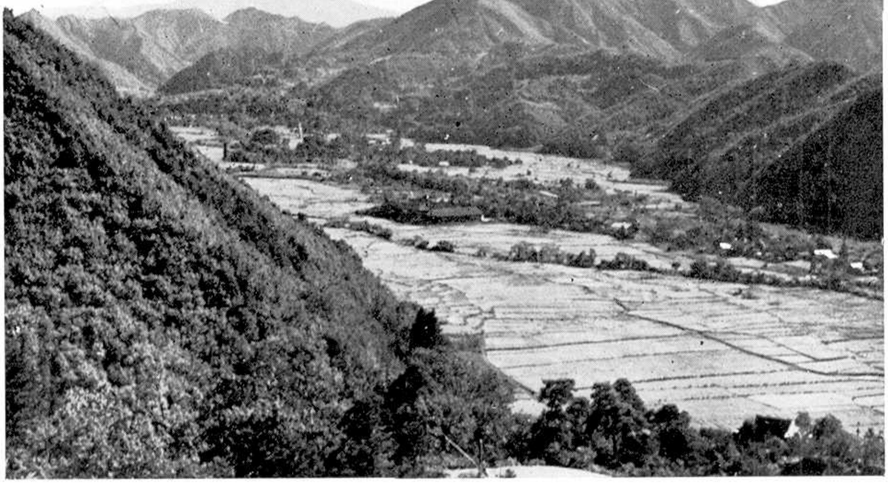

Fig. 4. Mountainous area composed largely of trachytic andesite which are well exposed at the upper course of the Takase-gawa. This picture was taken from Sanpō'oka.

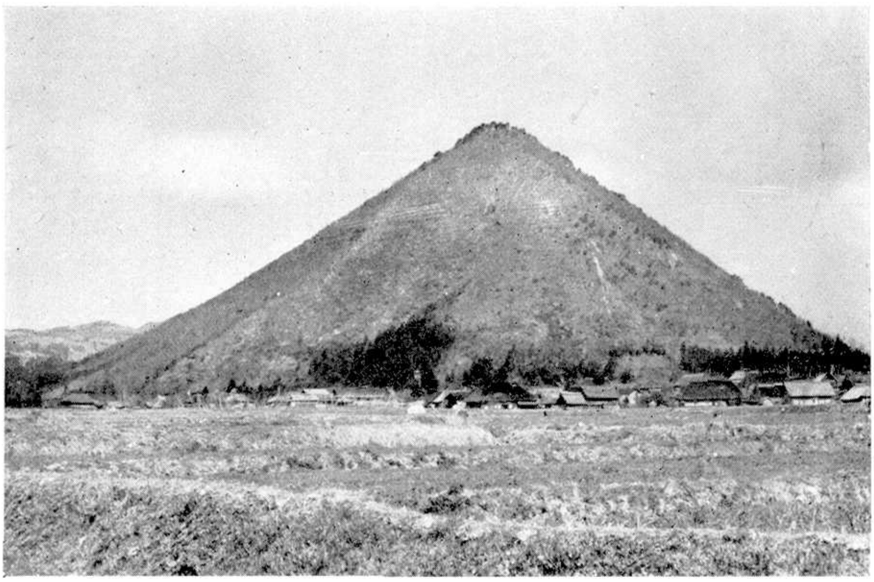

Fig. 5. Togami-yama, a small conical peak near Monden. It is built up of trachytic andesite. Such a topographical feature is very common in the area where plagioliparite, trachytic andesite and dacite are exposed.

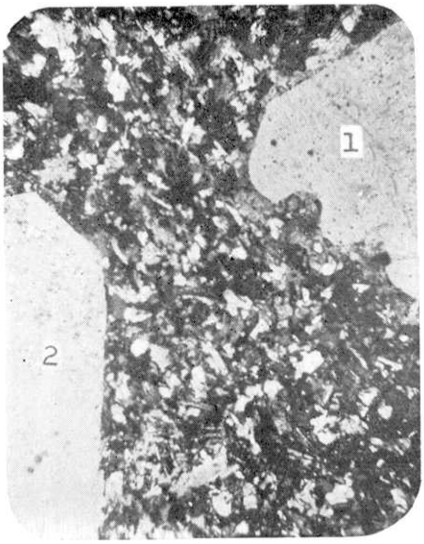

Fig. 6. Plagioliparite (The entrance of the Atera-zawa, a tributary of the Mamigasaki-gawa). 1=Quartz, 2=Plagioclase. ×100.

Fig. 7. Perlite (The cutting of the bus road between Iwanoshita and Sugarita). ×100.

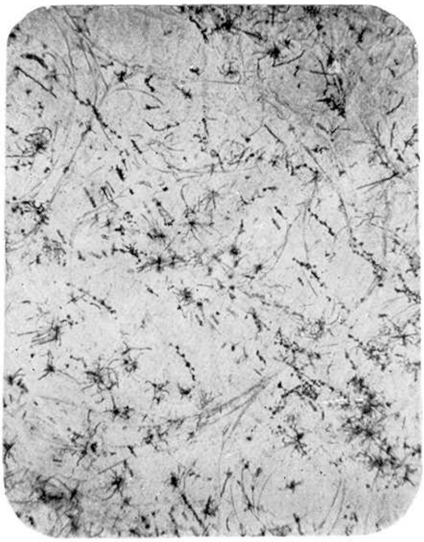

Fig. 8. Perlite with a swarm of trichite (Small hill 700 m. south from Urushibō). ×100.

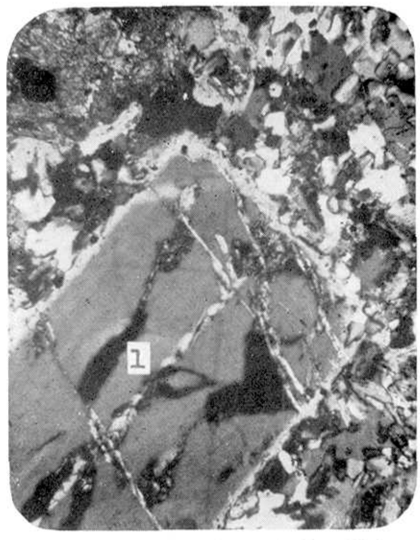

Fig. 9. Trachytic andesite (Fukazawa-fudō). The texture of groundmass resembles that of plagioliparite, but is quite free of quartz phenocrysts. 1=Plagioclase. ×100.

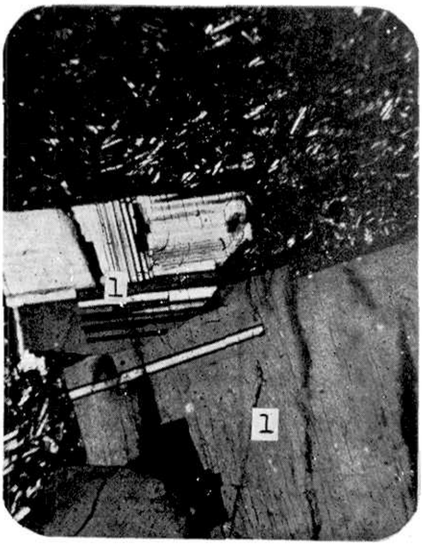

Fig. 10. Trachytic andesite (Togami-yama near Monden). The groundmass shows a trachytic texture. 1= Plagioclase. ×100.

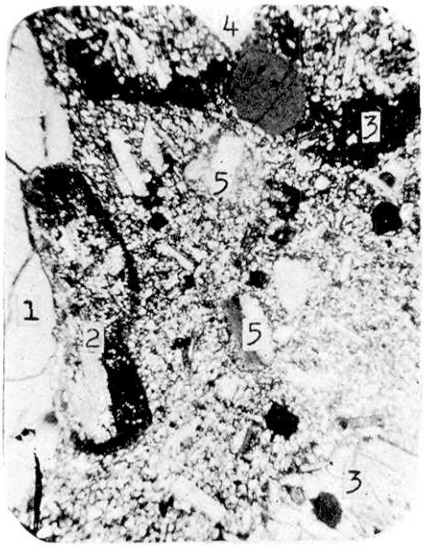

Fig. 11. Two-pyroxene hornblende dacite (Togami-yama near Iwanami). 1=Quartz, 2=Hornblende, 3=Augite, 4=Hypersthene, 5=Plagioclase. ×100.

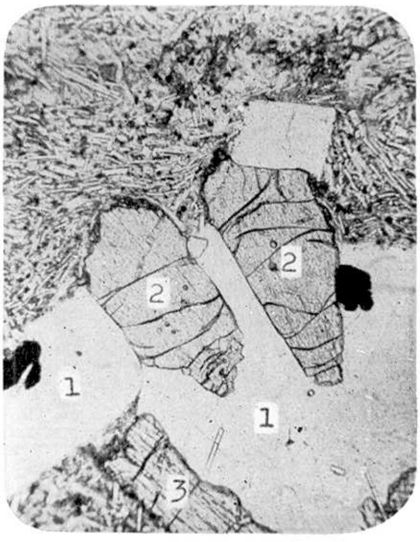

Fig. 12. Two-pyroxene andesite (Uchiyama — Nitazawa). 1 = Plagioclase, 2=Augite, 3=Hypersthene. ×100.

Fig. 13. Pink zircon (Plagioliparite exposed at the entrance of the Aterazawa, a tributary of the Momigasaki-gawa). ×100.

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