30. *Petrology of Some Lavas of Volcano Asama, Sinano Province, Japan.*

By Hiromichi TSUYA,

Earthquake Research Institute.

(Read April 17, 1933.—Received June 20, 1933.)

Introduction.

This paper presents the results of microscopical and chemical studies on some lavas of Volcano Asama.[1]

Asama, situated 36°24·5′N. and 138°31′E., on the boundary between the two provinces of Sinano[2] and Kôduké[3] in the central part of the Main Island, is one of the most active volcanoes in Japan. Its earliest recorded outburst dates back to 685 A. D. Of its many subsequent eruptions, the most violent was that which took place in August, 1783, when it poured out tremendous mud-and lava-flows, killing 1151 persons who inhabited the adjoining northeast terrane. Since Dec. 1909, its activities have culminated frequently in eruptions of a highly explosive character, but without outpourings of lava-flows. In recent years, since 1927, explosive activities of rather moderate intensity have occasionally been exhibited, the last explosion having taken place in July, 1932. The activity of this volcano last year, from June 1 to Sept. 12, is described in R. Takahasi's paper[4] relating to ground tilts observed during that period at Komoro,[5] a village at the southwest foot of the volcano. During Oct. 17–20, when the writer visited the active crater of the volcano, dense whitish vapor-clouds were issuing from the crater, which is 2000 m. in circumference with a depth of about 200 m., while through rifts in these clouds could be seen a mass of incandescent lava in the crater floor.

This volcano has been the object of study of not a few investigators, whose work however were practically confined to observations of its eruptions. As to its geology and petrology, what have been published thus far are only fragmentary. While studying the Volcano Kusatu-

1) 淺間火山. 2) 信濃國. 3) 上野國.
4) R. TAKAHASI, *Bull. Earthq. Res. Inst.*, **11** (1933), 25.
5) 小諸.

Sirane[6] on the occasion of its last activity in Oct., 1932, the writer had an opportunity of observing Asama and of examining its rocks. Unfortunately his field observations could not be extended beyond a limited area on the northeast side of the volcano, while the microscopic examination covers only six rock-specimens, of which three were collected by the late Dr. Mikio Kawamura. Since nothing like a complete systematic study, geological as well as petrological, of the volcano has yet been feasible, the writer intends here to lay the foundation for more detailed work to follow.

Morphological and Structural Outlines of Asama.

Asama, which rises 2542 m. above sea-level but no more than 1400 m. above the adjoining terranes, is a composite stratified volcano, consisting of triple conides disposed in a cone-in-cone structure. The oldest body, namely the outermost cone, of the volcano is the arcual mountains (2405–2280 m. above sea-level), Kurohuyama-Gippayama-Kengaminé,[7] occupying the western half of the volcano. They represent the outer somma of the present active cone, and is truncated at the top with a ring-wall surrounding a circular caldera about 2000 m. in diameter. This outer somma is built up of numerous layers, alternately accumulated lava-flows and agglomerates of andesitic nature, its stratiformed structure being well exposed on the steep inner slope of the ring-wall. The eastern half of the outer somma cannot be traced at present, being overlain by the central cone Mayékakéyama,[8] whose eruption-centre probably is not in the centre of the caldera, but more to the east of the latter. The crescent-shaped basin called Yunotaira[9] is the atrio between the outer somma on the west and the central cone on the east.

The central cone Mayékakéyama, which is 2521 m. above sea-level, but about 600 m. above the atrio floor, is a truncated cone with outer slopes of about 30°, representing the inner somma of the present active cone which lies in its summit-crater. The arc-shaped ridges—Mayékakéyama and Higasi (east)-mayékakéyama—which run along the west and the east margins respectively of the active cone, are the west and the east segments respectively of the crater-wall of the old summit-crater of the Mayékakéyama cone. The old summit-crater which, encircled with these ridges, must have been about 1000 m. in diameter, is now buried

6) H. TSUYA, *Bull. Earthq. Res. Inst.*, 11 (1933), 82.
7) 黒斑山——牙山——劍ヶ峯.
8) 前掛山. 9) 湯ノ平.

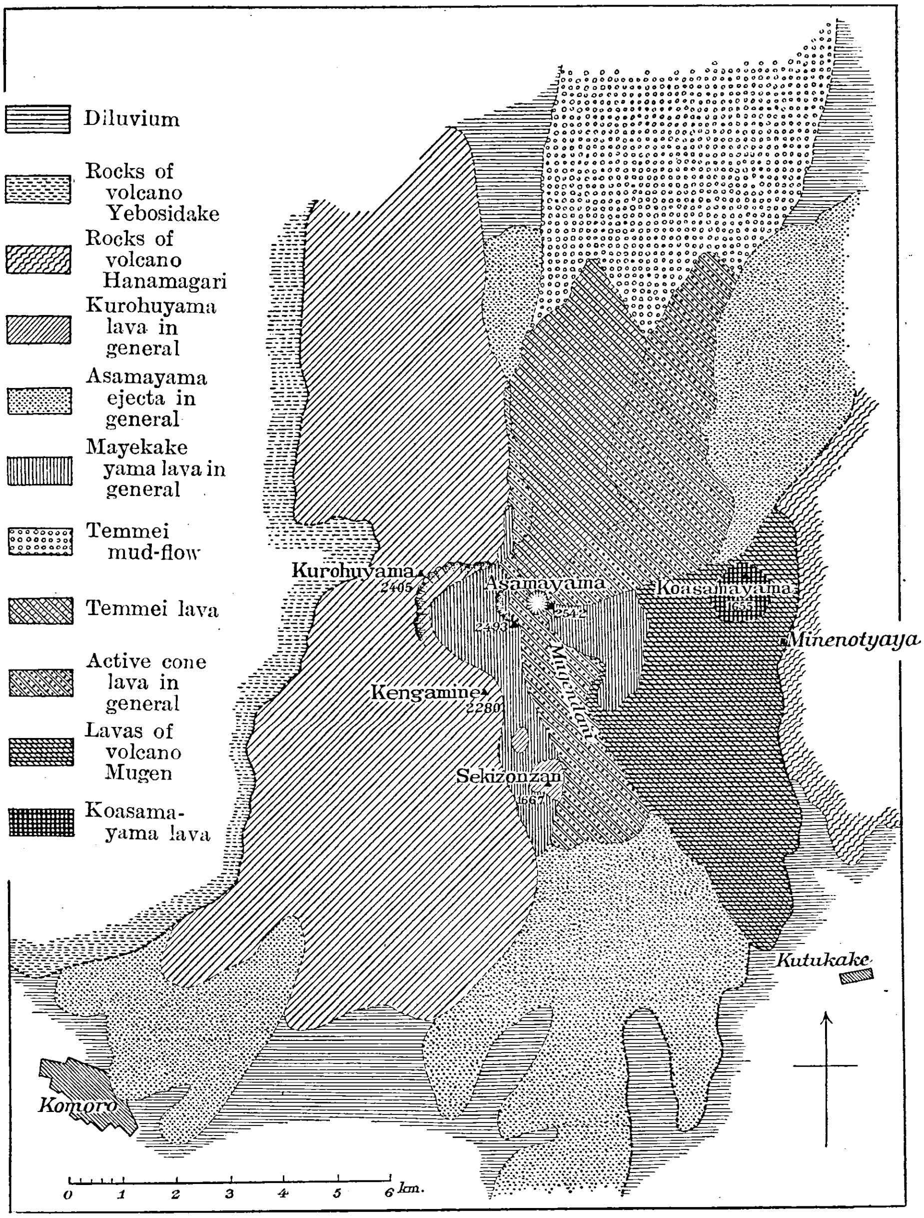

Fig. 1. Geologic sketch-map of Asamayama, based on Kawamura's geologic map.

almost completely under the products of later eruptions that took place in it and formed the present active cone, only shallow crescentic basins

—inner atrio—being left between its ring-walls and the active cone. The materials composing the Mayêkakêyama cone are the alternately accumulated lavas and fragmentary ejecta of andesitic nature. One of the lavas is exposed on the almost perpendicular inside cliff (about 80 m. in height), Byôbuiwa,[10] of the west wall of the old summit-crater, exhibiting well-developed columnar structure.

The active cone, Asamayama proper, stands in the centre of the summit-crater of the inner somma, Mayêkakêyama. Its highest point, which lies to the east of the crater-wall, rises 2542 m. above sea-level, but about 120 m. above the lowest point on the surrounding inner atrio surface. The outer sides of the active cone slope 25–30° and are covered by fragmentary ejecta (ash, sands, lapilli, and bombs). The active crater is a circular pit with almost vertical sides and a depth of about 200 m., but which is never stationary for long as the incandescent lava at the bottom moves up and down. The inside of the crater is obscured by vapor-clouds, which issue from its bottom as well as from numerous fissures and holes in its walls. Occasionally the wind affords a clearer view of the inside, and shows the strata of lavas and fragmentary ejecta, dipping away in all directions from the central axis of the crater. The volcanic products of the active crater, such as lavas and fragmentary ejecta, not only build up the cone surrounding the crater, but are also distributed over the surface of the somma bodies. Especially to the northeast of the volcano, the products are spread down far to the foot of the volcano. Thus, the so-called Temmei lava (Oni-osidasi)[11] and mud-flow, which erupted from the active crater in 1783, flowed down northward for a distance of about 15 km. through the lowest northern part of the crater-wall and Mayékakéyama, the northern gap of the ring-wall of the inner somma.

On the southern flank of the volcano is a knob called Sekisonzan[12] which, according to Kawamura,[13] is a parasitic cone of Kurohuyama, the outer somma. Besides it, there is in the southeastern part of the volcano an old volcanic body which he called Mugen volcano.[14] This body consists of several lava-flows of highly glassy rock (chiefly obsidian) which differ greatly petrographically from the volcanic products of the above-mentioned three centres—Kurohu, Mayékaké, and the active cone. The lavas are well exposed as precipitous lava-cliffs with columnar joints

10) 屏風岩. 11) 天明熔岩 (鬼押出). 12) 石尊山.
13) M. KAWAMURA, *MS.*, (1911).
14) 無限火山.

on the east wall of the upper course (at an altitude of 2000 m. above sea-level) of the valley Mugenno-tani, which starts from the southern gap of the ring-wall of the inner somma, Mayêkakêyama, and runs southeastwards along the southern boundary of Higasi-mayêkakêyama. Here they are covered by the volcanic products of Mayêkakêyama, while southeastwards they are distributed extensively, being covered by the products of later eruptions of Mayêkakêyama and of the active cone. But as to the eruption centre of these lavas and their geological relation to the Kurohuyama outer somma, no direct evidence has been discovered, although Kawamura has suggested that they might be traced to a local vent situated near the upper course (Mugen lava-cliff) of the valley Mugenno-tani, where they formed a massive volcano—Mugen volcano—which now, instead of looking like a volcano, has more the appearance of being a part of the Asama volcano itself.

At the eastern foot of Asama, and 1655 m. above sea-level, or about 200 m. above the surrounding ground, is a dome-shaped hill called Ko-asamayama (little Asama), which is a lava-dome, or tholoide, with sides sloping 35° (average), and having a slight crater-like depression at the centre of its summit. According to Kawamura, with whose conclusions the writer's own observations agree in the main, it forms a sort of parasitic cone, which has come up through the eastern flank of the Mugen volcano. The structure of the dome and its geological relation to the main body of Asama may be seen in the steep sloping sides of the dome. It consists of a single lava very similar, petrographically, to the lavas of the so-called Mugen volcano, rising from the foundation formed of the last-named. The upper parts of the flanks, except the western, of the dome consist of steep lava-cliffs, exhibiting onion-banding, which is a characteristic of the so-called Staukuppe, while their foot are concealed by talus-conoids that surround them. The western flank, where the dome is connected by a saddle to the main body, is gentle in slope. This part and the summit of the dome are covered by loose ejecta (lapilli, scoriae, and bombs) supplied by the present active crater of Asama. From the foregoing facts, there need be no question of the lava-dome Ko-asamayama having a direct structural relation to the Mugen volcano, and that, strictly speaking, it is a parasitic cone of the Mugen volcano, if the latter was a volcano at all, though it is used to be vaguely regarded as a parasitic cone of Asama.

The structural scheme above outlined may be shown in tabular form as follows :

Volcano Asama:

- The outer somma—a stratified conide truncated at its top with a ring-wall (Kurohuyama-Gippayama-Kengaminé) surrounding a caldera, with a parasitic cone (Sekison-zan).
- The volcanic body (Mugen volcano) that underlies the inner somma, with a lava-dome (Ko-asamayama) which is considered to have been formed during the development of that body.
- The inner somma (or the central cone of the outer somma) —a stratified conide truncated at its top with a ring-wall (Mayékakéyama and Higasi-mayékakéyama) surrounding an old summit-crater.
- The central cone—a stratified conide having an active crater.

Asama volcano is not old, geologically speaking, its birth dating probably in late Diluvium or later. The foundation on which the volcano rests consists of Neogene Tertiary formations and Diluvial deposits, besides various volcanic rocks, such as hornblende-andesite, pyroxene-andesite, and olivine-pyroxene-andesite and others, which have built up the extinct Diluvial volcanoes, the Yebosidaké[15] volcano group on its west and the Hanamagari (Tuno-otosi)[16] volcano group on its east.

Petrography of Volcano Asama.

Excluding fragmentary ejecta, the rocks of Asama have been divided by Kawamura as follows:

A. Lavas of the outer somma.
   1. Hypersthene-andesite.
   2. Olivine-bearing hypersthene-andesite.
   3. Hypersthene-augite-andesite.
   4. Two-pyroxene-andesite.

B. Lavas of the Mugen volcano.
   5. Obsidian.
   6. Two-pyroxene-andesite.

C. Lavas of the inner somma.
   7. Two-pyroxene-andesite.
   8. Hypersthene-augite-andesite.
   9. Augite-andesite.

D. Lavas of the active cone.

15) 烏帽子岳. 16) 鼻曲山 (角落山).

10. Two-pyroxene-andesite.
11. Olivine-bearing two-pyroxene-andesite.

Of these various rocks that form Asama, the writer examined microscopically and chemically four specimens of an andesitic and two of dacitic nature. Before discussing the petrology of the volcano, the genenal petrographic character of the andesitic and dacitic rocks will be described.

(*A*) *Andesites.*

I. Olivine-bearing two-pyroxene-andesite (one of the Kurohuyama lavas). (Fig. 6)

II. Olivine-bearing two-pyroxene-andesite (Yunotaira lava, an older lava of the Mayekakeyama centre). (Fig. 7)

III. Olivine-bearing hypersthene-augite-andesite (lava of 1783). (Fig. 8)

IV. Olivine-bearing hypersthene-augite-andesite (bread-crust bomb ejected in Sept., 1929). (Fig. 9)

Though each of these has certain distinguishable characters, both megascopic and microscopic, they all resemble one other in their important petrographic characters.

Megascopic Characters.—Megascopically, these rocks are dark gray to black and more or less scoriaceous, with vesicles less than 1·5 mm. in diameter. Phenocrysts of plagioclase, pyroxene, and olivine are scattered through the dark glassy base. Among these phenocrysts, the plagioclase, which is less than 1·5 mm. in diameter, is most dominant; while the olivine, which is less than 1 mm. in diameter, is rare.

Microscopic Characters.—Microscopically, these rocks are porphyritic, with phenocrysts of plagioclase, hypersthene, augite, olivine, and accessory magnetite. These phenocrysts are scattered, with no trace of any regular arrangement, through a dark brown or almost colorless groundmass. As they are present in variable quantities in all the rocks, the structure of the latter varies from nearly dosemic to sempatic. The quantities of the chief constituent minerals were measured volumetrically and their volume percentages calculated as shown in Table I. In the Table the volume percentage of the vesicles in each rock are also shown.

Table I.

Modal Compositions (Vol. %) of the Asama Andesites.

		I	II	III	IV
Phenocrysts	Plagioclase	26·89	28·30	24·58	31·67
	Hypersthene	2·03	3·53	2·25	4·01
	Augite	2·29	3·58	4·08	6·24
	Olivine	tr.	0·10	0·09	0·06
	Magnetite	1·13	0·61	0·68	0·64
Groundmass		67·66	63·88	68·32	57·38
Vesicles		23·00	14·31	19·36	16·96

I. Kurohu lava.
II. Yunotaira lava.
III. Temmei (1783) lava.
IV. Bread-crust bomb ejected in Sept., 1929.

Plagioclase.—The plagioclase phenocrysts which are euhedral and subhedral, are developed in prismatic and nearly equant habit, showing simple and polysynthetic twin-lamellae according to the albite, Carlsbad and pericline laws. Zonal structure due to chemical difference is clearly exhibited. The mode of change of chemical composition in successive zones is not regular. Although the innermost zone is commonly the most calcic and the outermost the most sodic, reversal, or recurrent, zoning is frequently met with. The refractive indices—n_{1D} in (010) or (001)—measured with Tsuboi's dispersion method[17] are shown in the

Table II.

	Plagioclase n_{1D}	Ab%	Hypersthene n_{1D}	Hy%	Augite n_{1D}	Hd%	Olivine β_D	Fay%
I	1·5653–1·5597	29–40	1·6983–1·7046	33–38	1·6964	39	1·6996	23
II	1·5668–1·5613	26–37	1·7016	35	1·6960	38	n. d.	
III	1·5643–1·5574	31–44	1·7032	37	1·6961	38	1·6856	17
IV	1·5662–1·5579	27–43	1·7030	37	1·6960	38	1·7020	25

I. Kurohu lava.
II. Yunotaira lava.
III. Temmei lava.
IV. Bread-crust bomb in Sept., 1929.

17) S. TSUBOI, *Miner. Mag.*, London, 20 (1923), 93.
S. TSUBOI, *Jour. Fac. Sci. Imp. Univ.*, Tôkyô, 1 (1926), 146.

first column of Table II, according to which the mineral is identified as labradorite, averaging $Ab_{35}An_{65}$ in chemical composition. It appears therefore that the plagioclase phenocrysts in the andesites concerned are practically identical in compositions with each other. It is noticeable however that the plagioclase phenocrysts contained in the historic lavas (Temmei lava and 1929 bomb) have sometimes more calcic cores (calcic bytownite as identified by their extinction angles) zonally surrounded by shells of labradorite. The mineral contains numerous minute inclusions of plagioclase, pyroxene, brown glass, and dust material.

Hypersthene.—Hypersthene occurs as euhedral phenocrysts of stout prismatic form measuring 0·5–1·0 mm. along the longest direction. Some regularity appears to exist in the relation between variation in the amounts of the mineral and the order of eruption of the andesite, as shown in Table I. Axial colors observed in thin section are:

X....brownish, Y....yellowish brown, Z....greenish.

The optical plane is always parallel to the c-axis of the mineral. The refractive indices—n_{1D} in (110)—measured with the dispersion method and the approximate chemical compositions determined with the aid of the Tomita diagram[18] are shown in the second column of Table II. A faint zonal structure due to chemical difference is observed in the hypersthene contained in Kurohu lava, the oldest andesite of the four examined specimens. It is clearly exhibited when the mineral flake is immersed in a liquid. The mode of zoning is not regular, the hypersthene with higher and lower refractive indices being alternately developed in successive zones.

Augite.—Augite occurs as euhedral and subhedral phenocrysts averaging 1·0 mm. in diameter. Its amount increases regularly according to the order of eruption of the andesites in which it is contained, the maximum reaching 6·5 vol. % in the latest one (1929 bomb). The mineral is a light greenish brown variety. Sometimes it occurs in a rim around the hypersthene in parallel growth. Twinning after (100) is often met with. Zonal structure due to chemical difference is not observed. Extinction angle $c \wedge Z$ is about 45°. Optic angle is always large. The refractive indices—n_{1D} in (110)—measured with the dispersion method and the approximate chemical composition determined by means of the Tomita diagram are shown in the third column of Table II. Thus, the augite phenocrysts in the four rock-specimens closely agree

18) T. TOMITA, *Jour. Geol. Soc.*, Tôkyô, **31** (1924), 364, (in Japanese).

in their important petrographic characters.

Olivine.—Olivine phenocrysts are present in all the four specimens, though very little in amount. They are always unhedral, pale yellowish green or nearly colorless in thin section, and surrounded by minute grains of a monoclinic pyroxene. The principal refractive indices—β_D—measured with the dispersion method and the approximate chemical compositions as determined by the refractive indices are shown in the fourth column of Table II. It is notable that the olivine in the Temmei lava (III) has much lower refractive indices compared with the mineral in the other lavas.

Magnetite.—Magnetite occurs in small amounts as isometrict grains less than 0·3 mm. in diameter.

Groundmass.—The groundmass consists entirely of either brown or colorless glass, except a few feldspar prismoids and pyroxene grains, which however cannot be optically analysed. The refractive index of the glass base in the Temmei lava was measured with the ordinary immersion method and found to be $n_D=1{\cdot}5240$. This value shows an intermediate basicity of the glass.

Chemical Compositions.—The chemical analyses of the andesites gave the results shown in the first four columns of Table III.

Of the four andesites, according to the C. I. P. W. quantitative system, three (I, II and IV) belong to bandose and one (III) to tonalose. An older analysis (IV′) of a bomb ejected in Dec. 1909, which was made by the Geological Survey and published by Denzo Sato[19] in his report on the eruption of that time, resembles on the whole the four preceding analyses, except in alkalies, showing that the bomb belongs to bandose. It is probable that the total alkalies (1·64%) in the bomb are too low, since S. Tanaka's partial analysis of another bomb ejected in Dec. 1909, showed that the Na_2O and K_2O contents of the bomb are 3·19% and 1·18% respectively. Consequently, the analysis reported by Sato seems to be at fault in these respects.

As is clear from the above table, all the four analysed Asama andesites resemble in bulk composition the rocks of the volcanoes Bandaisan, Tarumaisan, etc. of northeast Japan, all being characterised by normative labradorite. They may thus be classed as typical "bandaite," using Idding's term. While they show certain analogies with the volcanic rocks of the so-called Huzi Volcanic Zone, they differ

19) D. SATO, *Jour. Geogr.*, Tôkyô Geogr. Soc., 22 (1910), 196, (in Japanese).

Table III.

Bulk Compositions of the Asama Andesites.

	I	II	III	IV	IV′
SiO_2	58·39	59·67	62·37	60·24	59·76
Al_2O_3	17·89	16·83	15·90	16·43	16·90
Fe_2O_3	2·45	1·44	1·14	1·54	1·74
FeO	5·33	5·51	4·79	5·26	5·46
MgO	3·30	3·92	3·43	3·92	4·36
CaO	7·23	7·21	6·13	7·07	8·66
Na_2O	3 04	2·81	3·20	3·00	1·05
K_2O	0·71	1·00	1·49	1·16	0·59
H_2O +	0·36	0·28	0·30	0·17	0·13
−	0·12	0·13	0·12	0·06	
TiO_2	0·71	0·70	0·66	0·70	1·23
P_2O_5	0·15	0.14	0·13	0·13	tr.
MnO	0·14	0·12	0·11	0·11	0·38
Total	99·82	99·76	99·77	99·79	100·26
Norms.					
Q	15·20	15·92	17·84	15·98	23·84
Or	4·45	6·12	8·90	6·68	3·34
Ab	25·69	23·59	27·26	25·17	8·91
An	32·82	30·22	24·48	28·09	39·78
Di	1·83	3·87	4·12	5·02	2·48
Hy	14·19	15·89	13·63	14·66	16·90
Mt	3·49	2·08	1·62	2·31	2·55
Ap	0·31	0·31	0·31	0·31	tr.
Il	1·37	1·37	1·21	1·37	2·28
C. I. P. W. Symbols	II. 4.″4. 4 (5) Bandose	II. 4.″4. 4 Bandose	II. 4. 3″.4. Tonalose	II. 4. (3) 4. 4 Bandose	II.″4. 4 (5). 4 Bandose

I. Kurohu lava. S. Tanaka anal.
II. Yunotaira lava S. Tanaka anal.
III. Temmei lava. S. Tanaka anal.
IV. Bomb in Sept., 1929. S. Tanaka anal.
IV′. Bomb in Dec., 1909. The Imp. Geol. Surv. anal.

petrographically as well as chemically from late-Diluvium and recent basaltic rocks of the latter, which are characterised either by the dominance of calcic normative plagioclase phenocrysts (calcic bytownite or anorthite) or by calcic normative plagioclase (bytownite or anorthite), even when these rocks belong to the quardofelic order according to the C. I. P. W. quantitative system.

(*B*) *Dacites.*

V. Hornblende-two-pyroxene-dacite (Mugenno-tani obsidian). (Fig. 10)

VI. Hornblende-two-pyroxene-dacite (Ko-asamayama lava). (Fig. 11)

Of the two dacitic rocks, one (V) occurs at Mugenno-tani in several of the lava-flows without any noticeable layers of fragmentary ejecta between them, and the other (VI) occurs at Ko-asamayama in a single lava, forming a small domical hill of that name. They differ from one another both in megascopic and microscopic features, but agree closely in their important petrographic characters.

Megascopic Characters.—Megascopically, the one (V) is jet-black with glassy luster, and is mediophyric to minophyric with phenocrysts of plagioclase scattered through the black glass base; and the other (VI) is light gray or light brown, more or less vesicular, and is mediophyric with phenocrysts of plagioclase and pyroxene scattered through a dull, somewhat earthy, aphanitic groundmass.

Microscopic Characters.—Microscopically, both of them contain phenocrysts of plagioclase, hornblende, hypersthene, augite, and magnetite. The amounts of these phenocrysts and that of the groundmass through which the phenocrysts are scattered were measured volumetrically, and their volume percentages were calculated as shown in columns V and VI, Table IV.

Table IV.

Modal Compositions (Vol. %) of the Asama Dacites.

		V	VI.
Phenocrysts	Plagioclase	8·78	7·54
	Hornblende	0·25	tr.
	Hypersthene	0·21	0·36
	Augite	0·29	0·02
	Magnetite	0·56	0·56
Groundmass		89·91	91·52
Vesicles		—	10·91

V. Mugenno-tani obsidian. VI. Ko-asamayama lava.

Plagioclase.—The plagioclase phenocrysts are euhedral to subhedral, stout prismatic to equant, and twinned according to the albite, Carlsbad, and pericline laws. Occasionally, two or more individuals of the mineral form a grouped phenocryst. Polysynthetic twinning and zonal structure due to chemical difference are better exhibited in larger phenocrysts than in smaller ones. The refractive indices—n_{1D} in (010) or (001)—measured with the dispersion method and the chemical compositions determined by the refractive indices are shown in the first column of Table V. The mineral contains inclusions of plagioclase, pyroxene, glass, and slender prisms of colorless apatite.

Table V.

	Plagiocalse n_{1D}	Ab%	Hornblende n_{2D}	Hypersthene n_{1D}	Hy%	Augite n_{1D}	Hd%
V	1·5600–1·5556	39–48	1·6879	1·6973	33	1·6892	30
VI	1·5590–1·5533	41–51	n. d.	1·6970	33	1·6925	33

V. Mugenno-tani obsidian.
VI. Ko-asamayama lava.

Hornblende.—The hornblende is euhedral, prismatic, and is 0·5–0·1 mm. in the longest direction. The mineral is of a rather pale greenish brown color with the following pleochroism:

X....yellowish green, Y....green, Z... greenish brown.
Absorption; $X<Y<Z$

The hornblende in the Ko-asamayama lava is usually opacitized, while that in the Mugenno-tani obsidian is quite fresh. The larger refractive index—n_{2D}—measured with the cleavage flakes of the mineral is shown in the second column of Table V. $c \wedge Z' = 6{\cdot}5°$; twinning after (100).

Hypersthene.—The hypersthene is euhedral, prismatic, and is 0·5–0·1 mm. in the longest direction. Occasionally, two or three individuals of the mineral form a glomeroporphyritic phenocrysts associated with plagioclase and augite. It is usually pale greenish brown, and is moderately pleochroic, giving X—pale brown, Y—light yellow, and Z—pale green. Optical plane is parallel to the c-axis of the mineral. The refractive indices—n_{1D} in (110)—measured with the dispersion method and the approximate chemical compositions determined by the Tomita diagram are shown in the third column of Table V. Although the mineral has no inclusions, it is sometimes surrounded by a monoclinic pyroxene in parallel growth. Hypersthene in the Ko-asamayama lava is often rimmed with opacitic black margin.

Augite.—The augite is euhedral to subhedral, stout prismatic to equant, and is 0·5–0·2 mm. in average diameter. It is pale greenish brown with no pleochroism. Twinning after (100) is sometimes observed. $c \wedge Z = 44{\cdot}5°$; optic angle large. The refractive indices—n_{1D} in (110)—measured with the dispersion method and the approximate chemical compositions determined by the Tomita diagram are shown in the fourth column of Table V.

Magnetite.—The magnetite occurs in isometric form, 0·5–0·1 mm. in diameter.

Groundmass.—The groundmass of the Mugenno-tani obsidian is a colorless glass in thin section, through which microlites are arranged in a flow structure. The refractive index of the glass is 1·4955. The groundmass of the Ko-asamayama lava is colorless to pale brownish gray and is glassy, but it contains, besides small vesicles, feldspar prismoids (oligoclase-andesine according to their extinction angles), pyroxene grains, opacitized hornblende flakes, iron-ore, and a weak double refracting colorless mineral (tridymite ?), the last-named occurring as aggregates of minute anhedral units.

Chemical Compositions.—Chemical analyses of the dacites gave the results shown in Table VI.

According to the C. I. P. W. quantitative system, the two analysed dacites belong to lassenose.

The analysis of the Ko-asamayama lava (VI) shows lower SiO_2 and FeO content and higher Fe_2O_3 and H_2O content, compared with that of the Mugenno-tani obsidian (V), but in other respects they resemble each other. It is probable that analysis VI does not represent very faithfully the composition of the fresh rock, since microscopic examination shows that even the freshest specimen from newly obtained blocks of Ko-asamayama lava undergoes some alteration, as may be inferred from the fact that the hornblende in the rock is almost entirely opacitized. The higher ferric oxide and water content in analysis VI are thus seen to be results of oxidation and hydration of the analysed rock. By recalculation of the two analyses to percentages of the main oxides, exclusive of H_2O, TiO_2, P_2O_5, and MnO, we see that the two resemble each other in all particulars, except in the iron oxides, though the total amount of the last-named in the two analyses is the same.

As is clear from the microscopic description, the dacitic rocks do not contain quartz phenocrysts, but normatively they are characterized by oligoclase $Ab_{74}An_{26}$ and belong to the persalic class, containing quartz molecules in such quantities that they are classed in the quadofelic order near to quarfelic in the quantitative system. These rocks are, therefore, to be classed as dacite.[20]

Table VI.
Bulk Compositions of the Asama Dacites.

	V	VI
SiO_2	72·01	69·93
Al_2O_3	14·37	14·12
Fe_2O_3	0·73	2·45
FeO	1·81	0·45
MgO	0·57	0·58
CaO	2·56	2·42
Na_2O	4·35	4·04
K_2O	2·39	2·25
H_2O+	0·26	2·00
−	0·08	0·97
TiO_2	0·41	0·38
P_2O_5	0·07	tr.
MnO	0·08	0·09
Total	99·69	99·68
Norms.		
Q	30·39	31·77
Or	13·91	13·36
Ab	36·70	24·08
An	12·79	11·96
C	—	0·71
Hy	3·65	1·24
Mt	1·16	0·23
Hm	—	2·24
Ap	—	tr.
Il	0·61	0·76
C. I. P. W. Symbols	I.″4. 2″. 4 Lassenose	I. (3) 4. 2″. 4 Lassenose

V. Mugenno-tani obsidian. S. Tanaka anal.
VI. Ko-asamayama lava. S. Tanaka anal.

Genetical Relationships.

While this is not the place for a general discusssion of the petrology of volcano Asama, a few words may be devoted to the genetical relationship of the rocks whose analyses, optical as well as chemical, have just been given.

From the optical data given in Table II (p. 579) and V (p. 584), the paragenic relations between plagioclases and mafic minerals in the rocks of Asama are graphically represented in Fig. 2. In order to represent here the composition-variations of the mafic minerals, the refractive indices (β_D for olivine, n_{1D} for pyroxene, and n_{2D} for hornblende) have been adopted. The composition of the plagioclases are represented by those of the most sodic parts of the zoned crystals.

As will be seen in the figure, the andesites agree so closely in the paragenic relations between either plagioclase and augite or plagioclase

20) It is probable that some of the acid xenoliths, frequently enclosed in recent juvenile ejecta of the volcano, are derived from this dacite.

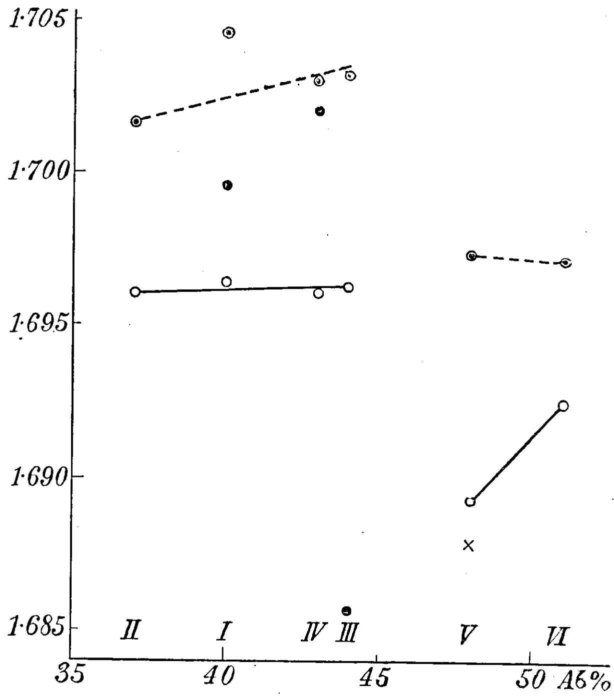

Fig. 2. The actual paragenic relations of plagioclases and mafic minerals (●: olivine, ○: augite, ◉: hypersthene, ×: hornblende) in the volcanic rocks of Asama. I—Kurohu lava; II—Yunotaira lava; III—Temmei lava; IV—Bomb in Sept, 1929; V—Mugenno-tani obsidian; VI—Ko-asamayama lava.

and hypersthene that they may be considered to represent only one stage in the cooling history of the magma from which they have been derived. The olivine in the Temmei lava (III) is distinctly lower in refractive index than the same mineral contained in the other three lavas (I, II, and IV). Probably the former is a relict mineral, which had ceased to react with the liquid at an earlier stage than the latter. In this connection it is notable that the Temmei lava carries plagioclase phenocrysts in which a calcic bytownite occurs as cores of labradorite.

The pyroxene in the dacites are distinctly lower in refractive index than that same minerals in the andesites. It is inferred that the dacites have been derived from a magma partially squeezed out from the parent magma at an earlier stage than that from which the andesites have been derived, if ever there was any genetical relation between the dacites and the andesites.

Since the optical constants of pyroxene vary with the chemical compositions of that mineral, the former may be reflected in the chemical compositions of normative pyroxenes in the rocks in which pyroxenes are the chief mafic minerals, besides plagioclase. Fig. 3 shows the compositions of the normative pyroxenes in the rocks of the Asama volcano. The lime contents in the normative pyroxene increase gradually from I to IV. On the other hand, Table I (p. 579) shows that the amounts of pyroxene phenocrysts, especially of augite, increase regularly from I to IV. This fact seems consistent with what has been said before, indicating that bulk compositions are greatly affected by the relative amounts of the phenocrystic minerals.

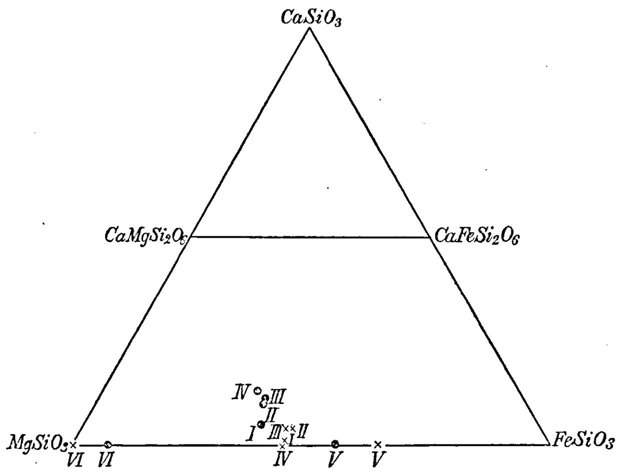

Fig. 3. Compositions of the normative pyroxenes in the rocks of Asama.

● : Normative pyroxene in the bulk composition.
× : Normative pyroxene in the groundmass composition.

I.	Kurohu lava.	IV.	Bomb in Sept., 1929.
II.	Yunotaira lava.	V.	Mugenno-tani obsidian
III.	Temmei lava.	VI.	Ko-asamayama lava.

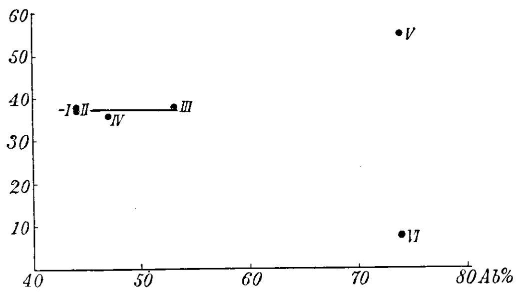

Fig. 4. The relation of normative plagioclase and normative pyroxene in the volcanic rocks of Asama. I—Kurohu lava; II—Yunotaira lava; III—Temmei lava; IV—Bomb in Sept., 1929; V—Mugenno-tani obsidian; VI—Ko-asamayama lava.

Since the refractive indices of pyroxenes change markedly according to the relative amounts of ferrous oxide and magnesia contained in them, the relation between the ratios of these two oxides held in normative pyroxenes and the compositions of normative plagioclases may be likened to the relation between the refractive indices of modal pyroxenes and the compositions of the modal plagioclases. Fig. 4 shows the former relation of the rocks of Asama. As is seen in the figure, all the andesites in which plagioclase and pyroxenes are the main phenocrystic minerals, agree closely in the compositions of the normative plagioclases as well as in the FeO : MgO ratios of the normative pyroxenes. This fact reflects the actual paragenic relation between the modal plagioclases and the modal pyroxenes held in them (Fig. 2). The FeO : MgO ratios in the normative pyroxenes of the dacites, in which hornblende is one of the chief constituents, are larger than the ratios in the normative pyroxenes of the andesites; while the refractive indices of the pyroxenes in the dacites are lower than the refractive indices of the pyroxenes in the andesites.

As is clear from Table I, the rocks of Asama contain various amounts of phenocrysts, so that the variation diagram of their bulk compositions may not represent the composition changes of the past magmatic liquids from which they have been derived. Comparing Table I and Fig. 3, we can readily understand that the normative pyroxenes in the andesites change in composition according to the relative amounts of the phenocrystic pyroxenes held in these rocks. Hence, the bulk compositions of such porphyritic rocks and any classification based upon them, as they stand, are of little use in petrogenesis. But, if some means could be devised for representing either directly or indirectly, the compositions of the groundmass of the porphyritic rocks, then the composition change of the liquids from which these rocks have been derived, may be inferred. One means of meeting this requirement is volumetric analysis of the porphyritic rocks.

The approximate chemical compositions of the phenocrystic minerals in the rocks of Asama are known from their optical constants (Tables II and V), though actually they may be very complex, especially is this the case with hornblende. The approximate chemical compositions of the groundmass of the rocks are obtained by subtracting the total compositions of the phenocrystic minerals from the bulk compositions of the rocks. Fig. 5 shows the variation of the Asama rocks with respect to both bulk and groundmass compositions.

If the bulk composition of the rocks should depart but little from the composition of a possible liquid, the indicative points of the rocks should lie approximately on the lines produced in the low silica side of the composition change of the groundmasses. Such a tendency is seen on the curves representing the variation of alumina and alkalies. This fact seems to indicate that the plagioclase phenocrysts remained approximately just where they were formed; while the mafic minerals are represented by lesser amounts than are possible in rocks formed by the direct congelation of any magmatic liquid.

The indicative points of the dacites show notable departure from the smoothed curves showing the variation of the groundmass composi-

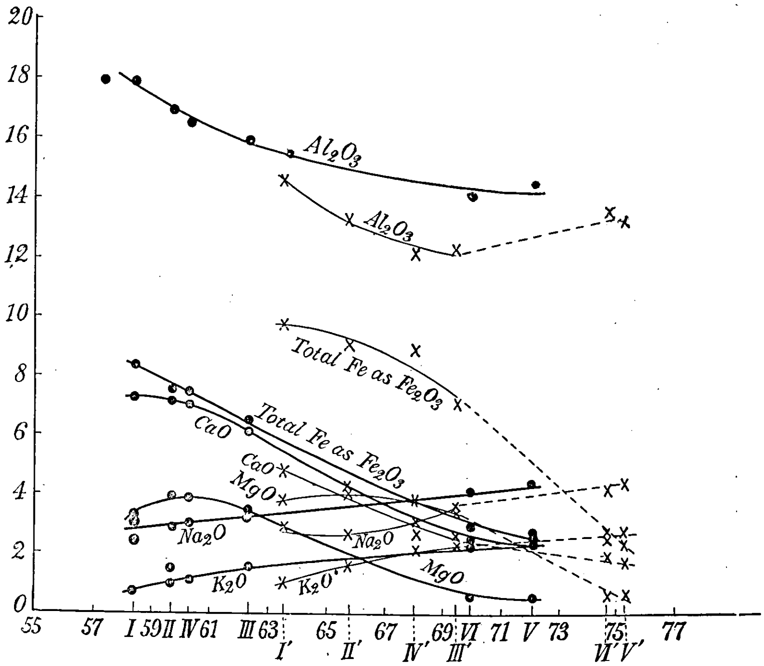

Fig. 5. Variation diagram of the rocks of Asama. Thick lines: bulk compositions; thin lines: groundmass compositions. I—Kurohu lava; II—Yunōtaira lava; III—Temmei lava; IV—Bomb in Sept., 1929; V—Mugenno-tani obsidian; VI—Ko-asamayama lava.

tions of the andesites. Very little can be said now concerning the genetical relationship between the andesites and the dacites of Asama, but by assuming a comagmatic origin, they may be considered to have been derived from their respective liquid lines of descent, separating from one another at an early stage in the cooling history of the original common magma.

30. 信濃國淺間火山の二三の熔岩の岩石學的研究

地震研究所 津屋弘逵

信濃國淺間火山は外輪山なる黑斑山 (海拔 2405 m.)——牙山——劍ヶ峯 (2280 m.), 其カルデラの東側に偏して噴出せる中央火口丘前掛山 (2521 m.), 及び前掛山の山頂火口内に噴出し現在活動しつゝある火口丘 (2542 m.) より成る三重の所謂 somma volcano である. 此火山を構成する岩石は主として中性の安山岩で所謂 bandaite に相當するものであるが, 其他に化學成分上石英安山岩に相當する比較的酸性の岩石が見出される. 此酸性の岩石は前掛山南東腹の無限谷に露出する黑曜石質熔岩と淺間山の寄生火山と考へられてゐる小淺間山の熔岩である. 本文では次の 6 種の岩石の顯微鏡的性質及び化學的性質を述べ, 之等の岩石相互の岩石學的關係に就いて若干の考察を加へた.

1. 黑斑山熔岩 (含橄欖石・複輝石安山岩)
2. 湯ノ平熔岩 (含橄欖石・複輝石安山岩)
3. 天明熔岩 (含橄欖石・紫蘇輝石・輝石安山岩)
4. 昭和 4 年 9 月拋出火山彈 (含橄欖石・紫蘇輝石・輝石安山岩)
5. 無限谷黑曜石 (角閃石・複輝石・石英安山岩)
6. 小淺間山熔岩 (角閃石・複輝石・石英安山岩)

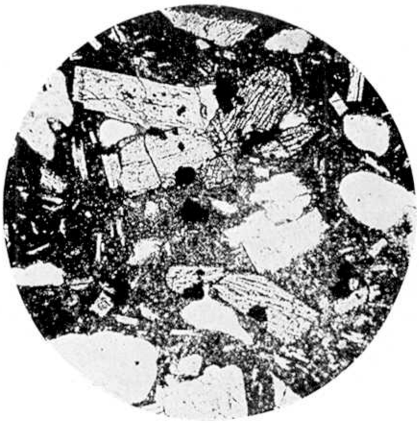

Fig. 6. Kurohuyama lava (Olivine-bearing two-pyroxene-andesite). ×35

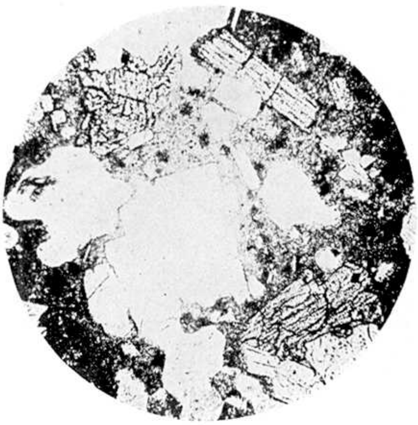

Fig. 7. Yunotaira lava (Olivine-bearing two-pyroxene-andesite). ×35

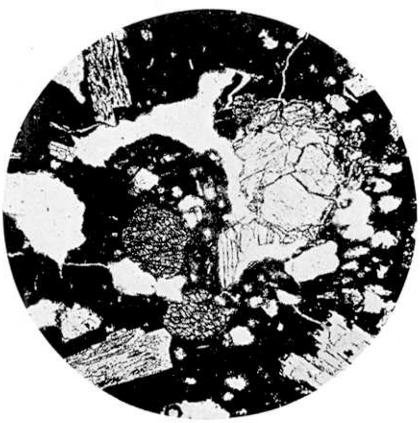

Fig. 8. Temmei lava (Olivine-bearing hypersthene-augite-andesite). ×35

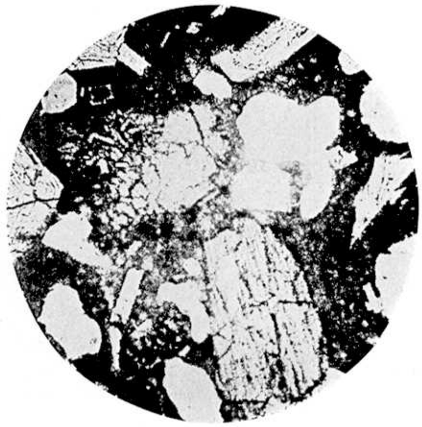

Fig. 9. Bomb in Sept., 1929 (Olivine-bearing hypersthene-augite-andesite). ×35

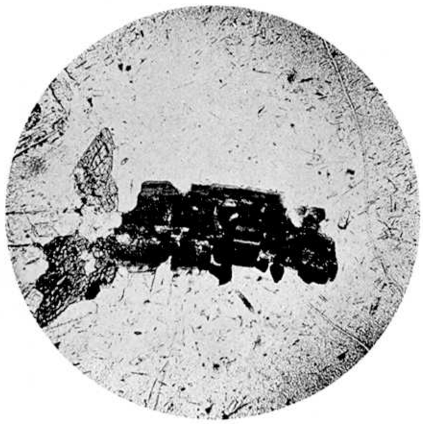

Fig. 10. Mugenno-tani Obsidian (Hornblende-two-pyroxene-dacite). ×35

Fig. 11. Ko-asamayama lave (Hornblende-two-pyroxene-dacite). ×35

MICROPHOTOGRAPHS OF THE ROCKS OF ASAMAYAMA.

（震研彙報、第十一號、圖版、津屋）

――所　報――

○談　話　會

第八十三回談話會（昭和八年六月二十日）

1. 筑波山に於ける傾斜變化觀測報告（其四）	井上宇胤
1. 地震と漁獲（第二報）	寺田寅彦
1. 津浪の光現象に就て	寺田寅彦
1. 富士川口以南の地質構造	大塚彌之助
1. 三陸海岸の地形と津浪被害	大塚彌之助
1. 不連續面が彈性波の傳播に及ぼす影響（其の三）	西村源六郎 金井清
1. 三陸津浪調査（第三報）「氣仙沼以南」	高橋龍太郎
1. 三陸地方港灣の形と津浪の高さとの關係	山口生知
1. 土地の高低と津浪の被害	那須信治

第八十四回談話會（昭和八年七月四日）

1. 仙臺にて觀察されたる斷層の一特例	矢部長克
1. 港灣の深さに及ぼす主風の影響	中野猿人
1. 地震波の走時に關する二三の問題	河角廣
1. 昭和六年二月二十日日本海北部の深發地震の調査（第一報）	河角廣 吉山良一
1. 水中爆發による薄板の彈性破損	西村源六郎
1. 風の爲め起される脈動に關係した問題（其の一）	西村源六郎
1. 三軸楕圓體ゲオイドの原因 1. 太平洋底の割れ目と大地震帶との關係	長岡半太郎 白井俊明
1. 須佐に於ける津浪	松澤武雄 神原健 水上武
1. 津浪の勢力と土木工事の被害	松尾春雄
1. 三月三日津浪發生機巧に就て	石本巳四雄

第八十五回談話會（昭和八年九月十九日）

1. 土地の高低と津浪の被害	那須信治
1. 日本の重力に就て	坪井忠二
1. 船舶に於ける重力測定の可能性	坪井忠二
1. 燒ケ嶽火山の活動	小平孝雄
1. 不連續面が彈性波の傳播に及ぼす影響	西村源六郎 金井清