20. *On the Volcanism of the Huzi Volcanic Zone, with Special Reference to the Geology and Petrology of Idu and the Southern Islands.*

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CONTENTS.

Introduction.

On the "fossa magna", a well-known tectonic zone traversing central Japan from the Japan Sea coast to the Pacific coast in a NNW.–SSE. direction, are arranged many volcanoes in a zone called the "Huzi Volcanic Zone" after the celebrated volcano. Since early Pleistocene this zone has been the seat of volcanism, the rocks of which are chiefly basalt followed by andesite. In this zone, which extends far south into the Pacific, we find a group of insular volcanoes, linearly-arranged, a group that comprises the Seven Idu Islands and the Southern Islands (except the Ogasawara), all of which rise up from a submarine ridge of what may be an underground manifestation of the geotectonic structure of the zone.

So far as we know, the volcanoes of this zone on the fossa magna are underlain largely by Neogene Tertiary formations, all the members of which, excepting a few clastic sediments and limestones, are volcanic in character, and include, in addition to pyroclastic beds, various lavas and minor intrusives. Although, structurally, the Ogasawara Islands appear to lie outside the zone, they are mostly composed of volcanic rocks which, with the intercalated limestones, have been assigned to Palaeogene, and which, petrologically, may be treated together with the rocks of the adjoining shores of that zone as a connected whole. Consequently, there is in the Huzi volcanic zone a profusion of petrological phenomena portraying the intensive volcanic activities that characterized the entire zone since the time of the early Tertiary.

In this paper the writer presents in some detail the results of his studies in the field as well as in the laboratory of the volcanic rocks with special reference to the Idu region and the Southern Islands. Although the area studied forms but a fraction of that vast region wherein similar geologic conditions prevailed contemporaneously, it may be wide enough for our purpose considering the large amount of data that studies of the region have yielded us. Indeed, in some respects the region studied typifies the whole, especially as it contains the principal centres, both of Quaternary and Recent volcanic activity—Huzi, O-sima, Miyake-sima, Hatizyo-sima, etc.—and one of the regions in which the Tertiary forerunner of the volcanic zone is most typically developed, namely, the Idu peninsula which is the southern expression of the fossa magna.

The writer has endeavoured to range the volcanic rocks in natural groups each belonging to a definite epoch, and these are treated, generally, in chronological sequence. Matters of convenience, however, sometimes make adherence to this intended order impossible, such for instance as when certain repetitions have to be avoided, although more often the reason for it is the lack of evidence to substantiate the particular order. As the principal object of this paper is to present both the general sequence and a general petrology of the region under discussion, petrographic descriptions must of necessity be concise with many details of the common and most widely represented rocks omitted in order not to emphasize unduly the rarer and more interesting rocks.

Most of the chemical analyses of rocks presented in this paper were made specially for this study by S. Tanaka. Petrographic descriptions have been given of the specimens that have been analyzed, although, for the sake of completeness, some additional specimens have been described unaccompanied by any chemical analyses. In the descriptions, the chemical compositions of both porphyritic minerals and groundmass constituents have been given, so far as they could be determined by measuring some of their optical constants. Plagioclase was determined by Tsuboi's method[1], monoclinic pyroxene by measuring both 2V and β (or n_1 on 110) and by means of Tomita's diagrams[2], hypersthene by measuring n_1 or n_2 on (110) and by means of curves for the indices of refraction of rhombic pyroxene as proposed by Bowen and Schairer[3], and olivine by measuring both 2V and the indices of refraction and by means of Winchell's diagram[4], but reduced to wt.% of the components. Excepting a few measurements of minute groundmass constituents, which were made by the ordinary

1) S. Tsuboi, *Jap. Jour. Geol. Geogr.*, **11** (1934), 325.

2) T. Tomita, *Jour. Shanghai Sci. Inst.*, Sec. II, **1** (1934), 41. H. Kuno has proposed a similar diagram useful for the same purpose. His diagram differs but slightly from Tomita's diagram in that the curves for β are chiefly based on common pyrogenic monoclinic pyroxenes with moderate amounts of sesquioxides and titania. H. Kuno, *Jap. Jour. Geol. Geogr.*, **13** (1936), 110.

3) N. L. Bowen and J. F. Schairer, *Am. Jour. Sci.*, **29** (1935), 198.

4) N. Winchell, Elements of Optical Mineralogy, Part II (1927), 168.

immersion method, the indices of refraction in all cases were measured by Tsuboi's dispersion method[5]. The optic angles were measured in all cases by using Fedorow's universal stage.

It should be emphasized that, in classifying the rocks into various rock types, the normative composition has been taken into account in the choice of rock names, especially those for the "basaltic" rocks that predominate in the region studied. To discriminate basalt and andesite from microscopical characters alone was found to be impracticable, seeing that there is every gradation of that character from normal basalt to andesite. Neither would we be justified in taking the presence or absence of olivine as a criterion for discriminating basalt and andesite; many rocks destitute of that mineral are probably quite as basic in composition as some of those with olivine. Tsuboi has proposed the term "miharaite" for the basaltic rocks from Mihara-yama, O-sima, which are characterized modally by some phenocrysts of bytownite and pyroxenes in a groundmass containing labradorite and monoclinic pyroxene[6]. As will be discussed later, similar rocks—most of them almost non-porphyritic (aphyric)—occur in several volcanoes, such as Hatizyo-sima, Miyake-sima, Taga. etc. The groundmass of the porphyritic (phyric) rocks from these volcanoes also greatly resembles miharaite in composition. Like the miharaite, similar non-porphyritic rocks may be called basalt (tholeiitic basalt)[7], which is also true for the porphyritic rocks, the groundmass of which is similar chemically to miharaite.

Washington, who distinguishes basalt from andesite on the basis of the relative amounts of the salic and the femic minerals shown in the norm, writes: "...andesite, in which plagioclase dominates over femic minerals, that is, plagioclase constitutes from 87·5 to 62 per cent of the norm; and basalt, in which the amounts of plagioclase and femic minerals are about equal, that is, the percentage of feldspar lies between 62·5 to 37·5, and conversely with femic minerals".[8] This scheme, however, fails to discriminate basalt and andesite among our rocks. Although no good purpose would be served by discussing them separately, the writer, for convenience of description, uses the term basalt for rocks in which $(Q+F)/(M+F)$ is less than 0·75 (3/4), and andesite for rocks in which $(Q+F)/(M+F)$ lies between 0·75 to 1·33 (4/3). Basalt thus includes, in addition to all the basic rocks characterized by phenocrysts of calcic plagioclase (anorthite and/or bytownite), either

5) S. TSUBOI, *Jour. Fac. Sci., Imp. Univ., Tokyo,* Sec. II, **1**~5 (1926), 139.
6) S. TSUBOI, *Jour. Col. Sci., Imp. Univ., Tokyo,* Art. 6, **43** (1920), 87.
7) W. Q. KENNEDY, *Am. Jour. Sci.,* **25** (1933), 239.
8) H. S. WASHINGTON, *Ibid.,* **5** (1923), 469.

together with or without olivine and pyroxenes, the miharaite and allied rocks which some writers might prefer to call "basaltic andesite" or "basaltic bandaite".

Some of the volcanoes in the region under study, especially those of the Idu peninsula and the outlying Seven Idu Islands, have been studied by a number of authors, whose works have been referred to in their proper places in this paper.

The writer desires to express his sincere thanks to Dr. S. Tsuboi, who went over this paper in manuscript, and also to Mr. H. Kuno, who supplied him with new analyses of rocks from the volcanoes Hakone and Taga. He is also greatly indebted to Mr. S. Tanaka, analyst of this Institute, who kindly made chemical analyses of a large number of rocks for this paper.

I. TERTIARY VOLCANISM.

General statement.

It is perhaps well to state at the outset that in none of the regions dealt with in this paper are there any rocks older than the Tertiary. They are all completely buried under more recent formations: not even fragments of pre-Tertiary rocks have ever been found among either the volcanics or the sedimentaries of these regions. What happened there during the Mesozoic and still older times is therefore at present a perfect blank. The oldest event known to us is Tertiary volcanism, which may be divided into the Palaeogene volcanism of the Ogasawara Islands and the Neogene volcanism of the Idu peninsula.

The Ogasawara Islands occupy in the Pacific an isolated position of exceptional interest, both structurally and geologically. Situated about 150 km east of Nisino-sima (Rosario I.)[9], and flanked on the east by the great depression—the Japan Trough—which within 400 km of the shores of the islands has a depth of more than 8000 m. These islands form a linearly-arranged chain stretching in N.–S. direction from 28°30′N. to 26°30′N. As shown in Fig. 1, they are the only peaks projecting from the submarine ridge that runs parallel to the much longer and larger submarine ridge lying beneath the insular volcanoes of the Huzi volcanic zone, there being a depression of more than 4000 m between the two ridges just mentioned. Although the islands are largely composed

9) A dissected volcanic island, situated 27°14′N. and 140°53′E., between Sohu-gan (Lots Wife Rocks) and Kita Io-sima (San Alessandro I.) on the southern extension of the Huzi volcanic zone.

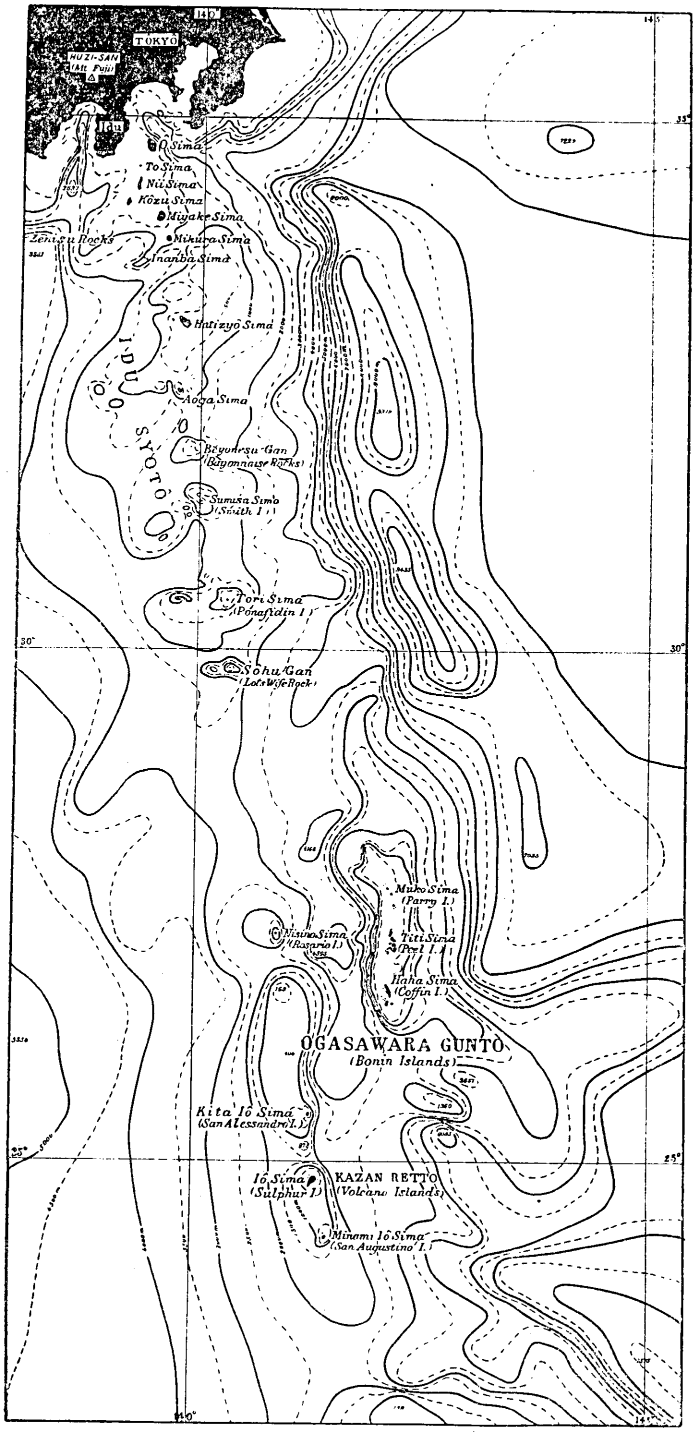

Fig. 1. Map showing the Seven Idu Islands and the Southern Islands in relation to the submarine areas about them (based on the chart Nos. 81, 83, and 86, of the Hydrographic Office, Imp. Japanese Navy).

of volcanic rocks of an andesitic character, none of them has that appearance, structural and morphological, characteristic of central volcanoes. The volcanics are locally intercalated with sedimentary rocks whose Paleogene age has definitely been proved by fossil evidence. Neither volcanics nor sediments of younger age, except the beach deposits on the present sea-shore, are represented. So far as observed, they appear to be tilted blocks traversed by numerous faults. They may thus be interpreted as relics of fault-blocks that have emerged since the end of the Palaeogene.

The Idu peninsula projects into the Pacific from the southern coast of the central Japan, separating the Suruga bay on the west from the Sagami bay on the east. Geologically speaking, this peninsula is the southernmost expression of the much larger region of the fossa magna. The southern half of the peninsula is composed largely of the so-called Idu Neogene formations, which continue beneath the Quaternary volcanoes (Amagi, Daruma, Usami, Taga, etc.) of the northern part of the peninsula into the Asigara mountains that border the peninsula on the north. Various volcanics are represented in the formations, together with contemporaneous sedimentary rocks composed practically of volcanic material. Consequently one finds here a wealth of phenomena testifying to the intensive volcanic activities that have characterized this region since the time of the Neogene. This is the case not only with the Idu peninsula, but also with the whole region of the fossa magna, of which the Idu peninsula forms but a very small part. The sequence of volcanic activities as inferred from the rock-sequence in various parts of the fossa magna are correlative with each other, although in detail the sequence of one part may be more complicated than that of another[10]. Throughout the region of the fossa magna the Neogene volcanism dates from the lower Miocene, which appear to have been concurrent with the period during which the fossa magna was formed. It is probable that the tectonic disturbance that brought about the fossa magna was responsible for the volcanism.

The Neogene formations of the Idu peninsula seem to continue farther south into the submarine ridge on which the Quaternary insular volcanoes of the Seven Idu Islands rest, seeing that the Zenisu Rocks[11], which are nothing but erosion-relics of a peak projecting from the submarine ridge (Fig. 1), are composed of volcanics (lava and agglomerate) similar to the altered lower Miocene andesites from the Idu

10) H. TSUYA, *Bull. Earthq. Res. Inst.*, 10 (1932), 253.

11) A group of small reefs, about 150 km off the suthern point of the Idu peninsula.

peninsula.

The structural relation of the Ogasawara Islands to the Idu peninsula and to other parts of the fossa magna is unknown at present. As will be described later, however, volcanics petrographically similar to the Palaeogene volcanics of Ogasawara are found amongst the Neogene volcanics of Idu. Moreover, many petrographic evidences show that most of the Tertiary volcanics of these two regions are comagmatic with the Quaternary volcanics of the Huzi volcanic zone. Accordingly, the Palaeogene volcanism of Ogasawara may be regarded as the forerunner of the Quaternary volcanism of the Huzi volcanic zone as well as of the Neogene volcanism of the entire region within the fossa magna.

A. *Palaeogene Volcanism of the Ogasawara (Bonin) Islands.*

The Palaeogene volcanics, which represent the oldest recognized volcanism in the region now under consideration, occupy the greater part of the Ogasawara island-group that comprises, in addition to the two larger islands, Titi-sima (Peel I.) and Haha-sima (Coffin I.), many uninhabited islets.

1. Eocene Volcanics of Haha-sima.

Haha-sima, situated 26°38′N. and 142°E., is an island with a very uneven profile, 250 m above the sea at its highest part, with an indented outline extending 17 km in a due N.–S. direction and 2 km in an E.–W. direction. The island is practically composed of volcanic rocks of an andesitic nature, with calcareous rocks next in abundance. Although the strata of these rocks throughout the island do not show any regular disposition, most of them dip at an angle of less than 20° south or north of west. The calcareous rocks (calcareous tuff and limestone) that are exposed patchwise and mostly in the central part of the island, yield abundant marine Eocene fossils. These fossils, which were examined first by S. Tokunaga (Yoshiwara)[12], were later revised by H. Yabe[13] and S. Hanzawa[14]. The last-named author divided them into two horizons—the Priabonian and the upper Lutetian stages. The Priabonian stage is represented by the *Pellatispira* limestone which is the youngest formation in the island. The upper Lutetian stage is represented by the *Nummulites* beds and the *Orthophragmina*-bearing

12) S. YOSHIWARA, *Geol. Mag.*, **9** (1902), 297.
13) H. YABE, *Jour. Geol. Soc., Tokyo*, **27** (1920), 19.
14) S. HANZAWA, *Ibid.*, **32** (1925), 470.

Globigerina beds, both of which are intercalated in the volcanic formations underlying the *Pellatispira* limestone.

These volcanic formations, which consist of lava, agglomerate, tuff-breccia, and tuff, are therefore of submarine eruptional origin ranging in age from middle to upper Eocene. The eruptions were probably of the central paroxysmal type that took place on the floor of the Eocene sea in the area adjoining the present island, seeing that the greater part of the formations consists of agglomerate and tuff, the agglomerate carrying abundant lava-blocks which are so large (1 m or more dia.) that they could scarcely have been derived from any remote eruption-centre.

So far as the writer's observations go, the volcanic formations comprise three kinds of andesitic rocks—two-pyroxene-andesite, quartz-bearing two-pyroxene-andesite, and olivine-bearing two-pyroxene-andesite. The following petrographic descriptions are those of eight specimens collected by the writer from the lava- and agglomerate-beds exposed along the road from Nankin-hama to Nisi-ura.

No. 1. *Two-pyroxene-andesite.* This rock, which forms the bulk of the volcanic formations, occurs as lava-flows, agglomerates, and as fragments in the tuff. Six specimens of the rock from various parts of the formations have generally similar petrographic characters, being porphyritic with many phenocrysts of plagioclase, augite, and hypersthene in an aphanitic groundmass. They are black to dark gray with a greenish tint that varies with the extent of alteration to which the rock has been more or less subjected. The freshest specimen of the rock that was collected south of Okimura has the following microscopic characters.

Phenocrysts: The plagioclase is distinctly zoned. Of the two kinds of the mineral distinguished, the one that occurs as the larger phenocrysts (2~5 mm dia.), is anorthite 99~91 An (n_1=1·5797~1·5756), and the other, the lesser one (0·1~1·0 mm dia.) is labradorite 68~54 An (n_1=1·5638~1·5560). The augite (0·1~0·5 mm dia.), which is pale brownish and non-pleochroic, has n_1=1·6910~1·6953 and 2V(+)=55°~51°. It often exhibits zonal structure as observed by differences in the optic angles in the manner: 2V(+)=55°, 52°, and 49° in the core, middle zone, and at the margin respectively. Average composition: $Wo_{35}En_{43}Fs_{22}$, assuming n_1=1·693 and 2V=52°. The hypersthene (0·1~0·5 mm long) is pale greenish with distinct pleochroism. n_1=1·6960, n_2=1·7080. 2V(−)=65°. Composition: $En_{62}Fs_{38}$. The mineral has a thin rim of monoclinic pyroxene in parallel intergrowth. The magnetite forms very small phenocrysts 0·2 mm across.

Groundmass: The groundmass is a dark-brown glass packed with plagioclase prismoids (0·05 mm long) and very minute granules of monoclinic pyroxene and magnetite.

The chemical composition of the rock just described is shown in column No. 1, Table I, where it is compared with a Tertiary (lower Miocene or older)[15] volcanic rock described by K. Tsuboya[16] as a hypersthene-andesite from Laulau Bay, Saipan

15) R. TAYAMA, *Sci. Rev. Geol. Palaeont. Inst., Tohoku Imp. Univ.*, **21** (1936), 43.

16) K. TSUBOYA, *Jap. Jour. Geol. Geogr.*, **9** (1932), 210.

Island, Marianas, and with a Tertiary andesite[17] from the top of Malakal Island, Palau[18]. As shown in the table, the Haha-sima andesite resembles in chemical composition the Tertiary pyroxene-andesites form the Marianas and Palau Islands. Still closer resemblances are found with some of the Tertiary pyroxene-andesites from the Idu peninsula (No. 12, Table V). As to its alkalies, the Haha sima rock is a normal andesite that is commonly met with in Japan, its normative plagioclase being labradorite 51 An. The normative pyroxene also is very close to that of the common Japanese pyroxene-andesite, its composition being $Wo_{20}En_{45}Fs_{35}$. As thus, plotted on

Table I.

	No. 1	A	B
SiO_2	58·47	56·45	56·69
Al_2O_3	16·47	18·97	16·47
Fe_2O_3	2·08	3·61	2·67
FeO	5·46	3·56	4·87
MgO	3·90	3·55	5·07
CaO	7·68	7·02	9·06
Na_2O	3·16	2·50	2·08
K_2O	0·91	0·43	0·43
H_2O+	0·75	1·68	0·74
H_2O-	0·33	1·14	0·60
TiO_2	0·80	0·61	0·64
P_2O_5	0·06	0·07	0·09
MnO	0·18	0·10	0·16
Total	100·25	99·69	99·57

Norm of No. 1.[19]

Q	12·85	QFM	Q	13
Or	5·57		F	61
Ab	26·74		M	26
An	28·09	NF	Or	9
Wo	4·18		Ab	44
En	9·74		An	47
Fs	7·39	NPl	An	51
Mt	3·01	NPy	Wo	20
Il	1·52		En	45
Ap	tr.		Fs	35
		Fe		65

No. 1. *Two-pyroxene-andesite.* Okimura, Haha-sima, Ogasawara (Bonin) Islands. S. Tanaka, analyst.
A. Hypersthene andesite. Laulau Bay, Saipan Island, Marianas Islands. S. Tanaka, analyst.
B. Pyroxene-andesite, Top of Malakal Island, Palau Islands. A. Soule, analyst.

the Wo-En-Fs diagram (or Di-Hd En Fs diagram), it falls within the area of the diagram, which, being occupied by the normative pyroxenes of the Japanese pyroxene-andesites, lies more to the En Fs side compared with the area representing the normative pyroxenes of the intra Pacific lavas.[20]

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17) R. TAYAMA, *Sci. Rep. Geol. Palaeont. Inst., Tohoku Imp. Univ.*, **18** (1935), 25.

18) W. H. HOBBS and W. F. HUNT, *Proc. Third Pan-Pacific Sci. Congr., Tokyo*, **1** (1926), 715.

19) For the convenience sake, the following abbreviated words are used in the tables of analyses throughout this paper.
QFM means the ratio (wt.%) Q: F: M in norm.
NF means normative feldspar (wt.%).
NPl means normative plagioclase (wt.%).
NPy means normative pyroxene (wt.%).
Fe means $100 \times (FeO+Fe_2O_3)/(FeO+Fe_2O_3+MgO)$.

20) S. TSUBOI, *Jap. Jour. Geol. Geogr.*, **10** (1932~33), 79.

No. 2. *Olivine-bearing two-pyroxene-andesite.* This rock, which is exposed as a weathered lava-flow south of Hyogo taira, is similar in texture and mineral constituents to the rock just described, except that it carries subordinate olivine phenocrysts that have been completely pseudomorphed by a chloritic substance.

No. 3. *Quartz-bearing two-pyroxene-andesite.* This rock was found as lava-blocks composing the bulk of the agglomerate bed exposed on the shore at Nisi-ura. Microscopically, it consists of phenocrysts of plagioclase, quartz, augite, hypersthene, and a light-greenish devitrified groundmass rich in secondary silica and zeolitic material. The agglomerate bed carries, in addition to the rock just mentioned, a few fragments of completely altered andesites which resemble microscopically some of the lower Miocene rocks from the Idu peninsula.

2. Upper Eocene or Lower Oligocene Volcanics of Titi-sima.

Titi-sima, situated about 30 km north of Haha-sima, in 27°N. and 142°E., is an indented island measuring about 8 km in a N.–S. direction and 4 km in a E.–W. direction. This island is virtually composed of a volcanic series of andesitic nature, although a small area in its southern extremity is occupied by a limestone bed. The lower part of the volcanic series is chiefly lava-flows, while the upper part consists of agglomerates (locally conglomeratic), tuff-breccia, and tuffs. The strata of these rocks, which generally dip gently southwest, are intruded in several parts of the island by small masses of a dacitic rock. According to Hanzawa[21], one of the lavas is conformably overlain by the limestone bed that is exposed at the southern extremity of the island as well as in the adjoining islets, and contains *Lepidocyclina* (*Eulepidina*) with some other foraminifera, for which reason it is referred to the Oligocene age. The volcanic series, therefore, is mostly lower Oligocene or upper Eocene, while the eruptions that gave rise to them were probably submarine, although the centre of eruptions cannot be traced at present.

The volcanic rocks are usually greatly altered, the alteration being exhibited in various ways. The commonest alteration product is a whitish to greenish flinty rock, infiltrated with calcedony, calcite, and zeolite. The following petrographic descriptions are those of ten of the least-altered specimens that were collected by the writer in 1935 from the volcanic series exposed near Omura and Okumura on the northern side of port Hutami. The alteration products and secondary minerals that were collected at the same time from the same series will form the subject of further study, although in a petrographic study of the island, they are quite important. Among the specimens examined, six are two-pyroxene-andesite, one aphyric andesite, one quartz-two-pyroxene-andesite, and the remainder tuff and tuff-breccia.

No. 4. *Two-pyroxene-andesite.* This rock, which, so far as observed, occupies the greater part of the volcanic series, occurs as massive lava and agglomerate. Mega-

21) S. HANZAWA, *loc. cit.*

scopically, the least-altered specimen, which is one of the angular lava-blocks composing an agglomerate bed exposed midway between Omura and Okumura, is pitch-black and more or less vesicular, the round vesicles (up to 3 mm dia.) of which are lined with a whitish zeolite. Although the rock carries megascopic phenocrysts of plagioclase and pyroxene, its porphyritic structure is rather inconspicuous. Microscopically, it contains phenocrysts of plagioclase, augite, and hypersthene scattered through a glassy groundmass packed with prismoids of plagioclase and monoclinic pyroxene and a few magnetite granules.

Phenocrysts: The plagioclase, which is very faintly zoned, is bytownites 87 An ($n_1=1{\cdot}5737$). The pale-brownish and non-pleochroic augite has $n_1=1{\cdot}6910$ and $2V(+)=53°$. Composition: $Wo_{36}En_{43}Fs_{21}$. The hypersthene, which is greenish with distinct pleochroism, shows $n_1=1{\cdot}6982$ and $2V(-)=65°$. Composition: $En_{61}Fs_{39}$. The mineral occurs either as isolated individuals or in parallel intergrowth with a monoclinic pyroxene ($c \wedge Z=39°$), the latter being usually on the outside.

Groundmass: Although the plagioclase appears to be a sodic bytownite, its composition could not be exactly made out, owing to its minute size. The optic angle of the monoclinic pyroxene, which last is rather pigeonitic, is about 44°.

Another specimen of the two-pyroxene-andesite is a lava-ball, 5~10 cm in diameter, a number of which occur in agglomerate exposed along a road at the eastern end of Omura. Megascopically, it is pitch-black with a resinous luster. Microscopically, it carries phenocrysts of plagioclase, augite, and hypersthene, all of which have the same optical properties as those in the preceding specimen. The groundmass is more glassy than that of the preceding rock, the greenish-brown glass ($n=1{\cdot}5198 \sim 1{\cdot}5245$) being packed with incipient crystals of plagioclase, monoclinic pyroxene and iron-ore, together with a few microphenocrysts of a pigeonitic pyroxene ($n_1=1{\cdot}7035$).

No. 5. *Aphyric andesite.* This rock, exposed on a cliff by the road immediately north of Okumura, occurs as a lava-flow, about 2 m thick, intercalated between agglomerate beds. Megascopically, it is black, aphanitic, and more or less vesicular, the vesicular cavities being lined with zeolites. When altered, it is grayish with various tints of green. Microscopically, the rock is entirely devoid of phenocrysts, except for a few augite (0·3 mm dia., $2V(+)\doteqdot 52°$), the whole mass being a greenish-brown glass densely packed with minute prismoids (0·05~0·1 mm long) of plagioclase and monoclinic pyroxene, and dusty magnetite granules, together with a few microphenocrystic laths of plagioclase and multiple-twinned monoclinic pyroxene. The plagioclase, as measured on one of the minute laths of the mineral is labradorite 68 An ($n_1=1{\cdot}564$). The monoclinic pyroxene is pigeonite, its optic angle being 30° and smaller and $\beta=1{\cdot}7026$. Composition: $Wo_{13}En_{47}Fs_{40}$.

The freshest part of the aphyric andesite was chemically analyzed by Tanaka, with the results shown in column No. 5 of Table II, where it is compared with three earlier analyses of samples from the same island, one from the neighbouring island, Ototo-sima, and with an analysis of augite-andesite obsidian from Saipan Island, Marianas. As the analysis No. 5 shows, the aphyric andesite just described is rather high in silica content, its norm showing abundant quartz. The normative plagioclase and pyroxene are 50 An and $Wo_{19}En_{26}Fs_{55}$ respectively. Hobbs and Hunt[22] give an analysis (A of Table II) of a specimen that they collected from "near the Church of England in the town of Bonin", and to which they refer with two other specimens as an augite-hypersthene-andesite with "large phenocrysts and broken crystals of hypersthene, augite (slightly sodic), andesine-labradorite-feldspar and large magnetite grains ……in a brownish glass containing numerous microlites of feldspar, green amphibole,

22) W. H. HOBBS and W. F. HUNT, *loc. cit.*

Table II.

	No. 5	A	B	C	D	E
SiO_2	62·22	59·65	54·44	53·92	53·18	63·58
Al_2O_3	13·81	13·24	12·90	17·98	16·18	14·57
Fe_2O_3	1·73	1·96	7·08	n.d.	10·30	1·52
FeO	6·54	5·66	n.d.	4 88	n.d.	5·92
MgO	2·07	5·92	12·75	4·57	6·72	1·60
CaO	6·51	6·70	5·12	7·59	10·12	4·58
Na_2O	2·70	2·51	2·06	3·92	1·85	4·86
K_2O	0·65	1·04	0·35	1·14	0·35	2·02
H_2O+	3·22	2·00	5·54	4·64	1·65	0·31
H_2O-	0·22	1·10				
TiO_2	0·24	0·29	n.d.	n.d.	n.d.	0·71
P_2O_5	tr.	0·06	n.d.	n.d.	n.d.	0·34
MnO	0·20	0·12	n.d.	n.d.	n.d.	tr.
Total	100·11	100·25	100·24	98·64	100·35	100·01

Norm of No. 5.

Q	23·96	QFM	Q	25
Or	3·90		F	52
Ab	23·07		M	23
An	23·36	NF	Or	8
Wo	3·72		Ab	46
En	5·12		An	46
Fs	10·55	NPl	An	50
Mt	2·55	NPy	Wo	19
Il	0·46		En	26
Ap	tr.		Fs	55
		Fe		80

No. 5. *Aphanitic andesite.* Okumura, Titi-sima, Ogasawara (Bonin) Islands. S. Tanaka, analyst.

A. Augite-hypersthene-andesite. Town of Bonin, Bonin Islands. K. McAlpine, analyst.

B. Andesite. Miyanoura, Titi-sima. Fukuda, analyst.

C. Bronzite-limburgite ("boninite"). Ogiura, Titi-sima. J. Petersen, analyst.

D. Andesite perlite. Kurose, Ototo-sima, Ogasawara (Bonin) Islands. Fukuda, analyst.

E. Augite-andesite obsidian. Saipan Island, Marianas Islands. Eyme, analyst.

minute grains of magnetite and prisms of apatite". The two analyses, columns 5 and A, are much alike, the only notable differences between them being the lower magnesia and the little higher silica of the aphyric andesite. Compared with these two analyses, the three old ones (B, C, and D of Table II) are certainly lower in silica, the other oxides showing diverse relations. Altogether, these three analyses are so in-complete and unsatisfactory that we cannot rely much upon them. The aphyric andesite is higher in silica and lower in alumina than the two-pyroxene-andesite from Haha-sima (No. 1 of Table I), the other oxides being approximately alike in both, if the higher water content of the former is taken into consideration. Containing almost the same amounts of silica and alumina, the aphyric andesite is more calcic and less alkalic than the augite-andesite obsidian (E of Table II) from Saipan Island, Marianas. Furthermore, in the matter of analyses of the Idu Neogene rocks, the aphyric andesite does not match in chemical composition with any of them. It is worth noting, however, as will be discussed presently, that the latter closely fits the variation diagram which, owing to its having been constructed exclusively from analyses of aphyric and aphanitic rocks from the Neogene and Quaternary volcanic rocks of Idu and the Southern Islands, represents variations in the magmatic liquids that have possibly characterized the volcanism of the region since the Neogene.

No. 6. *Two-pyroxene-dacite* (or *quartz-two-pyroxene-andesite*). This type of rock occurs in several parts of the island either as dikes or necks intruding into the two-pyroxene-andesite masses. The specimen which the writer collected from a dike (?) exposed on the sea-cliff, about 1·5 km south of Okumura, is megascopically pale-gray, compact, glassy, and porphyritic with phenocrysts of plagioclase and pyroxene. Microscopically, it contains phenocrysts of bytownite-labradorite 78~55 An (n_1=1·569~1·557), augite (n_1=1·703), hypersthene (n_1=1·7165), and indented quartz, in a glassy groundmass packed with microphenocrystic plagioclase, pyroxenes (both monoclinic and rhombic), and magnetite, besides incipient crystals of plagioclase and pyroxene.

B. *Neogene Volcanism of Idu.*

General statement.

The Neogene Tertiary volcanics, which are distributed extensively over the Idu peninsula, and which range in age from lower Miocene to upper Pliocene, comprise various rock-types from olivine-basalt to biotite-liparite, all accompanying their own pyroclastics, besides solid lavas. Since the sequence of these rocks has been given by the writer in his earlier papers[23], it will not be repeated here. However, in order to present in one whole view, the leading rock-types that erupted during the Neogene, the general rock-sequence as they erupted is given in Table III in a more or less revised form, together with the stratigraphic sequences as proposed by previous writers. This table may by taken as giving the sequence, generally, although in detail the sequence would naturally be much more complicated.

The oldest series in the Neogene volcanic sequence is represented by greenish andesitic rocks referred to as the so-called propylite, and their pyroclastics (green tuff, tuff-breccia, and agglomerate), intercalated with shale, sandstone, and conglomerate, all of which are mostly composed of volcanic material. The volcanic rocks of the series, which vary considerably in megascopical as well as in microscopical charac-

23) H. TSUYA, *Bull, Earthq. Res. Inst.*, 10 (1932), 247; *Proc. Fifth Pan-Pacific Sci. Congr.*, Victoria and Vancouver, B.C., Canada, (1933), 2385.

ters, have been subjected to various degrees of "propylitization". Those in which the primary constituents (plagioclase and mafic minerals) are entirely replaced by secondary calcite, chlorite, zeolite, epidote, silica, etc., are frequently met with, while highly albitized or highly silicified rocks are also represented. As may be judged from the less-altered parts of these rocks, most of them are altered pyroxene-andesite (and basalt), but some of them have certainly been derived from dacitic (or liparitic) rocks. Thus the oldest series, which is exposed in the upper course of the Kano-gawa (river) from Yugasima to Amagi-toge in central Idu, is regarded by Tayama and Niino[24] as the most typical representative of their "Yugasima series" (see Table III), which consists of altered dacitic rocks, besides altered andesites, together with green tuff and tuff-breccia containing abundant quartz fragments.

The oldest series is invaded by minor intrusives (dike and intrusive sheet) of basalt, diabase, altered andesite, dacite and liparite (or quartz-porphyry). It is worth noting that both the intrusives and their wall-rocks are altered in the same way, while the alteration in the wall-rocks is more intensive at their contacts with the intrusives than at distances from them.

Although the age of the oldest series has not yet been definitely determined, the upper limit to the possible range of the age is fixed by a lower Miocene series which consists chiefly of strata of more or less altered andesite, dacite, and their tuffs, intercalated with foraminifera limestones (Nasimoto beds and Simo-Siroiwa beds)[25], and which appear to overlie the oldest series. The writer has still no definite evidence that would enable him to determine the stratigraphic relation between the oldest series and the limestone-bearing series. Whether the former underlies the latter with unconformity between them, or without, it is possible that they are of about the same age. Notwithstanding that the limestone-bearing series has been assigned by Tayama and Niino to the "Sirahama group", the writer believes that the former is older than the Sirahama beds which, as developed in the vicinity of Sirahama, south Idu, are regarded as type-horizons of the Sirahama group.

The volcanic series next to the oldest one (including the limestone-bearing series), which is distributed extensively in the southern part, and rather locally in the northern part, of the Idu peninsula, consists largely of alternations of pumiceous tuff, tuff-breccia, and agglomerate,

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24) R. TAYAMA and H. NIINO, *Rep. Sci. Res., Saito Gratitude Foundation*, Nos. **11**, **13** (1931).

25) *Miogypsina* limestone of Nasimoto and *Lepidocyclina* limestone of Simo-Siroiwa. Cf. S. HANZAWA, *Sci. Rep., Tohoku Imp. Univ.*, **12** (1928~33), 159.

Table III. Tertiary Volcanic Sequence of Idu.

	Idu (Tsuya)		Idu (Tayama and Niino)			Atami, Yugawara, Hakone (Kuno)	
	Effusives	Minor Intrusives	Volcanics	Formations		Volcanics	Formations
Pliocene	Pyroxene-dacite Pyroxene-andesite Basalt Hornblende-pyroxene-dacite (Hiyekawa beds) Pyroxene-andesite	Pyroxene-porphyrite (dike)				Basalt Basalt Pyroxene-andesite Hornblende-dacite Basalt Olivine-pyroxene-andesite Pyroxene-andesite	Hata beds Aziro beds Tensyozan beds Mikasayama bed Ainohara beds Inamura beds
Miocene	Pyroxene-andesite Hornblende-dacite Biotite-plagio-liparite Potash-liparite (Simoda beds) Dacite, Pyroxene-andesite and tufts*	Dacite Liparite (or quartz-porphyry)	Pyroxene-andesite Andesite-tuff Liparite-tuff Liparite Dacite White tuff Pyroxene-andesite	Matuzaki group Sirahama group Tateiwa group Aoiti group	Simoda series	Pyroxene-andesite Dacite-tuff	Sukumogawa beds Hayakawa beds
	Propylite series Dacite and/or liparite Andesite Basalt (Yugasima beds)	Altered pyroxene-andesite Basalt Diadase Diabase-porphyrite	Dolerite Diabase Porphyrite Propylite Green tuff	Yugasima group	Yugasima series	Quartz-gabbro Quartz-diorite Green andesite Green tuff-breccia	Dogasima beds Hirogawara beds Sogayama beds

* Includes horizons of *Miogypsina* limestone (Nasimoto) and *Lepidocyclina* limestone (Simo-Siroiwa).

together with a few tufaceous shales and sandstones. Lavas are comparatively insignificant in amount and local in origin, though minor intrusives frequently occur. The rocks of this series are mostly of rather acid type, including varieties that range from potash-liparite, through plagioliparite, into dacite, although certain andesites are also represented, especially in the upper horizons of the series.

The oldest series is clearly distinguished from the last-mentioned one. The former has been subjected to more intense alteration than the latter, and although the rocks of the former are generally devoid of most of their primary constituent minerals, the rocks of the latter usually retain their primary structure with the least-altered minerals (feldspar, pyroxene, hornblende, biotite, etc.), while the pumiceous tuff of the former series contains much devitrified pumice, in contrast to which the allied rock of the latter consists of fresh pumice. The boundaries of the two series are often defined by faults. Were it not the case, they should lie one above the other unconformably, since certain rock-fragments belonging to the oldest series are contained in the tuff ane tuff-breccia of the other series.

Tayama and Niino mention the "Aoiti group" and "Tateiwa group", both of which, included in the "Simoda series", are supposed to be younger than the Yugasima series, but older than the Sirahama group. They refer to the Aoiti group as a bed of agglomerate consisting chiefly of hypersthene-andesite and two-pyroxene-andesite, while according to them, the Tateiwa group consists of alternating layers of dacitic and liparitic tuffs. So far as the writer's observations in northern Idu go, there is no need to place these two groups between the Yugasima and Sirahama group, seeing that, of the beds to which they have assigned the one or the other of these two groups, one may be correlated to the Yugasima group and the rest to the Sirahama group.

Only a few areas of upper Miocene and lower Pliocene volcanics have been recognized in Idu. This may be due largely to the difficulty of distinguishing between lower and upper Miocene, and between Miocene and Pliocene, particularly when there are only a few sedimentary rocks that probably belong to these periods, and which, so far, have yielded only fossils of small value as age markers. The upper horizons of the Tayama and Niino's Sirahama group, which, contrary to the dacitic and liparitic rock-types of its lower horizons, are chiefly represented by andesitic rock-types (tuff and tuff-breccia of pyroxene-andesite), are possibly upper Miocene, although there may be marked unconformity between the upper and lower horizons. Indeed, according to Y. Otuka[26], the shell beds at Sirahama (type locality of the Tayama and Niino's Sirahama group) may be correlated with the shell beds in the Hayakawa tuffite beneath the Hakone volcano, both of which contain fossils that point to their age as being upper Miocene or lower Pliocene.

The Tertiary beds exposed on the wall of the Tanna tunnel near its western entrance are examples of upper Miocene or lower Pliocene volcanics. These volcanics are divided into upper and lower horizons (Fig. 3, Table XII). The lower horizon consists of loosely-coherent sand beds containing abundant sandy pebbles of hornblende-dacite, one of the lower Miocene volcanics. According to Otuka[27], judging from the fossils they contain, the sand beds may be middle Neogene (upper Miocene or lower Pliocene). The upper horizon, which overlies unconformably (?) the lower, is represented by a volcanic series consisting of a glassy two-pyroxene-andesite lava, with its agglomerate and tuff-breccia[28]. A dike of similar andesite occurs as an intrusive into the lower horizon. These volcanics, which underlie another and wholly different series of volcanics and sedimentaries (lower Pleistocene beds referred to as the Simo-Tanna beds), may be lower Pliocene or slightly younger. They probably extend southward underneath the lavas from the Taga volcano into the Tertiary terrane in the vicinity of Nirayama, for similar rocks are exposed patchwise in this terrane. Here, however, they overlie lower Miocene rocks (green tuff-breccia, propylite, dacite, etc.), both forming steep slopes that border the overlying lavas from the Taga volcano on the east. The Tertiary volcanics, that is, those located west of the last-mentioned locality across the Kano-gawa Alluvial plain, and which form Wasidu-yama and Katuragi-yama, may also be of the same age. Besides these, similar volcanics are found in several Tertiary terranes of central and south Idu, although their age is not yet certain.

Upper Pliocene volcanics occur in the Tertiary terrane that borders the Amagi volcano on the north, their type localities being Hiyekawa, Kasiwa-toge, and thereabouts. Covered unconformably by the lower Pleistocene beds (Zyo beds) and by lavas from the Pleistocene volcanoes (Tensi-yama, Usami, and Amagi-san), they rest on the Mio-

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26) Y. OTUKA, *Jour. Geol. Soc., Tokyo*, **41** (1934), 564.

27) Y. OTUKA, *Bull. Earthq. Res. Inst.*, **11** (1933), 548.

28) This series may possibly be correlated with the Asigara formation which is distributed extensively in the Tertiary terrane that borders the Hakone volcano on the north, as rocks closely resembling the former are found among the volcanics from the latter.

cene beds exposed in the same district. Basalt, andesite, dacite, and plagioliparite are the rock-types represented in them. These upper Pliocene volcanics occur as solid lavas accompanying their own tuffs, tuff-breccias, and agglomerates, with a few intercalated tufaceous shales and mudstones. Of these, tuff, shale, and mudstone have yielded fossil shells and foraminifera. According to Otuka, the fossil shells that the writer collected from a tufaceous shale exposed along the driveway south of Kasiwa-toge, are either lower Pleistocene or upper Pliocene. They may be assigned more probably to the upper Pliocene, seeing that the beds in which they occur are older and more deformed than the lower Pleistocene Zyo beds. The Matuzaki group which, according to Tayama and Niino, consists practically of pyroxene-andesite (tuff and agglomerate), may be partly at any rate of the same age.

To summarize, since all the Neogene Tertiary volcanics from lower Miocene to upper Pliocene have yielded marine fossils in the intercalated tuffs and tufaceous sediments, they can be assigned to submarine eruptions during the Neogene. Now volcanics that thicken toward their centres have been taken to mark volcanoes of the central eruption type, but none of these volcanics do so sufficiently to warrant the supposed association. It is thus possible that the eruptions of the Tertiary age took place from numerous local vents. Some of the dikes and necks that occur among the Tertiary volcanic masses are probably indications of it.

The petrography of the Neogene Tertiary volcanics was studied with a few representative specimens from the large number that the writer collected, mostly from the Tertiary terrane round and about the Amagi volcano, and which include several rock-types ranging from basalt to plagioliparite. As to the acid rocks which, distributed extensively in the southern and southwestern parts of the peninsula, include dacite, plagioliparite, and potash-liparite[29], the writer reserves his comments as brief reference to them has already been made elsewhere[30].

3. Miocene Effusives.

Seven specimens of the Miocene effusives[31] were studied, both micro-

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29) Although the type-locality of the potash-liparite is Manzo-yama, near Simoda, a similar rock occurs at Kisami and Sitaru, about 1·5 km and 10 km southwest of Simoda. To these may be added the biotite-liparite exposed immediately south of Hama, Simo-Kawadumura, since the rock is similarly rich in potash (8·54% K_2O), Cf. T. YAMAGISHI, *Jour, Geol. Soc., Japan,* **43** (1936), 384.

30) H. TSUYA, *Bull. Earthq. Res. Inst.*, **7** (1929), 329.

31) The localities of the specimens examined are shown in Fig. 2 by corresponding numbers.

scopically and chemically, with results as shown in Tables IV and V. They are of the following rocks.

Table IV. Constituent Minerals of the Miocene Effusive Rocks, Idu.

		No. 7	No. 9	No. 10	No. 12	No. 13
Porphyritic Minerals	Plagioclase	$n_1=1·5795\sim1·5759$ 93~91 An	$n_1=1·5660$ 72 An	$n_1=1·5800\sim1·5762$ 100~92 An	$n_1=1·5615\sim1·5560$ 47~37 An	$n_1=1·5582\sim1·5542$ 58~50 An
	Augite	—	$n_1=1·6975$ $2V(+)=56°$ $Wo_{40}En_{37}Fs_{23}$	$n_1=1·6846\sim1·6910$ $2V(+)=54°$ (core) $2V(+)=49°$ (margin) $Wo_{33}En_{42}Fs_{25}$	$n_1=1·6914\sim1·6938$ $2V(+)=52°$ (core) $2V(+)=56°$ (margin) $Wo_{38}En_{42}Fs_{20}$	—
	Hypersthene	—	Completely replaced by chlorite	$n_1=1·6864\sim1·6916$ $2V(-)=60°$ (core) $2V(-)$ 72° (margin) $En_{69}Fs_{31}$	$n_1=1·7045\sim1·7087$ $2V(-)=62°$ (core) $2V(-)=57°$ (margin) $En_{54}Fs_{46}$	—
	Olivine	Completely replaced by chlorite	—	Largely replaced by chlorite	—	—
	Hornblende	—	—	—	—	$n_1=1·6610$ $n_2=1·6727$ $2V(-)=83°$ Largely replaced by chlorite
	Accessories	—	—	Quartz Magnetite	Quartz Magnetite	Quartz Magnetite Apatite
Groundmass	Plagioclase	$n_1=1·5652$ 70 An	$n_1=1·5630$ 66 An	$n_1=1·5710$ 82 An	n.d.	n.d.
	Pyroxene	$\beta=1·7114$ $2V(+)=43°$ $Wo_{24}En_{36}Fs_{40}$	n.d.	$n_1=1·6952$ $2V(+)=52°$ (core) $2V(+)=33°$ (margin) $Wo_{34}En_{42}Fs_{24}$	Augite: $n_1=1·6965$ $2V(+)=50$ Hypersthene: $2V(-)=61°\sim69°$	—
	Accessory and interstitial materials	Magnetite Cristobalite Glass base	Glass	Glass	Magnetite Apatite Acid feldspar Quartz Secondary chlorite and zeolite	Magnetite Apatite Acid feldspar Quartz

Table V. Analyses of the Miocene Effusive Rocks from Idu. S. Tanaka, analyst.

		No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13
SiO_2		49·62	53·13	54·40	54·55	55·72	59·91	63·16
Al_2O_3		20·37	17·75	18·00	16·54	16·08	16·42	15·68
Fe_2O_3		2·61	5·14	1·77	1·47	4·16	3·52	3·11
FeO		6·71	3·90	6·76	7·10	4·62	3·71	2·55
MgO		4·05	3·24	4·08	5·76	3·30	2·81	2·35
CaO		11·97	7·58	8·02	8·85	6·73	6·82	4·48
Na_2O		1·89	2·52	2·61	2·06	2·78	3·17	2·77
K_2O		0·31	0·23	1·19	0·62	0·48	1·07	2·33
H_2O+		0·39	1·71	1·63	1·41	1·44	0·74	1·30
H_2O-		0·71	3·80	0·91	0·87	3·38	0·73	1·20
TiO_2		0·87	0·87	0·78	0·70	0·82	0·72	0·52
P_2O_5		0·07	0·12	0·13	tr.	0·10	0·13	0·10
MnO		0·17	0·09	0·16	0·16	0·12	0·14	0·05
Total		99·74	100·08	100·44	100·09	99·73	99·89	99·61
Q		4·93	16·34	8·29	9·73	17·48	18·92	24·56
Or		1·67	1·11	7·23	3·90	2·78	6·12	13·91
Ab		15·73	21·50	22·02	17·30	23·59	26·74	23·59
An		46·45	36·44	33·93	33·93	30·04	27·54	21·42
Wo		5·11	0·12	2·09	4·18	1·05	2·32	C=0·71
En		10·04	8·03	10·13	14·36	8·23	7·03	5·92
Fs		8·97	1·59	9·90	10·95	3·96	3·03	1·32
Mt		3·70	7·41	2·55	2·08	6·02	5·09	4·40
Il		1·67	1·67	1·52	1·37	1·52	1·37	1·05
Ap		tr.	0·33	0·33	tr.	0·33	0·33	0·33
QFM	Q	5	17	8	10	18	19	25
	F	64	62	64	56	59	61	61
	M	31	21	28	34	23	20	14
NF	Or	2	2	11	7	5	10	24
	Ab	24	36	35	31	42	44	40
	An	74	62	54	62	53	46	36
NPl	An	75	63	61	66	56	51	48
NPy	Wo	21	2	9	14	8	19	—
	En	42	82	46	49	62	57	82
	Fs	37	16	45	37	30	24	18
Fe		69	72	67	59	72	71	69

No. 7. *Olivine-basalt.* Compact, greenish-gray, and porphyritic with plagioclase phenocrysts. Agglomerate in Kuno's Soga-yama beds (lower Miocene) underlying the two-pyroxene-andesite lave from the Taga volcano. Locality: about 1 km south of Atami along the driveway leading from Atami to Aziro, north Idu.

No. 8. *Two-pyroxene-andesite.* Compact to vesicular, greenish-gray, and slightly porphyritic with plagioclase phenocrysts and rare augite. Microscopically, the porphyritic minerals are anorthite 92 An ($n_1=1{\cdot}5763$), augite ($n_1=1{\cdot}698$), and chloritized hypersthene. The groundmass is occupied largely by a chloritic substance, besides a few plagioclase laths and magnetite grains. Lava, about 5 m, thick, intercalated between fossiliferous gray-tuff beds (lower Miocene) a short distance below the *Lepidocy-*

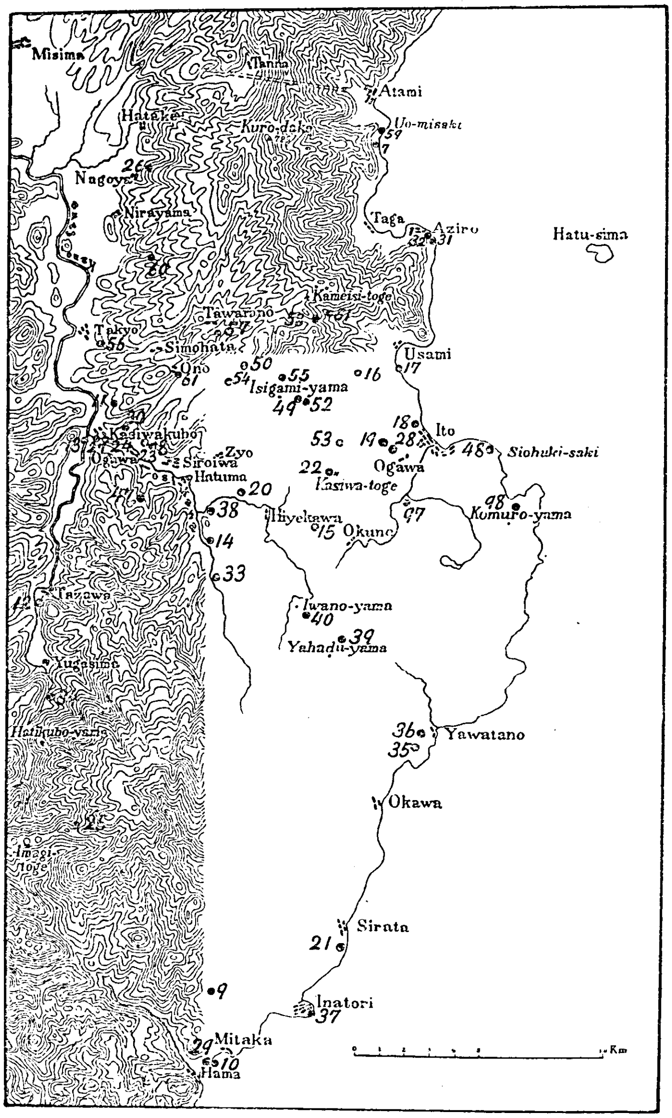

Fig. 2. Northeastern part of the Idu peninsula, showing the localities of the rock-specimens described in the text.

clina-limestone horizon. Locality: Simo-Siroiwa, Simo-Omimura, north Idu.

No. 9. *Two-pyroxene-andesite.* Compact, greenish-gray, and porphyritic with phenocrysts of plagioclase and pyroxene. Lava underlies a Miocene (lower ?) series composed of liparite and dacite, together with their tuff and tuff-breccia. Locality: about 2 km inland from Mitaka, Simo-Kawadumura, south Idu.

No. 10. *Quartz-olivine-bearing two-pyroxene-andesite.* Compact to slightly vesicular, dark-gray to black, and porphyritic with phenocrysts of plagioclase, pyroxene, olivine, and quartz. Agglomerate in the fossiliferous tuff and sandstone beds (Miocene, lower ?). Locality: sea-shore immediately north of Hama, Simo-Kawadumura, south Idu.

No. 11. *Two-pyroxene-andesite.* Vesicular, greenish-gray, and slightly porphyritic with plagioclase phenocrysts and a few pyroxene. Microscopically, it contains phenocrysts of faintly-zoned anorthite-bytownite 93~85 An (n_1=1·5766~1·5727) and partially-chloritized augite (n_1=1·6952), with completely chloritized hypersthene, all in a groundmass consisting of labradorite 60 An (n_1=1·5596), magnetite, and tridymite, with a base impregnated by a chloritic substance. The vesicles are lined with zeolite. Agglomeratic lava intercalated between fossiliferous tuff and tuff-breccia beds (Miocene, lower ?). Locality: mountain-side, 1·5 km east of Makinogo, Kita-Kanomura, north Idu.

No. 12. *Quartz-bearing two-pyroxene-andesite.* Compact to vesicular, pale-gray, and porphyritic with phenocrysts of plagioclase and pyroxene. Lava and agglomerate unconformably overlie the propylite series. Locality: east bank of Kano-gawa, midway between Tazawa and Itiyama, Kami-Kanomura, north Idu.

No. 13. *Hornblende-dacite.* Compact, greenish-gray, and porphyritic with phenocrysts of plagioclase, quartz, and hornblende. The agglomerate of this rock is overlain by strata of siliceous sandstone and tuff (lower Miocene), and intruded by dikes of green andesite. Locality: floor of the Kano-gawa, at Ko-Tatino, Kita-Kanomura, north Idu.

4. Pliocene Effusives.

Ten specimens of the Pliocene effusives were examined both microscopically and chemically, with the results as shown in Tables VI and VII. They are of the following rocks[32].

No. 14. *Hypersthene-bearing augite-olivine-basalt.* Compact, greenish-gray to black, and porphyritic with phenocrysts of plagioclase and olivine. Microscopically, augite phenocrysts are surrounded by sharp, narrow rim of pigeonite. The hypersthene occurs only in parallel intergrowth with the phenocrystic augite. The agglomerate, which overlies dacite (lava and agglomerate) and pumiceous tuff (upper Pliocene), is unconformably overlain by the Zyo beds and a lava-flow from the Amagi volcano. Locality: about 500 m south of Hatuma, Simo-Omimura, north Idu.

No. 15. *Olivine-basalt.* Compact, gray, and porphyritic with abundant plagioclase phenocrysts and a few olivine. Lava resting upon another lava (pyroxene-andesite, No. 16) which in turn overlies dacitic agglomerate. Locality: 3 km southeast of Hiyekawa along the mountain path from Hiyekawa to Okuno, Ito-mati, north Idu.

No. 18. *Two-pyroxene-andesite.* Compact, greenish-gray to black, and porphyritic with phenocrysts of plagioclase and pyroxene. Lava with platy joints. It is covered by the lavas from the Usami volcano. Petrographically, it closely resembles the

32) The localities of the specimens examined are shown in Fig. 2 by corresponding numbers.

Table VI. Constituent Minerals of the Pliocene Effusive Rocks, Idu.

		No. 14	No. 15	No. 18	No. 20	No. 21	No. 22
Porphyritic Minerals	Plagioclase	n_1=1·5748 89 An	n_1=1·5770~ 1·5749 94~90 An	n_1=1·5769~ 1·5684 93~77 An	n_1=1·5568~ 1·5537 55~49 An	n_1=1·5546~ 1·5515 50~46 An	n_1=1·5660~ 1·5540 70~50 An
	Augite	core margin 2V(+)=60°→53° →16° n_1=1·6970~1·6995 c∧Z≒45° $Wo_{40}En_{37}Fs_{23}$	—	2V(+)=50° n_1=1·6905 $Wo_{32}En_{45}Fs_{23}$	2V(+)=53° n_1=1·6950 $Wo_{37}En_{41}Fs_{22}$	n_1=1·6910	2V(+)=46°(min.) n_1=1·6965~1·6980 $Wo_{27}En_{43}Fs_{30}$
	Hypersthene	2V(−)≒79° (very rare)	—	2V(−)=64° n_1=1·6992 $En_{60}Fs_{40}$	2V(−)=61° n_1=1·7074 $En_{53}Fs_{47}$	2V(−)=63° n_1=1·6955 $En_{63}Fs_{37}$	2V(−)=62°
	Olivine	α=1·6715 β=1·6920 $Fo_{74}Fa_{26}$	2V(−)≒86° Largely replaced by chlorite	—	—	—	—
	Accessories	—	—	Magnetite Apatite	Hornblende Quartz Magnetite Apatite	Magnetite	Quaartz Magnetite
Groundmass	Plagioclase	n.d.	n_1=1·5633 67 An	n_1=1·5628 65 An	n.d.	Greenish-brown glass packed with microlites and spherulites (acicular tridymite, feldspar, and hornblende). Tridymite patches	Glass (n=1·491) packed with microlites, spherulites,and magnetite dust.
	Pyroxene	2V(+)=18°~0° β=1·7050 $Wo_{11}En_{40}Fs_{49}$	2V(+)=51°(core) −37° (margim) 17·30 $Wo_{24}En_{36}Fs_{40}$	Augite Hypersthene	Augite Hypersthene		
	Accessory and interstitial materials	Magnetite	Magnetite Tridymite	Magnetite Tridymite Quartz Acid feldspar	Magnetite Tridymite Glass		

Table VII. Analyses of the Pliocene Effusive Rocks from Idu.
S. Tanaka, analyst,

		No. 14	No. 15	No. 16	No. 17	No. 18	No. 19	No. 20	No. 21	No. 22
SiO_2		48·57	50·82	56·42	57·19	60·70	61·25	65·85	70·00	75·63
Al_2O_3		19·25	20·54	17·01	16·85	16·10	16·34	15·95	14·89	12·80
Fe_2O_3		2·56	3·78	3·06	3·91	2·79	3·28	2·84	2·03	0·47
FeO		7·70	5·44	4·97	3·97	3·92	3·30	1·89	1·32	1·95
MgO		6·38	3·30	4·36	4·28	2·78	2·35	1·92	0·73	0·28
CaO		11·21	10·60	8·49	7·74	6·26	6·02	4·44	3·05	2·20
Na_2O		1·73	2·29	2.12	2·46	3·39	3·51	3·51	4·14	3·71
K_2O		0·16	0·28	0·66	0·41	0·97	0·99	1·56	2·09	2·35
H_2O +		0·74	0·70	0·58	1·16	0·68	0·96	0·78	0·50	0·25
H_2O −		0·85	1·20	0·97	0·64	1·06	0·80	0·80	0·54	0·07
TiO_2		0·75	0·78	0·70	0·68	0·69	0·71	0·48	0·45	0·26
P_2O_5		0·10	0·04	0·06	0·09	0·27	0·18	tr.	0·13	tr.
MnO		0·15	0·14	0·16	0·19	0·11	0·11	0·11	0·09	0·06
Total		100·15	99·91	99·56	99·57	99·72	99·80	100·13	99·96	100·03
Q		1·86	7·81	15·92	18·08	19·40	20·42	26·55	30·75	38·56
Or		1·11	1·67	3·90	2·23	5·57	6·12	9·46	12·24	13·91
Ab		14·68	19·40	17·83	20·97	28·84	29·89	29·89	35·13	31·46
An		44·23	44·78	35·05	33·66	25·87	25·59	21·97	14·19	10·85
Wo		4·41	3·25	2·91	1·63	1·39	1·39	C=0·31	C=0·61	C=0·20
En		15·86	8·23	10·84	10·64	6·92	5·82	4·82	1·81	0·70
Fs		11·08	5·80	5·67	3·30	4·09	2·38	0·53	—	2·90
Mt		3·70	5·56	4·40	5·56	3·94	4·86	4·17	3·01	0·69
Il		1·37	1·52	1·37	1·37	1·37	1·37	0·91	0·91	0·46
Ap		0·33	tr.	tr.	0·33	0·65	0·33	tr.	0·33	tr.
QFM	Q	2	8	16	18	20	21	27	31	39
	F	61	67	58	58	61	63	62	63	56
	M	37	25	26	24	19	16	11	6	5
NF	Or	2	3	7	4	9	10	15	20	25
	Ab	24	29	31	37	48	49	49	57	56
	An	74	68	62	59	43	41	36	23	19
NPl	An	75	70	66	62	47	46	42	29	25
NPy	Wo	14	19	15	10	11	14	—	—	—
	En	51	48	56	68	48	61	90	100	19
	Fs	35	33	29	22	41	25	10	—	81
Fe		65	73	64	64	70	73	70	81	89

two-pyroxene-andesite agglomerate (lower Pliocene? or Otuka's middle Neogene) found on the wall near the west entrance of the Tanna tunnel. Locality: northern outskirt of Ito-mati, north Idu.

No. 16. *Two-pyroxene-andesite*. Lava-flow. Locality: about 2 km west of Nakazato, Usamimura, north Idu.

No. 17. *Two-pyroxene-andesite*. Lava-flow. Locality: sea-shore of Hadu, Usamimura, north Idu.

No. 19. *Two-pyroxene-andesite*. Lava and agglomerate intruded by a dike of quartz-bearing two-pyroxene-porphyrite (No. 28). Locality: Ogawa, immediately northwest of Ito-mati, north Idu.

Microscopically, these three rocks resemble the last-mentioned one (No. 18), so that the petrographic notes on them may be omitted, only their chemical analyses being given respectively in columns Nos. 16, 17, and 19, of Table VII.

No. 20. *Hornblende-augite-bearing hypersthene-dacite*. Pale-gray, compact but fragile, and porphyritic with abundant phenocrysts of plagioclase and pyroxene, besides a few hornblende and quartz. Glomeroporphyritic grouping of the phenocrysts, except the hornblende and quartz, is common. Lava and agglomerate, both associated with pumiceous tuff, are overlain by the basalt agglomerate (No. 14). Locality: Hiyekawa, Naka-Omimura, north Idu.

No. 21. *Two-pyroxene-dacite*. Pale-gray, compact but fragile, partly spherulitic, and porphyritic with phenocrysts of plagioclase and pyroxene. Lava with flow-banding, is unconformably overlain by both pyroclastic deposits and lava of the Amagi volcano. Locality: sea-cliff, 500 m south of Sirata, Kitomura, east coast of middle Idu.

No. 22. *Two-pyroxene-plagioliparite*. Obsidian with phenocrysts of plagioclase and pyroxene. Lava overlies a two-pyroxene-andesite lava, similar to rock No. 19, with ash beds between them. Although the basal part near the contact with the u-n derlying ash beds is obsidian, the main upper bulk of the lava is pale-gray to white, and lithoiditic. Locality: Kasiwa-toge, midway between Ito-mati and Hiyekawa, north Idu.

5. Minor Tertiary Intrusives.

Of the minor Tertiary intrusives in the Idu peninsula, the following eight[33] were examined microscopically and chemically, with results as shown in Tables VIII and IX.

No. 23. *Diabase*. Black to greenish-gray, crystalline, medium-grained, and porphyritic with abundant plagioclase phenocrysts. Intrusive sheet into a pumiceous tuff-breccia (lower Miocene). Locality: Simo-Siroiwa, Simo-Omimura, north Idu.

No. 24. *Aphric basalt*. Compact, black, and almost aphyric with negligible plagioclase phenocrysts. Intrusive sheet, about 10 m thick, into a pumiceous tuff carrying blocks of liparite (lower Miocene). Locality: southern bank of the Tosi-kawa (river), near Kadono, Simo-Kanomura, north Idu.

No. 25. *Diabase-porphyrite*. Greenish-gray, crystalline, medium-grained, and slightly porphyritic. Intrusive sheet (?) into a green tuff (lower Miocene, propylite series). Locality: northern side of the Amagi tunnel, Amagi-toge, Kita-Kanomura, middle Idu.

No. 26. *Green andesite*. Compact, greenish, and slightly porphyritic with phenocrysts of plagioclase. Microscopically, the plagioclase phenocrysts are almost unaltered, with the composition of bytownite 85 An ($n_1 = 1{\cdot}573$). The mafic phenocrysts

33) The localities of the specimens examined are shown by corresponding numbers in Fig. 2.

(augite?) are completely altered, their place being occupied by chlorite, calcite, and quartz. The groundmass consists of plagioclase laths and magnetite dust, together with chlorite, calcite, and quartz. One of the dikes intrude into a green tuff (lower Miocene . Locality: mountain side, east of Nagoya, Nirayamamura, north Idu.

No. 27. *Green andesite.* Compact, greenish, and porphyritic with plagioclase phenocrysts. Microscopically, the plagioclase phenocrysts are almost unaltered, with the composition of labradorite 54 An (n_1=1·5564), while the mafic phenocrysts (hornblende?) are completely altered to an aggregate of feldspar, magnetite, and chlorite. Accessory minerals: magnetite and apatite. The groundmass is a granular aggregate of quartz and feldspar, besides a few plagioclase prismoids and magnetite dust. The rock occurs as an intrusive sheet into a sandy tuff (lower Miocene) a short distance below the basalt sheet (No. 24). Locality: southern bank of the Tosi-kawa, Kadono, Simo-Kanomura, north Idu.

No. 28. *Quartz-bearing two-pyroxene-porphyrite.* Pale-gray, crystalline, medium to fine-grained, and slightly porphyritic. A dike intrudes into agglomerate of two-pyroxene-andesite (No. 19). Locality: quarry, immediately north of Ogawa, Ito-mati, north Idu.

No. 29. *Quartz-bearing two-pyroxene-porphyrite.* Dark-green, crystalline, medium-graind, and porphyritic. A dike intrudes into fossiliferous tuff and agglomerate

Table VIII. Constituent Minerals of the Minor Tertiary Intrusive Rocks, Idu.

		No. 23	No. 24	No. 25	No. 28	No. 29
Porphyritic Minerals	Plagioclase	n_1=1·5774~ 1·5750 95~90 An	n_1=1·5795~ 1·5749 98~90 An	n_1=1·5778~ 1·5665 95~73 An	n_1=1·5654 1·5620 71~65 An	n_1=1·5594 40 An
	Augite	—	—	2V(+)=52° n_1=1·700 $Wo_{34}En_{40}Fs_{26}$	2V(+)=50° n_1=1·694 $Wo_{32}En_{43}Fs_{25}$	2V(+)=57~ 53° n_1=1·6925~ 1·6952 c∧Z=43° $Wo_{38}En_{40}Fs_{22}$
	Hypersthene	—	—	2V(−)=65° n_1=1·698 n_2=1·702 $En_{61}Fs_{39}$	2V(−)≒77°	Completely replaced by chlorite.
	Accessories	—	—	Magnetite	Magnetite Quartz	Magnetite Quartz Apatite
Groundmass	Plagioclase	n.d.	n_1=1·562 65 An	n_1=1·5599 60 An	n_1=1·5540 50 An	n.d.
	Pyroxene	2V(+)=50° n_1=1·696 $Wo_{31}En_{42}Fs_{27}$	Pigeonite 2V very small	—	Augite Hypersthene 2V(−)≒67°~ 72°	Largely replaced by chlorite
	Accessory and interstitial material	Magnetite Secondary chlorite and zeolite	Magnetite Interstitial quartz Secondary chlorite	Interstital quartz Secondary chlorite	Magnetite Tridymite	Magnetite Interstitial quartz and feldspar

Table IX. Analyses of the Minor Tertiary Intrusive Rocks, Idu.
S. Tanaka, analyst.

		No. 23	No. 24	No. 25	No. 26	No. 27	No. 28	No. 29	No. 30
SiO_2		49·23	49·30	50·23	55·38	60·76	61·58	61·61	66·00
Al O_3		18·81	14·69	17·59	18·04	16·70	16·06	15·81	15·12
Fe_2O_3		4·16	5·27	2·44	2·69	2·76	3·92	2·84	3·70
FeO		5·85	7·70	6·69	4·07	3·31	2·75	3·75	0·91
MgO		4·64	5·75	5·84	2·42	3·71	2·45	2·67	1·38
CaO		9·82	7·58	10·28	7·84	4·18	6·36	5·88	3·73
Na_2O		1·97	1·89	2·13	2·40	2·98	3·31	3·53	4·13
K_2O		0·21	0·24	0·27	0·52	1·38	0·89	1·04	0·78
H_2O +		1·19	1·89	2·13	2·40	2·98	3·31	3·53	4·13
H_2O −		3·17	3·57	1·25	0·66	1·20	1·00	1·23	1·94
TiO_2		0·75	1·08	0·93	0·76	0·53	0·66	0·70	0·65
P_2O_5		0·08	0·06	0·06	0·13	0·05	0·08	0·08	0·15
MnO		0·18	0·13	0·27	0·11	0·08	0·13	0·17	0·08
Total		100·06	99·50	100·10	99·94	100·01	100·03	100·35	100·12
Q		7·81	10·33	4·80	21·86	22·16	22·76	20·18	29.25
Or		1·11	1·67	1·67	3·34	8·35	5·01	6·12	4·45
Ab		16·78	15·73	17·83	20·45	25·17	27·79	29·89	35·13
An		42·00	30·88	37·83	27·26	20·86	26·70	24·20	17·80
Wo		2·44	2·79	5·46	C=3·47	C=2·65	1·63	1·74	C=0·92
En		11·55	14·36	14·55	6·02	9·23	6·13	6·62	3·41
Fs		6·33	8·17	9·23	4·22	3·03	0·93	3·56	——
Mt		6·02	7·64	3·47	3·94	3·94	5·79	4·17	1·39
Il		1·37	2·12	1·82	1·52	1·06	1·21	1·37	1·21
Ap		0·33	tr.	tr.	0·33	tr.	0·33	0·33	0·33
Cc		——	——	——	3·90	——	——	——	Hm2·71
QFM	Q	8	11	5	24	24	23	21	31
	F	63	52	59	55	58	61	61	60
	M	29	37	36	21	18	16	18	9
NF	Or	2	3	3	7	15	8	10	8
	Ab	28	33	31	40	46	47	50	61
	An	70	64	66	53	39	45	40	31
NPl	An	71	66	68	57	45	49	45	34
NIy	Wo	12	11	19	——	——	19	15	——
	En	57	57	50	59	75	71	56	100
	Fs	31	32	31	41	25	10	29	——
Fe		67	69	60	73	61	70	70	75

beds (Miocene, lower ?). Locality: sea-cliff, immediately north of Hama, Simo-Kawadumura, south Idu.

No. 30. *Green andesite.* More or less vesicular, greenish, and almost aphanitic. Microscopically, the rock consists of plagioclase laths, magnetite granules, tridymite, and apatite, with a chloritic material, besides a few microphenocrysts of partially-altered labradorite 65 An (n_1=1·562). A dike intrudes into siliceous tuff and tuff-breccia (lower Miocene). Locality: top of Siro-yama, Kasiwakubo, Kita-Kanomura, north Idu.

II. QUATERNARY VOLCANISM.

General statement.

So far as could be observed in northern Idu, the earliest volcanism of Quaternary age is represented by the volcanics contained in the lower Pleistocene deposits, These deposits, which furnish a good horizon marker, enable the Quaternary volcanism to be dated with some degree of certainty. They are divided into the following two horizons:

The lower horizon of the lower Pleistocene deposits may be referred to as Zyo beds, named after the type-locality near the northern foot of Amagi volcano (see Fig. 2). It is an alternation of gravel, sand, and mud, containing numerous fossil shells and foraminifera, besides fossil leaves. According to Otuka[34], who made an exhausitive examination of these fossils, the Zyo beds may be either uppermost Pliocene or lowest Pleistocene, most probably his Dl. So far as examined, the constituent rock-materials of the Zyo beds are what may be expected to have been derived from the Tertiary rocks on which the beds rest unconformably. It is however worth noting that the mud carries not a few fragments of pumice—a possible indication that it is one of the earliest volcanics of the Pleistocene. The Zyo beds at the type-locality which, owing to dislocation by faulting dip generally 10°∼20°E. or NE. are overlain unconformably by lava-flows from the Usami volcano on the east.

The upper horizon of the lower Pleistocene deposits is an alternation of gravel, sandy tuff, and mud, and referred to as Ono beds, are typically exposed at Ono, about 6 km north of Zyo. There one of the typical exposures is seen on the northern bank of the Ono valley, where a landslide occurred at the time of the north Idu earthquake of 1931. Table X shows a detailed section of the exposure as actually measured by the writer.

The Ono beds, which at the type-locality are badly dislocated by faulting, overlie unconformably the tuff and tuff-breccia of lower Mio-

34) Y. OTUKA, *Bull. Earthq. Res. Inst.*, **11** (1933), 557.

Table X.

Thickness in meters	Rocks
8	Lava-flow (olivine-bearing two-pyroxene-andesite, No. 61).
0·05	Lapilli (olivine-bearing augite-andesite).
1	Ash containing plagioclase, pyroxene, and hornblende.
0·3	Gravel (aphanitic andesite, pyroxene-andesite, olivine-two-pyroxene-andesite, etc.).
	Unconformity.
0·5	Grayish mud.
0·1	Sandy tuff containing plagioclase, pyroxene, and olivine.
0·3	Grayish mud containing *Diatoms*.
0·2	Sandy tuff containing plagioclase, pyroxene, and fragments of pyroxene-andesite.
0·05	Grayish mud.
0·4	Sandy tuff containing plagioclase, pyroxene, and fragments of pyroxene-andesite.
5	Gravel (silicified dacite or liparite, aphanitic andesite, two-pyroxene-andesite, two-pyroxene-dacite, silicified rocks, etc.).
5	Yellowish mud.
2·5	Gravel (two-pyroxene-andesite, aphanitic andesite, quartz-porphyry, green rocks, etc.).
>15	Yellowish mud.
?	Gravel?
	Unconformity.
	Tertiary rocks (tuff and tuff-breccia).

cene, and are covered unconformably by lava-flow and pyroclastics from the Taga volcano. As will be seen from the foregoing table, volcanic materials become increasingly important upward, pyroxene-andesite being the rock-type represented.

The Ono beds may be correlated with the Simo-Hata beds which are typically exposed at Simo-Hata, about 2 km north of Ono, and which consist of gravel, mud, tufaceous shale, tuff, and tuff-breccia, all except the gravel containing fossil leaves and diatoms. Like the former, the latter, which dip 10°~30°NW. or SE., are unconformably underlain by Tertiary rocks, and underlie unconformably lava-flows from the Taga volcano. Table XI shows the rock-types represented in the beds.

Further north, at Simo-Tanna, are exposed Pleistocene deposits, referred to as the Simo-Tanna beds, and consisting of gravel, tufaceous sand, tufaceous shale, and tuff-breccia, all with fossil leaves except the gravel. These beds continue underground to beds similar to those found on the wall of the Tanna tunnel at a distance of 7000 ft and

Table XI.

Rocks	Volcanic Constituents and Fossils
Grayish tuff	Plagioclase, augite, olivine, and andesite scoria.
Volcanic sand	Olivine-two-pyroxene-andesite scoria and isolated crystals.
Tufaceous shale	Plagioclase, augite, hypersthene, and hornblende, with fossil leaves and diatoms.
Sandy tuff	Plagioclase, augite, and hypersthene.
Tufaceous mud	Plagioclase, augite, hornblende, and fragments of pyroxene-andesites, with fossil leaves and *diatoms*.
Gravel	

near it from its west entrance (Fig. 3). The latter consists of agglomerate, tufaceous shale, and sand, besides lapilli. The tufaceous

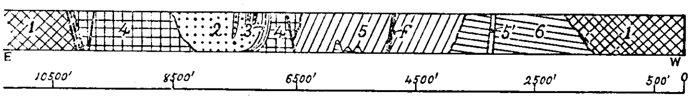

Fig. 3. Diagrammatic section showing the wall of the western half of the Tanna tunnel, north Idu.

1. Lava and agglomerate (olivine-basalt and olivine-pyroxene-basalt) from the Taga volcano.
2. Volcanic sand and agglomerate. ⎫
3. Pumice-tuff, lapilli, and gray tuff with diatoms. ⎬ Simo-Tanna beds.
4. Lava and agglomerate (two-pyroxene-andesite). ⎭
5. Lava, agglomerate, and tuff (two-pyroxene-andesite — lower Pliocene.

5'. Dike of two-pyroxene-andesite.

6. Sand and tuff with fossil shells—upper Miocene.

shale contains fossil leaves and diatoms. Table XII shows the rock-types of the Simo-Tanna beds, together with the underlying Tertiary rocks and the overlying lava and agglomerate, all as found on the wall of the tunnel[35]. Though detached from the outcrops of the Ono beds and the Simo-Hata beds, there is little doubt, as a comparison of Tables X, XI, and XII will show, that the Simo-Tanna beds are of the same age.

It is worth noting that the Simo-Tanna beds are possibly correlated, both petrographically and stratigraphically, with the Tutizawa beds that are distributed in the Oiso geologic province adjoining the north-

35) The writer is indebted to Y. Otuka for the rock-specimens from the tunnel wall.

Table XII. Stratigraphic Sequence and Volcanic Rocks as observed in the Wall of the Western Part of the Tanna Tunnel.

	Rocks represented	Locality of the specimens examined (distance in ft from the W. entrance of the tunnel.	Petrographic rock-types represented	Porphyritic minerals					
				Plagioclase	Augite	Hypersthene	Olivine	Hornblende	Quartz
Taga volcano	Lava and agglomerate	10923′	Olivine-augite-basalt	+	+	−	+	−	−
		10791′	Olivine-two-pyroxene-basalt	94 An $n_1=1·5572$	$n_1=1·6929$	$n_1=1·6892$	n.d.	−	−
		10461′	Olivine-basalt	92 An $n_1=1·5760$	$n_1=1·6983$	n.d.	$\alpha=1·6680$	−	−
Simo-Tanna beds	Pumice-tuff*	7821′	Hornblende-two-pyroxene-dacite	57∼48 An $n_1=1·5579$ ∼1·5527	$n_1=1·6930$	$n_1$1·6992∼1·7040	−	$n_1=1·6617$ $n_2=1·6757$	+
	Lapilli and gray tuff** with *diatoms*	7000′ 6963′	Olivine-two-pyroxene-basalt	+	+	+	+	−	−
	Lava and agglomerate	9669′	Two-pyroxene-andesite	92 An $n_1=1·5762$	$n_1=1·6928$	n.d.	−	−	−
		8283′	Do	96 An $n_1=1·5780$	$n_1=1·6925$	n.d.	−	−	−
		9141′	Do						
		6963′	Do						
Lower Pliocene or upper Miocene	Lava and agglomerate	4587′ (6435′)	Two-pyroxene-andesite	86 An $n_1=1·5730$	$n_1=1·6967$	n.d.	−	−	−
	Pumice-tuff	6435′	Two-pyroxene-andesite	87 An $n_1=1·5735$	$n_1=1·6970$	$n_1=1·6998$	−	−	−
	Agglomerate and tuff-breccia	5841′	Two-pyroxene-andesite	+	+	+	−	−	−
Miocene (Otuka's middle Neogene)	Tuff and sandstone with *fossil shells*	(6000′) 2145′	Hornblende-dacite (pebble)	57 An $n_1=1·5579$	−	$n_1≒1·712$	−	$n_2=1·680$	+

* Pumice glass n=1·5705.

** Carries fragments of olivine-basalt and pyroxene-andesite, besides isolated fragments of plagioclase, augite, hypersthene, olivine, and hornblende.

east foot of the Hakone volcano[36]. The Tutizawa beds are recognized by Otuka as lower Pleistocene (his Dl_f)[37].

Beneath the Taga volcano, in the vicinity of Aziro and Hata, lies a volcanic series which is composed of lavas and pyroclastic beds of basaltic nature, and is referred to by H. Kuno respectively as the Aziro beds and the Hata beds[38]. Although he has assigned these to upper Pliocene, definite evidence to justify the assignment is lacking. The writer believes them to be lower Pleistocene, seeing that the basaltic rocks in Kuno's Aziro beds and Hata beds are petrographically similar to some of the juvenile volcanic materials in the Simo-Hata beds as well as in the Simo-Tanna beds. Chemical analyses of two basaltic rocks from the Aziro beds are given in Table XIII[39].

From the foregoing remarks it may be said that either at the close of the Tertiary or in the beginning of the Pleistocene the Idu peninsula was subjected to crustal movement, generally in the sense of

Table XIII. Analyses of the Lower-Pleistocene Basalt and Andesite (Aziro beds) from Aziro.
S. Tanaka, analyst.

	No. 31	No. 32
SiO_2	51·10	56·62
Al_2O_3	18·90	15·49
Fe_2O_3	3·56	4·58
FeO	6·52	7·09
MgO	5·03	3·00
CaO	10·80	7·33
Na_2O	2·14	2·95
K_2O	0·32	0·55
H_2O +	0·50	0·35
H_2O −	0·28	0·72
TiO_2	0·83	0·96
P_2O_5	0·13	0·08
MnO	0·13	0·22
Q	6·01	15·50
Or	1·67	3·34
Ab	18·35	25·17
An	40·89	27·26
Wo	4.99	3·48
En	12·55	7·43
Fs	8·05	8·05
Mt	5·09	6·71
Il	1·52	1·82
Ap	0.33	0·33

		No. 31	No. 32
QFM	Q	6	16
	F	61	56
	M	33	28
NF	Or	3	6
	Ab	30	45
	An	67	49
NPl	An	69	52
NPy	Wo	19	18
	En	49	39
	Fs	32	43
Fe		66	79

No. 31. *Olivine-augite-hypersthene-bytownite-basalt.* Lava, south of Aziro-mati, north Idu. H. Kuno, Bull. Earthq. Res. Inst., **11** (1933), 400.

No. 32. *Aphyric andesite.* Lava, south of Aziro-mati, north Idu. H. Kuno, Bull. Volc. Soc., Japan, **3** (1936), 62.

36) H. Tsuya, *Bull. Earthq. Res. Inst.*, **9** (1931), 353.

37) Y. Otuka, *Jour. Geol. Soc., Tokyo*, **36** (1929), 435, 479.

38) H. Kuno, *Bull. Earthq. Res. Inst.*, **14** (1936), 96.

39) H. Kuno, *Bull. Earthq. Res. Inst.*, **11** (1933), 400; *Bull. Volc. Soc., Japan*, **3** (1936), 62.

uplift, followed during lower Pleistocene by marine and lacustrine deposition of the Zyo beds, and then by lacustrine depositions of the Ono, Simo-Hata, and Simo-Tanna beds in certain basins on the erosion relief of the Tertiary rocks. Quaternary volcanism became increasingly vigorous as the deposition of these lower Pleistocene beds proceeded, pyroxene-andesite, pyroxene-hornblende-dacite, and olivine-two-pyroxene-andesite (or basalt) being the rock-types represented. Since these rocks, except the dacite, resemble certain lavas of volcanoes Usami and Taga, it is possible that these volcanoes began their activities during the deposition of the lower Pleistocene beds. What is certain however is that the great subaerial volcanism in Idu occurred in full force after the lower Pleistocene beds had been more or less deformed, with the consequent formation of numerous volcanic cones.

Quaternary volcanism in the Idu peninsula was active mostly in its northern part; while in the southern part, Tertiary volcanism was succeeded by the relative quiescence of the Quaternary, whence it follows that the principal volcanoes in north Idu are Amagi, Omuro, Usami, Taga, and Yugawara (see Fig. 4), although there are some that have not yet been studied (Daruma, Tanabe, Nekko, and Tyokuro[40]). These volcanoes are all Pleistocene, Usami and Omuro representing the oldest and the youngest ones respectively. Taga is younger than Usami but older than Yugawara. Omuro-yama, together with its neighbours that are included in a volcano group of that name might have been formed by volcanism of a late date when the volcanoes Amagi, Usami, Taga, and Yugawara had already been more or less dissected and dislocated. Considering the youngest volcano, the volcanism in this group seems to have been the last to occur in the Idu peninsula, the time being the late-Pleistocene, although the present numerous hot-springs there represent a stage of post-volcanic thermal activity.

The volcanoes Hakone, Asitaka, and Huzi in the terrane adjoining the northern part of the Idu peninsula are also Quaternary. Of these, Hakone is younger than the Yugawara volcano on the south, and possibly younger than Asitaka; while Huzi whose eruptions have been recurrent in historical times, is the youngest.

The Seven Idu Islands and the Southern Islands, except the Ogasawara Islands, are all Quaternary insular volcanoes that rest upon a submarine ridge which, as will be seen from Fig. 1, runs in a NNW.–SSE. from the Idu region through the Volcano Islands toward the

40) R. TAYAMA and H. NIINO, *Rep. Sci. Res., Saito Gratitude Foundation*, No. **13** (1931).

Marianas. The ridge instead of being gentle and undulating, consists of several banks that are separated the one from the other by deeps

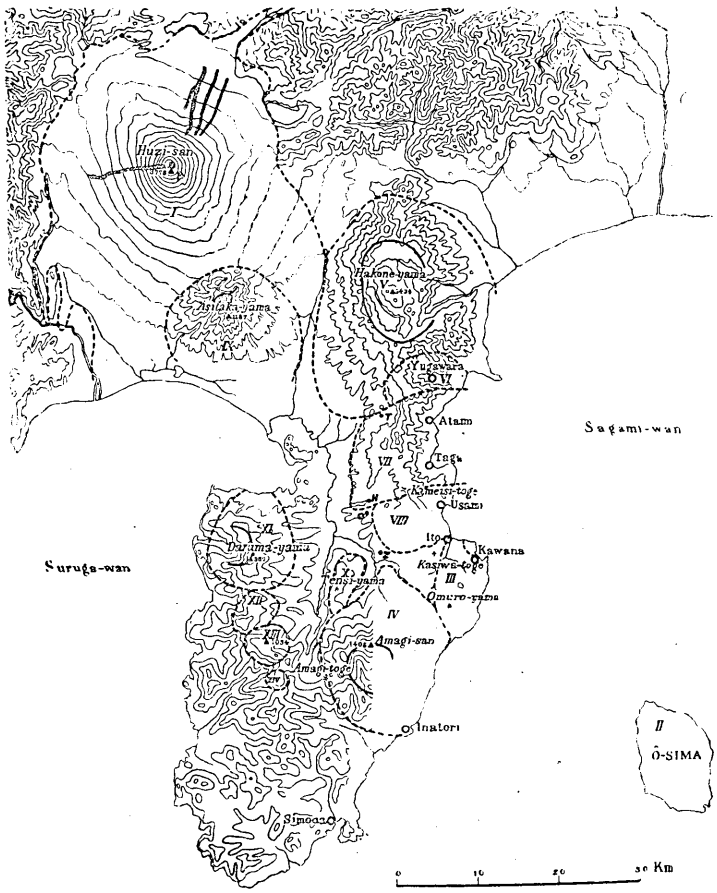

Fig. 4. Idu peninsula and its northern outskirt, showing distribution of the Quaternary volcanoes. I—Huzi, II—O-sima, III—Omuro-yama volcano group, IV—Amagi, V—Hakone, VI—Yugawara, VII—Taga, VIII—Usami, IX—Asitaka, X—Tensi-yama, XI—Daruma, XII—Tanaba, XIII—Nekko, and XIV—Tyokuro-yama.

and arranged *en echelon.* It is only by comparison with the much profounder depression of the adjacent Japan Trough that these banks can be recognized as belonging to the submarine ridge. The genesis of the insular volcanoes seems to be closely related to the geotectonic history of the underlying submarine ridge and the Japan Trough, although what that actual relation is, is a question we have no means

Table XIV. Quaternary Volcanoes in Idu and the Southern Islands in Relation to the Quaternary Stratigraphic Sequence.

	Diluvium: Lower	Diluvium: Upper	Alluvium
	Zyo beds; Simo-Tanna beds; Simo-Hata beds; Ono beds; Kuno's Hata and Aziro beds	Kano-gawa terrace deposits	Kano-gawa flood plain deposits
Volcanoes of Idu Peninsula and Vicinity	Usami; Taga; Yugawara; Hakone (Sommas); Asitaka-yama; Tensi-yama; Amagi (Main body)	Hakone (Central cones); Amagi (Parasitic cones); Omuro-yama	Huzi (Earliest visible lavas); Huzi (Uppermost part)
Volcanoes of the Seven Idu Islands and Southern Islands	Utone-sima; To-sima; O-sima (Demolished bodies near Okada); Mikura-sima; Hatizyo-sima (Higasi-yama); Kita-Io-sima; Tori-sima (Somma)	O-sima (Somma); Miyake-sima (somma); Aoga-sima (Somma); Tori-sima (Central cone); Minami-Io-sima; Io-sima	O-sima (Mihara-yama); Miyake-sima (Central cone and some flank openings); Hatizyo-sima (Nisi-yama); Aoga-sima (Central cone); Kodu-sima (Tenzyo-san); Nii-sima (Muko-yama); Submarine volcano near Minami-Io-sima

Table XV. Quaternary Stratigraphic Schemes of North Idu, as proposed by Previous Writers.

	Tayama Niino	Ishii and Ihara	Otuka	Kuno
Alluvium	Recent deposits PL-terrace beds	Alluvial deposits	Kanogawa Alluvial deposits Misima fan } a	Talus, gravel, volc. ash, and lake-deposits
Diluvium (upper)	Loam M-terrace beds T-terrace beds	Terrace deposits	Hirai terrace deposits Hatake terrace deposits Kasiwanokubo terrace deposits } du	Central cone ejecta of Hakone volcano Younger-somma ejecta of Hakone volcano
	Atami group	Talus and boulder deposits Kasiwatoge beds	Darumayama volc. deposits: Hakone volc. deposits Yugawara volc. deposits Tanakayama volc. deposits } dl_{II}	Ejecta of Kintokiyama parasitic cone Makuyama dome Older-somma ejecta of Hakone volcano Ejecta of Yugawara volcano Local dacite lavas
Diluvium (lower)	Zyo group	Aziro beds Zyo beds	Zyo beds: Simotanna beds (Hata beds of Kuno) } dl_{I}	Ejecta of Taga volcano Ejecta of Usami volcano Simotanna beds
	Tertiary	Tertiary	Idu old Neogene Tertiary	Hata and Aziro beds (Pliocene)

of answering at present. Whatever the relation may be, there can be little doubt that the insular volcanoes are all products of Quaternary volcanism. Of these, history records the eruptions of O-sima, Miyake-sima, Hii-sima, Kodu-sima, Hatizyo-sima, Aoga-sima, and Tori-sima. Table XIV shows the representative Quaternary volcanoes in relation to the Quaternary stratigraphic divisions of north Idu. For comparison, Quaternary stratigraphic schemes of north Idu, as proposed by previous writers, are shown in Table XV.

The Quaternary volcanoes, which, omitting those yet unstudied, may be divided into four groups, will now be described in the following order:

A. Complex volcanoes...1. Amagi-san and 2. Hakone-yama.

B. Basaltic and andesitic volcanoes...... 3. Tensi-yama, 4. Usami volcano, 5. Taga volcano, 6. Asitaka-yama, 7. Mikura-sima. 8. Tori-sima, 9. Kita Io-sima, 10. Aoga-sima, 13. O-sima, 14. Omuro-yama volcano group, and 15. Huzi-san.

C. Liparitic volcanoes...16. Nii-sima group (Nii-sima and Kodu-sima).

D. Trachyandesitic volcanoes ....17. Io-sima and 18. "Sin-to" volcano.

A. *Complex Volcanoes.*

This group of Quaternary volcanoes includes those that have yielded various rock-types ranging in microscopical and chemical characters from basalt to dacite; namely, the volcanoes Amagi and Hakone.

1. Amagi-san volcano.

Amagi-san, which is the largest and highest volcano in Idu, occupies the eastern half of the central part of the peninsula, and consists, besides the main body, of numerous parasitic volcanoes. This volcano, which differs in structure from most of the basaltic and andesitic volcanoes in the region under investigation, is a complex volcano built up of various rock-types ranging from basalt to liparitic dacite. The main body, which consists rather of accumulations without any particular structure of both agglomerates and lavas of andesitic nature, is a gigantic cone with a base about 15 km across. Its top forms a circular ridge—a ring-wall—surrounding a circular caldera about 6 km across. The highest point of the volcano is the top of Manzabro-dake, 1405 m above the sea, on the northeastern segment of the ring-wall.

The outer flanks of the main body do not show the regular slopes usual with conical volcanoes, not only because they are deeply dissected by valleys, but because numerous parasitic volcanoes protrude from them. Thus, several parasitic cones, composed of scoria and ash with lava-flows of basaltic nature, occur lower down the slopes, near the base, of the main body, the most typical of them being Hatikubo-yama on the northwest, Noboruo-yama and Hati-yama on the southwest, and Oike-Koike on the south. The two distinct lava-domes—Yahadu-yama and Iwano-yama—rise up from the northeastern skirt of the main body, and probably belonging to the same group, is a mass of glassy lava (pumice and obsidian) that issued from the Kawago-taira crater on the northwestern flank, near the summit of the main body. Besides these two groups of parasitic volcanoes—basaltic and dacitic—, is another group of parasitic cones situated near the snmmit and half way down the flanks, which cones are composed of andesitic rocks, practically similar to those of the main body. Toogasa-yama on the northeast flank is the largest of this group[41].

The base upon which the present volcano immediately rests is mostly composed of the Idu Neogene Tertiary rocks that are exposed in the terranes about the volcano. The western and southern skirts of the volcano rest directly on the lower Miocene rocks, while the northern skirt rests either directly on these rocks or with upper Pliocene rocks interposed between them. The eastern skirt, which is washed by the sea of Sagami bay, does not disclose its base rocks anywhere, although along the lower and the middle course of the Sirata-gawa (river), which rises in the caldera and flows through the eastern gap in the ring mountains eastward into Sagami bay at Sirata, we find exposed a Tertiary series composed of greenish, silicified tuff and tuff-breccia and lavas of a greenish pyroxene-andesite, dipping 10° or more E. Though detached from the main outcrop of the lower Miocene rocks about the volcano, there is little doubt that this series is of the same age. It is comparable in many respects to the lower Miocene volcanics exposed in the terrane that adjoins the northeastern part of the volcano near Okuno, and undoubtedly continues underneath the volcano into the latter. The northwestern skirt of the volcano covers, besides the Tertiary rocks, certain lavas from a lower Pleistocene volcano called the Tensi-yama volcano, whose centre seems to lie farther northwest near Tensi-yama. On the other hand, large quantities of pumice and obsidian that were

41) J. SUZUKI, *Jour. Geol. Soc., Tokyo.* 28 (1921), 431.

ejected from the Kawago-taira crater (one of the youngest parasitic craters of Amagi) are contained, together with gravels of older lavas from the main body of Amagi and of the Tertiary rocks, in the river-terraces that develop at a height of 5～10 m above the present stream-level in the upper courses of the Kano-gawa and its tributary Omi-gawa. These terraces are possibly correlative with those in the lower course of the Kano-gawa in the vicinity of Syuzendi and Ohito, which, according to Otuka, are of upper Pleistocene age (his Du)[42]. In view of these facts, it appears that the most, if not the whole, of the Amagi volcano was formed during the later half of the Pleistocene.

The surface of the foundation rock upon which the Amagi lavas rest is planed across the steeply dipping Tertiary beds. It lies at various altitudes; west of the volcano, near the Amagi pass, it is about 1000 m above the sea; in the Sirata-gawa valley, it is only 300 m at the highest; while in the Tertiary terranes bordering the south and northeast margins of the volcano, it is again 300 m. Very possibly, this surfaces, which at one time before the birth of the volcano, might have been an extensively continuous erosion-plane of low relief, was dislocated along faults at the base of the volcano, and the lavas that were consequently erupted through one of these faults, spread down a farther distance to the eastern terrane where the downthrown base-surface was much less in altitude than was the upthrown surface of the base west of the volcano.

The rock specimens studied are those which the writer collected mostly from the lower flanks of the volcano,[43] and which, however, include most of the representative rock-types of both the main body and the parasitic volcanoes. These are olivine-basalt, two-pyroxene-andesite, and olivine-bearing two-pyroxene-hornblende-dacite. They have the following petrographic characters.

(A) Basalts. The rocks of this type were studied from two specimens:

No. 33. *Olivine-basalt* (Zizodo lava).
No. 34. *Olivine-basalt* (Hatikubo-yama lava).

The Zizodo lava, intercalated between pyroclastic beds, is exposed at Zizodo, Kami-Omimura, and is a lava-flow that poured out of the parasitic volcano, Maruno-yama on the northern flank of Amagi. Megascopically, it is compact, dark-gray, and porphyritic with phenocrysts of plagioclase and olivine. Microscopically, the plagioclase of the phenocrysts is slightly zoned with an anorthite core 92 An (n_1=1.5760) surrounded by a bytownite shell 82 An (n_1=1.5709), while that in the groundmass is a bytownite 77 An (n_1=1.5684). The olivine phenocrysts, which show slight zoning,

42) Y. Otuka, *Bull. Earthq. Res. Inst.*, **11** (1933), 539.

43) The localities of the specimens examined are shown in Fig. 2 by corresponding numbers.

have 2 V=90° in the core and 2 V(−)=86° at the margin. β=1·6935 (mean). Composition: $Fo_{76}Fa_{24}$. The pyroxene in the groundmass is a pigeonite with 2 V(+)= 40°∼38°. The groundmass, besides the glass base, contains a little interstitial quartz.

The Hatikubo-yama lava that issued from the parasitic volcano Hatikubo-yama on the northwestern flank of Amagi, flowed northward into the steep-sided Kano-gawa valley and ran along the valley for about 2 km northward toward Yugasima. In this valley the lava occurs in two flows, separated from each other by a scoria bed, 3 m thick. The lower lava rests on the lower Miocene series (dacitic agglomerate, green tuff, and altered andesite) either directly or together with an agglomeratic two-pyroxene-andesite lava of the main body of Amagi interposed between them. The specimen examined was collected from the upper flow that is exposed at Yoitizaka along the driveway from Yugasima to the Amagi pass.

Megascopically, the rock is compact, dark-gray, and slightly prophyritic with phenocrysts of lath-shaped plagioclase and granular olivine. Microscopically, we find phenocrysts of plagioclase (0·2∼0·5 mm long) and olivine (0·5∼1·0 mm dia.) in a groundmass consisting of plagioclase laths, microphenocrystic olivine grains, microphenocrystic and smaller pyroxene grains, magnetite granules, cristobalite aggregates, and pale-brown interstitial glass.

Phenocrysts: The plagioclase is a slightly zoned bytownite 78 An (n_1=1·5689). Besides this, there are a few larger crystals of plagioclase (1∼3 mm dia.), which, identified as labradorite 58 An (n_1=1·5585), may be regarded as xenocrysts, possibly captured from the underlying two-pyroxene-andesite lava of the main body of Amagi when the present rock was being forced upward through this lava. Olivine, which is generally anhedral with a rim of iron-oxide, has 2 V(−)=88° and β=1·7020. Composition: $Fo_{76}Fa_{24}$.

Groundmass: The plagioclase may be either sodic bytownite or calcic labradorite, although its accurate composition could not be determined. The microphenocrystic olivine is identical with the phenocrystic one. The microphenocrystic pyroxene is augite with 2 V(+)=50° and β=1·7020. Composition: $Wo_{30}En_{38}Fs_{32}$. But the augite sometimes exhibits faint zoning, its optic angle becoming smaller outward. Thus, in a zoned crystal, the core has 2 V(+)=55∼51°, while the margin 2 V(+)=43°. The minute pyroxene grains in the groundmass may possibly be pigeonite with much smaller optic angle.

The chemical composition of the above two lavas are much alike as shown under columns Nos. 33 and 34 of Table XVII, although the Zizodo lava is slightly more basic than the other. Both have normative olivine instead of normative quartz, and in both the normative plagioclase is labradorite.

(B) Andesites. The rocks of this type were studied from four specimens:

No. 35. *Olivine-two-pyroxene-bearing andesite* (Akasawa lava).

No. 36. *Quartz-olivine-bearing two-pyroxene-andesite* (Yawatano lava).

No. 37. *Olivine-bearing two-pyroxene-andesite* (Inatori lava).

No. 38. *Two-pyroxene-andesite* (Yanagase lava).

The olivine-two-pyroxene-bearing andesite (No. 35), which was collected on the driveway about 1 km south of Akasawa on the northeast coast of the volcano, occurs as a lava-flow, about 10 m thick and 20 m wide, that poured out of a parasitic volcano-either Toogasa-yama or Iio-yama of the northeastern fank of Amagi. Megascopically, the rock is compact, dark-gray, and very slightly porphyritic with a few plagioclase phenocrysts. Microscopically, we find, besides the plagioclase, very sporadical phenocrysts of olivine and pyroxenes (augite and hypersthene) in a groundmass consisting of plagioclase, pigeonite, and magnetite, with a few silica mineral (tridymite?) and interstitial glass base. Although the optical properties of these constituent minerals are not yet studied, the chemical composition of the rock is shown in column No. 35 of Table XVII.

The quartz-olivine-bearing two-pyroxene-andesite (No. 36), which occurs as lava and agglomerate on the northeastern flank of Amagi, is widely exposed on the sea-cliff bounding the northeastern foot of the volcano. A specimen collected from the lava exposed along the driveway between Yawatano and Akasawa is, megascopically, pale-gray, compact, and porphyritic with phenocrysts of plagioclase and pyroxene. Microscopically, it contains phenocrysts of plagioclase, augite, and hypersthene, with negligible quantities of olivine, quartz, magnetite, and apatite, in a groundmass of very minute aggregates of plagioclase prismoids, monoclinic pyroxene granules, and magnetite dust, besides tridymite in druse. Phenocrysts occasionally occur in glomeroporphyritic patches.

The olivine-bearing two-pyroxene-andesite (No. 37) occurs as a lava-flow forming a terrace at Inatori on the southeastern foot of Amagi. The specimen examined was collected from the sea-cliff that bounds the terrace on the east. Megascopically, it is compact, pale-gray, and porphyritic with phenocrysts of plagioclase and pyroxene. Microscopically, the phenocrysts are plagioclase, augite, and hypersthene, together with subordinate olivine, magnetite, and apatite. These phenocrysts form occasionally glomeroporphyritic patches. Besides these, there are occasional aggregates, which,

Table XVI. Porphyritic Minerals in the Pyroxene-andesites from Volcano Amagi.

	No. 36	No. 37	No. 38
Plagioclase	n. d.	n_1=1.5605~1.5565 62~54 An	n_1=1.5563 54 An
Augite	core margin 2V(+)=57° — 47° 49° — 50° — 53° — 2V(+)=43°(rim enclosing the core of hypersthene)	n_1=1·6928 (mean) core margin 2V(+)=55°——45° 55° — 48° 57°——45° Average 2V=51° $Wo_{32}En_{44}Es_{24}$	n_1=1·6921 (mean) 2V(+)=55°~50° c∧z=46° $Wo_{37}En_{43}Fs_{20}$ Rim of green hornblende rarely present. Hypersthene inclusion present.
Hypersthene	core margin 2V(−)=63° —75° 64°—75° 2V(−)=65° (core enclosed by a rim of augite) 2V(−)=73° 78° — 63° (inner) (outer) (rim enclosing the core of olivine)	n_1=1·7000 (mean) n_2=1·7085 core margin 2V(−)=65°——78° 67°——75° 65°——69° Average 2V=72° $En_{60}Fs_{10}$	n_1=1·6975 (mean) core margin 2V(−)=67°—82°—69° 77°———75° 2V(−)=75° (inclusion in the augite) Average 2V=71° $En_{52}Fs_{33}$
Olivine	2V(−)≒90°~84°	2V(−)≒86°	——
Accessories	Magnetite Apatite Quartz	Magnetite Apatite	Magnetite Apatite

Table XVII. Analyses of Rocks from the Amagi Volcano.
S. Tanaka, analyst.

	No. 33	No. 34	No. 35	No. 36	No. 37	No. 38	No. 39	No. 40
SiO_2	49·51	51·48	54·81	59·11	60·09	62·60	68·87	71·16
Al_2O_3	18·19	18·25	18·09	16·31	16·64	15·98	14·78	14·72
Fe_2O_3	2·89	1·92	1·54	3·94	3·03	2·66	1·25	1·12
FeO	7·66	6·77	7·00	2·86	3·30	3·40	2·32	2·15
MgO	7·07	5·93	4·50	3·49	3·27	2·84	1·62	1·30
CaO	9·83	10·32	9·03	6·02	6·59	5·84	4·10	3·50
Na_2O	2·49	3·21	2·92	2·97	3·60	3·00	3·74	3·61
K_2O	0·48	0·34	0·57	1·47	1·40	1·66	2·00	2·06
H_2O +	0·45	0·43	0·50	1·48	0·68	0·45	0·68	0·27
H_2O −	0·27	0·25	0·50	1·00	0·70	0·24	0·10	0·10
TiO_2	0·64	1·03	0·79	0·76	0·80	0·65	0·40	0·36
P_2O_5	0·17	0·12	0·13	0·17	0·19	0·17	0·08	0·08
MnO	0·28	0·27	0·14	0·13	0·11	0·11	0·13	0·08
Total	99·93	100·32	100·18	99·71	100·40	99·60	100·07	100·51
Q	—	—	7·33	18·38	15·44	21·62	27·99	32·19
Or	2·78	2·23	3·34	8·90	8·35	10·02	11·69	12·24
Ab	20·97	27·26	24·64	25·17	30·41	25·17	31·46	30·41
An	36·99	34·21	34·49	26·70	25·03	25·31	17·80	16·41
Wo	4·53	6·74	3·95	0·93	2·91	1·16	0·70	C=0·51
En	16·06	14·30	11·24	8·73	8·13	7·02	4·01	3·21
Fs	10·29	9·30	10·42	0·92	2·51	3·17	2·77	2·51
Fo	1·06	0·39	—	—	—	—	—	—
Fa	0·71	0·25	—	—	—	—	—	—
Mt	4·17	2·55	2·32	5·79	4·40	3·94	1·85	1·52
Il	1·21	1·97	1·52	1·52	1·52	1·21	0·76	0·76
Ap	0·33	0·33	0·33	0·33	0·33	0·33	0·33	0·33
QFM { Q	—	—	7	19	16	22	28	32
QFM { F	61	64	63	62	64	61	61	60
QFM { M	39	36	30	19	20	17	11	8
NF { Or	5	4	5	15	13	17	19	21
NF { Ab	35	43	39	41	48	42	52	51
NF { An	60	53	56	44	39	41	29	28
NPl An	64	56	58	51	45	50	36	35
NPy { Wo	15	22	15	9	21	10	9	—
NPy { En	52	47	44	82	60	62	54	56
NPy { Fs	33	31	41	9	19	28	37	44
Fe	59	59	65	65	65	67	67	71

composed of plagioclase, monoclinic pyroxene, and magnetite, have outlines suggesting a hornblende ancestry. The groundmass is a very minute aggregate of plagioclase laths, monoclinic pyroxene granules, and magnetite dust, with interstitial quartz and acid feldspar.

The two-pyroxene-andesite (No. 38), which occurs as a lava-flow on the northern flank of Amagi, is exposed on the southern side of the Omi-gawa valley between Hatuma and Hiyekawa, where it forms a lava-scarp, 20 m or more in height, resting on a Tertiary series (upper Pliocene). A specimen collected from lava exposed on a cutting near Hatuma is megascopically compact, light-gray, and porphyritic with phenocrysts of plagioclase and pyroxene. Microscopically, we find phenocrysts of plagioclase, augite, and hypersthene, with subordinate magnetite and apatite in a groundmass of plagioclase prismoids (0·05 mm long), pyroxene and magnetite granules, and tridymite prisms. The phenocrysts occasionally show glomeroporphyritic grouping.

The last-mentioned three lavas—Yawatano lava, Inatori lava, and Yanagase lava—, which are the typical ones from the main body of Amagi, resemble each other in the optical properties of the porphyritic minerals that they contain in common. These are given in Table XVI. They are also greatly alike in chemical composition as shown in columns Nos. 36, 37, and 38 of Table XVII.

(C) Dacites. The rocks of this type were studied from two specimens:

No. 39. *Olivine-bearing two-pyroxene-hornblende-dacite* (Yahadu-yama lava).

No. 40. *Olivine-bearing two-pyroxene-hornblende-dacite* (Iwano-yama lava).

The Yahadu-yama lava forms a twin dome of that name, about 5 km NW. of Yawatano on the northeast foot of Amagi. The specimen, which the writer collected from the northern steep slope of the dome, resembles both megascopically and microscopically the Iwano-yama dacite next to be described. Microscopically, we find phenocrysts of andesine, hornblende ($2V(-) \doteqdot 70°$), hypersthene ($2V(-) \doteqdot 67°$), augite ($2V \doteqdot (+) \doteqdot 57° \sim 54°$ in the core and $2V(+) \doteqdot 48°$ at the margin) and olivine ($2V(-) \doteqdot 85°$), with quartz surrounded by a corona of pyroxene grains in a glassy groundmass packed with microlites of plagioclase, hornblende, and pyroxene, besides a few apatite and magnetite.

The Iwano-yama lava forms a parasitic lava-dome of that name, which, situated about 3 km SE. of Hiyekawa on the northern flank near the base of Amagi, is a small hill with steep sides and a slight crater-like depression on its summit. Megascopically, the specimen, which was collected from the east foot of the hill, is light-gray, glassy, and porphyritic with abundant phenocrysts of plagioclase, pyroxene, and hornblende. Microscopically, it contains phenocrysts of plagioclase (0·3~1·5 mm dia.), augite (0·3~0·5 mm dia.), hypersthene (0·1~0·5 mm long), and hornblende (0·1~0·5 mm long), with subordinate olivine and quartz, scattered through a glassy groundmass packed with minute prismoids of plagioclase, hornblende, augite, and hypersthene, besides a few apatite needles and magnetite grains.

Phenocrysts: The plagioclase is an andesine 48 An ($n_1 = 1{\cdot}5530$). The augite shows $2V(+) = 54°$ and $n_1 = 1{\cdot}696$. Composition: $Wo_{40}En_{38}Fs_{22}$. The hypersthene shows $2V(-) = 71°$ and $n_1 = 1{\cdot}6985$. Composition: $En_{62}Fs_{38}$. The hornblende, which is greenish-brown with moderate pleochroism, shows a slight zoning with $2V(-) = 75°$ in the core and $2V(-) = 70°$ at the margin. $n_1 = 1{\cdot}6740$, $n_2 = 1{\cdot}6915$. The olivine has $2V(-) = 87°$ and $\alpha = 1{\cdot}6740$, $\beta = 1{\cdot}6950$. Composition: $Fo_{72}Fa_{28}$,

The chemical composition of the above two dacites is shown in columns Nos. 39 and 40 of Table XVII. The two analyses are very much alike. Although the Yahadu-yama lava is slightly less acid than the Iwano-yama lava, the difference is rather small, both lavas having the usual composition of dacitic rocks.

2. Hakone-yama Volcano.

Hakone-yama, which lies immediately north of the Idu peninsula, is a great composite volcano measuring 25 km across the base and standing 1439 m above the sea. The geology and petrology of the volcano, which were studied by T. Hirabayashi,[44] are being restudied in detail by Kuno, who has already published a series of valuable notes on them.[45] According to him, the structural scheme of the volcano may be summarized as follows:

- (A) Older somma
  - Main body—a strato-volcano with a gigantic caldera whose walls are an ovally-arranged group of high peaks—Toga-mine, Myozyodake, Kintoki-yama, Mikuni-yama, and Hakugin-zan.
  - Parasitic volcanoes
    - Kintoki-yama—a strato-volcano on the NW. slope of the main body.
    - Maku-yama—a hybrid lava-dome protruding the SE. slope of the main body.
- (B) Younger somma—a shield volcano composed for the most part of lava-flows that erupted within the caldera of the older somma. Its western half has vanished by down-faulting, the eastern half consisting of Byobu-yama, Takanosu-yama, and Sengen-zan.
- (C) Central cones—six lava-domes (Hutago-yama, Komaga-take, Kami-yama, Daiga-take, and Koduka-yama) occupying the vanished portion of the younger somma.

It is noteworthy that the six central volcanoes are aligned, together with the parasitic cones on the older somma, in a NW.-SE. zone that coincides with the Huzi volcanic zone. Kuno regarded this zone as being the principal fracture line in the volcano, which is referred to as the Niizaki-gawa fault line. According to him, it was formed during the middle stage of the older somma's activities.

Hakone rests on Neogene Tertiary rocks that crop out not only in the valleys (Haya-kawa and Sukumo-gawa) that deeply cut its eastern slopes, but also in the Asigara mountains that border the volcano on the north. To the south, in the vicinity of Yugawara and Atami, lavas

44) T. HIRABAYASHI, *Rep. Earthq. Inv. Com.*, **16** (1898).

45) H. KUNO, *Jour. Geol. Soc., Japan*, **41** (1934), 347; *ibid.*, **42** (1935), 310; *ibid.*, **43** (1935), 376.

from the older somma of Hakone overlie the Yugawara volcano which in turn stands on the northern portion of the Taga volcano. In the valley of Kisegawa that borders Hakone on the northwest, the lower slope of the older somma is seen to be buried underneath lava-flows from Huzi either directly or with river-terrace deposits between them. At Oziri, which lies midway between Gotemba and Misima, one of the oldest visible lava-flows from Huzi is exposed on the southern bank of that valley, being directly underlain by the products (pumiceous breccia) of Hakone. In view of these facts, it seems reasonable to infer that, so far as the older somma is concerned, Hakone was active during the period between the upper half of lower Pleistocene and the upper Pleistocene. Although the younger somma and the central cones are in all probability upper Pleistocene. the latest volcanic activity that resulted in the explosion-craters and the mud-flows on the northwest flank of Kami-yama (one of the central cones) must surely be referred to a much later age. One of the explosion-craters—Owakudani—is still displaying solfataric activity.

According to Kuno, the rocks of the volcano are mostly two-pyroxene-andesite, although some of them are either basaltic or dacitic. He has published his petrological notes on six pyroxene-andesites from the older somma, special mention being made of those carrying phenocrysts of pigeonite.[46] Of the six andesites, three have the mineral compositions given in Table XVIII. Their chemical compositions are contained in Table XIX.

B. *Basaltic and Andesitic Volcanoes.*

Most of the Quaternary volcanoes in the region studied are composed of basaltic rocks or of basaltic and basic andesitic rocks. Since the classification of the rocks of these volcanoes into two kinds - basaltic and basic andesitic—is quite optional, it being immaterial which class is used, they may be treated as belonging to one group, whether basaltic or basic andesitic volcanoes.

3. Tensi-yama Volcano.

Lying northwest of the Amagi volcano is a dissected volcano, called the Tensi-yama volcano after its highest and most conspicuous remnant, 608 m above the sea, or about 250 m above the surrounding ground.

46) H. KUNO, *Jap. Jour. Geol. Geogr.*, Nos. 1~2, **13** (1936), 107.

Table XVIII. Constituent Minerals of Hakone Andesites (H. Kuno).

		No. 41	No. 44	No. 45
Porphyritic Minerals	Plagioclase	core margin n_1=1·574—1·557—lower 88—55 An	core margin n_1=1·576—1·552—{1·571, 1·567} 92—47 {81, 74} An	core margin n_1=1·580—1·566—lower 98—72 An
	Hypersthene	2V(−)= core margin 66°—58°—58°—47° γ=1·703—1·713 $En_{61}Fs_{39}$ (average)	2V(−)= core margin 62°—57°—72°—68° α =1·699—1·704, β =1·709—1·714, γ =1·712—1·717 } core $En_{55}Fs_{45}$ (average)	2V(−)=66°—53° γ =1·703—1·715 $En_{60}Fs_{40}$ (average)
	Augite	core margin 2V(+)=50°—48°—42° n_1=1·693—1·699 (β=1·699) c∧Z=42° $Wo_{30}En_{43}Fs_{22}$(average)	2V(+)= core margin 48°—43°—47°—43° α =1·701, β =1·706, γ =1·729 } core n_1=1·704, c∧Z=43° $Wo_{32}En_{37}Fs_{31}$(average)	2V(+)=49°—46° n_1=1·694—1·697 (β=1·698) c∧Z=43° $Wo_{34}En_{43}Fs_{23}$(average)
	Pigeonite	——	core margin 2V(+)=17°—10°—48° $\alpha \doteqdot \beta$=1·704 γ =1·728 c∧Z=43° $Wo_{13}En_{39}Fs_{48}$(average)	——
	Anorthoclase	Magnetite	Hornblende, Quartz, Magnetite, Apatite	Magnetite
Groundmass	Plagioclase	n_1=1·565—1·560—1·549 69—60—42 An	n_1=1·562—1·558 65—55 An	n_1=1·558—1·547 57—39 An
	Anorthoclase	$\alpha \leqq$1·525, γ=1·529	+	α=1·524, 2V(−)$\doteqdot$40°
	Pyroxene	Pigeonite 2V(+)=43° 2V(+)$\doteqdot$0° α =1·698 (min.) β =1·710 (max.) c∧Z=40° $Wo_{20}En_8 Fs_{42}$(average)	Hypersthene 2V(−)=55° Augite 2V(+)=46° α =1·699 (min.) β =1·705 (max.) c∧Z=43° $Wo_{32}En_{38}Fs_{30}$(average)	Pigeonite 2V(+)$\doteqdot$0° $\alpha \doteqdot \beta$=1·710—1·715 c∧Z=42° $Wo_9En_{34}Fs_{57}$(average)
	Accessories	Magnetite, Ilmenite, Quartz, tridymite, Biotite, Apatite	Magnetite, Ilmenite, Quartz, tridymite, Cristobalite, Biotite, Apatite	Magnetite, Ilmenite, Quartz, tridymite, Biotite, Apatite

Table XIX. Analyses of Rocks from Hakone[47]
S. Tanaka, analyst.

	No. 41	No. 42	No. 43	No. 44	No. 45	No. 46
SiO_2	55·83	56·70	57·07	57·22	59·77	67·37
Al_2O_3	17·75	15·90	17·53	17·46	17·00	15·28
Fe_2O_3	2·76	2·94	2·59	2·45	2·49	1·13
FeO	6·01	7·74	5·44	6·15	5·59	3·86
MgO	3·90	3·34	3·87	3·77	2·24	1·20
CaO	8·62	7·77	8·77	7·93	7·05	4·46
Na_2O	2·98	3·13	2·80	2·87	3·29	4·67
K_2O	0·55	0·74	0·52	0·75	0·62	0·92
H_2O +	0·19	0·36	0·27	0·30	0·41	0·14
H_2O −	0·17	0·09	0·12	0·23	0·51	0·09
TiO_2	0·61	1·24	0·77	0·73	0·63	0·72
P_2O_5	0·13	0·16	0·08	0·11	0·10	0·18
MnO	0·17	0·18	0·14	0·16	0·16	0·15
Total	99·67	100·29	99·97	100·13	99·86	100·17
Q	10·63	12·13	13·33	12·97	17·60	24·02
Or	3·34	4·45	3·34	4·45	3·90	5·57
Ab	25·17	26·22	23·59	24·12	27·79	39·32
An	33·38	27·26	33·66	32·54	29·76	18·08
Wo	3·60	4·41	3·72	2·44	1·86	1·39
En	9·74	8·33	9·64	9·44	5·62	3·01
Fs	8·04	10·15	6·86	8·44	7·39	5·27
Mt	3·94	4·17	3·70	3·47	3·70	1·52
Il	1·21	2·43	1·52	1·37	1·21	1·37
Ap	0·33	0·33	0·33	0·33	0·33	0·33
QFM Q	11	12	13	13	18	24
QFM F	62	58	61	61	62	63
QFM M	27	30	26	26	20	13
NF Or	5	8	6	7	6	9
NF Ab	41	45	39	39	45	62
NF An	54	47	55	54	49	29
NPl An	57	53	59	57	52	31
NPy Wo	16	20	18	12	9	15
NPy En	46	36	48	46	38	31
NPy Fs	38	44	34	42	53	54
Fe	69	76	67	69	78	80

No. 41. *Augite-hypersthene-labradorite-andesite* (33022003). One of upper lavas of the older somma of Hakone.

No. 42. *Aphyric andesite* (33081909a). One of the middle lavas of the older somma of Hakone.

No. 43. *Olivine-bearing hypersthene-augite-labradorite-andesite* (33082410). Hutago-yama lava, Hakone.

No. 44. *Quartz-hornblende-bearing augite-pigeonite-hypersthene-labradorite-andesite* (33022001). One of the upper lavas of the older somma of Hakone.

No. 45. *Augite-hypersthene-bytownite-andesite* (31072908). One of the upper lavas of the older somma of Hakone.

No. 46. *Hypersthene-augite-andesite* (33090504). The uppermost lava of the older somma of Hakone.

47) H. KUNO, *Bull. Volc. Soc., Japan*, **3** (1936), 53.

Tayama and Niino, who mention this volcano in their paper,[48] recognized the occurrence of a ruined, circular crater, about 1 km across, whose southern wall is the summit of Tensi-yama. Whether this crater is still in actual existence is not known for certain, because the original conical form of the volcano has suffered great changes through erosion and faulting, but that the principal vent was located probably close to, if not immediately on, the summit of Tensi-yama, is clear from the fact that the lavas usually dip outward from the latter and the neighbourhood as centre.

Of the many faults that traverse the volcano in various directions, the most remarkable is the Kumogane-Himenoyu fault that runs due W.-E. through the northern side near the summit of Tensi-yama. An earthquake fault (Himenoyu fault) appeared on this geologic fault-line at the time of the destructive north Idu earthquake of November 26, 1930.

The volcano is covered with a thin bed of pumice from the Amagi volcano. This bed thickens as one goes south toward Amagi, while at the northwest foot of the latter the products of the present volcano are covered with lavas from Amagi and the pumice bed. Underneath the pumice bed is a loam-like ash bed, which in turn rests on layers of lavas, agglomerates, and pyroclastics from Tensi-yama. The volcano, which is composed of these layers, rests either directly on the lower Miocene formation or with the upper Pliocene deposits interposed between them. These facts indicate that the volcano is of lower Pleistocene age.

The rocks of this volcano may be divided into three kinds: olivine-basalt, olivine-pyroxene-andesite, and two-pyroxene-andesite, of which only the last type will now be described.

No. 47. *Two-pyroxene-andesite.* This rock, which is one of the earliest lavas of the volcano, occurs as several flows and also as agglomerate and pyroclastic beds in the lower part of the mass. The specimen examined was collected at Ogawa (see Fig. 2), Naka-Omimura, on the northern slope near the base of the volcano, where, covered by an olivine-augite-andesite lava, it forms a flow about 10 m thick, overlying an agglomerate bed which in turn rests on Neogene Tertiary. Megascopically, the rock is compact, gray with a greenish tint, and porphyritic with phenocrysts of plagioclase and pyroxene. Microscopically, it contains two types of plagioclase phenocrysts, the one being the larger phenocrysts (10 mm dia.) of anorthite 94 An (n_1= 1·577) and the other the smaller (0·2~0·5 mm dia.) of faintly zoned bytownite 88~83 An (n_1=1·5742~1·5718). They are surrounded by narrow rims of the groundmass plagioclase. The porphyritic augite (0·3~2·0 mm dia.) has $c \wedge Z = 46°$, $2V(+) = 49°$, and n_1=1·6976. Composition: $Wo_{31}En_{42}Fs_{27}$. The porphyritic hypersthene (0·1~0·5

48) R. TAYAMA and H. NIINO, *Rep. Sci. Res., Saito Gratitude Foundation* No. **11** (1931).

mm dia.), which is always surrounded by pigeonite grains in the groundmass, has $2V(-)=66°$ and $n=1{\cdot}6992$. Composition: $En_{60}Fs_{40}$. A few porphyritic magnetite grains adhere to the pyroxene phenocrysts. The groundmass consists of faintly-zoned laths (0·05~0·1 mm long) of labradorite 63~55 An ($n_1=1{\cdot}5615\sim1{\cdot}5575$), pigeonite grains ($\beta=1{\cdot}7067$), and magnetite cubes, besides interstitial tridymite and a little chloritized base.

The chemical composition of this rock is shown in Table XX.

Table XX. Analysis of the Two-pyroxene-andesite, No. 47, from the Tensi-yama Volcano. S. Tanaka, analyst.

	No. 47	Norm				
SiO_2	53·95	Q	11·11	QFM	Q	11
Al_2O_3	18·93	Or	1·67		F	64
Fe_2O_3	3·73	Ab	22·55		M	25
FeO	5·55	An	38·94			
MgO	3·48	Wo	2·91	NF	Or	6
CaO	9·42	En	8·64		Ab	36
Na_2O	2·68	Fs	6·07		An	61
K_2O	0·28	Mt	5·33			
H_2O +	0·63	Il	1·52	NPl	An	63
H_2O −	0·84	Ap	0·33			
TiO_2	0·81			NPy	Wo	17
P_2O_5	0·09				En	49
MnO	0·16				Fs	34
Total	100·55			Fe		72

4. Usami Volcano.

Adjoining the southern part of the basaltic Taga volcano in the northeastern Idu lies a number of dissected mountains that are composed of andesitic lavas and pyroclastics, and which form a sinuous ridge, nearly 5 km long with a maximum elevation of 577 m (Ogawasawa-yama), running N.–S. from near Kameisi-toge to Kasiwa-toge. The western side of this ridge is a long, gentle slope having the appearance so usual to lower slopes of conical volcanoes, although it is badly dissected by ravines radiating from the crest of the ridge. The strata of andesitic lavas and pyroclastics that are exposed in the ravines show a gentle westward dip that coincides with the surface slope, gradually sweeps up to the crest of the ridge where it ends abruptly, overlooking the steeper eastern side of the ridge. The upper part, near the crest of the eastern slope, forms a scarp terminating in many branching spurs lower down the slope. Andesitic lavas and pyroclastics are well exposed on the scarp, their strata ending abruptly with the cliff. The volcanic mass may therefore be interpreted as the remnant of a huge conical volcano, the old centre of activity of which lay to the east, the greater part of the eastern half of the volcano having eroded away. It seems best to refer to this volcano as the Usami volcano, naming it after a village that lies east of it.

The foundation on which the present volcano rests consists of the Idu Neogene Tertiary formations, besides the lower Pleistocene deposits referred to as the Zyo beds. The Tertiary formations that border the volcano on the east and the south extend underneath the lavas, forming the ridge just mentioned. The Zyo beds, which are to be seen only to the west of the volcano, continue with the underlying Neogene Tertiary formations, eastward underneath the western slope of the latter. On the north, the volcano is bordered by the southern slope of the northerly Taga volcano, the lavas of which cover that of the former. At Kameisi-toge, close to the northern margin of the Usami volcano, is a fault that traverses the southern slope of the Taga volcano with a WNW–ESE trend, and forming a northward fault-scarp a few score meters high. The southeasterly extension of this fault is indicated by a valley which, taking a straight course southeast, opens into the sea at Usami. This valley in its upper and middle courses cuts into lavas of both the Usami and the Taga volcanoes, while in its lower course it cuts into the underlying Tertiary rocks (altered andesites and siliceous tuffs). Although the terrane adjoining the north of the valley is for the most part covered by lavas of the Taga volcano, there is a small outlier close to the north of Usami that belongs to the Usami volcano. In view of these facts, it seems reasonable to infer that the Usami volcano is one of the lower Pleistocene volcanoes of northern Idu, and that it is older than the Taga volcano. There is little doubt that the Usami volcano is older than the Omuro-yama volcano group, seeing that the southern part of the former is locally covered by a thin bed of basaltic scoria (Ito scoria bed) that came from a vent in the latter, and that the hill bordering the sea between Ito-mati and Kawana, which is regarded as an outlier detached itself from the main mass of the Usami volcano, is partly covered by basaltic lavas and pyroclastic beds of the Omuro-yama volcano group.

About 1 km south of Kameisi-toge is a dome-shaped, basaltic cinder-cone (Sukumo-yama), 581 m above the sea, or about 150 m above the surrounding ground, standing on the slope of the Usami volcano. This cinder-cone, which is underlain by an olivine-basalt lava and traversed by dikes of similar rock, seems much younger than the Usami volcano.

So far as examined, the rocks of the present volcano are all andesitic, though of varying petrographic characters. Eight specimens of rocks from the volcano (see Fig. 2) were examined microscopically and chemically with results as shown in Tables XXI and XXII. They are of the following rocks:

No. 48. *Olivine-bearing two-pyroxene-andesite.* This rock occurs in alternating layers of lava-flows and pyroclastics with a general southwestward dip, forming the hill that lies between Ito-mati aud Kawana. The specimen examined was collected from lava exposed near the base of the sea-cliff at Siohuki-zaki, 3 km east of Ito.

Megascopically, the rock is gray, compact to slightly vesicular, and porphyritic with abundant phenocrysts of plagioclase and pyroxene. Microscopically, we find, besides the phenocrysts of plagioclase (0·3~0·5 mm dia.), hypersthene (0·5~1·0 mm), and augite (0·5~1·0 mm), a few microphenocrysts of olivine, hypersthene, and accessory magnetite, in a groundmass of plagioclase, pigeonite, and magnetite,. together with interstitial tridymite and a little glass base.

There are two types of plagioclase phenocrysts; the larger ones being anorthite 95 An (n_t =1·5778) and the smaller anorthite-bytownite 93~88 An (n_t=1·5766~1·5742). The groundmass plagioclase is bytownite 77 An (n_t=1·5686). The hypersthene pheno-

Table XXIa. Constituent Minerals of the Andesites of the Usami Volcano.

		No. 49	No. 50	No. 51
Porphyritic Minerals	Plagioclase	n_t=1·5762~1·5745 93~89 An	n_t=1·5776~1·5745 95~89 An	n_t=1·5784~1·5755 96~90 An
	Augite	2V(+)=50° n_t=1·6970 c∧Z=45° $Wo_{33}En_{42}Fs_{25}$	2V(+)=51° n_t=1·6975 $Wo_{32}En_{42}Fs_{26}$	core margin 2V(+)=56°−54°−37° n_t=1·6949~1·6982 $Wo_{39}En_{39}Fs_{22}$(average)
	Hypersthene	2V(−)≒75°	2V(−)=70° n_t=1·6926 $En_{65}Fs_{35}$	2V(−)=69° n_t=1·700 $En_{60}Fs_{40}$
	Olivine	core margin 2V=89°(+)~82°(−)	——	——
	Accessories	——	——	——
Groundmass	Plagioclase	n.d.	n.d.	n_t=1·5637 68 An
	Pyroxene	Microphenocrysts 2V(+)≒48°(core)−20°(margin) Pigeonite prisms 2V(+)≒0°	Pigeonite	Hypersthene Pigeonite
	Accessory and interstitial materials	Magnetite Tridymite Glass base	Magnetite Cristobalite(?) Tridymite Glass base	Magnetite Tridymite Acid feldspar Glass base

Table XXIb. Constituent Minerals of the Andesites of the Usami Volcano.

		No. 52	No. 53	No. 54	No. 55
Porphyritic Minerals	Plagioclase	n_1=1·5778～ 1·5754 95～90 An	n_1=1·5798～ 1·5767 99～93 An	n_1=1·5690 78 An	n_1=1·5716 83 An
	Augite	core margin 2V(+)=55°−50° n_1=1·6970～ 1·6998 c∧Z=45° $Wo_{35}En_{40}Fs_{25}$ (average)	core margin 2V(+)=50°−45° n_1=1·6946～ 1·6985 $Wo_{28}En_{43}Fs_{29}$ (average)	2V(+)=46° n_1=1·6996 $Wo_{27}En_{42}Fs_{31}$	core margin 2V(+)=47°−50° 50°−40° 52°−40° n_1=1·6966(mean) $Wo_{28}En_{43}Fs_{29}$ (average)
	Hypersthene	core margin 2V(−)=60°−67° n_1=1·7070(mean) $En_{54}Fs_{45}$ (average)	core margin 2V(−)=63°−70° −63°, 61°−70° n_1=1·6980～ 1·7068 $En_{57}Fs_{43}$ (average)	2V(−)≑65°～62°	2V(−)=65° n_1=1·7007 $En_{59}Fs_{41}$
	Olivine	2V(−)=88° α=1·6695 β=1·6885 $Fo_{75}Fa_{25}$	2V(−)=87° β=1·6830 $Fo_{72}Fa_{28}$	—	—
	Accessories	Magnetite Apatite	Magnetite Apatite	Magnetite	Magnetite
Groundmass	Plagioclase	n_1=1·5707 81 An	n_1=1·5678 75 An	n.d.	n_1=1·554 50 An
	Pyroxene	Micro-phenocrysts: Augite Hypersthene Small grains: Pigeonite	Augite 2V(+)≑46° Hypersthene 2V(−)≑61°	Pigeonite	Pigeonite
	Accessory and interstitial materials	Magnetite Tridymite Glass base	Magnetite Tridymite Acid feldspar	Magnetite Tridymite Acid feldspar	Magnetite Tridymite(?) Acid feldspar

Table XXII. Analyses of Rocks from the Usami Volcano. S. Tanaka, analyst.

	No. 48	No. 49	No. 50	No. 51	No. 52	No. 53	No. 54	No. 55
SiO_2	50·57	50·59	51·67	53·08	55·96	57·61	59·00	62·70
Al_2O_3	19·38	19·73	19·88	20·01	16·92	15·88	15·26	16·09
Fe_2O_3	3·81	3·18	3·25	3·48	2·76	2·79	4·60	2·61
FeO	7·25	6·73	6·97	5·70	6·03	5·28	5·90	4·61

(to be continued.)

Table XXII. (*continued.*)

		No. 48	No. 49	No. 50	No. 51	No. 52	No. 53	No. 54	No. 55
MgO		3·89	4·15	3·30	2·80	4·39	5·92	2·14	1·49
CaO		11·43	10·31	9·46	9·80	8·06	7·58	6·36	5·25
Na_2O		1·86	1·94	2·18	2·29	2·07	2·59	2·83	3·26
K_2O		0·16	0·24	0·40	0·31	0·57	0·71	0·58	0·86
H_2O +		0·45	1·13	1·26	0·47	1·07	0·36	0·90	1·25
H_2O −		0·30	0·88	1·00	0·75	1·18	0·28	0·69	0·85
TiO_2		0·76	0·85	0·92	0·73	0·73	0·71	1·04	0·82
P_2O_5		0·10	0·10	0·10	0·06	0·08	0·07	0·11	0·17
MnO		0·13	0·15	0·16	0·17	0·17	0·15	0·18	0·12
Total		100·09	99·98	100·55	99·65	99·99	99·93	99·59	100·08
Q		7·57	7·75	9·31	11·65	15·68	13·33	21·98	24·80
Or		1·11	1·67	2·23	1·67	3·34	4·45	3·34	5·01
Ab		15·73	16·25	18·35	19·40	17·30	22·02	24·12	27·79
An		43·95	44·50	43·39	43·39	35·33	29·48	27·26	25·31
Wo		4·99	2·44	1·16	2·21	1·63	3·37	1·39	C=0·51
En		9·64	10·33	8·23	6·92	10·94	14·76	5·32	3·71
Fs		9·10	8·58	8·83	6·60	7·91	6·36	6·67	5·28
Mt		5·56	4·63	4·63	5·09	3·94	3·94	6·71	3·70
Il		1·52	1·67	1·82	1·37	1·37	1·37	1·97	1·52
Ap		0·33	0·33	0·33	0·33	0·33	0·33	0·33	0·33
QFM	Q	8	8	9	12	16	13	22	25
	F	61	64	65	65	57	56	56	60
	M	31	28	26	23	27	31	22	15
NF	Or	2	3	3	3	6	8	6	9
	Ab	26	26	29	30	31	39	44	48
	An	72	71	68	67	63	53	50	43
NPl	An	74	73	70	69	67	57	53	48
NPy	Wo	21	11	7	14	8	14	11	—
	En	40	48	45	44	53	60	43	41
	Fs	39	41	48	42	39	26	46	59
Fe		73	70	73	76	66	57	82	82

crysts, which are always surrounded by a thin rim of a monoclinic pyroxene ($c\wedge Z=$ 44), shows distinct zoning, their optic angles varying from core to margin in the manner: $2V(-)=78°\rightarrow70°$ and $79°\rightarrow68°\rightarrow79°\rightarrow68°$. $n_1=1{\cdot}6922\sim1{\cdot}6949$. Average composition: $En_{65}Fs_{35}$. The microphenocrystic hypersthene, which occurs in parallel intergrowth with a monoclinic pyroxene, shows $2V(-)=68°$. The augite phenocrysts, which are far less in amount than the hypersthene, has $n_1=1{\cdot}6965$. The groundmass pigeonite has $2V(+)=20°$, $c\wedge Z=37°$, and $\beta=1{\cdot}7048$. Composition: $W_{13}En_{40}Fs_{47}$. The olivine is anhedral and negligible in amount.

The chemical composition of the above-described rock is given in column No. 48 of Table XXII.

No. 49. *Hypersthene-bearing olivine-augite-andesite.* This rock occurs on the southwest slope of the volcano as a lava-flow, about 10 m thick, lying under another lava of olivine-bearing two-pyroxene-andesite (No. 52), with pyroclastic beds interposed between them. The specimen examined was collected from the eastern wall of the valley that bounds Isigami-yama on the east (4 km northeast of Zyo). Megascopically, it is compact, gray, and studded withlarge plagioclase phenocrysts (10 mm dia). Microscopically, it contains, besides the large plagioclase, phenocrysts of smaller plagioclase, olivine, and augite, with negligible quantities of hypersthene, in a groundmass consisting of plagioclase, microphenocrystic augite-pigeonite, pigeonite, and magnetite, together with interstitial tridymite and a little glass base.

No. 50. *Olivine-bearing two-pyroxene-andesite.* This rock occurs on the west slope of the volcano as a lava-flow, 10 m thick, intercalated between pyroclastic beds. The specimen examined was collected from the flow that is exposed at the southwest exit of the Tyozyaga-hara basin, about 2·5 km southwest of Kameisi-toge, on the north bank of the river that drains the basin. Megascopically, it is compact, dark-gray, and densely crowded with small plagioclase phenocrysts. Microscopically, the rock carries phenocrysts of augite and hypersthene, besides the plagioclase. Olivine is detected only as inclusions in the hypersthene phenocrysts, which in turn are usually surrounded by a thin rim of a monoclinic pyroxene. The groundmass is composed of plagioclase laths, pigeonite prisms, and magnetite granules, with interstitial tridymite and a little glass base.

No. 51. *Augite-hypersthene-andesite.* This rock occurs as a massive lava and agglomerate in the valley, which, situated between Usami and Kameisi-toge, separates the terrane of the Usami volcano from that of the Taga volcano. The specimen examined was collected from the floor of the valley that is situated midway between Usami and Kameisi-toge, where it forms a lava underlying a basaltic lava from the Taga volcano. Megascopically, the rock is gray with a greenish tint, compact to slightly vesicular, and porphyritic with plagioclase and pyroxene phenocrysts. Microscopically, the porphyritic minerals are anorthite with a narrow rim of labradorite similar to the groundmass plagioclase; hypersthene with a rim of pigeonite; and zoned augite with also a rim of pigeonite. The groundmass consists of labradorite laths, microphenocrystic hypersthene with pigeonite prisms, and magnetite granules, together with interstitial tridymite (?) and a little dusty glass base.

No. 52. *Olivine-two-pyroxene-andesite.* Rock of this type is distributed extensively in the southern and southwestern parts of the volcano, forming several lava-flows intercalated with pyroclastic beds. The specimen examined was collected at the same place as the locality of andesite No. 49, where it occurs as a lava above the last named. Megascopically, the rock is gray, compact, and porphyritic with phenocrysts of plagioclase and pyroxene. Glomeroporphyritic grouping of the phenocrysts is occasionally met with. Microscopically, we find phenocrysts of faintly zoned anorthite, zoned augite, zoned hypersthene with a rim of augite, and anhedral olivine, besides accessory magnetite and apatite, in a groundmass consisting of bytownite laths, microphenocrystic prisms of augite and hypersthene, pigeonite grains, and magnetite granules, together with tridymite and a little interstitial glass base.

No. 53. *Augite-bearing olivine-hypersthene-andesite.* Petrographically, this rock closely resembles the one just mentioned. The specimen examined was collected 5 km northeast of Hiyekawa, where it occurs as a lava about 15 m thick, intercalated between pyroclastic beds. Microscopically, the phenocrysts are slightly zoned anorthite;

zoned hypersthene with a rim of augite; anhedral olivine with a hypersthene rim; and augite in parallel intergrowth with the hypersthene, besides accessory magnetite and apatite. The groundmass consists of bytownite laths, hypersthene and augite prisms, and magnetite grains, together with interstitial tridymite and acid feldspar.

No. 54. *Aphyric two-pyroxene-andesite.* This rock, which is one of the earlier lavas of the volcano, occurs as a flow forming the lower part of the western slope. The specimen examined was collected from a lava exposed on the south wall of the valley that drains the Tyozyaga-hara basin, about 2 km southwest of that basin, where it rests upon gravel and sand beds (lower Pleistocene) which in turn rest on the Tertiary. Megascopically, it is dark-gray to black, compact, and carries negligible quantities of plagioclase phenocrysts. Microscopically, it contains, besides the plagioclase phenocrysts, a few microphenocrysts of augite and hypersthene, and accessory magnetite. The groundmass, which forms the bulk of the rock, is composed of plagioclase laths (0·01~0·03 mm long), pigeonite granules, and magnetite dust, with interstitial tridymite and feldspar,

No. 55. *Two-pyroxene-andesite.* This rock occurs as a lava-flow in a small area immediately north of Isigami-yama, where it forms the uppermost part of the central volcano. Megascopically, it is dark-gray to black, compact, and studded with plagioclase phenocrysts. Microscopically, it contains phenocrysts of faintly zoned bytownite with narrow rims of labradorite, zoned augite-pigeonite, hypersthene with thin rims of pigeonite, and accessory magnetite. The groundmass is composed of labradorite laths, pigeonite grains, and magnetite granules, together with interstitial tridymite and feldspar.

5. Taga Volcano.

The Taga volcano, which adjoins the northern part of the Usami volcano, occupies a wide tract extending from the mountains between Usami and Aziro to beyond Kuro-dake, and forms a long, semi-circular ridge, which at the last-mentioned mountain, reaches a maximum height of 799 m above the sea. The outer (western) side of this ridge slopes with a gentle sweep up to the crest of the ridge, where it ends abruptly overlooking the steeper inner (eastern) side. The upper part, near the crest of the inner side, are precipitous cliffs on which lavas and pyroclastics are clearly exposed, their strata ending in cliffs; while the lower part consists of numerous branching arêtes that separate deep valleys, on the walls of which older lavas and pyroclastics are exposed together with the bedrocks of this region. This volcanic mass, like the Usami volcano, is a remnant of a huge conical volcano, which H. Kuno calls the Taga volcano, naming it after the village near the probable former centre of activity.

Westward, the slopes of the volcano lead far down to the eastern margin of the Kano-gawa alluvial plain, although they are greatly dislocated by faults, the most striking being the Tanna fault which, connecting the tectonic basins of Tasiro, Ukihasi, and Tawarano, extends half way down the western slopes of the volcano from north to south. Southward, the slopes of the volcano end at the Usami volcano a short distance down the slopes of the latter, while northward they go under the volcano Yugawara, the slopes of which last in turn go underneath the Hakone volcano. Although the eastern half of the volcano has disappeared, it is possible that the vanished portions dropped down along a fault line into the sea that borders the volcano on the east.

The volcano rests on lower Pliostocene beds (Simo-Tanna beds, Simo-Hata beds, and Ono beds), besides the Neogene Tertiary (Kuno's Soga-yama beds, Nonaka beds, etc.). The volcano is of lower Pleistocene age. Although younger than the Usami volcano on its south, it is older than the Yugawara volcano on its north.

The rocks of this volcano show various types of basalt and andesite. The petrology of the volcano, together with its geology, will presently be published by H. Kuno[49], who made a detailed survey of the mass while he was studying the volcanoes of north Idu, in which study he is still engaged. The writer examined six rock-specimens from the volcano both microscopically and chemically, with results as shown in Tables XXIII and XXIV. The examined specimens, of which five were collected from the southwestern slope of the volcano and the remainder from Uomi-saki near Atami, are as follows:

No. 56. *Augite-olivine-basalt*. This rock occurs on the southwest slope of the volcano as a lava-flow resting on lower Pleistocene rocks (Simo-Hata beds). The specimen examined was collected from the northern bank of the Hukazawa, near Takyo, Kita-Kanomura, where it occurs as a flow about 15 m thick with columnar joints, overlying a gravel bed which in turn rests on Neogene Tertiary rocks (silicified tuff and green andesite, lower Miocene). Megascopically, the rock is compact, dark-gray, and porphyritic with abundant plagioclase phenocrysts, besides a few olivine and augite. Microscopically, it contains phenocrysts of anorthite, zoned augite-pigeonite, and zoned olivine, in a groundmass consisting of bytownite laths, zoned pigeonite prisms and magnetite cubes, besides cristobalite patches and a little dusty base.

No. 57. *Augite-bearing olivine-basalt*. This rock which also occurs as a lava-flow on the southwest slope of the volcano, resembles the foregoing, the only difference being in the amount of the porphyritic augite. The specimen examined was collected from the flow exposed near the southwest exit of the Tawarano basin, on the banks of the valley that drains this basin.

No. 58. *Two-pyroxene-olivine-basalt*. This rock occurs as a lava-flow, together wish its agglomerate, on the south slope of the volcano. The specimen examined was collected from the flow exposed on a ridge, 1 km southeast of Kameisi-toge, where it rests on products of the Usami volcano. Megascopically, the rock is compact, gray, and rich in phenocrysts of plagioclase, olivine, and pyroxene. Microscopically, the phenocrysts are anorthite-bytownite with narrow rims of the groundmass plagioclase, anhedral olivine with rims of augite grains, augite, and zoned hypersthene with augite

49) H. KUNO, *Jour. Geol. Soc., Tokyo*, 40 (1933), 376.

Table XXIII. Constituent Minerals of the Rocks of the Taga Volcano, Idu.

		No. 56	No. 57	No. 58	No. 59	No. 60	No. 61
Porphyritic Minerals	Plagioclase	$n_1=1\cdot5794\sim1\cdot5757$ 98~91 An	$n_1=1\cdot5786\sim1\cdot5748$ 97~90 An	$n_1=1\cdot5790\sim1\cdot5745$ 98~89 An	$n_1=1\cdot5765$ 93An	—	$n_1=1\cdot5757$ 91An
	Augite	core margin $2V(+)=54°-38°$ $n_1=1\cdot6988\sim1\cdot7030$ $Wo_{27}En_{41}Fs_{32}$ (average)	core margin $2V(+)=58°-52°$ $n_1=1\cdot6968$(mean) $Wo_{38}En_{39}Fs_{23}$ (average)	$2V(+)=55°$ $n_1=1\cdot6944$ $Wo_{38}En_{39}Fs_{23}$	$2V(+)=50°$ $n_1=1\cdot6899$ $Wo_{34}En_{46}Fs_{20}$	—	$n_1=1\cdot6976$
	Hypersthene	—	—	core margin $2V(-)\doteqdot77°-65°$ $72°-65°$	core margin $2V(-)=70°-75°$ $71°$ $n_1=1\cdot6942$ (mean) $En_{65}Fs_{35}$	—	$n_1=1\cdot700$
	Olivine	core margin $2V(-)=88°-82°$ $\alpha=1\cdot672, \beta=1\cdot6915$ $Fo_{74}Fa_{26}$	core margin $2V(-)=85°-79°$ $\beta=1\cdot7122$ $Fo_{62}Fa_{38}$	$2V\doteqdot90°$	—		$2V(-)\doteqdot78°$
Groundmass	Plagioclase	$n_1=1\cdot5698\sim1\cdot5643$ 79~69 An	$n_1=1\cdot5640$ 68 An	$n_1=1\cdot5718$ 84 An	$n_1=1\cdot5726$ 84 An	$n_1=1\cdot5615$ 64 An	$n_1=1\cdot5655\sim1\cdot5597$ 71~60 An
	Pyroxene	core margin $2V(+)=41°-30°$ $48°-30°$ $\beta=1\cdot7154$ (max.) $Wo_{16}En_{35}Fs_{49}$	$2V(+)=38°\sim20°$ $\beta=1\cdot715$ (max.) $Wo_{12}En_{35}Fs_{53}$	$2V(-)\doteqdot41°\sim36°$	$\beta=1\cdot703$	$2V(+)=40°$ $\beta=1\cdot715$ $Wo_{19}En_{35}Fs_{46}$	$2V(+)=39°$ $\beta=1\cdot716$ $Wo_{19}En_{34}Fs_{47}$
	Accessory and interstitial materials	Magnetite Cristobalite Glass base	Magnetite Cristobalite Tridymite Glass base	Magnetite Tridymite Glass base	Magnetite Cristobalite Glass base	Magnetite Tridymite Glass base	Magnetite Cristobalite Tridymite Glass base

Table XXIV. Analyses of Rocks from the Taga Volcano. S. Tanaka, analyst.

		No. 56	No. 57	No. 58	No. 59	No. 60	No. 61	No. 62	No. 63	No. 64	No. 65	No. 66
SiO_2		50·17	50·38	50·71	50·94	52·13	52·85	50·45	51·68	52·35	54·00	57·85
Al_2O_3		19·65	20·36	18·84	19·32	15·68	18·37	19·45	19·70	20·35	18·84	16·94
Fe_2O_3		2·54	2·86	2·42	4·14	4·36	3·48	2.27	2·69	2·23	2·07	2·23
FeO		7·92	7·26	7·13	5·52	9·81	7·83	8·41	6·78	6·25	7·71	5·30
MgO		4·54	4·45	6.08	4·20	4·08	2·96	3·73	4·15	3·72	2·72	4·31
CaO		11·29	11·28	10·05	10·62	8·87	10·12	11·23	10·78	9·62	9·74	7·80
Na_2O		1·66	1·95	2·03	2·15	2·44	2·07	1·75	1·94	2·74	2·95	3·32
K_2O		0·29	0·33	0·24	0·32	0·32	0·36	0·33	0·32	0·44	0·41	0·60
H_2O +		0·41	0·36	0·69	0·73	0·67	0·39	0·42	0·22	0·90	0·30	0·26
H_2O −		0·20	0·25	0·38	1·04	0·50	0·16	0·30	0·20	0·41	0·20	0·32
TiO_2		0·87	0·84	0·67	0·78	0·74	0·93	1·04	0·81	1·19	1·02	0·80
P_2O_5		0·10	0·10	0·13	0·07	tr.	tr.	0·09	0·13	0·15	0·11	0·13
MnO		0·17	0·15	0·15	0·18	0·32	0·17	0·20	0·16	0·13	0·29	0·15
Total		99·81	100·57	99·52	100·01	99·92	99·69	99·67	99·56	100·41	100·36	100·04
Q		5·77	4·93	4·44	7·87	8·35	11·11	6·37	8·17	6·49	7·87	12·07
Or		1·67	2·23	1·67	1·67	1·67	2·23	2·23	1·67	2·78	2·23	3·34
Ab		14·16	16·25	17·30	18·35	20·45	17·30	14·68	16·25	23·07	25·17	28·31
An		45·34	45·89	41·44	42·28	31·15	39·78	44·23	44·23	41·44	36·90	29·48
Wo		4·06	3·83	3·14	4·30	5·34	4·30	4·11	3·48	2·32	4·41	3·48
En		11·35	11·04	15·16	10·44	10·14	7·33	9·34	10·34	9·23	6·73	10·84
Fs		11·21	9·77	10·29	5·80	13·93	10·16	12·27	9·10	7·92	11·21	6·86
Mt		3·70	4·17	3·47	6·02	6·25	5·09	3·24	3·94	3·24	3·01	3·24
Il		1·67	1·67	1·21	1·52	1·37	1·82	1·97	1·52	2·38	1·97	1·52
Ap		0·33	0·33	0·33	0·33	tr.	tr.	0·33	0·33	0·33	0·33	0·33
QFM	Q	6	5	5	8	8	11	6	8	7	8	12
	F	62	64	61	63	54	60	62	63	68	64	61
	M	32	31	34	29	38	29	32	29	25	28	27
NF	Or	3	3	3	3	3	4	4	3	4	3	5
	Ab	23	25	29	29	38	29	24	26	34	39	46
	An	74	72	68	68	59	67	72	71	62	58	49
NPl	An	76	74	71	70	60	70	75	72	64	60	51
NPy	Wo	15	15	11	21	18	19	17	15	12	20	16
	En	43	45	53	51	34	34	36	45	47	30	51
	Fs	42	40	36	23	48	47	47	40	41	50	33
Fe		69	69	60	69	77	79	74	69	69	78	63

in parallel intergrowth. The groundmass consists of bytownite, microphenocrystic hypersthene and augite in parallel intergrowth, pigeonite, and magnetite, together with interstitial tridymite and a dusty glass base.

No. 59, *Two-pyroxene-andesite.* This rock, which is one of the earlier lavas of the volcano, occurs as a lava-flow, besides agglomerate, resting on lower Miocene rocks (Kuno's Sogayama beds). The specimen examined was collected from the lava exposed on a sea-cliff, near Uomi-saki, along the road from Atami to Aziro. Megascopically, the rock is compact, gray with a greenish tint, and studded with large plagioclase phenocrysts, besides a few pyroxene. Microscopically, we find phenocrysts of anorthite, zoned hypersthene with rims of augite grains, and augite, in a groundmass consisting of bytownite laths, pigeonite prisms, and magnetite granules, together with cristobalite, interstitial feldspar, and a little glass base.

No. 60. *Aphanitic basalt.* This rock occurs on the western foot of the volcano, near Nirayama, as a lava-flow sandwitched between lavas of porphyritic augite-olivine-basalt. The specimen examined was collected from the flow exposed on the south wall of a dale, about 1 km east of Hansyaro, Nirayama. Megascopically, it is compact, gray, and wholly aphanitic. Microscopically, it consists of labradorite laths (up to 0·2 mm long), pigeonite prisms (0·1 mm), and magnetite granules, together with interstitial tridymite and a little glass base, except a few microphenocrystic traces of olivine completely replaced by iron-ore.

No. 61. *Olivine-two-pyroxene-bearing andesite.* This rock occurs in the vicinity of Ono, Kita-Kanomura, as a massive lava, about 15 m thick, resting on the Ono beds (lower Pleistocene), either directly or with pyroclastic beds interposed between them. The specimen examined was collected from the lava exposed on the Ono landslide (cf. Table X). Megascopically, the rock is compact, gray, and densely packed with plagioclase phenocrysts. Microscopically, it contains in addition to the anorthite phenocrysts, a few olivine, augite, and negligible hypersthene in a groundmass consisting of labradorite laths, pigeonite prisms, and magnetite cubes, together with interstitial cristobalite, tridymite, and a little glass base.

Table XXIV contains in addition to the analyses of the foregoing rocks, five analyses[50] of specimens collected by Kuno from the volcano. These are as follows:

No, 62. *Augite-bearing olivine-bytownite-basalt* (31041812). The uppermost lava of the Taga volcano. Locality: middle course of a dale northwest of Usami, Idu.

No. 63. *Hypersthene-augite-olivine-bytownite-andesite* (31050201). An upper lava of the middle stage lavas of the Taga volcano. Locality: upper course of a dale southwest of Simo-Taga, Idu.

No. 64. *Olivine-bearing augite-hypersthene-labradorite-andesite* (31041909). A middle lava of the middle stage lavas of the Taga volcano. Locality: midway between Usami and Kameisi-toge, Idu.

No. 65. *Two-pyroxene-andesite* (32090104). The lowest lava of the middle stage lavas of the Taga volcano. Locality: midway between Taga and Yamabusi-toge, Idu.

No. 66. *Olivine-augite-hypersthene-labradorite-andesite* (32082602). The lowest lava (Wada lava) of the Taga volcano. Locality: upper course of a dale west of Wada, Atami-mati, Idu.

50) The analyses Nos. 58, 60, 62~64, 66, were published in H. KUNO, *Bull. Volc. Soc., Japan*, **3** (1936), 55. No. 65 is yet unpublished analysis, for which the writer is indebted to Kuno.

6. Asitaka-yama Volcano.

Adjoining the southern part of Huzi is a large ruined volcano, Asitaka-yama, whose base is more than 15 km across. If this ruined volcano is viewed from the southwest, its gently sloping and almost symmetrical flanks sweeping to its summit, are seen to be excellently preserved. The lower half of the northern flank is entirely buried under the lava-flows from Huzi. The summit of the volcano is divided into five peaks —Etizen-dake (1504 m), Yobiko-dake (1313 m), O-dake (1253 m), Ihai-dake (1457 m), and Asitaka-yama (1187 m)—which form a sinuous, serrated range extending N.–S. According to T. Hirabayashi[51], these peaks, except the northernmost Etizen-dake, are remains of the ring-wall that surrounds a horseshoe-shaped, central crater, about 2 km across, and opening toward the southwest. He also mentions another explosion-crater adjoining the central crater on the northeast, which, surrounded by Etizen-dake, Yobiko-dake, and Nokogiri-dake, in a horseshoe-shape, opens toward the northeast.

The volcano is composed of lava-flows and pyroclastics of andesitic nature. According to Hirabayashi, the lavas are divided into three kinds: Nagakubo lava (two-pyroxene-andesite), Kamiya lava (olivine-two-pyroxene-andesite), and Asitaka lava (augite-bearing hypersthene-olivine-andesite). In addition, He mentions more than fifty dikes, most of which are inside the craters, and which are classified petrographically into seven types, namely olivine-two-pyroxene-andesite, augite-andesite, hypersthene-vitroandesite, aphyric andesite, and three subtypes of two-pyroxene-andesite.

The bedrock beneath the volcano is entirely hidden and no outcrops of it have been seen in the terranes bordering it. There can be no doubt, however, that the lower Neogene rocks (referred to as the Misaka series) which border the Huzi volcano on the east, north, and west, continue underneath the Huzi-Asitaka region into the Tertiary mountains of north Idu. It therefore seems permissible to infer that this volcano, situated at the northern extremity of the trough depression of the Suruga Bay, together with Huzi, rests on down-faulted lower Neogene rocks, either directly or together with certain younger rocks interposed between them.

This volcano is older than its neighbours—Huzi and Hakone. It is certainly older than the Huzi basalts that bound it on all sides except the southwest; indeed its lower flanks were eroded before the eruption of the latter, as an inspection of their observable contacts will indi-

51) T. Hirabayashi, *Rep. Earthq. Inv. Com.*, **24** (1899).

cate. The southeastern skirt of the volcano is separated from the northwestern slope of Hakone by the Huzi lavas that run into the valley (Kise-gawa valley) between them. It is possible, however, that the former is covered by the latter at the base of the Huzi lavas, as shown in Fig. 5, seeing that there are, close to and at a higher level than former, several small hills which, composed of loosely coherent pyroclastics (pumice, scoria, ash, etc.) may be regarded as outliers of the latter. On the evidence of erosion alone, it may be supposed that the Asitaka-yama volcano, most if not all of it, is older than Hakone. As far as can be judged from these rather meager evidences, it may be

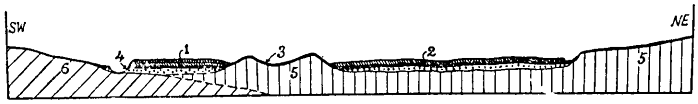

Fig. 5. Diagrammatic section across the valley of the Kise-gawa, showing the geological relation of the visible oldest lava-flows from Huzi to the NW. and SE. slopes respectively of Hakone and Asitaka. 1, 2: Lava-flows from Huzi. 3: Loam-like ash bed. 4: Gravel bed. 5: NW. slope of Hakone. 6: SE. slope of Asitaka.

said that the present volcano is of lower Pleistocene age, although at present there is no means of telling when its activity began.

The rocks of this volcano, which, so far as they are represented by the writer's specimens, are all andesitic, may be referred to two types, hypersthene-olivine-basalt and hypersthene-andesite.

No. 67. *Hypersthene-olivine-basalt.* This rock, which was collected from the northwestern foot of the volcano, 1 km west of Suyama, occurs as a lava-flow interposed between pyroclastic beds. Megascopically, it is compact, dark-gray, and porphyritic with abundant small phenocrysts of plagioclase. Microscopically, we find in addition to the plagioclase, phenocrysts of olivine and hypersthene in a groundmass of plagioclase laths, hypersthene prisms, augite and magnetite granules, and apatite needles, with interstitial tridymite.

Phenocrysts: There are two types of plagioclase phenocrysts; the megascopic phenocrysts, which microscopically exhibit faint zoning, are anorthite 98~90 An (n_1= 1·5794~1·5753), and the microphenocrysts (up to 0·3 mm dia.) which are bytownite 74 An (n_1=1·568). The olivine, which is partly replaced by greenish antigorite and iron oxide, has $2V(-)\doteqdot 75°$. The hypersthene shows $2V(-)=77°$ and $\gamma=1{\cdot}699$. Composition: $En_{70}Fs_{30}$. The mineral contains inclusions of olivine grains.

Groundmass: The plagioclase is labradorite 67 An (n_1=1·563). The hypersthene, which occurs as microphenocrysts in the groundmass, has $2V(-)=61°$. The monoclinic pyroxene is so small so that no accurate measurement of its optical properties could be made.

No. 68. *Hypersthene-andesite.* This rock, which occurs as a lava-flow on the eastern slope of the volcano, is well exposed in the valley between Imasato and Simo-

Wada that borders the volcano on the east. There, the lava, about 3 m thick, is sandwitched between ash beds, both overlain by a lava-flow (olivine-basalt) from Huzi. Megascopically, the rock is compact, gray, and densely packed with plagioclase phenocrysts. Microscopically, it contains in addition to the plagioclase (1~3 mm dia.), phenocrysts of hypersthene (0·5~1·0 mm dia.) in a groundmass consisting of plagioclase laths (0·1~0·3 mm long), pyroxene grains (0·1~0·2 mm eia.), and magnetite granules, with interstitial feldspathic material (alkali feldspar ?) and a little glass base.

Table XXV. Analysis of the Hypersthene-andesite, No. 68, from Asitaka-yama.
S. Tanaka, analyst.

	No. 68	Norm				
SiO_2	54·70	Q	7·21	QFM	Q	7
Al_2O_3	20·18	Or	4·45		F	72
Fe_2O_3	2·40	Ab	30·93		M	21
FeO	5·10	An	36·16			
MgO	2·67	Wo	1·74	NF	Or	6
CaO	8·33	En	6·63		Ab	43
Na_2O	3·65	Fs	6·07		An	51
K_2O	0·77	Mt	3·47			
H_2O +	0·75	Il	1·82	NPl	An	54
H_2O −	0·40	Ap	0·33			
TiO_2	0·93			NPy	Wo	12
P_2O_5	0·20				En	46
MnO	0·10				Fs	42
Total	100·22					
				Fe		73

Phenocrysts: The plagioclase is faintly zoned, its average composition being bytownite 72 An (n_1=1·5657). The hypersthene, which is surrounded by pigeonite grains, is distinctly zoned with 2V(−)=74° in the core and 2V(−)=65° at the margin. γ= 1·7065 (mean). Composition: $En_{67}Fs_{33}$.

Groundmass: The plagioclase, which exhibits distinct zoning, is labradorite 68~58 An (n_1=1·522~1·5585). The hypersthene is identical in composition with the margin of the phenocrystic hypersthene, its optic angle being 2V(−)=64°. The pigeonite, which occurs in the corona surrounding the hypersthene and as prisms dispersed through the groundmass, has 2V(+)=44°~38° and β=1·706. Composition: $Wo_{21}En_{39}$-Fs_{40}.

The chemical composition of this rock is shown in Table XXV.

7. Mikura-sima Volcano.

Mikura-sima, which is one of the Seven Idu Islands, lying about 100 km SSE. of Miyake-sima, in 35°52′N. and 139°37′E., is an extinct insular volcano, 851 m above the sea, and about 5 km in diameter at its visible base. The volcano is greatly dissected; its flanks are cut by numerous radial valleys, while its skirt is cut into precipitous sea-cliffs varying in height from 250～350 m on the southwest shore to about 150 m on the opposite side. The summit of the volcano is a truncated horseshoe-shaped ring-wall surrounding a deep valley (Kawaguchi-no-sawa or Hirasimizu-gawa) which, opening toward the south, suggests a former caldera. The northeastern segment of the ring-wall forms a saddle between the northern ridge (Oyama) and the eastern ridge (850m peak). This saddle may be the result of a side explosion that probably occurred on the northeastern flank at the head of a deep valley (Simawakono-sawa), as a result of which the upper part of the northeastern ring-wall might have been blown away. On the southwestern flank, near the shore, is a knob (Akasawa-yama or Takao-yama) suggestive of a parasitic cone.

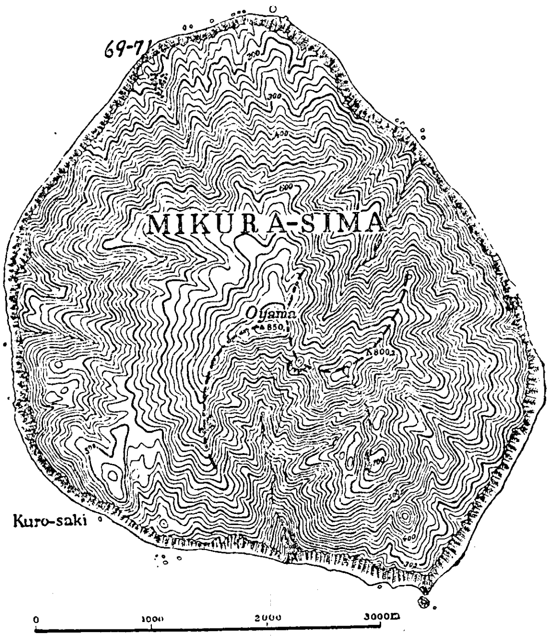

Fig. 6. Mikura-sima, showing the locality of the rock-specimens described in the text.

The volcano is composed of alternating layers of lava-flows and pyroclastic products of a basaltic nature. These layers are cut by numerous dikes of allied rocks, as is seen from exposures in the sea-cliffs around the island. According to N. Fukuchi[52], similar dikes occur in the walls of the caldera.

The following petrographic descriptions are of four specimens, all of which were collected by the writer in 1925 from the lava-flows exposed on the sea-cliff near the landing place on the northern shore of the island (see Fig. 6). Of these, two are olivine-basalt, one hypersthene-bearing olivine-basalt, and the remainder olivine-two-pyroxene-andesite.

52) N. FUKUCHI, *Jour. Geogr., Geogr. Soc., Tokyo*, **14** (1902), 854.

No. 69. *Olivine-basalt.* Of the two specimens of this type, one is grayish, compact, and only slightly porphyritic with very sporadic phenocrysts of plagioclase and olivine, while the other, which also is grayish and compact, is strongly porphyritic with abundant plagioclase and less conspicuous olivine phenocrysts.

(a) Almost-aphyric olivine-basalt. Microscopically, we find a few phenocrysts of plagioclase (0·5~2·0 mm dia.) and lesser microphenocrysts of olivine (0·05~0·2 mm dia.) in a groundmass of plagioclase laths (0·1~0·3 mm long), pigeonite prisms (0·1 mm long), magnetite granules, tridymite aggregates, and a little interstitial glass base.

Phenocrysts: The plagioclase is slightly zoned, its composition varying from anorthite 96 An (n_1=1·5783) to calcic bytownite 88 An (n_1=1·5741). The olivine, which is surrounded by pigeonite grains, shows a faint zoning with 2V(−) varying from 88° in the core to 81° at the margin.

Groundmass: Plagioclase zonally built, the most sodic part being labradorite 66 An (n_1=1·5627). The pigeonite shows $c \wedge Z$=38° and 2V(+) smaller than 30°.

Table XXVI. Analysis of the Olivine-basalt, No. 69 (a), from Mikura-sima, Seven Idu Islands. S. Tanaka, analyst.

	No. 69(a)	Norm				
SiO_2	50·50	Q	6·55	QFM	Q	7
Al_2O_3	15·86	Or	2·78		F	55
Fe_2O_3	4·03	Ab	19·40		M	38
FeO	10·00	An	31·31			
MgO	4·64	Wo	4·30	NF	Or	5
CaO	8·63	En	11·54		Ab	36
Na_2O	2·28	Fs	13·19		An	59
K_2O	0·51	Mt	5·79			
H_2O +	1·26	Il	2·58	NPl	An	62
H_2O −	0·86	Ap	0·33			
TiO_2	1·33			NPy	Wo	15
P_2O_5	0·11				En	40
MnO	0·23				Fs	45
Total	100·24					
				Fe		75

The chemical composition of this rock is shown in Table XXVI.

(b) Porphyritic olivine-basalt. Microscopically, this rock carries abundant phenocrysts of plagioclase and olivine. We find two types of plagioclase phenocrysts, the larger one being a slightly zoned anorthite 97~91 An (n_1=1·5786~1·5757), and the smaller one bytownite 82 An (n_1=1·5712). The olivine, which is surrounded by minute pigeonite grains, has 2V(−)≑89°. The groundmass consists of bytownite 75 An (n_1=1·568), pigeonite $Wo_{13}En_{40}Fs_{47}$ (β=1·7053, $c \wedge Z$=40°, and 2V(+)=27° or smaller), magnetite, cristobalite, and a little interstitial glass base.

No, 70. *Hypersthene-bearing olivine-basalt.* Megascopically, this rock is grayish, compact, and studded with conspicuous plagioclase and less conspicuous olivine phenocrysts. Microscopically, the phenocrysts are zoned anorthite-bytownite 95~81 An

(n_l = 1·5772~1·5705) and zoned olivine (2V(−)≒87° in the core and 2V(−)≒81° at the margin). The groundmass consists of bytownite 71 An (n_l = 1·5655), anhedral olivine surrounded by pigeonite grains either directly or with hypersthene between them, hypersthene (2V(−)=66°) with a rim of pigeonite in parallel intergrowth, pigeonite $Wo_{12}En_{41}Fs_{47}$ (β=1·7027, 2V(+)=17° or smaller), and tridymite, with a little interstitial glass.

No. 71. *Olivine-two-pyroxene-andesite.* Megascopically, this rock also is grayish, compact, and strongly porphyritic with phenocrysts of plagioclase and pyroxene. Microscopically, we find phenocrysts of faintly-zoned anorthite-bytownite 94~85 An (n_l = 1·5770~1·5724) with a thin rim of the groundmass plagioclase, hypersthene $En_{62}Fs_{38}$ (2V(−)=71°, γ=1·7031 or n_l=1·6966) with a thin rim of monoclinic pyroxene, augite (2V(+)=48°), olivine (2V(−)≒87°) surrounded by pigeonite grains, and accessory magnetite. The groundmass consists of labradorite 62 An (n_l=1·5603), pigeonite $Wo_{12}En_{40}Fs_{48}$ (2V(+)=18°~10°, β=1·705), magnetite, and cristobalite, with a little interstitial glass base.

8. Tori-sima (Mitugo-sima or Ponafidin I.) Volcano.

Tori-sima, in 30°28′N. and 140°14′E., is an insular volcano with a circular outline of about 2·5 km in diameter, and consisting of a somma and a central cone. The somma has a circular crater, 1 km in diameter, surrounded by a ring-wall, the east and west segments of which are clearly the respective crest-lines around them—Asahi-yama (387 m) on the east and Tukiyo-yama (374 m) on the west. The central cone, Komoti-yama (361 m above the sea or about 100 m above the eastern atrio of the somma), stands in the centre of the caldera, its top, with the walls of two circular craters, being truncated. These craters, together with two other smaller ones in the atrio—Kitano-kubo in the northern atrio and Butano-kubo in the southern—, besides a horseshoe-shaped depression (Titose Bay) on the northern shore, rest on a line that suggests a fissure and traverses the island in a N.–S. direction through the central cone. In addition, there are two explosion-craters that were formed by the disasterous explosions of August 1902, which were the last and only recorded explosive activity on the island. One of these, A, is a rift-crater, 900 m long, 300 m wide, and 100 m deep, stretching in a N.–S. direction on the west flank of

Fig. 7. Tori-sima.

the central cone; and the other, B, a horseshoe-shaped explosion-crater (Hyogo Eay) on the NNW. shore of the island[53] (see Fig. 7).

The volcano is composed of alternating layers of lava, agglomerate, and other pyroclastic products. Although the writer did not landed on the island, he examined two out of a number of specimens that were collected by T. Akagi from the shore of the Bay of Hyogo, and which are preserved in the collection of the Geological Institute of the Tokyo Imperial University. One of these is augite-olivine-basalt and the other two-pyroxene-andesite, their respective petrographic characters being as follows:

No. 72. *Augite-olivine-basalt.* This rock is grayish, rather compact with a few round vesicular cavities and strongly porphyritic with abundant phenocrysts of plagioclase, olivine, and pyroxene. Microscopically, we find phenocrysts of plagioclase (0·5 ~1·0 mmd ia.), olivine (0·5~2·0 mm dia.) and augite (0·5~2·0 mmd ia.), in a groundmass of plagioclase laths (0·1~0·2 mm long), augite prisms (0·1~0·2 mm long), magnetite grains, and a few tridymite, with a little interstitial glass base packed with dust material.

Phenocrysts: The plagioclase may be referred to two types: the larger crystals of anorthite 97 An (n_1=1·5790) and the smaller ones of less calcic anorthite 91 An (n_1=1·5760). They are surrounded by a thin rim of the groundmass plagioclase. The olivine, which occurs as anhedral round crystals enclosed by pyroxene grains, has $2V(-)=86°$ and β=1·7067. Composition: $Fo_{67}Fa_{33}$. The augite is faintly zoned, its optic angle varying from the core to the margin in the manner: $2V(+)=51° \rightarrow 42°$

Table XXVII. Analysis of the Augite-olivine-basalt, No. 72, from Tori-sima, Southern Islands. S, Tanaka, analyst.

	No. 72	Norm				
SiO_2	48·70	Q	0·60	QFM	Q	1
Al_2O_3	20·08	Or	1·11		F	61
Fe_2O_3	1·80	Ab	13·11		M	38
FeO	8·14	An	47·29			
MgO	5·53	Wo	7·55	NF	Or	2
CaO	13·20	En	13·75		Ab	21
Na_2O	1·56	Fs	12·79		An	77
K_2O	0·17	Mt	2·55			
H_2O +	0·20	Il	1·21	NPl	An	78
H_2O −	0·13	Ap	0·33			
TiO_2	0·64			NPy	Wo	22
P_2O_5	tr.				En	40
MnO	0·20				Fs	38
Total	100·35					
				Fe		64

53) K. JIMBO, *Rep. Earthq. Inv. Com.*, **43** (1903).

or 58°→48°→36°. n_l=1·6906 (mean). Average composition: $Wo_{23}En_{47}Fs_{25}$.

Groundmass: The plagioclase is bytownite 85~81 An (n_l=1·5776~1·5758). The monoclinic pyroxene is zonally built, its optic angle varying from 2V(+)=50°~45° in the core to 34° or smaller at the margin. β=1·7020 (mean). Average composition: $Wo_{20}En_{41}Fs_{39}$. The magnetite occurs either as isolated equant individuals or in an ophitic intergrowth with the plagioclase and pyroxene laths.

The chemical composition of this rock is given in No. 72 of Table XXVII. The rock is high in alumina and lime, and low in alkalies, indicating a predominance of the calcic plagioclase. The normative plagioclase has the composition of bytownite 78 An which is a little more sodic than the modal plagioclase. The analysis closely resembles that of the augite-olivine-basalt from Kita Io-sima (No. 75, Table XXVIII), although the former is more aluminous and more calcic, but less alkalic, compared with the latter, and although the former shows a little normative quartz instead of the normative olivine which appears a little in the latter. The present rock is also very similar in chemical composition to the porphyritic olivine-basalt from the demolished igneous body of the northwestern coast of O-sima (No. 90, Table XXXIII).

No. 73. *Two-pyroxene-andesite*. This rock is dark-gray, compact, and less porphyritic than the rock above described, with sporadic phenocrysts of plagioclase and pyroxene. Microscopically, the phenocrysts are two types of plagioclase—anorthite (n_l=1·578) and calcic bytownite 86 An (n_l=1·574)—, faintly zoned augite $Wo_{32}En_{43}Fs_{25}$ (2V(+)=53° in the core and 2V(+)=48° at the margin, β=1·6964 or n_l=1·6933), and hypersthene $En_{65}Fs_{35}$ (2V(−)=73°, n_l=1·6942). Most of the hypersthene phenocrysts are enclosed in a rim of augite (c/\Z=47°) in parallel intergrowth, while a few occur as randomly-oriented inclusions in the aguite phenocrysts. The groundmass consists of bytownite 84 An (n_l=1·5720), monoclinic pyroxene (β=1·710), Magnetite, and tridymite, with a little interstitial glass base. The tridymite, as minute grouped crystals, is more plentiful in this than in the preceding rock.

9. Kita Io-sima (San Alessandro I.) Volcano.

Kita Io-sima, situated 25°25′N. and 141°16′E., is the northernmost member of the Volcano Islands, southwest of the Bonin Islands. Its elliptical coastline, the major and minor axes of which are 3 km from NNW. to SSE. and 2 km from ENE. to WSW., respectively, has but few indentations. The island is a much dissected volcanic cone; its summit, instead of being a pointed peak as in the usual conical volcano, is a ridge stretching in a NNW.–SSE. direction along the major axis of the island from the highest southern peak, Sakakiga-mine (804 m above the sea) to the lowest northern peak, Aono-mine (523 m), through the 665 m peak that lies between them. The lateral slopes of the ridge, which are generally inclined more than 35°, showing numerous slips and scars, are broken in an irregular manner and deeply dissected by ravines, of which the Isino valley on the northeast slope between the south and north peaks, is the largest and most striking. The steep slopes of the upper part of the ridge end abruptly with precipitous sea-cliffs up to 400 m high and are fringed with narrow gravel beaches along the whole coast. The gravel beach, which, at the base of the sea-cliffs rises a few meter above the sea, gradually descends seaward without being cut by coastal terraces of any height, and continues to a shallow-water wave-cut platform offshore.

So far as the writer's observations go, the volcano is built up of much agglomerate, a few lava sheets, and numerous dikes, all of basaltic nature. Thus, the precipitous cliff near the landing place on the north-east side shows strata of agglomerate which, dipping apparently to the south, are traversed by numerous dikes. In places the agglomerate carries huge lava-blocks (2 m or more in diameter), but in others it is a bed of material so fine that it may be called an ash bed. Dikes of thicknesses up to several meters stand almost vertically with a NW.–SE. strike, some of them extending for more than 300 m from the base to the upper edge of the cliff.

Fig. 8. Kita Io-sima, showing the localities of the rock-specimens described in the text.

On the top of the south peak is a small depression suggestive of a former crater, which however can scarcely be the main crater of the volcano, seeing that the strata of agglomerate do not show a quaquaversal dip from the top of the south peak as the centre. It is possible that the former main crater of activity of the volcano is at the head of the Isino valley already referred to. T. Wakimizu[54] regarded the valley as an old explosion-crater. The steep wall that surrounds the valley in a horseshoe-shape is covered in places with a whitish to yellowish material that may owe its origin to a former solfatara—a vestige of the last phase of volcanic activity. A rocky pinnacle suggestive of a neck rises above the steep wall adjoining the southern part of the valley. There is no historic record either of a volcanic eruption or of active solfataras of any extent in the supposed crater nor elsewhere else in the island, although a submarine volcano, about 2 km northwest of the island, continued activities for a number of years until 1889.

Six rock specimens were collected by the writer in 1935 from the

54) T. WAKIMIZU, *Publ. Earthq. Inv. Com.*, No. 22 C (1908).

northeastern part of the island. Petrographically, they may be referred to two types, olivine-basalt and augite-olivine-basalt.

No. 74. *Olivine-basalt.* This rock is represented by lava-blocks collected from an agglomerate bed exposed on the precipitous cliff on the northeast coast. Megascopically, it is grayish, either compact or slightly vesicular, and porphyritic with abundant phenocrysts of plagioclase, together with a few olivine. Microscopically, the plagioclase of the phenocrysts is faintly zoned, its composition varying from anorthite 99 An ($n_t=1{\cdot}5797$) to bytownite 82 An ($n_t=1{\cdot}5715$). The olivine, which occurs in rounded crystals, is altered to brownish iddingsite along its cracks. Zoning is distinct: $2V(-)=88°$ in the core, and $2V=80°\sim78°$ at the margin. $\beta=1{\cdot}7180$ (mean). Average composition: $Fo_{62}Fa_{38}$. Besides occurring in comparatively larger phenocrysts, the olivine is found in the groundmass as very minute crystals surrounded with pyroxene grains. The plagioclase in the groundmass is calcic labradorite 66 An ($n_t=1{\cdot}5627$). The monoclinic pyroxene, which occurs in the groundmass only, is zonally built, its optic angle varying from the core to the margin in the manner: $2V(+)=46°\rightarrow34°$, $52°\rightarrow40°$, or $52\rightarrow35°$. $\beta=1{\cdot}711$ (mean). Average composition: $Wo_{24}En_{37}Fs_{39}$. The groundmass contains in addition to the plagioclase and pyroxene, magnetite granules and interstitial tridymite, together with a little dusty glass base.

No. 75. *Augite-olivine-basalt.* This rock occurs both as lava-sheets and dikes, besides occurring also in the agglomerate bed. The four specimens (one from agglomerate, two from dikes, and one from lava) belonging to this rock type are greatly alike in their petrographic characters, although megascopically they differ from each other according to their mode of occurrence. One of them, collected from a dike traversing the agglomerate bed, being the freshest specimen, will be described here as representing the rock-type. Megascopically, the specimen is dark-gray with a greenish tint,

Table XXVIII. Analysis of the Augite-olivine-basalt, No. 75, from Kita Io-sima, Volcano Islands.
S. Tanaka, analyst.

	No. 75	Norm				
SiO_2	48·49	Q	——	QFM	Q	—
Al_2O_3	18·72	Or	2·23		F	61
Fe_2O_3	2·77	Ab	17·30		M	39
FeO	8·18	An	40·89			
MgO	5·17	Wo	8·71	NF	Or	4
CaO	12·47	En	12·60		Ab	29
Na_2O	2·02	Fs	11·67		An	67
K_2O	0·33	Fo	0·18			
H_2O +	0·38	Fa	0·15	NPl	An	70
H_2O −	0·60	Mt	3·94			
TiO_2	0·76	Il	1·52	NPy	Wo	26
P_2O_5	0·05	Ap	tr.		En	38
MnO	0·22				Fs	36
Total	100·16					
				Fe		67

vesicular to compact, and porphyritic with phenocrysts of plagioclase, pyroxene and olivine. Microscopically, the phenocrysts of plagioclase (0·5∼3·0 mm dia.), augite (0·3∼1·5 mm dia.) and olivine (0·1∼1·0 mm dia.) are scattered through a groundmass of plagioclase (0·1 mm), augite (0·03∼0·1 mm) and magnetite, with a greenish-brown interstitial glass.

Phenocrysts: The plagioclase is anorthite 95∼90 An (n_1=1·5774∼1·5752) surrounded by a thin rim of the groundmass plagioclase. The olivine, which is partly serpentinized, has 2V(−)=86° in the core and 2V(−)=82° at the margin. β=1·7038 (mean). Average composition: $Fo_{65}Fa_{35}$. The augite shows a distinct zoning, its optic angle varying from the core to the margin in the manner: 2V(+)=50°→58°→→50°, 58°→52°→45°, or 53°→50°. n_1=1·6953 (mean). Average composition: Wo_{32}-$En_{33}Fs_{35}$.

Groundmass: The plagioclase, which occurs either as stout prismoids or as equant grains, is bytownite 78 An (n_1=1·5692). The augite has 2V(+)=50→46° and n_1=1·6982. Approximate composition: $W_{30}En_{42}Fs_{28}$. The magnetite, which occurs rather sporadically, is ophitically intergrown with the groundmass plagioclase laths and pyroxene grains. No silica mineral was observed in the groundmass.

The specimen just described was chemically analyzed with results as given in Table XXVIII. It is low in silica, but high in alumina and lime. The norm shows a little olivine instead of quartz.

10. Aoga-sima Volcano.

Aoga-sima, situated about 50 km SSE. of Hatizyo-sima, in 31°28′N. and 139°45′E., has an elliptical outline measuring 3·5 km from NNW. to SSE. and 2 km from ENE. to WSW. It is a composite insular volcano consisting af a somma and a central cone. The somma, 423 m above the sea, is deeply eroded, resulting in the formation of steep outer slopes surrounded by high sea-cliffs on all sides except in the northwest, where a gentle slope of the original conical volcano has been left intact. The top of the somma is truncated, with a ring-wall surrounding a circular crater (Ikeno-sawa), about 1 km in diameter and 300 m deep from the highest crest of the ring-wall. The central cone, which rises 100 m above the floor of the crater of the somma, is a truncated cone with a circular crater, 200 m in diameter, having very young morphological features. Recent known

Fig. 9. Aoga-sima.

eruptions of the volcano occurred in 1780~1785 when the central cone was formed; and if the records are trustworthy, what may be guessed as an eruption occurred in 1652[55].

As to the geologic structure of the volcano, and its rocks, our knowledge is very meagre, for the mountain has rarely been visited and what descriptions we have of it are of the briefest. The following petrographic descriptions refer to four specimens, all of which were collected by T. Akagi from the island, and which are in the collection of the Geological Institute of the Tokyo Imperial University. Of the specimens, two are olivine-bearing two-pyroxene-andesite, and the remainder olivine-basalt. Their petrographic characters are as follows:

No. 76. *Olivine-bearing two-pyroxene-andesite.* Megascopically, this rock is black and almost aphyric, but occasionally contains small phenocrysts of plagioclase and pyroxene. One part of the rock is scoriaceous with small vesicular cavities, while the other part is compact, showing that luster so characteristic of obsidian. Microscopically, we find a few phenocrysts of plagioclase (0·1~1·0 mm dia.), augite (0·1~1·0 mm dia.), hypersthene (0·1~1·0 mm), and olivine (0·1~0·2 mm dia.), in a glassy groundmass. Angular, accessory xenoliths (1~5 mm dia.) of more crystalline andesite are sporadically found. The plagioclase of the phenocrysts is bytownite 80~74 An (n_1=1·5701~1·5670). The augite shows n_1=1·7015, 2V(+)=50°, and c/\Z=45°. Composition: $Wo_{29}En_{35}Fs_{36}$. The hypersthene, which is greenish brown with distinct pleochroism, has n_1=1·715. Composition: $En_{47}Fs_{53}$. The amount of olivine is negli-

Table XXIX. Analysis of the olivine-bearing two-pyroxene-andesite, No. 76, from Aoga-sima. S. Tanaka, analyst.

	No. 76	Norm				
SiO_2	61·73	Q	20·36	QFM	Q	21
Al_2O_3	14·60	Or	2·78		F	56
Fe_2O_3	1·75	Ab	29·89		M	23
FeO	7·70	An	22·53			
MgO	1·82	Wo	2·79	NF	Or	5
CaO	6·07	En	4·52		Ab	54
Na_2O	3·52	Fs	11·34		An	41
K_2O	0·47	Mt	2·55			
H_2O +	0·48	Il	1·97	NPl	An	43
H_2O −	0·22	Ap	0·33			
TiO_2	1·05			NPy	Wo	15
P_2O_5	0·20				En	24
MnO	0·22				Fs	61
Total	99·83					
				Fe		84

55) F. OMORI, *Rep. Earthq. Inv. Com.*, **43** (1903).

gible. The groundmass is a pale to dark brown glass with $n=1{\cdot}5443\sim1{\cdot}5660$. It carries a few plagioclase microlites (0·05 mm long). The chemical composition of this rock is shown in Table XXIX.

No. 77. *Olivine-basalt.* Megascopically, this rock is black, vesicular, and porphyritic with abundant phenocrysts of plagioclase. Microscopically, besides the plagioclase, it contains a few phenocrysts of olivine. The plagioclase is faintly zoned, its composition varying from anorthite 93 An ($n_1=1{\cdot}5770$) to calcic bytownite 87 An ($n_1=1{\cdot}5735$). The olivine has $2V\doteqdot90°$. The groundmass is an opaque glass carrying a few plagioclase microlites.

11. Hatizyo-sima Volcano.

Hatizyo-sima, which is the southernmost member of the Seven Idu Islands, lying in 139°50′E. and 33°05′N., is a gourd-shaped volcanic island measuring about 14 km in a NNW.–SSE. direction and 7·5 km E.–W. It is composed of two volcanoes—Higasi-yama (Mihara-yama) and Nisi-yama (Hatizyo-huzi). Higasi-yama, which occupies the southeastern half of the island, is a dissected composite volcano consisting of a somma (Todaisi-yama, 837 m above the sea) and a central cone (Higasi-yama proper, 701 m). Besides these, there are, near the skirt of the somma, several small dissected hills, 100~300 m high above the sea, which are morphologically separated from the main body of the somma, and which suggest remains of an old volcano buried beneath the somma. K. Niinomi[56] regarded them as representing detached segments of the ring-wall of an older somma. Nisi-yama, a typical volcanic cone, 854 m above the sea, occupies the rest of the island. It is in marked contrast with the preceding volcano in that its morphological features are quite young. The top of the cone is truncated, with a ring-wall surrounding the circular crater (O-ana), which is about 400 m in diameter. In the crater is a small central

Fig. 10. Hatizyo-sima, showing the localities of the rock-specimens described in the text.

56) K. NIINOMI, *Jour. Geogr., Geogr. Soc., Tokyo*, 24 (1912), 45.

cone (Naka-yama). There are several parasitic cones and vents on the flanks of the Nisi-yama volcano. History records a number of eruptions from this volcano, which at present is dormant without any sign of activity. The last known eruption occurred in 1605, when, according to Niinomi, a lava-flow that issued from the southeast slope of Nisi-yama reached the sea at Mitune on the east side of the island, while other eruptions are recorded as having occurred in 1487, 1518, and 1522.

Both volcanoes—Higasi-yama and Nisi-yama—are composed of alternate layers of lavas and pyroclastic products of basaltic nature. The Higasi-yama lavas are olivine-basalt and augite-bearing olivine-basalt, so far as they are represented by the specimens which the writer collected in 1935 from the lower part of the northwest flank of the volcano, although Niinomi speaks of olivine-two-pyroxene-andesite as being among them. The Nisi-yama lavas, which generally appear to be a little less basic than the Higasi-yama lavas, are poor in phenocrysts of mafic minerals. These lavas may however be referred to three types: aphyric basalt, two-pyroxene-basalt, and olivine-basalt. Besides these, Niinomi mentions hypersthene-andesite and olivine-bearing two-pyroxene-andesite from the volcano. Of the specimens collected by the writer, the most representative ones have the following petrographic characters:

(A) Higasi-yama lavas.

No. 78. *Olivine-basalt.* This rock occurs on the northwest flank of Higasi-yama, where it forms a lava-flow, 10 m or more in thickness, intercalated between pyroclastic products. The specimen examined was collected from the lava exposed on the road about 2 km south of Ogago. Megascopically, the rock is gray, compact, and porphyritic with phenocrysts of plagioclase and olivine. Microscopically, two types of plagioclase phenocrysts are distinguished: the larger phenocrysts are anorthite 95 An, while the smallar ones are calcic bytownite 88 An ($n_1=1.574$). The olivine, which occurs as anhedral crystals surrounded with pyroxene grains, has $2V(-)\fallingdotseq 86°$. The groundmass consists of labradorite 75 An ($n_1=1{\cdot}5678$), zoned augite $Wo_{26}En_{40}Fs_{34}$ ($2V(+)=50°\rightarrow 43°$ or $52°\rightarrow 47°$, $\beta=1{\cdot}7015$ (mean)), and magnetite, with a little interstitial feldspathic material. The feldspathic material, which has very weak double refraction and low refractive indices, appear to be an alkali-feldspar; definite identification being impossible owing to its minute size.

No. 79. *Augite-bearing olivine-basalt.* This rock occurs as a lava-flow some distance below the lava above described. Megascopically, the rock is grayish, compact, and porphyritic with abundant phenocrysts of plagioclase and olivine and subordinate ones of pyroxene. Microscopically, it contains phenocrysts of anorthite 98~91 An ($n_1=1{\cdot}5790\sim 1{\cdot}5766$), olivine ($2V(-)\fallingdotseq 86°$) with rims of pyroxene grains, and faintly zoned augite. The optic angle of the last-named mineral varies from the core to the margin in the manner: $2V(+)=52°\rightarrow 45°$, $50°\rightarrow 44°$, or $52°\rightarrow 43°$. The groundmass consists of bytownite 75 An ($n_1=1{\cdot}5675$), monoclinic pyroxene $Wo_{27}En_{41}Fs_{32}$ ($2V(+)=46°\sim 43°$ and $\beta=1{\cdot}700$), and dusty magnetite, with a little interstitial, colorless material exhibithing weak double refraction and low refractive indices.

(B) Nisi-yama lavas.

No. 80. *Two-pyroxene-bearing basalt.* Covered with beds of pyroclastic products, about 2 m in thickness, this rock occurs as a lava-flow on the east-southeast slope of Nisi-yama, about 2·5 km north of Mitune. It is a vesicular, black, slightly porphyritic rock with a few phenocrysts of plagioclase. Microscopically, it contains, besides the plagioclase, a few microphenocrysts of a monoclinic pyroxene. Although no hypersthene could be detected in the thin section, the mineral must be present as very rare phenocrysts in the rock, for a pyroxene megacryst picked out of the rock was identified through its optical characters as that mineral. The plagioclase phenocrysts are a faintly zoned bytownite 90~83 An (n_1=1·5758~1·5716). The microphenocrystic pyroxene is pigeonitic, with n_1=1·702. The hypersthene, which was picked out of the rock, showed n_1=1·6975. Composition $En_{65}Fs_{35}$. The groundmass consists of very minute plagioclase microlites, pigeonite prisms, and magnetite cubes, with tridymite (?) and interstitial feldspar.

No. 81. *Olivine-bearing basalt.* This rock occurs on the beach adjoining the northern side of the landing place, Mitune, as a lava-flow underlying the lava of aphyric basalt, No. 83. A similar lava is exposed extensively on the rear side of the island, near the landing place, Yaene. Megascopically, the rock is dark-gray, vesicular, and strongly porphyritic with numerous phenocrysts of plagioclase. Microscopically, we find a few phenocrysts of olivine, besides the plagioclase. The plagioclase is distinctly zoned, its composition varying from anorthite 94 An (n_1=1·5769) to bytownite 86 An (n_1=1·5730). The olivine has 2V(−)=88° and β=1·7180. Composition: $Fo_{60}Fa_{40}$. The groundmass consists of minute laths of sodic bytownite 70 An (n_1=1·5648), pigeonite (2V small, β=1·718), and magnetite grains, with cristobalite and interstitial brown glass.

No. 82. *Basalt free from phenocrysts of mafic minerals.* This rock occurs as a lava-flow covering the surface of the lower part of the southeast slope adjoining the southern part of the area occupied by the lava, No. 80. Megascopically, it is vesicular, gray to black, and porphyritic with plagioclase phenocrysts. Microscopically, it contains abundant phenocrysts of plagioclase only, the composition of which is anorthite-bytownite 92~84 An (n_1=1.5760~1·5721). The groundmass is a dark-brownish glass packed with bytownite laths (80 An, n_1=1·5698), pigeonite prisms (β≒1·700, 2V very small or nearly zero), and magnetite dust.

No. 83. *Aphyric basalt.* This rock occurs as a lava-terrace, 5~10 m high above the sea, on the eastern coast near the landing place, Mitune. The lava, which is the youngest flow exposed on that coast, may possibly be what Niinomi regarded as having issued in 1605 from the southeastern slope of the Nisi-yama cone. The specimen examined was collected from a cliff cut in the terrace-forming lava about 100 m north of the landing place. Megascopically, the rock is compact, dark-gray to black, and almost completely aphyric without any noticeable phenocrysts except a few small plagioclase. Microscopically, it consists of plagioclase, pigeonite, and magnetite, with a little interstitial material. The plagioclase occurs, rarely, as microphenocrysts (0·5 mm dia.), besides minute laths (0·03~0·1 mm long). The microphenocrystic plagioclase is bytownite 87 An (n_1=1·5735) with a thin rim of a little less calcic bytownite; while the minute lath-shaped plagioclase is bytownite 80 An (n_1≒1·570). The pigeonite also occurs as microphenocrysts (0·5 mm long), besides minute slender prisms (0·1 mm long). The microphenocrystic pigeonite has β=1·7045 (n_1=1·7025), while the minute pigeonite β=1·7070. Their optic angles are very small. The magnetite is found as equant granules, 0·01 mm in diameter. There is a small amount of colorless base, which is almost isotropic and has a refractive index smaller than that of balsam.

Table XXX. Analysis of the Aphyric Basalt, No. 83, from Nisi-yama, Hatizyo-sima. S. Tanaka, analyst.

	No. 83	Norm				
SiO_2	54·67	Q	10·51	QFM	Q	11
Al_2O_3	14·47	Or	2·78		F	51
Fe_2O_3	1·86	Ab	22·02		M	38
FeO	12·30	An	26·42			
MgO	3·03	Wo	5·23	NF	Or	5
CaO	8·03	En	7·53		Ab	43
Na_2O	2·59	Fs	18·86		An	52
K_2O	0·50	Mt	2·78			
H_2O +	0·45	Il	3·19	NPl	An	54
H_2O −	0.09	Ap	0·33			
TiO_2	1·64			NPy	Wo	17
P_2O_5	0·16				En	23
MnO	0·32				Fs	60
Total	100·11					
				Fe		82

The results of Tanaka's analysis of this rock are given in Table XXX. The analysis closely resembles those of the basaltic rocks from O-sima and Miyake-sima, although the former is slightly more acidic than the latter. Thus the present rock, like the analyzed rocks from O-sima and Miyake-sima, is rather low in alumina and high in iron-oxides compared with the porphyritic basalts from Tori-sima, Kita Io-sima, etc. The norm shows abundant quartz. The normative plagioclase and pyroxene are 54 An and $Wo_{17}En_{23}Fs_{60}$ respectively. In the analyses of basaltic rocks from the region now under investigation, the present analysis shows the highest percentage of ferrosilite molecule in the normative pyroxene.

12. Miyake-sima Volcano.

Miyake-sima, situated in 34°03′N. and 139°30′E., is an insular volcano with a circular outline measuring about 7 km in diameter. It is a composite stratified volcano consisting of a somma and a central cone. The somma is truncated at the top, with a ring-wall whose northern segment is clearly seen as a semi-circular crest-line around it. The highest point (815 m above the sea) of the somma is the northern crest of this ring-wall. The caldera, whose northern part is preserved as a crescentic atrio encircled by the ring-wall, must have originally been about 1·5 km in diameter. The central cone (O-yama), which is 814 m above the sea or about 120 m above the floor of the atrio, lies slightly south of the caldera. Its top is truncated, with walls surrounding a composite crater consisting of four crater-bowls aligned in an E.–W. direction. Of these, the easternmost crater (the first crater), the principal one of the central cone, is the largest (about 400 m in

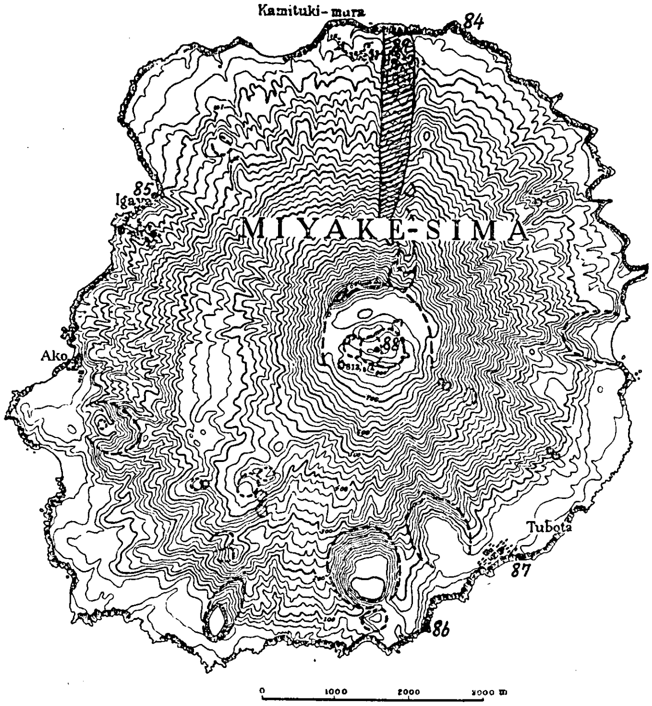

Fig. 11. Miyake-sima, showing the localities of rock-specimens described in the text. Hatched area is the lava of 1874.

diameter); the second crater (200 m dia.) lying immediately west of the first, is the deepest (about 115 m below the highest rim of the crater-wall), while the others are smaller and shallower than those just mentioned (see Fig. 11).

The somma has more than twenty parasitic knobs and flank-vents, most of which lie on the NNE. snd SSW. slopes, but none of them are large enough to affect much the regular outline of the somma. The central cone also has a parasitic knob on its southwest slope.

The somma is composed of alternate accumulations of lava-flows and fragmentary material. Although the thick accumulation of fragmentary ejecta and the absence of deep ravines on the slopes preclude detailed study of the earlier products lower down the somma, the best exposures of its inner structure are to be seen on the sea-cliffs around the island and on the ring-wall surrounding the caldera, where many superposed lava-flows, most of them only a few meters thick, are exposed, intercalated by layers of fragmentary ejecta. Some of the flows, especially those exposed on the southwest shore, must have come from the parasitic cones or from the vents on the slopes.

The central cone also is built up of lava-flows and fragmentary ejecta as may be seen on exposures in the walls of the summit-craters. On the east wall of the second crater is exposed a columnar lava, about 20 m thick, which, covered with a thin bed of bombs, lapilli and ash, must have once been a lava-lake that filled the first crater[57].

Although in the last half century the volcano has been entirely quiescent without any trace of activity, previous to which it was active several times, the last recorded eruption of the volcano occurred in 1874, when a lava-flow from the NNE. slope of the somma through a fissure-like opening, reached the sea east of Kamituki on the north coast of the island. Flank-eruptions occurred in 1643, 1712, and in 1835, summit- and flank-eruptions in 1763 and 1811; and what have been reported as eruptions in 1085, 1154, 1469, and 1595.

Although, petrographically, the lavas of the volcano differ more or less, they are all of basaltic in nature and may be distinguished by the combinations of the phenocrystic minerals into four types: (1) olivine-basalt, (2) augite-olivine-basalt, (3) olivine-two-pyroxene-basalt, and (4) two-pyroxene-basalt. The fragmentary products consist of juvenile and accessory ejecta of the rocks enumerated above, besidesanorthite lapilli and micro-allivalite bombs. The following petrographic descriptions refer to six representative specimens from the seventy that the writer collected in 1925, when studying the structural details of the volcano.

(A) Somma lavas.

No. 81. *Olivine-basalt.* This rock occurs in several superposed lava-flows exposed on the northeast coast between Akon-saki and Ano-saki. The specimen examined was collected from the lowest of the three flows exposed at Akon-saki. It is grayish, compact, and porphyritic with phenocrysts of plagioclase and olivine. Microscopically, the plagioclase phenocrysts are faintly zoned with composition varying from 98 An (n_1=1·5793) to 92 An (n_1=1·5764). The olivine shows very faint zoing: 2V(−)88° in the core, and 2V(−)=79° at the margin. β=1·7033 (mean). Composition: $Fo_{65}Fa_{35}$. The groundmass, which is highly crystalline, consists of bytownite 77 An (n_1=1·5684), monoclinic pyroxene, and magnetite, with a very little interstitial glass base. The monoclinic pyroxene is zonally built, the variation in its optic angle from core to margin being: 2V(+)=49°→36°, 48°→37°, or 52°→41°. β=1·711 (mean). Average composition: $Wo_{21}En_{37}Fs_{39}$.

In another specimen of the same rock type collected from the sea-cliff, about 2 km southeast of Akon-saki, the phenocrystic olivine has 2V=90°, and the groundmass pyroxene is zonally built, its optic angle varying from 2V(+)=49°∼47° in the core to 2V(+)=34°∼0° at the margin.

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57) I. FRIEDLAENDER, *Mitteil. d. Deutch. Gesell. f. Natur- u. Volkerkunde Ostasiens*, **12** (1909), 76.

No. 85. *Augite-olivine-basalt.* This rock, which is the most abundant of the somma lavas, occurs as lava-flows at several places on sea-cliffs around the island as well as in the ring-wall surrounding the caldera. A specimen from the lava exposed on the shore of Ohunato Bay adjoining Igaya (a village on the northeast coast) on its north, was examined as being a representative of this type. Megascopically, it is grayish, compact, and slightly porphyritic with a few inconspicuous phenocrysts of plagioclase and pyroxene. Microscopically, it contains phenocrysts of plagioclase (1~1·5 mm dia.) and augite (0·5~1·0 mm dia.), and microphenocrysts of olivine (0·1~0·2 mm dia.), in a highly crystalline groundmass of plagioclase laths (0·05~0·3 mm long), pigeonite prisms (0·05 mm long), and magnetite granules, with interstitial cristobalite and negligible amount of glass base.

Phenocrysts: The plagioclase is faintly zoned, its composition varying from anorthite ($n_1=1·5798$) to calcic bytownite 89 An ($n_1=1·5746$). The olivine, which occurs only as anhedral microphenocrystic individuals surrounded by minute grains of the groundmass pyroxene, has $2V(+)\doteqdot 86°$. The augite is zoned with 2V varying from the core to margin in the manner: $2V(+)=52°\rightarrow 46°$, or $50°\rightarrow 40°$. $n_1=1·6933$ (mean). Average composition: $Wo_{28}En_{45}Fs_{27}$.

Groundmass: The plagioclase is bytownite 74 An ($n_1=1·5670$) to calcic labradorite 69 An ($n_1=1·5643$). The pigeonite has $2V(+)=38°$ and $\beta=1·7148$. Composition: $Wo_{18}En_{35}Fs_{47}$.

The chemical composition of the specimen just described is shown in column No. 85 of Table XXXI.

Another specimen of the same rock-type, which was collected from a lava exposed some distance above the base of the northern ring-wall, consists of the following mineral ingredients:

Phenocrysts: Anorthite 95 An ($n_1=1·5774$), olivine ($2V(-)\doteqdot 88°$), and augite $Wo_{31}En_{43}Fs_{26}$ ($n_1=1·6934\sim1·6963$, $2V(+)=52°\sim47°$) with pigeonite rim ($2V(+)=43°-15°$). Groundmass: Bytownite 79 An ($n_1=1·5694$), pigeonite ($\beta=1·7124$, 2V very small), magnetite, and interstitial brown glass.

No. 86. *Olivine-two-pyroxene-basalt.* Somma lavas of this type occur on the southeast coast near Tubota, where they underlie the lavas of two-pyroxene-basalt next to be described. The specimen studied was collected from a lava-flow exposed on the sea-cliff adjoining the southern part of Tubota. Megascopically, it is gray to almost black, more or less vesicular, and porphyritic with phenocrysts of plagioclase, pyroxene, and olivine. Microscopically, the phenocrysts are anorthite ($n_1=1·579$) surrounded by a thin rim of bytownite 88 An ($n=1·574$), faintly zoned augite $Wo_{30}En_{43}Fs_{27}$ ($2V(+)=55°$ in the core and 43° at the margin. $n_1=1·6964$ (mean)), hypersthene $En_{57}Fs_{43}$ ($2V(-)=60°\sim70°$ and $n_1=1·700$), and olivine ($2V(-)\doteqdot 87°$). The groundmass consists of bytownite (the same as the rim of the phenocrystic plagioclase), monoclinic pyroxene ($\beta=1·70$), and magnetite, with a brown glass base.

No. 87. *Two-pyroxene-basalt.* The lavas of this type occur on the south, southeast, and southwest coast in several lava-flows. Megascopically, they are usually dark to light gray, compact to slightly vesicular, and almost aphyric without any conspicuous phenocrysts except very sporadical ones of plagioclase and pyroxene. Microscopically, one specimen collected from a lava-flow on the southeast coast, about 2 km northeast of Tubota, is dark-gray and slightly vesicular and carries a few phenocrysts of plagioclase (0·3~1·0 mm dia.), and microphenocrysts (up to 0·2 mm dia.) of augite and hypersthene. The plagioclase phenocrysts show two types: the larger anorthite phenocrysts 94 An ($n_1=1·5773$) and tne microphenocrysts of bytownite 79 An ($n_1=1·5692$). The augite has the composition $Wo_{30}En_{42}Fs_{28}$ ($2V(+)=49°$ and

$n_1 \fallingdotseq 1{\cdot}697$). The hypersthene, which occurs either as isolated individuals or in parallel growth with a monoclinic pyroxene, the latter being usually outside, is identified as $En_{65}Fs_{35}$ with $n_1=1{\cdot}698$. The groundmass is a dark-brown glass packed with slender laths of plagioclase and very minute grains of pyroxene and magnetite.

Another specimen of the same rock-type collected from a lava-flow exposed on the sea-cliff at Tubota, when compared with the preceding one, is more compact, more crystalline, and less porphyritic. Microscopically, we find very sporadic phenocrysts of plagioclase (0·5∼1·0 mm dia.), augite (0·1∼0·3 mm dia.), hypersthene (0·1∼0·3 mm long), and accessory magnetite. The plagioclase is bytownite 84 An ($n_1=1{\cdot}572$.) The augite has $2V(+)=49°\sim47°$ and $n_1=1{\cdot}698$. Some individuals of the augite are distinctly zoned with a rim of pigeonite ($2V(+)=30°$ or smaller). The hypersthene, which is usually enclosed in a thin rim of monoclinic pyroxene in parallel growth, has $2V(-)=72°$. The groundmass consists of plagioclase laths (0·1 mm long), minute grains of pyroxene and magnetite, tridymite, and a little interstitial glass base.

The specimen just mentioned was analyzed by Tanaka, with results as given in column No. 87 of Table XXXI.

(B) Central cone lavas.

No. 88. *Augite-olivine-basalt.* The central cone lavas are exclusively augite-olivine-basalt. A specimen collected from the east wall of the second crater, and representing the rock of the solidified lava-lake in the first crater of the central cone, is grayish, compact, and almost aphyric without any conspicuous megascopic phenocrysts except a few very small plagioclase and olivine. Microscopically, we find phenocrysts of faintly zoned anorthite-bytownite 94∼82 An ($n_1=1{\cdot}577\sim1{\cdot}571$), olivine ($2V(-)=86°$) with a rim of iron-oxide, and augite ($2V(+)=53°\sim48°$ in the core and 43° at the margin), all scattered sporadically through a groundmass of bytownite 78 An ($n_1=1{\cdot}5692$), pigeonite ($\beta=1{\cdot}708$), magnetite, and cristobalite, with a little interstitial glass base.

Another specimen collected from a lava in the northern wall of the second crater of the central cone is more porphyritic, compared with the preceding one, with magascopic phenocrysts of plagioclase, pyroxene and olivine. Microscopically, it contains phenocrysts of anorthite 95 An ($n_1=1{\cdot}5775$) with a rim of bytownite 87 An ($n_1=1{\cdot}5735$), augite $Wo_{26}En_{42}Fs_{32}$ ($2V(+)=45°$, $\beta=1{\cdot}698$) with a rim of pigeonite ($2V(+)=34°$ or smaller) and olivine ($2V(-)\fallingdotseq80°$) in a groundmass of bytownite 76 An ($n_1=1{\cdot}568$), pigeonite $Wo_{11}En_{36}Fs_{53}$ ($2V(+)=10°$, $\beta=1{\cdot}7125$), magnetite, cristobalite, and interstitial glass base.

The chemical composition of one of the central cone lavas is shown in the analysis (No. 88, Table XXXI) made by M. Dittrich of a specimen that was collected by I. Friedlaender and described by C. Bacher as augite-andesite[58]. As will be seen from the analysis, the central cone lava resembles chemically the lavas from O-sima and Hatizyo-sima (Nisi-yama). Thus, it is rather low in alumina but high in iron-oxides. The norm shows plagioclase 62 An and pyroxene $Wo_{20}En_{39}Fs_{41}$, with considerable quartz.

(C) Lava of 1874.

No. 89. *Olivine-augite-basalt.* This lava occupies a narrow area on the northern slope of the somma, stretching for about 3 km from its vent half way down the slope to the northern sea-shore, with a maximum width of 800 m. Although the slope adjoining the east of the lava field on the east is covered with scoriae and anorthite lapilli

58) C. BACHER, Über die Laven der Kleineren Izu-Inseln. Ein Beitrag zur Petrographie Japans. München (1914), 20.

Table XXXI. Analyses of Rocks from Miyake-sima.

		No. 85	No. 87	No. 88	No. 89
SiO_2		53·25	54·10	54·55	53·35
Al_2O_3		16·30	15·24	16·26	15·62
Fe_2O_3		2·89	2·87	4·07	4·21
FeO		9·00	10·38	8·02	8·12
MgO		4·51	3·63	3·66	4·44
CaO		9·52	8·38	8·91	9·68
Na_2O		2·67	2·86	2·44	2·18
K_2O		0·38	0·49	0·32	0·84
H_2O +		0·30	0·30	0·29	0·40
H_2O −		0·18	0·16	n.d.	n.d.
TiO_2		1·12	1·38	1·19	1·18
P_2O_5		0·06	0·11	——	——
MnO		0·22	0·23	——	tr.
Total		100·40	100·13	99·95*	100·02
Q		6·85	8·95	12·97	9·61
Or		2·23	2·78	1·67	5·01
Ab		22·55	24·12	20·45	18·35
An		31·43	27·26	32·82	30·32
Wo		6·62	5·57	4·76	7·43
En		11·24	9·03	9·14	11·05
Fs		12·66	14·77	9·49	9·50
Mt		4·17	4·17	5·79	6·02
Il		2·12	2·58	2·28	2·28
Ap		tr.	0·33	——	——
QFM	Q	7	9	13	10
	F	56	54	55	54
	M	37	37	32	36
NF	Or	4	5	3	9
	Ab	40	45	37	34
	An	56	50	60	57
NPl	An	58	53	62	62
NPy	Wo	22	19	20	27
	En	37	31	39	39
	Fs	41	50	41	34
Fe		72	78	76	73

* includes CO_2 0·24.

ejected at the time of the lava outflow, the lava still remains almost bare.

This lava, which mostly occurs in the aa form, is dark-gray to black, vesicular, and either almost aphyric or porphyritic with conspicuous phenocrysts of anorthite and less conspicuous ones of pyroxene and olivine, according to the part of the flow whence the specimen came. Microscopically, the porphyritic specimen carries phenocrysts of plagioclase, augite, and olivine, scattered through a glassy groundmass packed with plagioclase prismoids (0·05~0.1 mm long), and minute grains of monoclinic pyroxene and magnetite; while the aphyric specimen is a brownish glass in which, besides a few microphenocrysts of plagioclase, augite, and olivine, numerous minute plagioclase laths and dusty grains of pyroxene and magnetite are found.

Phenocrysts: There are two types of plagioclase phenocrysts. One type is represented by anorthite 95 An (n_1=1·5775), which occurs only in the porphyritic specimen as megascopic phenocrysts (2~15 mm dia.); and the other as bytownite 88 An (n_1=1·5741), which is found both in the porphyritic and the aphyric specimens, mostly forming microphenocrysts up to 0·5 mm in diameter. The olivine (0·3 mm dia.) has $2V(-)\doteqdot 88°\sim 82°$. The augite is identified as $Wo_{33}En_{39}Fs_{28}$, with $2V(+)=53°\sim 51°$ and n_1=1·6972 (β=1·700).

Although the groundmass minerals could not be analyzed optically, the plagioclase laths appear to be a calcic labradorite, and the pyroxene grains a pigeonite.

The chemical composition of the 1874 lava is given by the analysis (No. 89, Table XXXI) made by M. Dittrich of a specimen collected by I. Friedlaender and described by C. Bacher as olivine-bearing feldspar-basalt[59]. Chemically, the lava closely resembles the central cone lava just described, and consequently to the lavas of O-sima and Hatizyo-sima. S. Kozu speaks of a chemical analysis of the lapilli that were ejected at the same time as the 1874 lava[60]. It is much like Dittrich's analysis of the lava, the only notable difference being the lower magnesia in the former as compared with the latter.

13. O-sima Volcano.

O-sima, situated in the bay of Sagami, and the largest of the Seven Idu Islands, is an insular volcano consisting of a somma and a central cone, with numerous parasitic knobs and explosion-pits on the flanks of the somma, besides the ruins of volcanic bodies underlying the northwestern skirt of the somma. According to S. Tsuboi[61], who studied the volcano in detail, this volcano came into being at a late date, probably late Diluvium. The central cone, Mihara-yama, seems to have been continuously active for many centuries, the activities culminating, whenever they did so, in spasmodic eruptions of a rather minor explosive character. Its earliest recorded eruption dates back to 684 A.D. Of its many subsequent eruptions, that in 1777~1778 poured out tremendous lava-flows (An'ei lavas), one of which reached the sea on the east. In the last period of eruption, which lasted for three years from 1912, newly erupted lava (Meidi-Taisyo lava) filled the

59) C. BACHER, *loc. cit.*, mentions two specimens representing the 1874 lava: the one being olivine-bearing feldspar-basalt and the other a "hypersthene-basalt transitional to hypersthene-andesite". So far as the writer's observations go, no part of the lava is represented by the latter rock-type.

60) S. KOZU, *Bull. Volc. Soc., Japan*, **1** (1932), [illegible].

61) S. TSUBOI, *Jour. Col. Sci., Imp. Univ. Tokyo, Art.* 6, **43** (1920), 139.

crater of the central cone to only a short distance below the lowest part of its rim. Its activity today is confined to the pit-crater (about 250 m across and 350 m deep as measured in May, 1933) situated in the center of the old summit-crater, with incandescent lava in its bottom. Occasionally sharp staccato sounds like those of a pistol discharged in the open air are heard at intervals of a few minutes, accompanying emissions of whitish vapor-clouds mixed with small quantities of magma-ash.

The rock of the volcano are exclusively basaltic. Tsuboi divided them into three main types: basalt, basaltic bandaite, and miharaite.

Table XXXII. Constituent Minerals of O-sima Basalts.

		1	2	3
Porphyritic Minerals	Plagioclase	$n_1 = 1{\cdot}5780 \sim 1{\cdot}5747$ 96~89 An	$n_1 = 1{\cdot}5776 \sim 1{\cdot}5740$ 95~88 An	$n_1 = 1{\cdot}5780 \sim 1{\cdot}5740$ 96~88 An
	Hypersthene	$2V(-) \doteqdot 74°$	—	$2V(-) = 73°$ $n_1 = 1{\cdot}6927$ $n_2 = 1{\cdot}7000$ $En_{66}Fs_{34}$
	Augite	$2V(-) \doteqdot 49° - 30°$ (core – margin)	—	$n_1 = 1{\cdot}6927$ (very rare)
	Olivine	$2V \doteqdot 88°(+) - 86(-)$ (core – margin)	—	—
Groundmass	Plagioclase	$n_1 = 1{\cdot}5695$ 79 An	$n_1 = 1{\cdot}5675$ 75 An	$n_1 = 1{\cdot}568 \sim 1{\cdot}571$ 76~82 An
	Pyroxene	Pigeonite $2V = 0°$ $\beta = 1{\cdot}7078$ $Wo_{10}En_{38}Fs_{52}$	Pigeonite $2V(+) = 30° \sim 10°$ $\beta = 1{\cdot}707$ (mean) $Wo_{12}En_{39}Fs_{49}$ Augite, Hypersthene } micro-phenocrysts	Pigeonite $2V(+) = 30° \sim 0°$ $\beta = 1{\cdot}7067$ (mean) $Wo_{12}En_{38}Fs_{50}$
	Accessory and interstitial materials	Magnetite Cristobalite Glass absent	Magnetite Glass	Magnetite Glass

1. "Basaltic bandaite" (Tsuboi's fourth type of the somma lava). Dark-gray, vesicular, and slightly porphyritic with a few plagioclase and olivine phenocrysts. Locality: Lava-cascade exposed on the road from Motomura to the summit, about 250 m above the sea.
2. "Miharaite" (lava of 1778). Dark-gray, vesicular, and slightly porphyritic with a few phenocrysts of plagioclase. Locality: Lava-field on the northern foot of the central cone, Mihara-yama.
3. "Miharaite" (lava of 1912~14). Black, vesicular, and porphyritic with moderate phenocrysts of plagioclase. Locality: Northern lava-field within the crater of the central cone, Mihara-yama.

Table XXXIII. Analyses of Rocks from O-sima.

	I. Iwasaki, analyst.					Imp. Geol. Surv. analyst.	
	No. 90	No. 91	No. 92	No. 93	No. 94	No. 95	No. 96
SiO_2	48·02	51·25	51·23	52·45	52·53	51·45	53·01
Al_2O_3	20·48	14·73	15·24	13·48	15·25	16·84	14·73
Fe_2O_3	2·13	3·82	4·18	4·60	2·69	1·49	3·38
FeO	7·05	10·22	8·99	10·02	10·57	10·95	9·42
MgO	5·79	5·47	4·85	4·78	4·54	4·48	4·97
CaO	14·14	11·73	11·14	10·23	10·76	10·71	9·09
Na_2O	1·28	1·85	2·19	1·99	1·89	1·23	2·09
K_2O	0·30	0·26	0·54	0·52	0·43	0·37	0·44
H_2O +	n.d.	n.d.	n.d.	n.d.	n.d.	0·72	1·22
TiO_2	0·78	0·81	0·83	1·39	0·74	1·27	1·03
P_2O_5	0·01	0·13	0·03	0·33	0·41	0·26	0·11
MnO	0·26	0·28	0·33	0·31	0·24	0·19	0·34
Total	100·363(a)	100·708(b)	99·68(c)	100·319(d)	100·157(e)	99·96	99·87(f)
Q	0·24	5·41	5·35	9·61	7·87	8·83	9·61
Or	1·67	1·67	3·34	3·34	2·78	2·23	2·78
Ab	11·01	15·73	18·35	16·78	15·73	10·49	17·83
An	49·23	30·88	30·04	26·15	31·99	39·22	29·21
Wo	8·71	11·03	10·57	9·41	7·78	4·99	6·24
En	14·46	13·65	12·05	11·95	11·34	11·14	12·35
Fs	10·42	14·77	12·01	12·80	16·36	17·14	13·46
Mt	3·01	5·56	6·02	6·71	3·91	2·08	4·86
Il	1·52	1·52	1·52	2·58	1·37	2·43	1·97
Ap	tr.	0·33	tr.	0·65	0·99	0·65	0·33
QFM Q	tr.	5	5	10	8	9	10
QFM F	62	48	52	46	50	52	51
QFM M	38	47	43	44	42	39	39
NF Or	3	3	6	7	6	4	6
NF Ab	18	33	35	36	31	20	36
NF An	79	64	59	57	63	76	58
NPl An	82	66	62	61	67	79	62
NPy Wo	26	28	31	28	22	15	20
NPy En	43	35	35	35	32	33	38
NPy Fs	31	37	34	37	46	52	42
Fe	61	71	72	75	74	73	71

(a) includes $(CeY)_2O_3$ 0·003, ZrO_2 0·002, BaO 0·010, S 0·108.
(b) includes $(CeY)_2O_3$ 0·002, ZrO_2 0·005, BaO 0·014, S 0·137.
(c) includes $(CeY)_2O_3$ 0·003, ZrO_2 0·002, BaO 0·025, S 0·100.
(d) includes $(CeY)_2O_3$ 0·003, ZrO_2 0·004, BaO 0·030, S 0·182.
(e) includes $(CeY)_2O_3$ 0·004, ZrO_2 0·002, BaO 0·023, S 0·078.
(f) includes. ZrO_2 0·04.

No. 90. *Hypersthene-bearing olivine-basalt* (old lava of O-sima, I). Phenocrysts: anorthite-bytownite, olivine, and hypersthene. Groundmass: plagioclase, pigeonite ($2V(+)=40°\sim0°$), magnetite, and cristobalite. Locality: sea-cliff immediately west of Okada, O-sima.

No. 91. *Aphyric basalt* (old lava of O-sima, II). Phenocrysts (very few): plagioclase and olivine. Groundmass: plagioclase, monoclinic pyroxene ($2V(-)=45°$ or smaller), magnetite, and cristobalite. Locality: sea-cliff immediately west of Okada, O-sima.

No. 92. *Hypersthene-bearing olivine-basalt* (somma lava of O-sima). Phenocrysts: plagioclase, olivine, and hypersthene. Groundmass: plagioclase, pigeonite ($2V(+)=30°\sim0°$), magnetite, ilmenite, tridymite, and calcite. Locality: southwestern part of the ring-wall of the somma, O-sima.

No. 93. *Hypersthene-bearing basalt* (Mihara-yama lava, I—An'ei lava). Phenocrysts: plagioclase and hypersthene. Groundmass: plagioclase, pigeonite ($2V(+)=30°\sim0°$), magnetite, and cristobalite (tridymite?), with brownish glass. Locality: northern foot of Mihara-yama, O-sima.

No. 94. *Basalt* (Mihara-yama lava, II—Meidi-Taisyo lava. Phenocrysts: plagioclase. Groundmass: plagioclase, pigeonite ($2V(+)=30°\sim0°$), and magnetite, with brownish glass. Locality: northwestern part of the floor of the old summit-crater of Mihara-yama, O-sima.

No. 95. *Miharaite.* Average of four analyses of the lavas of 1912~14.

No. 96. *Basaltic bandaite almost free from phenocrysts of mafic minerals* (the first type of the somma lavas). Locality: southern coast east of Sasikidi, O-sima.

The petrographic characters of these rocks are described by him with a petrogenic discussion. A few additional data obtained by the writer are given in Table XXXII.

The chemical composition of the O-sima rocks may be seen from the seven analyses shown in Table XXXIII, of which two (Nos. 95, 96) are referred to by Tsuboi and the remainder by Iwasaki[62]. Besides these, are analyses of the lavas of 1912–14, which however are not cited here, because, so far as the determinations go, they are almost duplicates of the two analyses (Nos. 94, 95) given in the above table. As will be seen from the table, all the analyses but one (No. 90) —namely, that of a hypersthene-bearing olivine-basalt from the ruins of the old volcanic bodies near Okada - are in most respects greatly alike, alumina being the most variable constituent. Although the iron-oxides show more marked differences, their total amounts are about the same in the six analyses. Iwasaki's analyses, except in the case of the basalt just mentioned, concerned specimens in which porphyritic minerals were either absent or were very few. They, together with the other two analyses (Nos. 95, 96), may therefore be regarded as representing approximately the composition of magmatic liquids. The analysis of

62) I. Iwasaki, *Jour. Chem. Soc., Japan*, **56** (1935), 1511.

basalt No. 90 differs considerably from the remaining ones, the former, compared with the latter, showing much higher alumina and lime and lower iron-oxides. This may be ascribed to the effect of porphyritic minerals, seeing that the basalt contains abundant phenocrysts of calcic plagioclase and olivine, both of which are either absent or are very few in the other rocks.

14. Omuro-yama Volcano Group.

Outside the boundary of the northeastern foot of the Amagi volcano, there is a group of basaltic volcanoes—the Omuro-yama volcano group —which, ramparted on the west and northwest by dissected Tertiary mountains, forms a less dissected hill-land extending to the southern part of the Ito hot-spring resort on the northeastern coast of the Idu peninsula. As already described in an earlier paper[63], this group comprises, besides the Ito scoria bed, four volcanoes: Omuro-yama, Komuro-yama, Zyobosi, and Umenoki-taira, of which Omuro-yama is the youngest and Umenoki-taira the oldest. A structural characteristic, common to these volcanoes, is that they are built up of lava-flows that had effused at an earlier stage and pyroclastics that were ejected at a later stage of their respective volcanic activities. The Omuro-yama and Komuro-yama volcanoes are much alike in structure, each representing a typical aspi-conide. Zyobosi is a plateau-like volcano, consisting of lava-flows with some overlying pyroclastics. The Umenoki-taira volcano consists of a somma and a central cone. Although the cone is composed practically of pyroclastics, the somma is built up of superposed lava-flows overlain by a thick accumulation of pyroclastics. On the southwest flank of the somma lies a parasitic volcano called Takamuro-yama, which consists of twin cinder-cones. The Ito scoria bed, which covers a wide area west of Ito-mati without forming an outstanding volcanic cone, has its own vent located about 1 km northwest of the town.

Of the four volcanoes referred to, one (Umenoki-taira) is composed of both olivine-basalt and olivine-two-pyroxene-basalt, and the others entirely of olivine-basalt. The Ito scoria bed also is composed of fragmentary products of olivine-basalt (bombs, lapilli, sand and ash).

No. 97. *Olivine-two-pyroxene-basalt.* This rock occurs as several lava-flows composing the lower parts of the Umenoki-taira volcano. Megascopically, these lavas are usually dark-gray to black, either vesicular or compact, and porphyritic with abundant phenocrysts of plagioclase, pyroxene, and olivine. They often contain like the olivine-basalt next to be described, sporadic xenocrysts of quartz, andesine, and hornblende. The following petrographic description is of a specimen that was collected from a lava-flow on the northwestern foot, near the base of the volcano (see Fig. 2).

63) H. TSUYA, *Bull. Earthq. Res. Inst.*, **8** (1930), 409.

The specimen studied is dark-gray, compact, and strongly porphyritic with conspicuous phenocrysts of plagioclase, olivine, and pyroxene. Microscopically, the phenocrysts of plagioclase (1~10 mm dia.), olivine (0·2~1·0 mm dia.), hypersthene and augite (0·5~2·0 mm dia.), are thickly packed in a groundmass, which is merely interstitial relative to the phenocrysts, consisting of plagioclase laths (0·05 mm dia.), pyroxene grains (0·05 mm dia.) and magnetite granules, with interstitial cristobalite and a little dusty glass, besides some microphenocrysts of hypersthene and pigeonite.

Phenocrysts: The plagioclase occurs in two types: the larger phenocrysts are anorthite 98~94 An (n_1=1 5795~1·5770), and the smaller ones (0·5 mm dia.) anorthite-bytownite 91~87 An (n_1=1·5756~1·5736). The olivine, which is occasionally altered to iddingsite, shows a distinct zoning, with 2V(−)=88° in the core and 2V(−)=84° at the margin. β=1·706 (mean). Composition: $Fo_{67}Fa_{33}$. The hypersthene is very faintly zoned, its optic angle varying from 2V(−)=78° in the core to 2V)−)=76° at the margin. n_1=1·6892~1·6932. Average composition: $En_{67}Fs_{33}$. The mineral, which carries inclusions of olivine, is almost always surrounded by a thin rim of augite ($c \wedge Z$=47°). The augite also is faintly zoned, its optic angle varying from 2V(+)=53° in the core to 2V(+)=43° at the margin. n_1=16938−1·700. Average composition: $Wo_{30}En_{43}Fs_{27}$.

Groundmass: The plagioclase is bytownite 75 An (n =1·528). The hypersthene microphenocrysts (n_1=1·6983, $En_{64}Fs_{36}$) is always surrounded by pigeonite (2V(+)=43°~41°) in parallel intergrowth. The pigeonite occurs as minute prisms, besides as microphenocrysts. The cristobalite, together with the dusty glass base, fills the interstices of the other minerals in the groundmass.

This rock was chemically analyzed by Tanaka, with results as shown in column No. 97 of Table XXXIV. The analysis differs from that of the olivine-basalt next to be described in its lower silica and alkalies, and higher alumina, lime, magnesia, and iron-oxides. The nearest approach to it is found in the analyses of some porphyritic

Table XXXIV. Analyses of the Basalts from the Omuroyama Volcano Group. S. Tanaka, analyst.

	No. 97	No. 98	Norms						
				No. 97	No. 98			No. 97	No. 98
SiO_2	50·17	56·03	Q	4·62	9·85	QFM	Q	5	10
Al_2O_3	19·30	17·90	Or	1·11	5·01		F	60	63
Fe_2O_3	2·60	1·69	Ab	14·68	24·12		M	35	27
FeO	8·52	6·16	An	44·23	33·66	NF	Or	2	8
MgO	5·60	4·33	Wo	2·91	2·55		Ab	24	38
CaO	10·30	8·40	En	13·96	10·74		An	73	54
Na_2O	1·72	2·83	Fs	12·66	8·97	NPl	An	75	58
K_2O	0·15	0·83	Mt	3·70	2.55	NPy	Wo	10	11
H_2O +	0·87	0·60	Il	1·37	1·37		En	47	48
H_2O −	0·42	0·27	Ap	tr.	0·65		Fs	43	41
TiO_2	0·73	0·74				Fe		66	64
P_2O_5	0·06	0·22							
MnO	0·16	0·11							
Total	100·60	100·11							

lavas from the Usami and Taga volcanoes adjoining the northern part of the present volcano group.

No. 98. *Olivine-basalt.* In their important petrographic characters, the olivine-basalts of the group are much alike, although megascopically they vary from vesicular to compact, and from dark-gray to black. They are almost aphyric with very few, or usually with no, megascopic phenocrysts. Almost all of them, except the olivine-basalt composing the Ito scoria bed, carry sporadic xenocrysts, either megascopic or microscopic, of quartz and andesine, probably derived from a hornblende-dacite, the presence of which at the base of the volcano group is inferred from the fact that blocks of this rock are frequently met with in the pyroclastics of the Umenoki-taira volcano. A specimen that was collected from a lava-flow on the east side of the Komuro-yama volcano, and which represents this rock-type will next be described.

Megascopically, the rock is black, more or less vesicular, containing a few conspicuous crystals of plagioclase and quartz, with less conspicuous ones of olivine. Microscopically, we find phenocrysts of plagioclase (1~3 mm dia.) and olivine (1~2 mm dia.), with quartz (0·5~1·0 mm dia.), scattered through a groundmass consisting of plagioclase laths (0·05~0·1 mm long), pyroxene prisms (0·05~0·1 mm long), magnetite granules, and interstitial pale-brown glass, besides microphenocrysts of plagioclase (0·3~0·5 mm dia.), olivine (0·1~0·3 mm dia.), augite (0·1~0·2 mm dia.), and hypersthene (0·1~0·5 mm long).

Phenocrysts: The plagioclase, which occurs sporadically as faintly zoned euhedral phenocrysts, is anorthite varying in composition from anorthite to calcic bytownite 99~90 An (n_1=1·5799~1·5755). The olivine has the composition $Fo_{77}Fa_{23}$, as identified from 2V(−)=89° and β=1·6693. Besides these phenocrysts, we find a few xenocrysts of andesine 46 An (n_1=1·5518) and quartz. The quartz, which is either round or indented with inlets of the groundmass, has a corona consisting of a granular aggregate of the groundmass augite.

Groundmass: The plagioclase is bytownite 76 An (n_1=1·568). The augite shows undulatory extinction, with 2V(+)=46°, n_1=1·700, and $c\wedge Z$=45°. Composition: $Wo_{27}En_{42}Fs_{31}$. The hypersthene, which is surrounded with a thin rim of monoclinic pyroxene, shows a very faint zoning, with 2V(−)=75° in the core and 2V(−)=69° at the margin. The olivine is identical with the phenocrystic one.

The results of Tanaka's analysis of this rock are given in column No. 98 of Table XXXIV. D. Sato[64] speaks of an analysis of "pyroxene-andesite" from the Komuro-yama volcano. Regard its silica content, the new analysis, like Sato's one, may be referred to as andesite rather than normal basalt. The norm thus shows considerable quartz, the normative plagioclase and pyroxene having the compositions respectively of 58 An and $Wo_{11}En_{43}Fs_{41}$. Compared with the new, the old analysis is still higher in silica with more abundant normative quartz, although the normative plagioclase and pyroxene, which are respectively 59 An and $Wo_{14}En_{41}Fs_{45}$, closely approach those of the former. The high silica contents of the analyses, both new and old, may be due, partly at any rate, to the presence of quartz xenocrysts in the basalt.

15. Huzi-san Volcano.

Huzi-san, situated near the shore of Suruga Bay, is a large conical volcano, 3776 m above the sea, measuring 50 km across the base, with gracefully curving slopes diminishing from 34° near the summit to 25°

64) D. SATO, Ganseki-tisitugaku (Textbook of Petrological Geology). Tokyo, (1925), 339.

~17° in the middle to almost level at the base. Of the geology and petrology of this volcano, full details are expected to be published shortly when the investigation now being made of them is completed; an investigation in which the writer has been engaged alone, since July 1935 under the auspieces of the Nippon Gakuzyutu-sinkokwai. A brief summary, however, of the results already found[65], together with some additional remarks, will be given here.

As the volcano is still in the earlier stages of dissection, its lower bulk is inaccessible to observation. So far as the visible parts are concerned, however, the volcano is composed of many superposed lava-flows, mostly a few meters thick, with intercalations of pyroclastic beds. Most of the lava-flows end abruptly, forming a series of lava-coulee, the length of each successive flow being shorter with diminishing distance from the summit crater. In volume, the lava-flows as a whole appear to exceed the pyroclastic beds. It should be remembered, however, that the core of the volcano may be composed for the most part of pyroclastic material, seeing that underneath the lowest visible lavas (Hirabayashi's Misima-Omiya lavas[66]) that form the lower slopes of the southern half of the volcano, there lie in places thick mud-flow deposits.

On the outer slopes of the volcano are a number of bare lava-flows not covered by any pyroclastic ejecta. Most of these flows, except those on the upper slopes near the summit, originated either in parasitic cones or in flank openings. Of these recent flows, the Aokiga-hara lava which, in 864 A. D., poured out of the boccas on the northwest flank (Koori-ike and Hakudai-ryuo), about 1500 m above the sea, and flowed down toward the northwestern foot, is the most conspicuous, covering as it does an area of about 32 sq. km with an average thickness of more than 10 m. Another lava, which probably dates from the same time as the Aokiga-hara lava, is the "Ken-marubi" lava that poured out of the northwest flank and descended northeastward near the town of Yosida.

Most of the parasitic cones and flank vents, of which there are more than forty in all, occur halfway down the slopes of the main volcano. There are no such parasitic bodies on the upper slopes near the summit, the Hoei explosion-crater of the last eruption in 1707 on the southeast slope being the highest, lying about 1000 m below the summit. Many of the parasitic cones are probably arranged either con-

65) H. Tsuya, *Bull. Earthq. Res. Inst.*, **13** (1935), 645; *Bull. Volc. Soc., Japan*, **2** (1935), 149.

66) T. Hirabayashi, *Rep. Earthq. Inv. Com.*, **24** (1899).

centrically or spirally with the summit crater as the centre[67], while many others are aligned in a zone which, running NW.-SE. through the summit and coinciding with the Huzi volcanic zone, represents in all probability the principal fracture in the ground beneath the volcano. The parasitic cones on the lower slopes are generally larger than those on the upper slopes, mainly because material ejected through vents on the gentler lower slopes fall within a smaller area than if they had been thrown out from greater heights.

Although the inner structure of the parasitic cones is rarely exposed to view, most of them may be known at once from their morphological features. There are, however, a number of knobs which, morphologically and structurally, differ considerably from the parasitic cones. Of these knobs, the two that deserve special mention are Hoei-zan and Komitake, lying respectively on the SE. and N. flanks of the volcano.

Hoei-zan, situated about 1000 m below the summit, is a prominent shoulder forming the south wall of the Hoei explosion-crater. The projection is an obtuse-angled ridge, without any trace of a former parasitic cone. The inner side of the ridge slopes about 35° toward the bottom of the Hoei crater, while the outer side (southeastern side) is bounded by steep cliffs overlooking the lower SE. slope of the volcano. Although the ridge is thinly covered by the Hoei ejecta (bombs, lapilli, accessory lava-blocks, and accidental ejecta of both volcanic and sedimentary rocks), its main, lower mass is composed of loosely-coherent beds of yellowish ash and sandy breccia carrying a few blocks of a black, scoriaceous lava. These beds, which are discordantly overlain by the structureless accumulation of the Hoei ejecta, show evident stratification, and are traversed by numerous minor faults mostly striking NE.-SW. and less so N.-S. The ridge is thus divided into several minor blocks, the steep cliffs of its outer side being fault-scarps. The dips of the beds differ with the block, although within the block itself it is quite regular. They vary from 40° to 20°, with an E., W., SW., or SE. direction. Thus the beds do not dip away from the summit of Huzi, nor from the Hoei crater. Neither lava-flows nor intrusive bodies of any sort have been found in the beds. S. Kambara's hypothesis[68] is that the ridge is an upturned block that detached itself from the northern wall of the Hoei crater on the occasion of the Hoei explosion in 1707. Nowhere on the wall do we see similar beds, the wall being

67) S. FUJIWARA, *Proc. Fifth Pan-Pacific Sci. Congr.*, Victoria and Vancouver, B. C., Canada (1933).

68) S. KAMBARA, *Jour. Geogr., Geogr. Soc. Tokyo,* **47** (1934).

composed entirely of alternating strata of lava-flows and pyroclastic beds that came from the summit crater, besides numerous dikes that traverse the strata. It is probable that the Hoei-zan beds are much older than any that are exposed in the Hoei crater or on the outer slopes in its vicinity. Evidently one is dealing here with an older volcanic body that had largely, if not wholly, been demolished by block-faulting and much erosion before the explosion of 1707 opened the Hoei crater on the northwest side of that body. It is suggested that the Hoei-zan ridge is what remains of a former parasitic cinder-cone of comparatively early date lying on a former slope of the main volcano, which last is now buried deep, although definite evidence in support of this suggestion is yet lacking.

Komitake, stuated about 1500 m below the summit, is a deeply dissected knob projecting above the northern slope of the volcano. The knob, which is discordantly overlain by younger ejecta from the summit crater, is composed of several lava-flows, besides pyroclastic beds interposed between them. The strata of these lava-flows and pyroclastic beds that are exposed in the deep ravines on the northern side of the knob show a steep northward dip (about 35°) that coincides with the surface slope on that side. Petrographically, the lava-flows are quite identical with some of the oldest lava-flows that are exposed on the lower slopes of the southern half of the volcano. In view of these facts, it seems reasonable to infer that the knob is a remain of an older volcano—Komitake volcano—which had been badly dissected before the present cone of Huzi was formed. The volcanism of Huzi may therefore be divided broadly into two periods—earlier activities of the Komitake volcano and later activities of the present Huzi volcano—interposed by a dormant period, during which period the Komitake volcano was subjected to deep erosion. Kambara believes that Komitake and another, Kohuzi, on the east slope, are ruins of the rim of an ancient somma volcano that may underlie the top part of the present cone of Huzi.

The terrane through which the lavas of Huzi have been erupted is a depression in the Tertiary (lower Miocene) mountains that lies at the northern extremity of the fault trough represented by Suruga Bay. The bedrock underneath the volcano are thus continuations of the Tertiary rocks (Misaka series) that bound the volcano on the east, north, and west. That Huzi is younger than the neighbouring volcanoes, Asitaka and Hakone, is evident from the fact that some of the earliest visible lavas of Huzi flow southeastward into the intervale, Kise-gawa valley, between Asitaka and Hakone (see Fig. 5). So far as fhe visible parts are concerned, therefore, it is inferred that Huzi began its activity at a late date, probably later than the uppermost Pleistocene. During historical times, there were at least fifteen outbursts from Huzi, the earliest and the last ones being the eruptions of 781 and 1707 respectively. At present the volcano is entirely dormant, although there is a feeble fumarole (77°∼85°C. in August, 1935) in the rocks on the eastern rim of the summit crater.

The rocks composing the volcano are mostly olivine-bytownite-basalts with or without phenocrysts of pyroxenes. Six basalts from the volcano, the petrography of which was already published in the earlier papers, have the mineral compositions as shown in Table XXXV. Their chemical compositions are contained in Table XXXVI, where they are accompanied by three yet unpublished analyses of rocks from the volcano. From the table it will be seen that the Huzi basalts are generally slightly richer in potash than any of the basalts from the Idu region, the former bearing a closer resemblance to the "plateau basalt" (Deccan basalt, Oregonian basalt, etc.) than to the latter. It

Table XXXV. Constituent Minerals of Huzi Basalts.

		No. 101	No. 102	No. 103	No. 104	No. 105	No. 106
Porphyritic Minerals	Plagioclase	$n_1=1.5663$ 73 An	$n_1=1{\cdot}5776$ $n_1=1{\cdot}5710$ 95 An, 84 An	$n_1=1{\cdot}5676$ 75 An	$n_1=1{\cdot}5660$ 72 An	$n_1=1{\cdot}5744$ $n_1=1{\cdot}5717$ 95 An, 83 An	$n_1=1{\cdot}5655$ 71 An
	Augite	—	$n_1=1{\cdot}6967$	$2V(+)=52°$ $n_1=1{\cdot}6956$	n.d.	n.d.	$n_1=1{\cdot}6979$
	Hypersthene	—	$n_1=1{\cdot}6987$ $n_2=1{\cdot}7077$ $En_{60}Fs_{40}$	—	$n_1=1{\cdot}6983$ $n_2=1{\cdot}7078$ $2V(-)=71°$ $En_{61}Fs_{39}$	—	$n_1=1{\cdot}6983$ $n_2=1{\cdot}7076$ $2V(-)=71°$ $En_{61}Fs_{39}$
	Olivine	$2V(-)\doteqdot 89°$ $\sim 84°$	$2V(-)=85°$ $\alpha=1{\cdot}6794$ $\beta=1{\cdot}6985$ $Fo_{69}Fa_{20}$	$2V=90°$ $\alpha=1{\cdot}6667$ $\beta=1{\cdot}6843$ $Fo_{80}Fa_{20}$	$2V\doteqdot 90°$	$2V(-)=84°$ $\alpha=1{\cdot}6788$ $\beta=1{\cdot}7002$ $Fo_{67}Fa_{33}$	$2V\doteqdot 90°\sim$ $86°(-)$
Groundmass	Plagioclase	$n_1=1{\cdot}5630$ 67 An	$n_1=1{\cdot}5670$ 74 An	$n_1=1{\cdot}5654$ 71 An	n.d.	$n_1=1{\cdot}5695$ 78 An	n.d.
	Olivine	n.d.	—	n.d.	—	—	—
	Pyroxene	$2V(+)\doteqdot 52°$ $\sim 46°$	$2V(+)\doteqdot 51°$ $\sim 41°$	$2V(+)\doteqdot 49°$	n.d.	—	$2V(+)\doteqdot 40°$
	Accessory and interstitial materials	Magnetite Glass	Magnetite Glass	Magnetite Glass	Magnetite Glass	Dark-brown glass packed with dust material.	Magnetite Glass

Table XXXVI. Analyses of Rocks from Huzi.
S. Tanaka, analyst.

	No. 99	No. 100	No. 101	No. 102	No. 103	No. 104	No. 105	No. 106	No. 107
SiO_2	49·60	49·60	50·28	50·64	50·66	51·05	51·09	51·30	63·84
Al_2O_3	16·96	16·14	18·30	18·58	18·25	18·35	17·62	18·74	15·82
Fe_2O_3	5·40	3·67	4·50	3·04	4·78	2·76	2·64	1·83	0·95
FeO	6·65	9·90	6·89	7·29	5·72	7·72	8·42	8·34	5·02
MgO	5·92	4·79	3·80	5·58	4·94	4·63	5·09	4·80	1·67
CaO	10·03	8·80	9·76	10·00	9·98	9·90	9·68	9·76	4·88
Na_2O	2·48	2·90	2·87	2·64	2·78	2·81	2·80	2·55	3·88
K_2O	0·58	0·93	0·94	0·61	0·77	0·81	0·76	0·71	2·12
H_2O +	0·50	0·55	0·20	0·20	0·38	0·40	0·28	0·22	0·45
H_2O −	0·12	0·14	0 08	0·06	0·13	0·11	0·06	0·06	——
TiO_2	1·40	1·97	1·78	1·15	1·38	1·41	1·38	1·43	0·87
P_2O_5	0·20	0·31	0·34	0·16	0·25	0·24	0·26	0·29	0·22
MnO	0·21	0·23	0·20	0·17	0·17	0·18	0·21	0·28	0·17
Total	100·05	99·93	99·94	100·12	100·19	100·37	100·29	100·31	99·89
Q	3·78	1·26	3·96	1·98	4·14	2·34	2·04	2·82	18·14
Or	3·34	5·57	5·57	3·34	4·45	5·01	4·45	4·45	12·80
Ab	20·97	24·64	24·14	22·55	23·59	23·59	23·59	21·50	33·03
An	33·38	28·09	34·49	36·99	35·05	35·05	33·38	37·55	19·19
Wo	6·50	5·69	5·11	4·88	5·34	5·23	5·46	3·83	1·28
En	14·76	11·95	9·43	13·85	12·34	11·54	12·65	11·95	4·11
Fs	5·80	12·27	6·47	9·24	4·62	9·89	11·35	12·01	7·25
Mt	7·87	5·33	6·48	4·40	6·95	3 94	3·94	2·55	1·39
Il	2·73	3·79	3·34	2·12	2·58	2·73	2·58	2·73	1·67
Ap	0·33	0·65	0·65	0·33	0·65	0·65	0·65	0·65	0·65
QFM { Q	4	1	4	2	4	2	2	3	18
QFM { F	58	59	64	63	63	64	61	64	65
QFM { M	38	40	32	35	33	34	37	33	17
NF { Or	6	10	9	5	7	8	7	7	20
NF { Ab	36	42	38	36	37	37	38	34	51
NF { An	58	48	53	59	56	55	55	59	29
NPl An	61	53	59	62	60	60	59	64	37
NPy { Wo	24	19	24	17	24	19	18	14	10
NPy { En	55	40	45	50	56	44	49	49	33
NPy { Fs	21	41	31	33	20	37	33	37	57
Fe	66	73	74	64	67	69	68	68	78

No. 99. *Olivine-basalt* (almost aphyric). One of the lava-flows exposed on the western wall of the Hoei explosion-crater, Huzi.

No. 100. *Olivine-basalt* (almost aphyric). Lava-flow at Tawarano-taki (water-fall , Toka-itiba.

No. 101. *Olivine-basalt*, $F_{67\text{-}a}$.
No. 102. *Two-pyroxene-bearing olivine-basalt*, $F_{67\text{-}b}$.
No. 103. *Augite-bearing olivine-basalt*, $F_{67\text{-}d}$.
No. 104. *Hypersthene-augite-olivine-basalt*, $F_{67\text{-}e}$.
} Lava- ows at Maku-iwa on the SE. slope of Huzi.

No. 105. *Augite-bearing olivine basalt*. Scoriaceous lava-block, one of the ejecta of 1707 explosion of the Hoei crater.

No. 106. *Two-pyroxene-olivine-basalt*. Aokiga-hara lava of 864 eruption, NW. foot of Huzi.

No. 107. *Aphanitic andesite* (pitchstone). Karasuisi lava at Nagamine on the SE. slope.

is worth noting that, although the Huzi rocks are mostly basalts, a few of them are evidently andesitic. Analysis No. 107 shows the composition of one of these andesitic rocks. The specimen analyzed was collected at Nagamine, a short distance down the southwest slope of Hoei-zan, where it occurs in an agglomerate bed and is also found scattered here and there. Although not a single massive lava-flow of the rock has been found, the rock is evidently juvenile, and comparable with Hirabayashi's "Karasuisi lava". Megascopically, it is pitch-black and densely aphanitic. Microscopically, it is composed wholly of dark-brownish glass densely packed with minute microlites. The analysis shows that, like the basalts, the andesite is richer in potash than any andesite with corresponding silica content from the Idu region.

C. *Dacitic and Liparitic Volcanoes.*

Dacitic and liparitic rocks play but a very subordinate part among the Quaternary volcanics of the region under consideration. It has already been mentioned that the Simo-Tanna beds in north Idu contain, besides basaltic pyroclastics, a quantity of pyroxene-hornblende-dacitic pumice which may be correlated, both petrographically and stratigraphically, with similar pumice from the Tutizawa beds in the Oiso geologic province. The pumice therefore suggests the former existence of one or more lower Pleistocene dacitic volcanoes that yielded it, although, so far as the observations in north Idu go, there is no sign of such a volcano to which the pumice can be traced. Dacites occur in parasitic domes on the Amagi volcano, Iwano-yama and Yahadu-yama being the representative ones. Reference has also been made to the fact that, according to Kuno, the Hakone volcano has some dacitic masses, of which the Maku-yama dome (Kuno's Quellkuppe) is the most striking. In addition to the foregoing, we find several dacitic masses in the vicinity of Atami (pyroxene-dacite of Hikane-yama, pyroxene-hornblende-dacite of Idusan and Kami-Taga), which, according to Kuno, extruded later than the products of the Taga volcano, but earlier than those of the Yugawara volcano. The limited spread and volume of every one of these masses suggest that they are nothing but local lavas, possibly representing domical protrusions, although none of them retain the original form that we associate with dome-shaped volcanoes.

The above-mentioned masses comprise all the Quaternary dacitic volcanoes, recognized so far in the Idu peninsula. Leaving aside for a while these masses, we have now to refer more particularly to the Quaternary liparitic volcanoes, Nii-sima group, in the Seven Idu Islands, which in many respects are undoubtedly the most important group in the acidic suite of the Quaternary volcanic rocks in the region studied.

16. Nii-sima Group.

The Nii-sima group consists of three main islands, Nii-sima, Sikine-sima, and Kodu-sima, besides several dependent islets which, being aligned NE.-SW. off the southern point of the Idu peninsula, form a short but distinct volcanic chain, called by B. Koto the Kodu-sima Volcanic Chain.[69] The volcanism of this group has already been discussed in an earlier paper[70], with special reference to the geology and petrology of Kodu-sima, which leaves little to added here. It seems desirable, however, for the sake of completeness, to give a brief summary of the structure and the rock sequence of this group.

Nii-sima consists of several liparitic masses (lava-dome, lava-mesa, pumice-cone, and pumiceous ejecta bed), of which the Muko-yama double volcano (central lava-dome, Muko-yama, and outer pumice-cone, Omine)[71] in the southern part of the island and the Miyatuka-yama lava-dome, slightly north of the central part, are the most striking. The rocks constituting these masses are grouped under three main headings—pyroxene-plagioliparite, hornblende-plagioliparite, and biotite-plagioliparite—in order of eruption.[72] Biotite-plagioliparite forms both the Muko-yama and Miyatuka-yama volcanoes, besides a number of relatively younger masses in the island, while the rocks of the remaining two types occur in older, local masses, most of which are overlain by one or more masses of biotite-plagioliparite. Besides these liparites, in the northernmost part of the island, we find basaltic scoria and ash piled up in beds, 10 m or more in thickness, covering oldest pyroxene-plagio-

69) B. KOTO, *Jour. Fac. Sci., Imp. Univ. Tokyo*, **3** (1929~34), 205.
70) H. TSUYA, *Bull. Earthq. Res. Inst.*, **7** (1929), 269.
71) T. TSUJIMURA, *Rep. Earthq. Inv. Com.*, **89** (1918).
72) N. FUKUCHI, *ibid.*, **39** (1902).

liparite mass (Fukuchi's Nebu-saki type), and forming the coastal terrace that borders the mass on the west on the coast of Wakago village. In the island itself there is no sign of a volcanic centre to which the basaltic ejecta can be traced. I. Friedlaender[73] inferred that they came from the ruined volcano Utone-sima lying 3 km off the northern point of the island. But, as may be seen on the coast of Wakago, the basaltic ejecta bed thickens toward the south, and the fragments in the bed increase their sizes in the same direction. Although, petrographically, the ejecta closely resemble the basalt of Utone-sima, it is unlikely that the former came from the vent of the latter. The ejecta could only have come from a vent lying somewhere south, and while this obviously does not prove that the source is in Nii-sima itself, it is not impossible that the basaltic ejecta were erupted by a volcano that subsequently broke up to form the base of some younger liparitic masses bordering the ejecta bed on the south.

Sikine-sima, situated immediately south of Nii-sima, and which was once in land-connection with the latter, is nothing but a single lava-plateau of biotite-plagioliparite.

Kodu-sima consists, like Nii-sima, of several liparitic masses, of which the Tenzyo-san lava-dome in the centre of the island is the youngest as well as the largest. The structural scheme, together with the rock-types represented may be summarized as follows:

1. Lavas forming the lowest visible part of Kodu-sima (the first period lavas)	Potash-liparite. Hypersthene-plagioliparite. Hornblende-bearing hypersthene-plagioliparite. Hornblende-plagioliparite. Biotite-plagioliparite. Aphanitic liparite.	
2. Titibu-yama ejecta bed	Biotite-plagioliparite (juvenile pumice).	
	Liparite Quartz-porphyry Porphyritic hornblende-diorite Hornblende-andesite	Accessory or accidental ejecta.
3. Takodo-yama and Nati-san domes (the second period lavas)	Biotite-plagioliparite.	

73) I. FRIEDLAENDER, *loc. cit.*

4. Zyogoro-yama, Anagi-yama, and Kobe-yama domes (the third period lavas) ...	Do.
5. Sriomama ejecta bed............	Biotite-plagioliparite (juvenile ejecta).
6. Siro-sima and Kusigamine pumice cones	Do.
7. Tenzyo-san dome (the fourth and last period lava	Biotite-plagioliparite.

As will be seen from the foregoing, the first period of activity is represented by liparites of various types and the subsequent ones exclusively by biotite-plagioliparite. This accord generally with the sequence observed in Nii-sima.

Although within the islands of the group themselves, pre-volcanic bedrocks are nowhere exposed, there can be no doubt that the Neogene Tertiary rocks of the Idu peninsula extend southward to the sea-floor in the vicinity of the group, seeing that the Zenisu bank, situated 40 km SW. of Kodu-sima, consists of these rocks. This bank is a projected peak in the submarine ridge trending NE.-SW. upon which the Nii-sima group rests, and according to H. Niino,[74] it is headed by several stacks, besides shoals, consisting of lava and agglomerate. The specimens collected by him from these masses are exclusively of altered pyroxene-andesites that are comparable in many respects to allied rocks in the lower Miocene series of the Idu peninsula. Similar rocks were also found among the pebbles collected by dredgings made by Niino on the same bank. With these facts in view, it is inferred that similar rocks underlie the whole of the Nii-sima group. Some support is lent to this inference by the finding of not a few fragments of Tertiary volcanic rocks from the pyroclastic beds of Kodu-sima and Nii-sima. The accessory or accidental rock-fragments (quartz-porphyry, hornblende-andesite, two-pyroxene-andesite, etc.) in the Titibu-yama ejecta bed of Kodu-sima closely resemble the allied rocks in the Tertiary volcanics of the Idu peninsula. So also do some of the accessory or accidental rocks (silicified tuff, diabase, propylite, pyroxene-andesite, etc.) that are contained in the pyroclastic ejecta bed (Fukuchi's siromama bed) of Nii-sima. It is also worth noting that the potash-liparite of Kodu-sima, which occurs as a small mass underlying the Anagi-yama plagioliparite dome on the northern coast of the island, is quite similar

74) H. Niino, *Jour. Geogr., Geogr. Soc. Tokyo*, **47** (1935), 32.

chemically to the potash-liparite of Manzo-yama and vicinity in the southern part of the Idu peninsula.

Nothing can be said concerning the time of genesis of the liparitic volcanoes of the Nii-sima group, except that most of them appear to have been formed by subaerial eruptions during the Quaternary. In this connection we may repeat the statement that in Nii-sima the biotite-liparite masses are nowhere covered by the Quaternary basaltic ejecta, although the latter overlie the oldest pyroxene-plagioliparite mass. Further evidence for the age of the group has been supplied by the basic xenoliths found in some of the lavas from Nii-sima and Kodu-sima. The biotite-plagioliparite exposed on Awaiura (east coast of the northern part of Nii-sima) is packed with not a few basic xenoliths. So also is the hypersthene-plagioliparite that forms the southwest headland of Kodu-sima. Most of these xenoliths are basaltic, consisting of a few phenocrysts of calcic plagioclase and augite, with a groundmass of plagioclase. augite, magnetite, and interstitial glass, although the pyroxenes, both of the phenocrysts and in the groundmass, are partially transformed to greenish-brown hornblende (Table XXXVII). One of the xenoliths is, chemically, much like the basalts from Utone-sima and To-sima (Table XXXVIII). While this obviously does not prove a common source, the possibility arises that most of the xenoliths are fragments of basalts that were torn from certain Quaternary basaltic masses during the eruptions of the liparites in which they were caught.

Table XXXVII. Constituent Minerals of the Basaltic Xenoliths in Liparites from Kodu-sima and Nii-sima.

	1	2	3
Plagioclase	$n_1=1{\cdot}5615$ 63 An	$n_1=1{\cdot}5667$ 71 An	$n_1=1{\cdot}572$ 85 An (phenocrysts) $n_1=1{\cdot}552$ 46 An (groundmass)
Augite	$n_1=1{\cdot}6965$	$n_1=1{\cdot}6945$ $2V(+)=56°\sim52°$	Phenocrysts n.d. $n_1=1{\cdot}659$ (groundmass)
Hornblende	$n_1=1{\cdot}682$ $c\wedge Z'=7°$ Greenish-brown	$n_1=1{\cdot}6725$ (mean) $c\wedge Z'=15°$ Greenish-brown	$n_1=1{\cdot}713$ Reddish-brown
Accessories	Magnetite Glass	Magnetite Glass	Magnetite Glass

1, 2. Xenoliths in the hypersthene-plagioliparite, Himmasi-hana, Kodu-sima.
3. Xenolith in the biotite-plagioliparite, Awai-ura, Nii-sima.

Table XXXVIII.

		A	No. 108	No. 109
SiO_2		50·74	50·79	49·91
Al_2O_3		18·59	16·61	18·13
Fe_2O_3		9·23	6·96	3·87
FeO		1·01	3·51	5·48
MgO		5·37	7·63	6·16
CaO		10·21	10·03	9·90
Na_2O		2·35	2·58	2·33
K_2O		0·57	0·55	0·37
H_2O +		0·74	0·38	0·78
H_2O −		0·16		
TiO_2		0·98	1·01	0·87
P_2O_5		0·06	——	——
MnO		0·16	——	——
Total		100·31*	100·24**	99·80
Q		7·69	4·50	4·32
Or		3·34	3·34	2·23
Ab		19·92	32·02	19·92
An		38·38	31·99	37·83
Wo		5·11	7·43	4·76
En		13·35	18·97	15·36
Fs		——	——	5·41
Mt		0·46	8·33	5·56
Il		1·82	1·97	1·67
Ap		tr.	——	——
Hm		8·62	1·28	——
QFM	Q	8	5	4
	F	62	57	62
	M	30	38	34
NF	Or	5	6	4
	Ab	32	38	33
	An	63	55	63
NPl	An	66	59	65
NPy	Wo	28	28	19
	En	72	72	60
	Fs	——	——	21
Fe		63	56	59

* includes NaCl 0·14. ** includes CO_2 0·19.

A. Basaltic xenolith (Table XXXVII, 1) in the hypersthene-plagioliparite. Himmasi-hana, Kodusima.

No. 108. *"Olivine-bearing feldspar-basalt"*. Phenocrysts: labradorite-bytownite, augite, and olivine. Groundmass: plagioclase, augite, magnetite, and olivine. Utone-sima. M. Dittrich, analyst. C. Bacher, *loc. cit.*

No. 109. "*Olivine-bearing feldspar-basalt*". Phenocrysts: labradorite-bytownite, augite, olivine, and biotite. Groundmass: plagioclase, augite, magnetite, and glass. Lava, 100 m north of the top of Tosima. M. Dittrich, analyst. C. Bacher, *loc. cit.*

From what has been said, it is indisputable that the Nii-sima group is as young as the basaltic volcanoes (O-sima group) in the Seven Idu Islands. Both Nii-sima and Kodu-sima, according to records, have had only one eruption each, namely Nii-sima in 886 and Kodu-sima in 838. It is not certain whether these eruptions were of such a nature as to erupt new lavas in quantity sufficient to form distinct volcanic masses, but both Muko-yama in Nii-sima and Tenzyo-san in Kodu-sima have morphological features so youthful that they were probably formed by the last known eruptions. If so, the major eruptions that resulted

Table XXXIX. Constituent Minerals of the Liparites from Kodu-sima.

		No. 110	No. 111	No. 112	No. 113	No. 114
Porphyritic Minerals	Quartz	+	—	+	+	—
	Sanidine	$n_1=1{\cdot}520$	—	—	—	+
	Plagioclase	—	—	$n_1=1{\cdot}540$ 24 An	$n_1=1{\cdot}539\sim1{\cdot}544$ 23∼32 An	$n_1=1{\cdot}533\sim1{\cdot}535$ 12∼15 An
	Biotite	—	—	—	—	$\gamma=1{\cdot}665$ $2E=37°38'$ $\gamma>1{\cdot}700$ 2E large
	Hornblende	—	—	$2V(-)=87°\sim83°$ $n_1=1{\cdot}644$ $c\wedge Z'=11°$ Greenish-brown	—	—
	Hyper-sthene	—	—	—	$2V(-)=52°$ (core)∼62° (margin) $n_1=1{\cdot}7005$ (mean) $En_{59}Fs_{41}$	—
Groundmass		Sanidine Quartz Magnetite Secondary pyrite and epidote	Glass Microlites of feldspar and biotite	Glass ($n=1{\cdot}497$) Microlites of feldspar and biotite	Glass ($n=1{\cdot}497$) Microlites of feldspar and biotite	Glass ($n=1{\cdot}490$)

Table XL. Analyses of Liparites from Idu. S. Tanaka, analyst.

		No. 110	No. 111	No. 112	No. 113	No. 114	No. 115	No. 116
SiO_2		71·64	74·93	75·10	75·35	76·60	76·05	76·05
Al_2O_3		14·13	13·52	13·36	13·49	13·22	12·44	12·79
Fe_2O_3		0·34	0·76	0·30	0·95	0·27	0·84	1·47
FeO		0·50	0·72	0·74	0·55	0·43	0·22	0·31
MgO		0·08	0·32	0·27	0·36	0·19	0·17	0·08
CaO		0·17	0·93	1·43	1·61	0·75	0·87	1·60
Na_2O		0·50	4·50	4·21	4·28	4·62	4·31	3·89
K_2O		10·77	3·39	1·58	2·52	1·61	2·88	1·82
H_2O +		0·80	0·46	2·27	0·61	1·50	1·66	0·74
H_2O −		0·23	0·33	0·17	0·06	0·11	0·11	0·52
TiO_2		0·55	0·13	——	0·20	——	0·12	0·19
P_2O_5		0·08	0·08	——	——	——	tr.	tr.
MnO		tr.	0·08	0·10	0·08	0·16	0·07	0·05
Total		99·97*	100·15	99·53	100·06	99·46	99·74**	99·51
Q		27·57	33·27	40·36	36·76	41·20	37·48	42·88
Or		63·44	20·04	9·46	15·03	9·46	17·25	10·57
Ab		4·19	38·27	35·65	36·18	39·32	36·70	33·03
An		——	3·89	7·23	8·07	3·61	4·45	8·07
C		1·73	1·02	2·04	0·71	2·55	0·51	1·43
En		0·20	0·80	0·70	0·90	0·50	0·40	0·20
Fs		——	0·53	1·19	——	0·79	——	——
Mt		——	1·16	0·46	1·39	0·46	0·46	0·69
Il		1·06	0·30	——	0·46	——	0·30	0·30
Ap		0·33	0·33	——	0·33	——	tr.	tr.
Hm		0·32	——	——	——	——	0·48	0·96
QFM	Q	28	35	42	37	43	38	44
	F	70	62	55	60	55	60	53
	M	2	3	3	3	2	2	3
NF	Or	94	32	18	25	18	30	20
	Ab	6	62	68	61	75	63	64
	An	——	6	14	14	7	7	16
NPl	An	——	9	17	18	8	11	20
NPy	En	100	60	37	100	39	100	100
	Fs	——	40	63	——	61	——	——
Fe		91	81	79	80	78	85	95

* includes S 0·18. ** includes NaCl 0·47.

No. 110. *Potash-liparite.* Kaesu-hama, northerne coast of Kodu-sima.
No. 111. *Aphanitic liparite.* Ombasi-zima, 4 km southwest of Kodu-sima.
No. 112. *Hornblende-plagioliparite.* Ko-hama, southern part of Naga-hama, Kodu-sima.

No. 113. *Hypersthene-plagioliparite.* Himmasi-hana, southwestern point of Kodu-sima.
No. 114. *Biotite-plagioliparite.* Top of Tenzyo-san, Kodusima.
No. 115. *Biotite-plagioliparite.* Muko-yama, southern part of Nii-sima.
No. 116. "*Augite-hypersthenic hornblende-andesine-dacite*". Kami-Taga, north Idu. H. Kuno, Bull. Volc. Soc., Japan, **3** (1936), 55.

in the Nii-sima group must surely be referred to Pleistocene and Recent.

The mineral constitution and chemical composition of the representative rock-types of Kodu-sima are shown in Table XXXIX and Table XL respectively. The three rock-types of Nii-sima are, petrographically, much like the corresponding types of Kodu-sima.

D. *Trachyandesitic Volcanoes.*

In the Volcano Islands group are two volcanoes composed of andesitic rocks instead of basalt, the rocks showing a distinct alkalic tendency as indicated by their microscopical and chemical characters. One of them is the insular volcano Io-sima (Sulphur Island) situated midway between Kita Io-sima and Minami Io-sima[75] and the other, that submarine volcano which, situated about 3 miles off the northeastern coast of Minami Io-sima, displayed violent eruptions twice (in 1905 and 1914), forming in each case an ephemeral volcanic island "Sin-to" or "Sin Io-sima" (New Sulphur Island).

17. Io-sima Volcano.

Io-sima, situated 24°47′N. and 141°18′E., or Naka Io-sima, as it is frequently called to distinguish it from Kita Io-sima and Minami Io-sima, is a gourd-shaped island measuring about 8 km NE.-SW. and 1~5 km NW.-SE. Morphologically, the island may be divided into three parts: Moto-yama, Suribati-yama, and Tidoriga-hara. Occupying the northeastern half of the island, Moto-yama is a flat-topped, dome-shaped hill (116 m above the sea) surrounded by uplifted wave-cut terraces on all sides, except at its southwest side where it is connected by a flat (Tidoriga-hara) with Suribati-yama. Suribati-yama (Mt. Pipe), which occupies a small area in the southwestern part of the island, is a

75) Minami Io-sima (San Augustino Island), situated 24°14′N. and 141° 29′E., is an insular, conical volcano measuring 3 km across the visible base, with a pointed peak (926 m above the sea) and steep lateral slopes (40° or steeper) ending abruptly with precipitous sea-cliffs. As to the rocks of the volcano, our knowledge is very meagre, for the desert island has rarely been visited, and what descriptions we have of it are of the briefest.

truncated conical volcano, 165 m above the sea, with a funnel-shaped crater (300 m in diameter and 100 m deep) at its summit. Tidoriga-hara, by means of which the preceding two parts are connected with each other, is a flat (40 m～100 m above the sea) veneered with drifting dune sand.

Of the geologic structure and the rocks of the island, a brief summary of the results already found[76] will be given here. The island is formed entirely of volcanic rocks and their detritus, which may be separable from older to younger into the following seven formations: (1) Moto-yama bluff tuff and Suribati-yama bluff tuff, (3) Moto-yama intrusive rock and Suribati-yama lava, (3) Suribati-yama cone ejecta, (4) Tidoriga-hara sand bed, (5) terrace deposits, (6) dune sand, and (7) beach deposit. These formations are, geologically speaking, very recent. The Moto-yama and Suribati-yama bluff tuffs, which are the visible oldest beds of the island, show that the volcanic activity began with the submarine explosive outbursts that gave rise to these beds. From a central vent, now represented by Suribati-yama, a submarine outflow of the Suribati-yama lava followed. Almost contemporaneously with the outflow began an injection of the Moto-yama intrusive rock into the previously deposited Moto-yama tuff. The intrusion, which might have originated satellitically at moderate depth from the conduit of the Suribati-yama, rose apparently through one or a number of fissures until it reached the lower horizon of the Moto-yama tuff, where it spread laterally and upward to form a laccomorphic intrusive mass. The beginning of the extensive uplift that brought the Moto-yama tuff above the sea and changed it into a dome of much the same form as we now see, appear to date back to the time of that intrusion. By continued upwarping of the ocean-bottom, both the Moto-yama dome and the basal part (Suribati-yama tuff and Suribati-yama lava) of Suribati-yama rose above the water. But a small part between them, now represented by Tidoriga-hara, would have remained as a shallow water. The sandy material transported by the waves from the shores of Moto-yama and Suribati-yama of that time, were deposited on the shallow-sea platform as the Tidoriga-hara sand bed. It was to the time of the deposition of this bed that subaerial eruptions took place from a central vent, now represented by the Suribati-yama crater. The Suribati-yama cone ejecta are the products of these eruptions. Together with the subsequent uplift of both Moto-yama and Suribati-yama, Tidoriga-hara also emerged, the three parts having joined together into one

76) H. TSUYA, *Bull. Earthq. Res. Inst.*, **14** (1936), 453; *Bull. Volc. Soc., Japan*, **3** (1936), 28.

Table XLI. Constituent Minerals of the Trachyandesites from Io-sima, Volcano Islands.

		No. 117	No. 118	A	B
Porphyritic Minerals	Plagioclase	$n_1=1·5493$ $n_2=1·5567$ 43 An Anorthoclase rim 2V(−)=62°, 49°, 46°	$n_1=1·5499$ 2V(+)=83° 45 An Anorthoclase rim absent	Extinction angle on (010)=−7·5° 23 An	n (mean)=1·5525 36 An Extinction angle on(010)=−2°(core), −8·5°(margin) 34∼42 An
	Augite	2V(+)=55°(core), 48° (margin) 2V(+)=57°, 61° $n_1=1·6974$ (core) $Wo_{40}En_{37}Fs_{23}$	2V(+)=54·5° $n_1=1·6970$ $Wo_{40}En_{37}Fs_{23}$	c∧Z=46°∼48° Pleochroism weak X−yellowish-gray Y=Z−yellowish-green	n>1·700 c∧Z=45° Deep to pale green
	Olivine	2V(−)=84° β=1·7020 $Fo_{66}Fa_{34}$	2V(−)≒83°	+	n (mean)=1·671 Opt. ch. negative
	Accessories	Magnetite Apatite	Magnetite Apatite	Magnetite Apatite	Magnetite
Groundmass	Anorthoclase	α=1·5253 γ=1·5325 2V(−)=71°(core), 48°(margin)	Pale to dark-brown glass (n=1·5237∼1·5277) packed with microlites of feldspar and pyroxene.	Pale-brown glass packed with microlites of monoclinic pyroxene (pale yellowish-green, maximum extinction angle=52°).	Magnetite Apatite Monoclinic pyroxene Glass
	Plagioclase	$n_1=1·5439$ 2V(−)=82°∼86° 28 An			
	Pyroxene	Augite 2V(+)=55° $n_1=1·6997$ c∧Z′=51·5° (max.) $Wo_{40}En_{36}Fs_{24}$ Acmite X−pale green Y−green Z−greenish-brown X>Y>Z 2V(−)=68°∼73° α>1·750 c∧X small			
	Hornblende	$n_1=1·6465$ $n_2=1·6552$ Z(or Y)−reddish-brown Z (or Y)>X c∧Z′=21° (max.)			
	Accessories	Magnetite			

A. "Olivine-pyroxene-andesite". Pumice and obsidian of 1904 eruption, "Sin-to", Volcano Islands. According to Wakimizu (*loc. cit.*), the rock contains, in addition to the minerals given under column A of the above table, a few phenocrysts of rhombic pyroxene.

B. "Olivine-bearing augite-vitroandesite". Pumice, obsidian, and lava, of 1914 eruption, "Sin Io-sima", Volcano Islands. T. Ogura, *loc. cit.*

Table XLII. Analyses of the Trachyandesites from Io-sima, Volcano Islands.

	No. 117	No. 118	No. 119
SiO_2	58·91	59·60	60·82
Al_2O_3	17·71	16·81	16·63
Fe_2O_3	2·81	0·83	1·15
FeO	2·67	5·87	3·46
MgO	0·88	1·34	1·79
CaO	3·47	3·10	3·35
Na_2O	6·01	6·11	5·62
K_2O	3·94	4·17	4·21
H_2O +	0·34	0·25	1·84
H_2O −	0·30	0·10	(ign. 1.)
TiO_2	0·82	0·86	0·45
P_2O_5	0·49	0·50	0·22
MnO	0·16	0·26	0·39
Total	100·23*	99·80	99·93

* includes S 1·71.

No. 117. *Olivine-augite-andesine-trachyandesite.* Suribati-yama (Mt. Pipe), Io-sima. S. Tanaka, analyst.

No. 118. Do. Moto-yama, Io-sima. S. Tanaka, analyst.

No. 119. *"Olivine-pyroxene-andesite."* Pumice of 1914 eruption, "Sin Io-sima". Imp. Geol. Surv., analyst.

Norms		No. 117	No. 118	No. 119
Q		1·62	—	1·98
Or		23·37	24·49	25·04
Ab		50·83	51·91	47·71
An		9·74	6·12	7·51
Wo		1·97	2·32	3·02
En		2·20	1·10	4·42
Fs		1·45	3·43	5·27
Fo		—	1·55	—
Fa		—	4·48	—
Mt		4·17	1·16	1·52
Il		1·52	1·67	0·91
Ap		0·99	1·32	0·65
QFM	Q	2	—	2
	F	86	83	82
	M	12	17	16
NF	Or	28	30	31
	Ab	61	63	59
	An	11	7	10
NPl	An	16	11	14
NPy	Wo	35	16	24
	En	39	22**	34
	Fs	26	62	42
Fe		86	83	71

** includes olivine as metasilicate.

island as we see at present. The uplift of the island was not continuous, but occurred intermittently for a long period with frequent halts of the sea, during which intervals marine erosion was active on weaker rock like the Moto-yama tuff, giving to the island its present terraced feature. Such stepwise uplift will be naturally expected, it being likely that the intrusion of the Moto-yama intrusive rock occurred recurrently through a long period of volcanic activities.

There is no volcanic material that was ejected since the Suribati-yama cone ejecta had been formed, nor is there any historic record of an eruption in the island. But volcanic activity is manifested in the island even at the present day by numerous solfataras. One of these solfataras on the northwestern side of Moto-yama is said to have been culminated a few years ago in ejecting a small volume of solid material. It is also said that detonations are often heard from the sea northeast of the island.

The rocks of the island may be called trachyandesite since they are close in petrographic characters, microscopical as well as chemical, to some trachytes from the Pacific islands rather than to the common Japanese pyroxene-andesites. Thus, as will be seen from Tables XLI and XLII, the Suribati-yama lava and the Moto-yama intrusive rock are crystalline olivine-augite-andesine-trachyandesite and vitrophyric olivine-augite-andesine-trachyandesite respectively. Both the tuffs andt he Suribati-yama cone ejecta are petrographically very similar to either the Suribati-yama lava or the Moto-yama intrusive, although of diverse appearances such as pumiceous, vitreous, scoriaceous, and felsitic.

18. Sin Io-sima Volcano (a submarine volcano near Minami Io-sima).

Sin Io-sima volcano, lying about 3 miles off the NE. shore of Minami Io-sima, might have existed for untold ages, but its actual existence was ascertained for the first time on Nov. 28, 1904, when it violently erupted. These eruptions continued for more than two months, from Nov. of the year to the following January, culminating in forming a new volcanic island "Sin Io-sima" or "Sin-to". According to T. Wakimizu,[77] the new island, which was composed of pumice and obsidian, all but disappeared after 135 days of existence. Thus while in Feb., 1905, it measured about 150 m above the sea and 5 km in circumference, in June of that year only a shoal about 100 m in diameter remained to mark the site of the island. In subsequent years, the shoal also disappeared, while in 1910 there was about 424 m of water where the island once stood. On Jan. 34, 1914, after ten years of quiescence, the submarine volcano was again in eruption, culminating in the formation of the second new volcanic island at the site of the 1904 island. According to T. Ogura[78], who visited the scene of the eruptions the following month, the island, which was a conical volcano of pumice and obsidian, stood about 120 m above the sea and 3.5 km in circumference. Nearly tow years later, the island

77) T. WAKIMIZU, *Publ. Earthq. Inv. Com.*, 22-C (1908), 15; *Rep. Earthq. Inv. Com.*, **56** (1907).

78) T. OGURA, *Rep. Earthq. Inv. Com.*, **79** (1914).

also had disappeared. The submarine volcano has not erupted since, its site being marked only by a submarine bank about 200 m deep which drops abruptly to the much more profounder depression of the adjoining sea. In 1935, when the writer sailed round Minami Io-sima, nothing out of the ordinary could be noticed from the sea above the submarine volcano.

The rocks ejected from the volcano in 1904 and 1914 are described by Wakimizu and Ogura respectively as olivine-augite-andesite and olivine-bearing augite-andesite. Petrographic characters of these rocks are excerpted from the descriptions of the respective authors in A and B, Table XLI, where they are compared with those of the trachyandesites from Iosima. The table shows that the products of the submarine volcano resemble petrographically the glassy type of the trachyandesites from Io-sima. Whereas, therefore, they are characterized by phenocrysts of andesine, olivine, and augite, they may be called trachyandesite, instead of andesite. This is justified from the chemical side also, as an analysis (No. 119, Table XLII) of a pumice[79] ejected from the submarine volcano in 1914 was found to agree practically with analyses of the trachyandesites from Io-sima, and because of the large quantity of alkalies, especially soda.

III. GENERAL PETROLOGY.

The foregoing descriptions practically cover all the important volcanic bodies of the region under investigation. The rocks composing these bodies show a fairly wide range of petrographic characters according to which they may be divided into the following principal rocks-types:

1. Basalts ......
   - phyric basalts ...
     - olivine-basalt.
     - augite-olivine-basalt.
     - hypersthene-olivine-basalt.
     - two-pyroxene-olivine-basalt.
     - two-pyroxene-basalt.
     - feldspar-phyric basalt.
   - aphyric basalt.
2. Andesites...
   - phyric andesites...
     - olivine-two-pyroxene-andesite.
     - two-pyroxene-andesite.
     - hypersthene-andesite.
   - aphyric or aphanitic andesite.
3. Dacites..............................
   - two-pyroxene-dacite.
   - two-pyroxene-hornblende-dacite.
   - hornblende-dacite.

79) T. WAKIMIZU, *Toyo Gakugei-zassi*, **37** (1919), 257.

4. Liparites ...
   - plagioliparites ...
     - augite-plagioliparite.
     - hypersthene-plagioliparite.
     - pyroxene-hornblende-plagioliparite.
     - hornblende-plagioliparite.
     - hornblende-biotite-plagioliparite.
     - biotite-plagioliparite.
   - aphanitic liparite.
   - potash-liparite.
5. Trachyandesite .... olivine-augite-trachyandesite.

All the above rock-types are represented; basalts and andesites predominating the dacites and liparites, both of which occur mostly as local masses in the Teriary terrane of the southern half of the Idu peninsula, excepting however the liparites of the Nii-sima group, the last-named constituting only a small proportion of the total volume of the volcanics in the region studied. Trachyandesite is found only in the Volcano Islands group—in Io-sima. Besides the five rock-types enumerated, we find diabase, porphyrite, and quartz-porphyry among the minor Tertiary intrusives from the Idu peninsula. Gabbro and quartz-diorite have been reported from near Atami[80].

A. *Mineralogical Characters.*

There are not many rock-forming minerals; the salic minerals are feldspar, quartz, tridymite, and cristobalite, while the mafic minerals are olivine, pyroxene, hornblende, and biotite, with accessory magnetite and apatite, the first-named two being the most usual. The general characters of these minerals may be briefly summarized as follows:

Plagioclase. The plagioclase in the various rock-types as determined by measuring the indices of refraction exhibits a large rang of composition. The porphyritic plagioclase varies from anorthite add bytownite in basalt and basic andesite, through labradorite and andesine in acid andesite and dacite, to oligoclase in liparite. The groundmass plagioclase is naturally less calcic than the porphyritic plagioclase in the same rock. The porphyritic plagioclase in basalts from the region studied is, generally speaking, more calcic than that in allied rocks from other regions of the world[81]. So also do the porphyritic plagioclases that are contained in the other rock-types. Some porphyritic basalts contain large plagio.

80) H. KUNO, *Jour. Geol. Soc., Tokyo*, **40** (1933), 379.

81) The porphyritic plagioclases in lime sub-basalt and lime basalt from Hawaii are bytownite (75 An) to labradorite (51 An) and labradorite (65~70 An) respectively. T. F. W. BARTH, *Am. Jour. Sci.*, **21** (1931), 517. The porphyritic plagioclase in some of the Deccan traps is labradorite.

clase phenocrysts (usually 1∼1·5 cm dia.), together with or without phenocrysts of olivine and pyroxene. When such largep lagioclase occurs in basalts, it is invariably anorthite, though with a certain range of composition according to the particular rocks. Thus, on Miyake-sima, anorthite (95 An) occurs as crystal-bombs among pyroclastic ejecta besides as phenocrysts in some of the porphyritic lavas. A similar anorthite is also found in some porphyritic basalts from Taga and Tori-sima as well as in some porphyritic andesites from Usami and Tensi-yama. Although the plagioclase phenocrysts in numerous Huzi lavas are bytownite, nearly 75 An by chemical composition, large anorthite phenocrysts are also found in some lavas from the volcano. The trachyandesite from Io-sima carries plagioclase phenocrysts of large size, but in this case the mineral is andesine (43 An).

The plagioclase, both of the phenocrysts and in the groundmass, often exhibits zoning due to chemical differences, in which case the marginal part of the mineral is usually less calcic than the core of the same crystal, although reverse or recurrent zoning also occurs. The zoning of plagioclase in the basic rock-types is in most cases rather faintly exhibited, the variation in composition in different parts of the same crystal being small—that is, anorthite to anorthite-bytownite, calcic bytownite to sodic bytownite, or sodic bytownite to calcic labradorite. In some cases, however, a broad core, either homogeneous or very slightly zoned, of porphyritic plagioclase, is sharply bordered by a rim of some other feldspar, usually the plagioclase in the groundmass, which is considerably less calcic than the core. In the trachyandesite from Io-sima, the almost homogeneous andesine phenocrysts are surrounded by a thin rim of an anorthoclase which is an essential constituent of the groundmass of the same rock. The zoning of the plagioclase in acid andesites and dacites is generally more pronounced than that in basalts and basic andesites. Thus, porphyritic

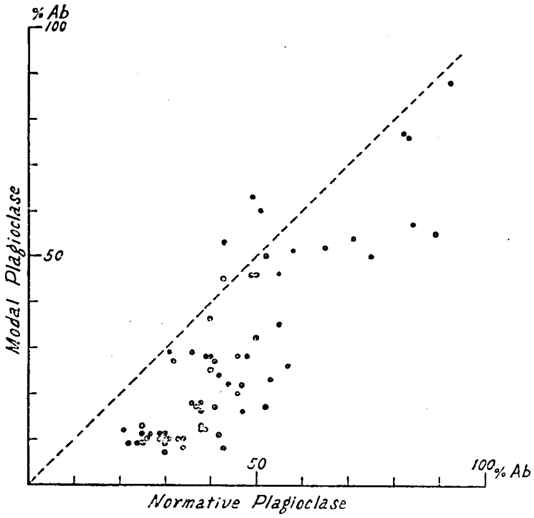

Fig. 12. Composition-relation between normative plagioclase and modal plagioclase (most sodic part).

plagioclases with a large range of composition in the same crystal have been described from Hakone. The core, for instance, may be anorthite (95 An), while the margin is labradorite (60 An).

The modal plagioclase is usually more calcic than the normative plagioclase in the same rock. But, in some rocks, such as those from Hakone, in which the groundmass is highly crystalline and the plagioclase is strongly zoned, the most sodic part of the mineral may naturally be less calcic than the normative plagioclase. Fig. 12 shows the composition relation between the most sodic part of the porphyritic plagioclase and the normative plagioclase of the same rock.

The plagioclase is usually quite fresh; even in Tertiary rocks, this mineral, except in some highly altered rocks the plagioclase of which has been subjected to saussuritization, is in most cases unaltered.

Alkali-feldspar. Alkali-feldspar is less in quantity than plagioclase, although different kinds of it are sometimes met with in certain acid and sub-acid rocks. Porphyritic sanidine with small optic angle occurs in the potash-liparite from Kodu-sima. Similar feldspar is also found in the potash-liparite from Manzo-yama and vicinity, south Idu, but the mineral is not fresh enough for precise examination of its optical properties. The plagioliparites from both Nii-sima and Kodu-sima also carry phenocrysts of sanidine, although they are usually far less in quantity than the plagioclase phenocrysts (oligoclase) contained in the same rock. Anorthoclase occurs in the trachyandesite from Io-sima as a rim around the plagioclase that is both in the phenocrysts and in the groundmass, besides filling the interstices of the other minerals. The boundary between the plagioclase and the associated anorthoclase is either sharp or rather continual. Zoning due to chemical difference is sometimes discernible through variations in the optic angle in different parts of the same crystal of the anorthoclase. When this is shown, the optic angle usually decreases from core ($2V=70°$) to margin ($2V=40°$). Anorthoclase has also been observed in the groundmass of some pyroxene-andesites from Hakone. Beyond these few examples, no alkali feldspar has yet been definitely identified in the course of the present study, although some of the rocks with high crystallinity from Amagi and Asitaka might carry certain kinds of alkali feldspar in their groundmass.

Olivine. Olivine is naturally found much more in the basalts and basic andesites than in the other rock-types, although small amounts of it occur in the trachyandesite from Io-sima and in the dacites from Amagi. In many basalts the mineral is usually present in relatively small and accessory amounts, especially in rocks the norms of which do not show olivine. Indeed, some basalts from O-sima, Miyake-sima, Hatizyo-sima, as elsewhere in the Idu peninsula, are entirely devoid of this mineral. In a few basalts, however, such as those from Kita Io-sima, Tori-sima, Amagi, Huzi, and from the other volcanoes, the mineral is very conspicuous and so great in amount that their norms yield but scanty quartz (residual silica) or a little olivine instead of the quartz. In most olivine-bearing rocks, such as those from Huzi, Amagi, and Kita Io-sima, it occurs, besides the phenocrysts in the same rock, as a groundmass constituent.

Although the olivine sometimes shows a euhedral outline with the usual habit, more often it forms either rounded or indented individuals surrounded with or without a corona of some other minerals. The corona, when present, usually consists of aggregates of monoclinic pyroxene, either augite or pigeonite. But in some rocks, in which olivine and hypersthene occur together in addition to monoclinic pyroxene, the olivine is often enclosed by a shell of hypersthene, which in turn is surrounded by grains of monoclinic pyroxene. In a few cases the olivine, on the contrary, encloses a core of hypersthene.

The composition of the olivine as determined by measuring the optic angle and the indices of refraction, ranges from nearly $Fo_{80}Fa_{20}$ to $Fo_{60}Fa_{40}$ (wt. %). On the whole, zoning due to chemical difference does not seem very common, although sometimes it is noticed through variations in the optic angle in different parts of the same crystal, the variation recognized being about 3° to 10°. In most zoned olivines, the core is richer in the forsterite molecule than in the margin, while reversed zoning is also met with. No definite paragenic relation could be detected between the composition of the olivines and that of the associated feldspars (see Fig. 13).

In most of the olivine-bearing rocks from the Quaternary volcanoes, the mineral is usually fresh or only slightly altered, which if altered, it gives rise sometimes, marginally, to iron-oxide, and sometimes both marginally and along cracks in the crystal to a reddish-brown iddingsite or to a greenish chlorite. In similar rocks among the Tertiary volcanics, especially those of lower Miocene (Idu) and older (Haha-sima, Bonin Islands), the mineral is more or less completely pseudomorphed by some other mineral, usually a greenish chlorite or calcite, or both.

Pyroxene. Pyroxene is the commonest mafic mineral found in the rocks under investigation, it being met with in one form or another in almost every rocks, although in varying amounts. They are mostly in the form of either augite, hypersthene, or pigeonite.

Augite occurs in all rock-types from basalt to liparite, usually as porphyritic individuals, although in some rocks, such as the basalts from

Huzi, Amagi, and Kita Io-sima, as well as in the andesites from Hakone, Usami, and Amagi, it occurs, besides the phenocrysts, as a constituent of the groundmass. In some cases the mineral may be present to the exclusion of other mafic minerals, but in many others it is accompanied by one or more of these. When augite occurs together with olivine in the same rock, the former often encloses the latter, besides forming isolated individuals. In many rocks, in which augite and hypersthene occur together, the two pyroxenes, in addition to forming their own individuals, are intergrown with each other, either lamellarly or zonally, the augite as a rule forming the exterior of the intergrown crystal.

The augite is generally euhedral with the usual habits. Lamellar twinning is very often met with. Zoning due to chemical difference is very frequently recognized by measuring the optic angle in different parts of the same crystal; although if zoned, the angle is usually larger in the core than in the margin, reversed and recurrent zonings are also met with. The range of the optic angle is nearly 2V=57° to 45°, while tne extreme margin of zoned augite may become more pigeonitic—that is, 2V=40° or smaller. When the augite is bordered by pigeonite having a small optic angle, as observed in many basalts, the boundary separating them is usually very sharp,

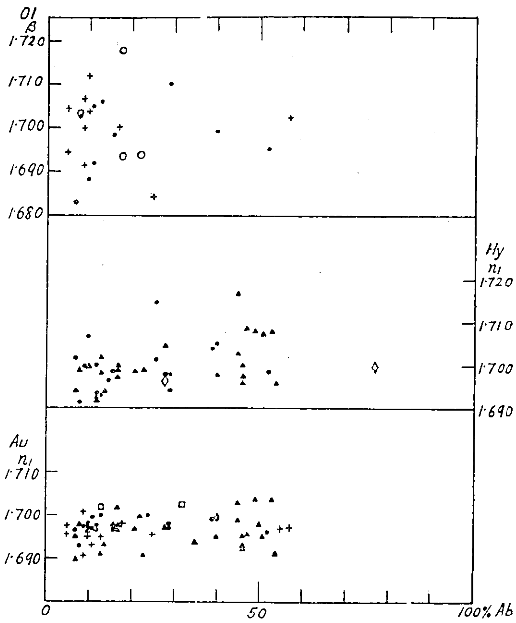

Fig. 13. Paragenic relations between porphyritic plagioclases and ma´c minerals—olivine (Ol), hypersthene (Hy), and augite (Au).

Open circles: olivine from olivine-basalts.
Crosses: olivine and augite from augite-olivine-basalts.
Solid circles: olivine, augite, and hypersthene, from olivine-two-pyroxene-basalts and -andesites.
Open squares: augite from augite-andesites.
Open diamonds: hypersthene from hypersthene-andesite.
Solid triangles: hypersthene and augite from two-pyroxene-basalts and -andesites.

Hypersthene also, though in varying amounts, is found in all the rock-types from basalt to liparite, usually as a porphyritic ingredient. In some rocks, such as those from Asitaka, Hakone, Usami, and Amagi, however, the mineral occurs, together with augite or pigeonite or both, as micro-phenocrysts in the groundmass besides occurring as phenocrysts. Although in most olivine-rich basalts the hypersthene may be entirely absent or merely accessory, in many olivine-poor and olivine-free rocks it occurs as an essential constituent, together with augite, taking in a sense the place of olivine. In these rocks the quantity of hypersthene often exceeds that of augite, while in some exceptional rocks, as those from Asitaka, the former make up the bulk of the porphyritic mafic constituents, with or without negligible olivine or augite or both. Besides occurring as isolated individuals, hypersthene is very often intergrown with augite or groundmass pigeonite, while the former is surrounded by granular aggregates of one of the two last-named. A lamellar intergrowth of porphyritic pigeonite and hypersthene has been described from Hakone. Sometimes, porphyritic hypersthene encloses a core of augite with random crystallographic relations, while more often, the reverse is the case. Reference has already been made to the fact that a similar relation holds between hypersthene and olivine. In certain liparites from Nii-sima and Kodu-sima, hypersthene is present, either to the exclusion of or in company with one or more of either augite, hornblende, or biotite.

In most cases, hypersthene is well-shaped with the usual habits and normal optic orientation (optic plane parallel to c-axis), although a clino-hypersthene has been described from the miharaite of O-sima. Pleochroism is moderately exhibited; usually, X—yellowish brown, Y—greenish brown, and Z—green. Zoning due to chemical difference is frequently met with. In zoned crystals, the optic angle about X usually decreases from core to margin of the same crystal either continuously or stepwise. Reversed and recurrent zonings are more often met with in hypersthene than in augite. The range of the optic angle is nearly $2V(-)=79°$ to $2V(-)=61°$, although a much smaller angle has been measured in a hypersthene from Hakone with the minimum $2V(-)=47$.

A bronzite in a tuff from Titi-sima, Bonin Islands, has been described independently by both Y. Kikuchi[82] and S. Kozu[83]. In the andesites from the same island, rhombic pyroxene occurs, besides as porphyritic individuals, together with monoclinic pyroxene as incipient crystals with various habits in the glassy groundmass. Since, optically, the rhombic pyroxene is much like the hypersthene in the andesites from the adjoining shores, there is no need for special comment.

82) Y. Kikuchi, *Jour. Col. Sci., Tokyo Imp. Univ.*, **3** (1889), 81.
83) S. Kozu, *Jour. Jap. Assoc. Min. Petr. Econ. Geol.*, **6** (1931), 275.

Pigeonite occurs frequently in the form of a rim surrounding olivine, augite, and hypersthene of the phenocrysts, as well as in the groundmass of basalts and andesites. The porphyritic pigeonite in some andesites from Hakone has been studied by its discoverer, Kuno, with valuable results concerning the crystallization of pyroxenic components from magma. Pigeonite, which usually occurs as prisms with occasional lamellar twinning on (100), is characterized by its smaller optic angle than that of common augite. Although, in some instances, the optic angle 2V is as large as 40° or more, in many others it is usually smaller than 30°, while nearly-uniaxial pigeonite is not infrequently met with. Zoning due to chemical difference is sometimes recognizable through variations in the optic angle in different parts of the same crystal. If zoned, however, the margin is usually smaller in the optic angle than in the core.

Alkali-pyroxene is all but absent. In its solitary occurrence in the trachyandesite from Io-sima it is restricted to the groundmass, in which it occurs as a rim enclosing a core of colorless or pale-green augite (diopsidic), besides occurring as isolated prismatic individuals. To judge from its optic angle about X, its pleochroism, and its indices of refraction, this alkali-pyroxene has an acmitic composition.

The paragenic relations between the porphyritic pyroxenes and the porphyritic plagioclases are shown in the diagrams, Fig. 13, where the indices of refraction of the pyroxenes and the compositions of the plagioclases are taken as ordinates and abscissae respectively. No systematic paragenic relation can be recognized on these diagrams. But, as has been pointed out in previous papers[84] on the basis of similar diagrams, the well-differentiated Amagi rocks belong exclusively to one and the same genetical lineage, and the basaltic rocks from the Seven Idu Islands to another genetical lineage. It is thus inferred that, although all the rocks from the region studied may belong to a common magmatic suite (a regional mother magma), they are probably divided into several local groups, each of which belongs to a particular genetical lineage, possibly due to different rate of cooling and different crystallization history of local magmas.

The compositions of the pyroxenes, so far determined by measuring the optic angles and the indices of refraction, are plotted in the diagram, Fig. 14. Another similar diagram, Fig. 15, shows the compositions of the pyroxenes from Hakone andesites studied by Kuno. As will be seen from these diagrams, the plots of the porphyritic augite fall exclusively

84) H. TSUYA, *Bull. Earthq. Res. Inst.*, **7** (1929), 329; *Proc. Third Pan-Pacific Sci. Congr.*, Tokyo, **1** (1926), 2393.

within Kuno's *two-pyroxene field*[85] of the $CaSiO_3$-$MgSiO_3$-$FeSiO_3$ diagram.

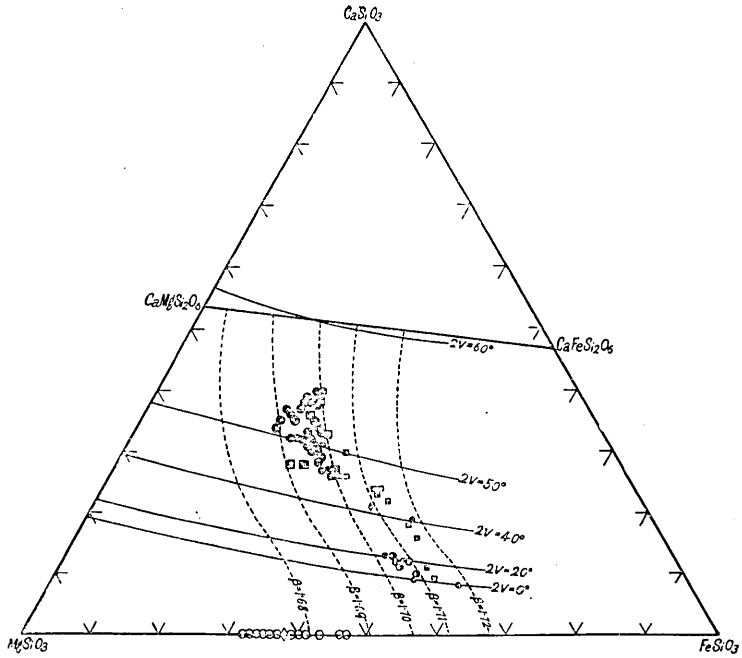

Fig. 14. Compositions of pyroxenes in the volcanic rocks from Idu and the Southern Islands.

Large solid circles: Porphyritic augite from two-pyroxene (±olivine)-bearing rocks.
Large open circles: Porphyritic hypersthene from two-pyroxene (±olivine)-bearing rocks.
Large solid squares: Porphyritic augite from augite (±olivine)-bearing rocks.
Open diamond: Porphyritic hypersthene from hypersthene-andesite.
Half-solid circles: Groundmass pyroxene from two-pyroxene (±olivine)-bearing rocks.
Small solid squares: Groundmass pyroxene from augite (±olivine)-bearing rocks.

To judge from their average optic angles and mean indices of refraction, the porphyritic augites that are plotted in the diagrams seem to be poorer in lime and richer in iron-oxide than the chemically analyzed, pyrogenic monoclinic pyroxenes from various localities in Japan. Most of them, however, are zonally built in the manner as already mentioned, suggesting that the margin of zoned augite is probably richer in iron-oxide and poorer in lime than its core. The augites from Wadaki, Idu,

85) H. KUNO, *Jap. Jour. Geol. Geogr.*, **13** (1936), 141.

and from Yone-yama, Etigo, both of which were chemically analyzed,

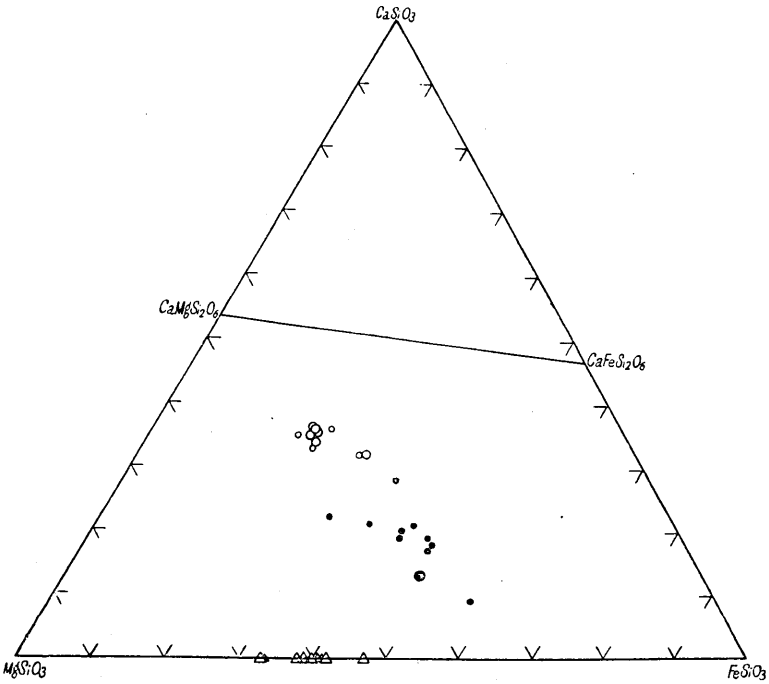

Fig. 15. Compositions of pyroxenes in the andesites from Hakone and in the basalt from Aziro, Idu. (Data given by H. Kuno, *loc. cit.*)

Large open circles: Porphyritic augites.
Large solid circle: Porphyritic pigeonite.
Small open circles: Groundmass augites.
Small solid circles: Groundmass pigeonites.
Large open triangles: Porphyritic hypersthenes.
Small open triangles: Groundmass hypersthenes.

also show a similar zoning.[86] From these facts in view, it is inferred that, although the monoclinic pyroxene that lies within the two-pyroxene field may have a composition-range (a limit of miscibility of the $MgSiO_3$-$FeSiO_3$ series in the $CaMgSi_2O_6$-$CaFeSi_2O_6$ series)[87], the pyroxene within that range becomes richer in iron-oxide and poorer in lime with advancing crystallization.

Like the hypersthenes in the andesites from the Kusatu-Sirane volcano[88], those in the rocks under investigation do not fit well into the

86) H. Kuno and M. Sawatari, *Jap. Jour. Geol. Geogr.*, **11** (1934), 323.
87) S. Tsuboi, *ibid.*, **10** (1932), 67.
88) H. Tsuya, *Bull. Earthq. Res. Inst.*, **12** (1934), 67.

curve for the optic angle in Winchell's diagram showing the variations of composition and optic properties in the rhombic pyroxene series, if the curves for the indices of refraction in that diagram be taken as normal. With the corresponding indices of refraction, they are characterized by more or less smaller optic angles as compared with the hypersthenes upon which Winchell's diagram is based. This character thus confirms Tsuboi's note[89] concerning the relation between the optic angles and the indices of refraction of a number of rhombic pyroxenes from various localities in Japan. In the above figures the hypersthenes are plotted on the basis of the curves proposed by Bowen and Schairer for the variations of composition and indices of refraction in the rhombic pyroxene series, which curves seem better for our rhombic pyroxenes than Winchell's. As the chemical analyses of rhombic pyroxenes from various localities in Japan show, the hypersthenes studied also may contain $CaSiO_3$ and other minor constituents, besides the two main components, $MgSiO_3$ and $FeSiO_3$. But, since the actual contents of $CaSiO_3$ and other minor constituents in them cannot be determined from their optical properties alone, the approximate compositions of the hypersthenes as expressed in terms of the two main components, are plotted in the above figures. Thus, they rang from nearly $(MgSiO_3)_{80}(FeSiO_3)_{20}$ to $(MgSiO_3)_{54}(FeSiO_3)_{46}$ (wt. %), all lying within the two-pyroxene field[90]. As to the course of crystallization of hypersthene, nothing can be said with certainty at present, although the manner of variation of the optic angle in different parts of zoned hypersthene suggests that with advancing crystallization the mineral becomes, in most cases, richer in ferrosilite molecule.

The groundmass pyroxenes, except the augite and hypersthene that occur together as microphenocryst in the groundmass of some two-pyroxene-bearing rocks, are exclusively monoclinic pyroxenes which are usually poorer in lime and richer in iron-oxide than the porphyritic augites, and most of which have compositions lying within Kuno's *pigeonite field* of the $CaSiO_3$-$MgSiO_3$-$FeSiO_3$ diagram.

In most of the Quaternary rocks, pyroxenes are usually quite fresh, while in many Tertiary rocks, especially in some of the lower Miocene rocks from Idu, they are more or less completely replaced by chlorite. Augite is often left almost unaltered even though adjacent to chloritized olivine or hypersthene. The augite of the basalt-xenoliths in the liparites

89) S. Tsuboi, *Jap. Jour. Geol. Geogr.*, **12** (1935), 109.

90) The hypersthene in the almost aphyric olivine-bearing two-pyroxene-andesite (No. 76) from Aoga-sima has exceptionally high indices of refraction ($n_1=1{\cdot}715$), and its composition, so far judged from the indices of refraction, is $(MgSiO_3)_{47}$ $FeSiO_3)_{53}$.

from Nii-sima and Kodu-sima is converted partly to a green hornblende. Being a phenomenon similar to that observed in the Omogo acidic rocks[91], this seems to be an example confirming Bowen's view regarding the effect of acid magma upon inclusions of less acid igneous rocks.

Hornblende. Hornblende is found in liparites as well as in dacites and also in some few andesites. In most of these cases, the mineral occurs as porphyritic individuals either in association with the other mafic minerals—usually pyroxene or biotite or both—or to the exclusion of these, but in a few rocks, such as the dacites from Amagi, it is found, besides as phenocrysts, as microphenocrystic flakes in the glassy groundmass. The trachyandesite from Io-sima also carries hornblende in the groundmass. Most of the pyroxene-andesites from Amagi might carry hornblende, which however has been completely converted to a granular aggregate of magnetite, plagioclase, and pyroxene. A similar conversion of hornblende has been described from the pigeonite (porphyritic)-bearing andesites of Hakone. Hornblende occurs as rare phenocrysts in some liparites from Nii-sima and Kodu-sima, in most of which the mineral is found associated with minute biotite flakes. The hornblende in some of the Tertiary rocks from Idu is sometimes quite fresh or only slightly altered, but more often it is completely altered in the same way as that from Amagi or pseudomorphed by secondary material, usually chlorite.

When fresh, hornblende is greenish-brown with moderate pleochroism and usual habits: neither basaltic nor alkaline hornblende is presented. Zoning due to chemical difference in different parts of the same crystal is rarely met with: if zoned, the optic angle is usually larger in the core than in the margin.

Biotite. Biotite is distributed less extensively than hornblende, its occurrence being virtually restricted to certain liparites and to a few dacites. Greenish-brown biotite in the form of very minute flakes is found in most of the liparites from Nii-sima and Kodu-sima. Accompanying this biotite, which has usually $\gamma = 1{\cdot}656 \sim 1{\cdot}665$ and $2E = 38°$ or smaller, there often occurs biotite of another type in flakes of a deep reddish-brown color, with much higher indices of refraction and larger optic angle. From a thermal study of biotite flakes from the Tenzyo-san lava of Kodu-sima, it was proved that this reddish-brown biotite is a thermally-decomposed product of the other greenish-brown biotite in the same rock[92].

Silica mineral. Most of the basalts and andesites carry silica mineral in their groundmass, but in such amounts sufficient to account for

91) H. TSUYA, *Bull. Earthq. Res. Inst.*, **13** (1936), 910.
92) H. TSUYA, *Bull. Earthq. Res. Inst.*, **7** (1929), 306.

the normative quartz (residual silica) that we find in their analyses. The silica mineral occurs in three different forms: cristobalite, tridymite, and quartz. A reference to the occurrence of these minerals has been specially made by Kuno in connection with the petrography of a basalt from Aziro, north Idu[93].

Cristobalite and tridymite occur either together or by themselves, interstitially as well as in shapeless patches, and/or as well-shaped plates and prismoides in the groundmass. They can be verified rather easily in rocks with a coarse-grained groundmass, whereas in a fine-textured groundmass certain areas of patchy polarization indicate the presence of one or more of these minerals. In some rocks with microscopic vesicles, besides as interstice-fillings, they are found in the form of a lining to the vesicles.

Quartz also may sometimes be detected in the interstices of a less glassy, coarser-grained groundmass. Porphyritic quartz is met with in most of the liparites and dacites, though in varying amounts, in which it usually occurs with rounded or irregularly broken outlines, and although exceptionally, in the bipyramidal form. The potash-liparite from Manzo-yama, Simoda, carries locally bipyramidal quartz of large size (up to 8 mm dia.), although by far the greater part of the mass is destitute of that mineral. In some andesites from Amagi and Hakone accessory quartz occurs in the form of rounded grains. Most of the olivine-basalts from the Omuro-yama volcano group carry porphyritic crystals of quartz, often rimmed by grains of pigeonitic augite, as in the case of quartz in many of the quartz-basalts from other regions. Like the porphyritic crystals of andesine that occur in the same rocks, the quartz is xenocrysts, the apparent source of which is the dacite agglomerate underlying the basalts of the group. An exposure of this dacitic agglomerate is seen at Yosida on the southwest foot of the Komuro-yama volcano, where it carries abundant well-shaped crystals of quartz (up to 1 cm dia.).

Magnetite. Almost all the rocks contain, though in varying amounts, an opaque mineral of the iron-ore group, usually magnetite: in basalts and basaltic andesites the mineral usually occurs in the groundmass only, whereas in some andesites and more acid rocks it is found, besides in the groundmass, as a rare accessory of the phenocrysts. The magnetite is usually in distinct crystals, sharply bounded or with rounded edges and angles. Sometimes, and especially in coarser-grained basalts, it occurs in shapeless patches, tending to enwrap the other minerals of the groundmass. Porphyritic magnetite is found intimately associated with

93) H. KUNO, *Bull. Earthq. Res. Inst.*, **11** (1933), 400.

the other mafic minerals in the same rock. Ilmente has been reported from the andesites of Hakone.

Apatite. This mineral is observed more frequently in andesites and the more acid rocks than in basalts: it is almost constantly met with in the andesites from Amagi, Usami, and Hakone. The trachyandesite from Io-sima contains slender needles of almost-colorless apatite as inclusions in the porphyritic minerals and as isolated individuals dispersed through the rock.

B. *Chemical Characters.*

The chemical analyses accompanying descriptions of rocks in this paper total 106 exclusive of those from the Marianas Islands, and these may be itemized as shown in Table XLIV, according to their locality and silica content. In the table, the numerals in brackets indicate the number of analyses that were published before 1925, while the others are those that were made later. Besides these, there are some 40 older analyses that have not been quoted in this paper. Of the 95 analyses made during recent years, since 1925, 76 were made by Tanaka for the writer, including 59 hitherto unpublished results. The 6 analyses for Hakone, 5 for Taga, and 2 for local masses near Aziro, north Idu, were made by the same analyst for H. Kuno. The following discussion concerns the analyses given in this paper, excluding however those in the columns that are headed by capital letters in the tables of chemical analyses.

The general chemical characters of a series of volcanic rocks are usually discussed with the aid of variation diagrams, that is, by plotting the chemical analyses of the rocks on rectangular co-ordinates with silica as abscissae and the other oxides as ordinates. It should be emphasized, however, that a variation diagram, in which many analyses of porphyritic rocks with large phenocrysts are incorporated, may not be a "magma variation diagram", for the reason that the bulk analyses of porphyritic rocks may depart more or less from the composition of any past magmatic liquid, unless the phenocrysts in such a rock include all the material that separated from some other liquid while it was changing to that liquid in which they are now suspended[94]. It follows, therefore, that magma variation diagrams should be drawn only for rocks that either virtually represent or closely approach the composition of magmatic liquids. The rocks that come within this category are the

94) S. TSUBOI, *Jour. Fac. Sci., Imp. Univ., Tokyo,* 1 (1925), 77.
N. L. BOWEN, The Evolution of the Igneous Rocks. Princeton (1928), 92.

Table XLIV. Number of the Chemical Analyses accompanying Descriptions of Rocks in this Paper.

		Localities \ SiO_2 contents	<50%	>50% <55%	>55% <60%	>60% <65%	>65% <70%	>70%	Total
Tertiary	Ogasawara Islands	Haha-sima	—	—	**1**	—	—	—	**1**
		Titi-sima	—	(3)**	(1)	**1**	—	—	(4) **1**
	Idu Peninsula		**1**	**5**	**5**	**6**	**3**	**1**	**24**
Quaternary	Idu Peninsula and its northern outskirt	Local masses near Aziro	—	1	1	—	—	1	3
		Tensi-yama	—	—	**1**	—	—	—	**1**
		Usami Volcano	—	**4**	**3**	**1**	—	—	**8**
		Taga Volcano	—	5 **5**	1	—	—	—	6 **5**
		Asitaka-yama	—	**1**	—	—	—	—	**1**
		Hakone-yama	—	—	5	1	—	—	6
		Amagi-san	**1**	**2**	**1**	**2**	**1**	**1**	**8**
		Omuro-yama Group	—	**1**	**1**	—	—	—	**2**
		Huzi-san	**2**	5	—	**1**	—	—	5 **3**
	Seven Idu Islands	Utone-sima	—	(1)	—	—	—	—	(1)
		To-sima	(1)	—	—	—	—	—	(1)
		Mikura-sima	—	**1**	—	—	—	—	**1**
		Nii-sima	—	—	—	—	—	1	1
		Kodu-sima	—	1	—	—	—	5	6
		Hatizyo-sima	—	**1**	—	—	—	—	**1**
		Miyake-sima	—	(2) **2**	—	—	—	—	(2) **2**
		O-sima	1	(2)4	—	—	—	—	(2)5
	Southern Islands	Kita Io-sima	1	—	—	—	—	—	1
		Io-sima	—	—	2	(1)*	—	—	(1)2
		Tori-sima	**1**	—	—	—	—	—	**1**
		Aoga-sima	—	—	—	**1**	—	—	**1**
Total			(1) 2 **8**	(8) 16 **22**	(1) 9 **12**	(1) 1 **12**	**4**	7 **2**	(11) 35 **60** = 106

* Analysis of 1914 pumice from the submarine volcano ("Sin Io-sima" volcano) near Minami Io-sima. ** Includes one from Ototo-sima.

The number of hitherto unpublished analyses are distinguished by gothic letters from those already published.

aphyric, or aphanitic rocks, since they were formed by direct consolidation of magmatic liquids. The groundmass of porphyritic rocks also is expected to come in the same category, provided its composition is known either micrometrically or chemically. With this in view, the ordinary variation diagram for rocks with various porphyricity may be called either a "rock variation diagram" or a "rock comparison diagram". Although a diagram of this kind may be of little use in petrogenesis, comparison of the general chemical characters of a series of rocks with another is facilitated by constructing such diagrams for both series and observing the similarities and differences between them.

Magma variation diagram. Of all the analyses given, those shown in Table XLV (each reduced to 100% as water-free) are the most suitable for fixing a magma variation diagram. They are of aphyric, or aphanitic rocks, entirely free from phenocrysts or with but a very small proportion of phenocrysts. Fig. 16 is a magma variation diagram for the 10 analyses so chosen. As will be seen from the figure, all the points representing these rocks lie close to smooth curves for the oxides.

Table XLV. Analyses of Aphyric, or Aphanitic, Rocks from Idu and Southern Islands (calculated to 100% as water-free).

	1	2	3	4	5	6	7	8	9	10
SiO_2	50·97	52·62	52·79	54·28	54·91	57·27	60·21	62·27	64·36	75·41
Al_2O_3	14·65	15·68	15·88	15·29	14·53	15·67	15·57	14·73	14·29	13·61
Fe_2O_3	3·80	5·62	4·42	2·88	1·87	4·63	4·69	1·77	1·79	0·77
FeO	10·16	8·22	9·94	10·41	12·35	7·17	6·02	7·77	6·77	0·72
MgO	5·44	6·14	4·13	3·64	3·04	3·03	2·19	1·84	2·14	0·32
CaO	11·67	8·09	8·98	8·41	8·07	7·41	6·49	6·12	6·73	0·94
Na_2O	1·84	2·02	2·47	2·87	2·60	2·98	2·89	3·55	2·79	4·53
K_2O	0·26	0·26	0·32	0·49	0·50	0·56	0·59	0·47	0·67	3·41
TiO_2	0·80	1·15	0·75	1·39	1·65	0·98	1·06	1·06	0·25	0·13
P_2O_5	0·13	0·06	tr.	0·11	0·16	0·08	0·11	0·20	tr.	0·08
MnO	0·28	0·14	0·32	0·23	0·32	0·22	0·18	0·22	0·21	0·08

1. Basalt (No. 91, Table XXXIII), O-sima.
2. Basalt (No. 24, Table IX), Kadono, Kita Kanomura, north Idu.
3. Basalt (No. 60, Table XXIV), Taga volcano.
4. Basalt (No. 88, Table XXXI), Miyake-sima.
5. Basalt (No. 83, Table XXX), Hatizyo-sima.
6. Andesite (No. 32, Table XIII), Aziro, north Idu.
7. Andesite (No. 54, Table XXII), Usami volcano.
8. Andesite (No. 76, Table XXIX), Aoga-sima.
9. Andesite (No. 5, Table II), Titi-sima.
10. Liparite (No. 111, Table XL), Ombasi-zima.

The groundmass compositions of some porphyritic rocks from Hakone, Taga, and O-sima were calculated by Kuno[95], with results as shown

95) Kuno has drawn a magma variation diagram for 19 analyses (including 10 of the calculated groundmass of porphyritic rocks) from Hakone, Taga, and O-sima. The left half of the writer's diagram naturally resembles Kuno's diagram though it was drawn independently before the latter was published. H. KUNO, *Bull. Volc. Soc., Japan*, 3 (1936), 53

in Table XLVI, in which the average groundmass composition of four

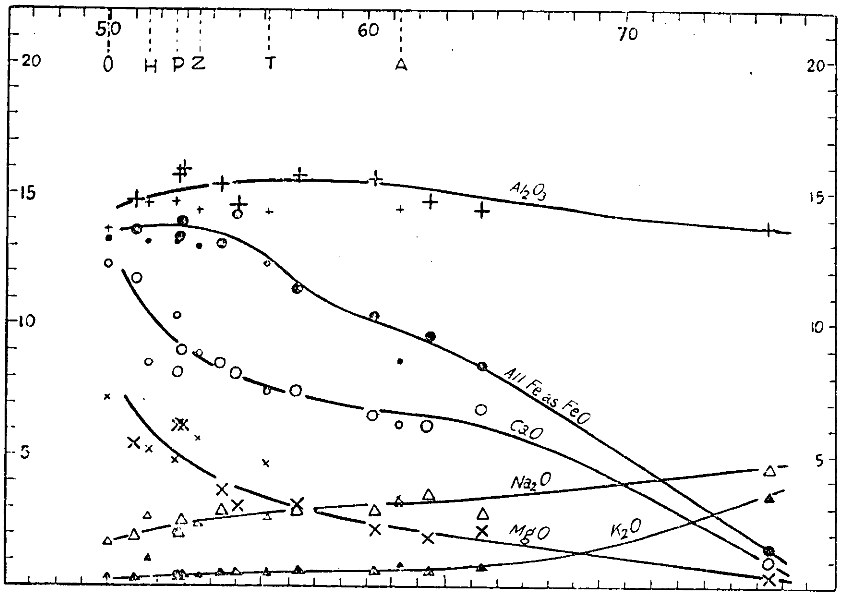

Fig. 16. Magma variation diagram of Idu and the Southern Islands.

The plots of the 10 analyses given in Table XLV are distinguished by larger symbols from the plots of the calculated groundmass compositions given in Table XLVI. P is the average of 4 O-sima basalts (Nos. 92, 93, 94, 96, Table XXXIII), each of which has a small proportion of phenocrysts.

Huzi basalts is also quoted[96]. They are plotted, together with the average of 4 slightly porphyritic basalts from O-sima, on the magma variation diagram, Fig. 16. As will be seen from the diagram, their indicative points, except those of Huzi basalts, lie fairly close to the curves of the diagram, although most of the points for magnesia deviate rather notably from the curve for that oxide. Since the analyses plotted on the diagram are of rocks that have been collected from widely separated points and horizons (Tertiary and Quaternary) within the region studied they suggest that the magmas that generated in the region during the whole course of volcanism from Tertiary to Recent belong to a common suite. According to the fourfold division of igneous rocks suggested by Peacock, the magma suite belongs to a calcic series, the alkali-lime index—that is, the silica value on the variation diagram at which the curves for total alkalies and lime intersect—being about 67[97]. The magma suite

96) H. TSUYA, *Bull. Earthq. Res. Inst.*, **13** (1935), 655.

97) The alkali-lime index calculated from the curves of Kuno's diagram is about 66·3.

Table XLVI. Groundmass Composition of the Porphyritic Rocks from O-sima, Huzi, Taga, and Hakone.

	O	H	Z	T	A
SiO_2	49·9	51·46	53·4	56·1	61·2
Al_2O_3	13·7	14·70	14·4	14·3	14·4
Fe_2O_3	3·2	4·52	5·1	3·3	2·6
FeO	10·4	9·07	8·4	9·3	6·3
MgO	7·2	5·10	5·7	4·7	3·4
CaO	12·3	8·51	8·9	7·6	6·2
Na_2O	1·7	2·73	2·4	2·7	3·3
K_2O	0·4	1·06	0·4	0·6	0·9
TiO_2	1·2	1·97	1·1	1·4	1·3
P_2O_5	tr.	0·34	0·2	0·2	0·1
MnO	——	0·27	——	——	——

O. Groundmass of the basalt, No. 90, Table XXXIII, from O-sima.
H. Average groundmass of 4 basalts, Nos. 101, 103, 104, 106, Table XXXVI, from Huzi.
Z. Groundmass of the basalt, No. 31, Table XIII, from Aziro, north Idu.
T. Average groundmass of one basalt, No. 62, and 3 andesites, Nos. 63, 64, 66, Table XXIV, from Taga.
A. Average groundmass of 4 andesites, Nos. 41, 43, 44, 45, Table XIX, from Hokone.

of the present region is thus the most calcic so far known in the world. In the shape of the curve for each oxide, excepting certain differences in the heights of the curve, the magma variation diagram resembles the variation diagram of the world's type-average (average basalt, andesite, dacite, and rhyolite) as calculated by Daly[98], the alkali-lime index for the latter being about 60.

The groundmass of the Huzi basalts is distinctly richer in alkalies and poorer in lime than the aphyric basalts (or the groundmass of the porphyritic basalts) from Idu[99]. So also does the aphanitic andesite from Huzi (No. 107, Table XXXVI, not plotted on the diagram, Fig. 16) compared with the aphyric andesites (or the groundmass of the porphyritic andesites) from Idu. The bulk compositions of the Huzi rocks differ in the same way from those of the Idu rocks. No explanation can be offered at present for these differences between the rocks of Huzi and Idu. It is worth noting, however, that the Huzi rocks bear a closer

98) N. L. BOWEN, *loc. cit.*, 123.

99) The affinities of the Huzi basalts with the "plateau basalt" and their differences from the O-sima basalts have already been pointed out in the previous paper of mine. H. TSUYA, *Bull. Volc. Soc. Japan*, 2 (1934), 149.

resemblance in chemical composition to rocks from the volcanoes Kayagatake-Kurohuzi[100] and Iidunayama-Kurohimeyama[101] than to the Idu rocks. Thus, these two volcanoes have yielded basaltic and andesitic rocks which, like the Huzi rocks, are distinctly high in alkalies and low in lime compared with the Idu rocks (Tables XLVII and XLVIII). They lie independently in the northern part of the Huzi volcanic zone

Table XLVII. Analyses of Rocks from the Volcanoes Kayagatake-Kurohuzi and Iidunayama-Korohimeyama. S. Tanaka, analyst.

	1	2	3	4	5	6	7	8
SiO_2	52·35	64·41	48·70	55·06	55·32	55·91	58·05	59·44
Al_2O_3	18·86	17·11	20·07	21·13	19·04	19·49	17·90	19·00
Fe_2O_3	3·68	2·57	3·62	2·28	2·25	2·33	3·50	5·24
FeO	5·29	2·62	7·16	5·61	5·93	5·70	2·64	1·42
MgO	4·42	2·02	3·95	2·15	3·92	3·56	2·56	2·15
CaO	8·32	5·80	10·56	7·55	8·22	8·08	7·05	6·85
Na_2O	3·62	3·57	2·73	2·27	3·26	2·56	3·01	2·58
K_2O	0·97	1·23	0·92	0·99	1·15	1·19	0·91	1·25
H_2O +	1·03	0·45	0·50	1·15	0·36	0·28	1·32	0·78
H_2O −	0·75	0·11	0·92	0·74	0·12	0·14	1·65	0·57
TiO_2	1·05	0·56	0·88	0·70	0·60	0·67	0·45	0·50
P_2O_5	0·27	0·13	0·14	0·24	0·20	0·24	0·16	0·20
MnO	0·10	0·07	0·16	0·15	0·14	0·15	0·10	0·18
Total	100·71	100·65	100·31	100·02	100·51	100·30	100·50*	100·16

* includes S 1·20.

1. Olivine-bearing augite-labradorite-andesite. Kayagatake.
2. Green-hornblende-andesine-dacite. Kurohuzi.
3. Augite-olivine-basic-bytownite-basalt. Iidunayama.
4. Olivine-bearing two-pyroxene-bytownite-andesite. Iidunayama.
5. Augite-bearing brown-hornblende-hypersthene-bytownite-andesite. Kurohimeyama.
6. Two-pyroxene-bytownite-andesite. Kurohimeyama.
7. Brown-hornblende-two-pyroxene-dacite. Kurohimeyama.
8. Basaltic-hornblende-labradorite-andesite. Iidunayama.

—namely Kayagatake-Kurohuzi about 50 km NNW. of Huzi and Iiduna-Kurohimeyama about 170 km NNW. of Huzi—but beyond the region that we concern in this paper. It is inferred, therefore, that the Huzi volcanic zone in a wide sense may be divided petrologically into two parts —the northern part (inland part) including the inland volcanoes Huzi-

100) M. Ichiki, *Bull. Earthq. Res. Inst.*, **7** (1929), 335.
101) S. Yamada, *ibid.*, **12** (1933), 96.

Table XLVIII. Comparison of Lime and Alakli Contents of Rocks from Huzi, O-sima, Kayagatake and Iidunayama.

	Huzi		Iiduna	Kayagatake	O-sima	
	No. 99	No. 106	3	1	No. 90	No. 95
SiO_2	49·60	51·30	48·70	52·35	48·02	51·45
CaO	8·80	9·76	10·56	8·32	14·14	10·71
Na_2O	2·90	2·55	2·73	3·62	1·28	1·23
K_2O	0·93	0·71	0·92	0·97	0·30	0·37

san, Kayaga-take, Yatuga-take, Iiduna-yama, Kurohime-yama, Myoko-zan, etc., in the central Japan, and the southern part (oceanic part) including, in addition to the volcanoes in the Idu peninsula, the insular and submarine volcanoes of the Seven Idu Islands and the Southern Islands. These two parts—northern and southern—of the so-called Huzi volcanic zone may be referred to respectively as the *Huzi Volcanic Zone proper* and the *O-sima Volcanic Zone*, after the most celebrated volcanoes in the respective parts. So far as data now available are concerned, *the rocks from the Huzi volcanic zone proper are relatively high in alkalies and low in lime, while those from the O-sima volcanic zone, with a few exceptions of local masses of alkaline rocks, are relatively low in alkalies and high in lime.* Asitaka and Hakone, which may be included respectively in the Huzi volcanic zone proper and the O-sima volcanic zone, lie near the possible boundary separating the two zones. Whether or not the petrological differences of these two zones are in any way connected with some differences in the geotectonic structure of them is a matter of pure speculation.

Rock variation diagrams. When the analyses of a series of rocks with various porphyricity have been plotted on a variation diagram, it is usually seen that the points for each oxide scatter considerably from any smooth curve, so that a better understanding of the general chemical characters of a number of such rocks can be had from type-averages of the analyses than from individual analyses, Although, in the case of the silica content, the analyses now under investigation may be divided broadly into four groups corresponding respectively to four petrographic types—basalt, andesite, dacite, and liparite—, the silica range of each group so divided is wide and consequently overlaps that of its neighbour. In calculating the type-averages, therefore, the analyses (each reduced to 100% as water-free) were divided from the purely chemical point of view into seven types, as follows:

Chemical type	Silica range in %	Rock type
I	<50	Basalt
II	50< <55	Andesite-basalt
III	55< <60	Andesite
IV	60< <65	Dacite-andesite
V	65< <70	Dacite
VI	70< <75	Liparite-dacite
VII	75<	Liparite

The analyses for each chemical type were then averaged.

In according with the foregoing plan, the type averages for the Tertiary and the Quaternary rocks were calculated separately with

Table XLIX. Type Averages of the Tertiary Porphyritic Rocks from Idu and Bonin.

	I	II	III	IV	V	VI*
SiO_2	49·28	51·38	57·49	62·30	66·72	73·31
Al_2O_3	19·53	19·86	17·67	16·60	15·99	13·94
Fe_2O_3	2·60	3·35	3·15	3·25	3·30	1·26
FeO	7·81	6·35	5·25	3·53	1·83	1·64
MgO	6·47	4·59	4·03	2·86	1·93	0·51
CaO	11·38	10·96	8·12	6·05	4·33	2·64
Na_2O	1·76	2·13	2·60	3·39	3·56	3·96
K_2O	0·16	0·27	0·65	1·08	1·59	2·23
TiO_2	0·76	0·85	0·79	0·69	0·59	0·36
P_2O_5	0·10	0·07	0·09	0·13	0·08	0·07
MnO	0·15	0·19	0·15	0·12	0·08	0·08

* Two analyses with $SiO_2 > 70\%$ were averaged as one type.

Table L. Type Averages of the Quaternary Porphyritic Rocks from Idu and the Southern Islands.

	I	II	III	IV	V	VI	VII
SiO_2	49·21	51·93	56·80	61·83	68·39	71·06	77·29
Al_2O_3	18·51	18·64	17·56	16·67	15·09	14·70	13·31
Fe_2O_3	3·12	3·27	2·44	3·00	1·20	1·12	0·78
FeO	7·97	7·33	6·07	4·01	3·10	2·15	0·46
MgO	5·74	4.54	4·14	2·71	1·41	1·30	0·22
CaO	11·46	10·19	8·29	6·25	4·30	3·49	1·28
Na_2O	2·13	2·33	2·94	3·28	4·22	3·60	4·35
K_2O	0·47	0·44	0·67	1·22	1·46	2·06	2·12
TiO_2	1·04	1·05	0·81	0·75	0·56	0·36	0·10
P_2O_5	0·12	0·12	0·13	0 16	0·13	0·08	tr.
MnO	0·23	0·16	0·15	0·12	0·14	0·08	0·09

results as given in Tables XLIX and L respectively, the averages being

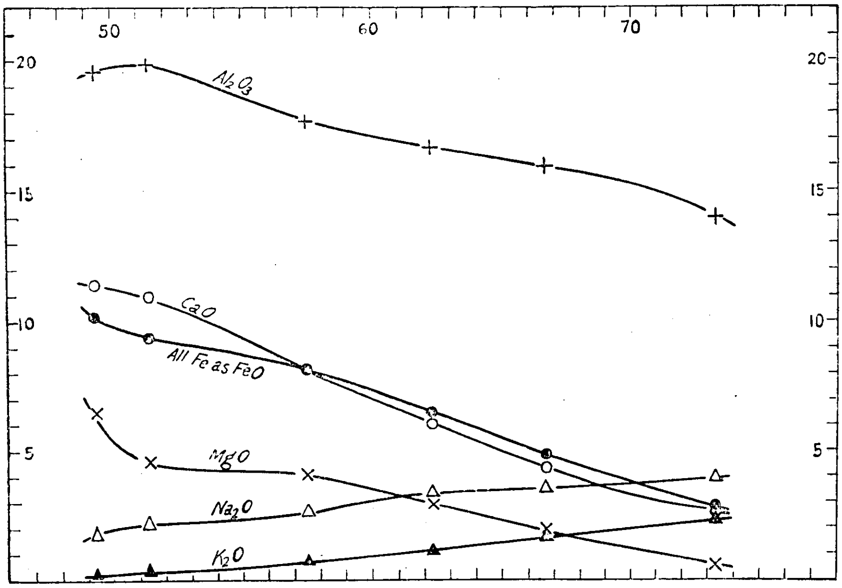

Fig. 17. Variation diagram of the Tertiary porphyritic rocks from Idu and Bonin.

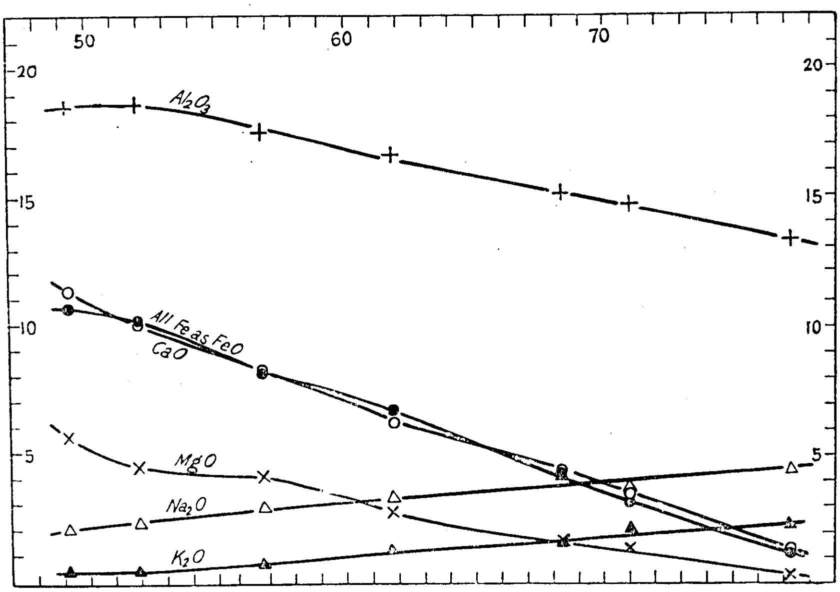

Fig. 18. Variation diagram of the Quaternary porphyritic rocks from Idu and the Southern Islands.

based on the porphyritic rocks only, the alkaline rocks (potash-liparite and trachyandesite) calling for separate treatment. Had the type averages been based on both the porphyritic and non-porphyritic rocks, they would have showed slightly lower alumina and slightly higher iron-oxides than the results given in the above tables.

In Figs. 16, 17, the type averages are plotted of the Tertiary and the Quaternary rocks respectively. The figures for the two are much alike, the corresponding curve in one being almost a duplicate of the other. The alkali-lime index is 65·2 for the Tertiary series and 65·7 for the Quaternary series.

The lavas of the Amagi volcano form a graded series extending from basalt, through andesite, to dacite. The serial relations are admirably shown by the analyses (Table XVII) of the eight representative rocks that have been plotted as a variation diagram, Fig. 19. The

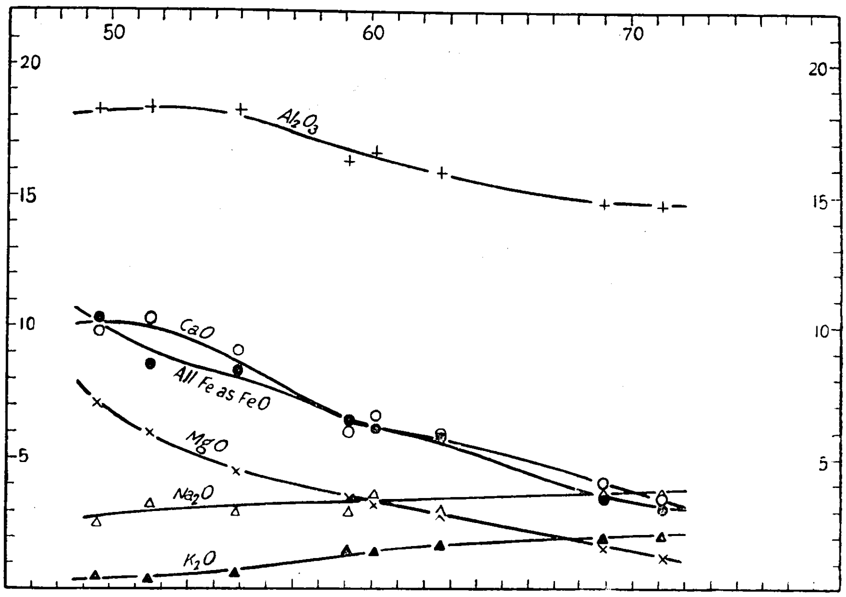

Fig. 19. Variation diagram of rocks from the Amagi volcano, Idu.

alkali-lime index for the Amagi series is 65·2. A comparison of the diagram with either of the previous two diagrams, Figs. 17, 18, shows that both are much alike without any systematic difference between them, thus supporting the view that all the rocks from the region, with the rare exception of the alkaline rocks, belong to a common suite, and that their variation is represented by that of the well-differentiated series of the Amagi volcano.

Upon comparing any one of the rock variation diagrams of Figs. 17, 18, 19 with the magma variation diagram, Fig. 16, the former will be found to show a decidedly higher alumina curve and lower iron-oxides curve. The deviation is more marked in the low silica side of these diagrams that in the opposite side. This accords with the fact that

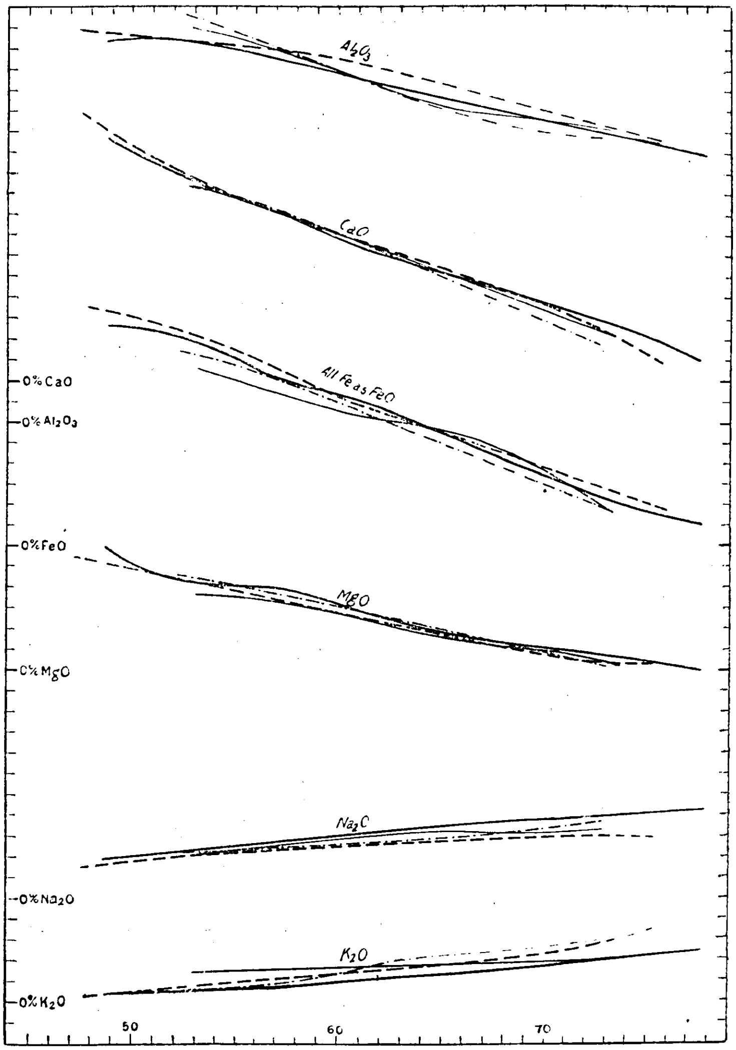

Fig. 20. Variation diagrams:
Thick full lines—the Quaternary series of Idu and the Southern Islands.
Broken lines—Yamada's type-averages of the Japanese volcanic rocks.
Thin full lines—Ryukyu Volcanic Zone.
Broken lines with dots—Medial Volcanic zone of NE. Japan.

basic rocks are generally more porphyritic with phenocrysts of calcic plagioclase and earlier members of mafic minerals, hence diverge more from possible magma liquid than acid rocks.

Assuming that the variation diagram, Fig. 18, for the Quaternary series represents the general chemical variation in the rocks from the region under discussion, it is compared in Fig. 20 with similar diagrams for rocks from two other volcanic zones in Japan, namely, Koto's Medial Volcanic Zone of NE. Japan[102], which includes the volcanoes Asama, Kusatu-Sirane, Nikko-Sirane, Nantai, Bandai, Iwate, Komagatake (Hokkaido), Usu, Tarumai, etc.; and the Ryukyu Volcanic Zone, which includes the volcanoes Aso, Kirisima, Sakura-sima, Io-sima (Osumi), etc.[103] In the figure they are also compared with the variation diagram of the type averages of the Japanese volcanic rocks[104].

As will be seen from the above figure, the variation in the rocks from the region under discussion follows, on the whole, that of the rocks from either one of the two other volcanic zones and that of the Japanese volcanic rocks, exhibiting the common characteristics that distinguish them from rocks of other regions of the world, namely, higher lime, lower alkalies, and larger ratios of iron oxides to magnesia. But, as contrasted with the type-averages of the Japanese volcanic rocks and with the rocks of the two other volcanic zones, the rocks of this region are slightly higher in soda but lower in potash[105]. The alkali-lime indices for the medial zone of NE. Japan, the Ryukyu zone, and for the Japanese type-averages, are 65·0, 65·7, and 66·2, respectively.

102) B. KOTO, *Jour. Geol. Soc., Tokyo*, **23** (1916), 1.

103) The variation diagrams for these zones have been drawn only for the analyses made during recent years, since 1925. The sources of these analyses are as follows:

Asama—H. TSUYA, *Bull. Earthq. Res. Inst.*, **11** (1933), 575.

Kusatu-Sirane—H. TSUYA, *ibid.*, **12** (1933), 52.

Komagatake—H. TSUYA, *ibid.*, **8** (1930), 238.

Usu and Tarumai—J. SUZUKI, *Bull. Volc. Soc., Japan*, **2** (1935), 123.

Nantai—S. TSUBOI and K. SUGI, *Guide-Book, Third Pan-Pacific Sci. Congr.*, Tokyo, (1926).

Nikko-Sirane—two new analyses, yet unpublished.

Aso—H. TSUYA, *Jour. Geol. Soc., Tokyo*, **36** (1929), 17.

Sakura-sima—K. YAMAGUCHI, *ibid.*, **35** (1928), 195, 241.

Io-zima—H. TANAKADATE, *Proc. Imp. Acad.*, **11** (1935), 371.

104) S. YAMADA, *Jour. Geol. Soc., Tokyo*, **37** (1930), 1.

105) Kuno has remarked that the basalts from the Huzi Volcanic Zone in general are poorer in alkalies, especially potash, than the basalts from the volcano Alaid and its new adjunct Taketomi-sima—a volcano in the NE. part of the Tisima (Kurile) Volcanic Zone. H. KUNO, *Jap. Jour. Geol. Geogr.*, **12** (1835), 153. The basaltic andesites from Tokati-dake, another volcano in the SW. part of that zone, are also high in alkalies compared with the former. H. TSUYA and F. TADA, *Bull. Earthq. Res. Inst.*, **2** (1927), 49.

Variation in the norm composition. The Q:F:M, Or:Ab:An, and Wo:En:Fs: ratios in the norms of the rocks from the region under discussion are plotted respectively in Figs. 21, 22, 23, in each of which they are compared with similar ratios for the type-averages of the Japanese volcanic rocks.

As will be seen from Fig. 21, the Q:F:M ratios of the aphyric rocks differ from those of the phyric rocks, the difference being more marked

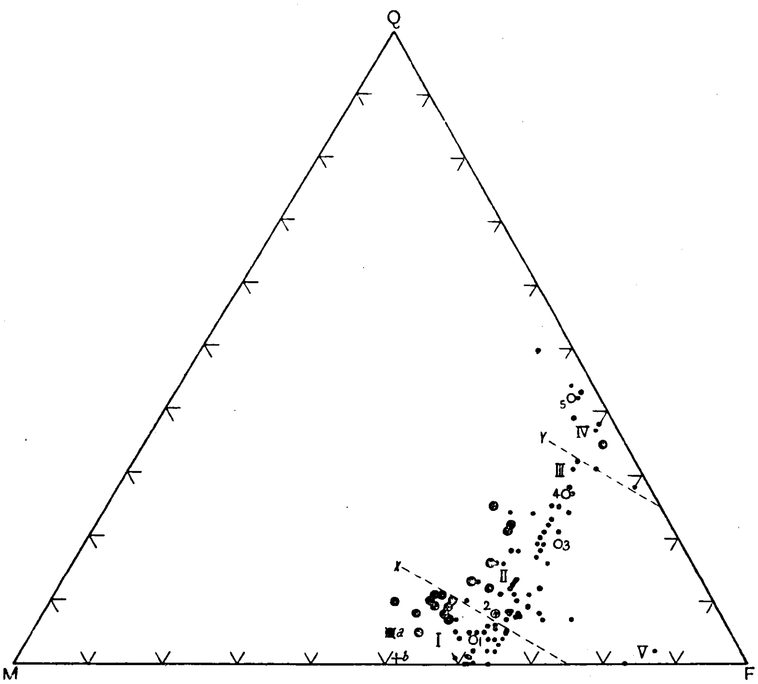

Fig. 21. Q:F:M ratios (wt. %) of rocks from Idu and the Southern Island. Q—normative quartz, F—normative feldspar, M—normative mafic minerals.

Large solid circles: Aphyric rocks.
Small solid circles: Phyric rocks.
Open circles: Yamada's type-averages of the Japanese volcanic rocks.
Crosses: a—average of 14 Deccan basalts.
b—Daly's average of 43 plateau basalts.

I. Basalt field. II. Andesite field. III. Dacite field. IV. Liparite field. V. Trachyandesite field. The lines X, Y, on which the ratios (Q+F)/(M+F) equal respectively to 0·75 (or 3/4) and 1·33 (or 4/3), are the most suitable boundaries that separate the andesite field from the basalt field and the liparite field respectively.

in the basic rocks (basalts and basaltic andesites) than in the more acid rocks. The aphyric basalts are poorer in F and richer in Q and M than the phyric basalts. This accords with the fact that the phyric basalts of the present region contain usually large quantities of plagioclase phenocrysts. The line X, every point on which has (Q+F)/(M+F)=0·75 (or 3/4), is the most suitable boundary that separates the basalt field (I) from the andesite field (II). The other line Y, every point on which has (Q+F)/(M+F)=1·33 (or 4/3), is the most suitable boundary that separates the liparite field (IV) from the dacite field (III) (cf. the introduction of this paper). The points for the aphyric basalts

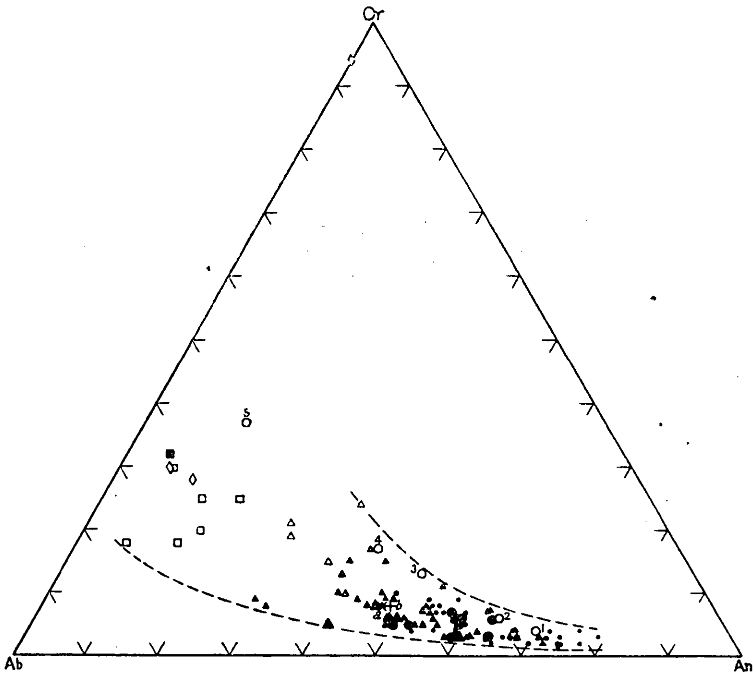

Fig. 22. Or:Ab:An ratio (wt. %) of rocks from Idu and the Southern Islands. Or—normative orthoclase, Ab—normative albite, An—normative anorthite.

Large solid circles: Aphyric basalts.
Small solid circles: Phyric basalts.
Large solid triangles: Aphyric andesites.
Small solid triangles: Phyric andesites.
Open triangles: Dacites.
Open squares: Phyric plagioliparites.
Solid square: Aphanitic liparite.
Open diamonds: Trachyandesites:
Solid diamond: Potash-liparite.
Open circles: Type-averages of the Japanese volcanic rocks.

lie more close to the plot of the average of 14 Deccan basalts[106] than to the plot of Daly's average of 43 basalts in the world[107].

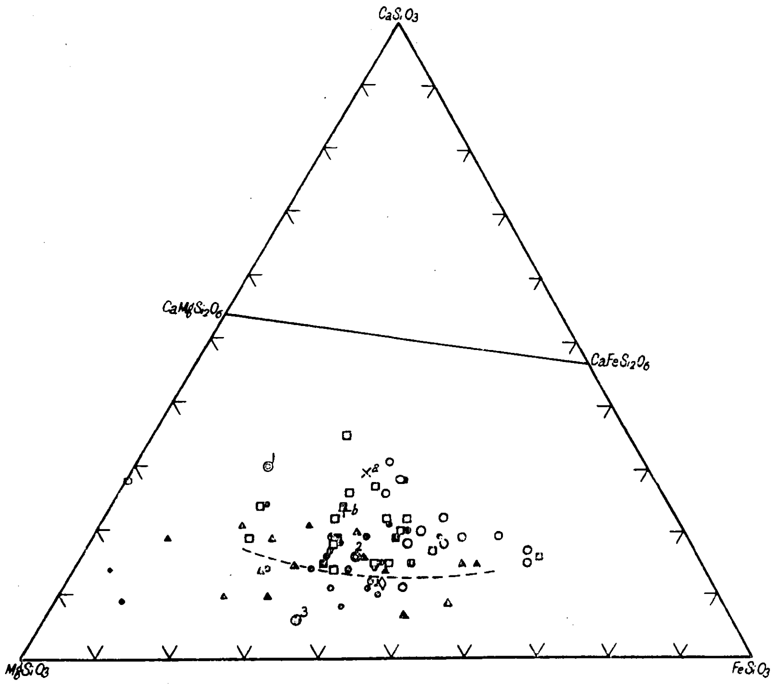

Fig. 23. Wo: En: Fs ratios (wt. %) of rocks from Idu and the Southern Islands. Wo—normative wollastonite, En—normative enstatite, Fs—normative ferrosilite. Rocks with normative corundum (C) are omitted.

Open circles: Aphyric rocks.
Solid circles: Olivine-hypersthene-augite-bearing rocks.
Solid triangles: Hypersthene-augite-bearing rocks.
Open squares: Olivine-augite-bearing rocks.
Solid squares: Olivine-bearing rocks.
Open diamond: Hypersthene-andesite from Asitaka.
Crosses: a—average of 14 Deccan basalts.
b—average of 43 world's plateau basalts.
Double circles: Type-averages of the Japanese volcanic rocks. 1—type basalt, 2—type basalt-andesite, 3—type andesite.

Fig. 22 shows that the normative feldspars of rocks from the region under discussion are, as a whole, poorer in Or than the type averages of the Japanese volcanic rocks. The normative feldspars of the aphyric basalts are poorer in An and richer in Ab and Or than those of most of the phyric basalts, but compared with the normative feldspar of the

106) L. L. FERMOR, *Rec. Geol. Surv., India*, 48 (1935), 344.
107) R. DALY, Igneous Rocks and the Depths of the Earth. New York (1933), 17.

average of Deccan basalts, the former are richer in An[108].

The normative pyroxenes, Fig. 23, of most of the aphyric rocks are richer in Fs than those of most of the phyric rocks, the Fs-richest pyroxenes being shown by the norms of the aphyric basalt (No. 83) from Hatizyo-sima, the almost-aphyric andesite (No. 76) from Aoga-sima, and of the vitrophyric trachyandesite (No. 118) from Io-sima. Comparing Figs. 23 and 14, we find that the normative pyroxenes of most of the phyric rocks correspond in composition to the mixtures of the modal pyroxenes (augite, hypersthene, and groundmass pigeonite) of the same rocks, whereas the normative pyroxenes of most of the aphyric rocks correspond in composition to the modal pigeonites of the same rocks. The brocken line in the figure is the two-pyroxene boundary[109], namely, the boundary that separates the field of augite (±olivine)-bearing rocks (upper side of the line) from that of hypersthene (±olivine)-bearing rocks (lower side of the line). The points for hypersthene-augite (±olivine)-bearing rocks lie scattered through both fields, while those for olivine-basalts and most of the aphyric rocks are included in the field of augite (±olivine)-bearing rocks. The normative pyroxenes of most of the basalts from the present region are poorer in Wo and richer in Fs than the normative pyroxenes of the plateau basalts (average Deccan basalt and Daly's average of world's plateau basalts).

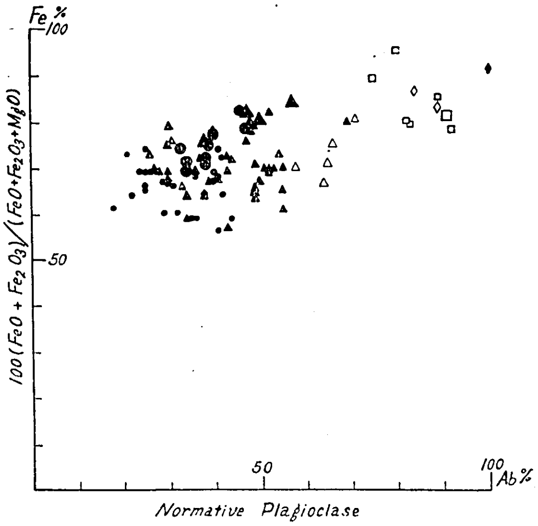

Fig. 24. Variation in the Fe-values, $100\times(FeO+Fe_2O_3)/(FeO+Fe_2O_3+MgO)$, in relation to the compositions of the normative plagioclases of rocks from Idu and the Southern Islands. The symbols are the same as those in Fig. 22.

Variation in the Fe-values. The variation in the Fe-values—ratios of iron-oxides to iron-oxides plus magnesia in the analyses of rocks—is

108) The normative feldspars of Huzi basalts lie in composition more close to those of Deccan basalts compared with the normative feldspars of basalts from Idu and the Southern Islands.

109) S. TSUBOI, *Jap. Jour. Geol. Geogr.*, **10** (1932~33), 77.

shown in Fig. 24, in which the Fe-values (in per cent) are plotted with the compositions of normative plagioclases as abscissae. Although this values inclease as a whole as the normative plagioclases become richer in Ab, the increase is not marked. It has been pointed out elsewhere[110] that, as in the case of the actual paragenic relations between modal pyroxenes and modal plagioclases, the relations between the Fe-values and the compositions of normative plagioclases differ according to the particular genetical lineages of rocks (cf. Fig. 13 and the discussion thereof).

IV. SUMMARY AND CONCLUSIONS.

When volcanic activity began in the region studied is a matter of conjecture. There is no doubt, however, that volcanoes were already in existence in Eocene times, seeing that the Ogasawara (Bonin) Islands are composed almost exclusively of andesitic rocks, both explosive and effusive, with a few intercalated Eocene limestones. If these islands were located on the submarine ridge that underlies the insular volcanoes of the Huzi volcanic zone, it would be more than likely that the Ogasawara volcanics are products of the earliest recognized forerunner of volcanic activity in that zone, but their more or less outlying position seem to militate against this view. However, notwithstanding the lack of positive evidence indicating structural similarity, the writer presents the above view as a possible explanation, because the Ogasawara andesites show the same general characteristics, both microscopical and chemical, as the allied rocks from the Huzi volcanic zone.

The first indisputable record of volcanic activity in the Huzi volcanic zone dates to early Miocene. This seems to be the case not only with the Idu region, in the study of which the writer is chiefly concerned, but also with the much larger region of the "fossa magna", of which Idu forms but a small part. Through the whole of the period that succeeded it, the same general sequence of volcanic activity has beeu maintained in most parts of the fossa magna with certain local differences. It is therefore highly probable that, although local volcanic activity had already manifested itself in Eocene times in the Ogasawara Islands, more active and more regional activity had started contemporaneously with the tectonic disturbances, the result of all which is the fossa magna, which severed the geologic continuation between southwestern and northeastern Japan. As to whether or not the Ogasawara Islands were sub-

110) H. TSUYA, *Bull. Earthq. Res. Inst.*, 7 (1929), 332; *Proc. Third Pan-Pacific Sci. Congr.*, Tokyo, **1** (1926), 2396.

jected to the same disturbances, the writer is unable to say.

The lower Miocene volcanism in Idu, which occurred beneath the sea of that time, is represented by a thick series of highly altered volcanics (lavas and pyroclastics), referred to as the Yugasima beds (or the propylite series). This series consists for the most part of basaltic and andesitic rocks, although dacites and liparites are also represented, especially in the upper horizons of the series. The succession of these rocks implies considerable time, during which certain structural deformations might possibly have recurred, resulting in several periods of volcanic accumulation. But its actual duration is a question we have no means of answering at present, the only precise datum being the faunal evidence (*Lepidocyclina* limestone from Simo-Siroiwa and *Miogypsina* limestone from Nasimoto), which assigns certain dacitic volcanics lying some distance above the base of the series to lower Miocene.

The propylite series is invaded by numerous minor intrusives (dikes, sheets, and necks) of various rock-types—diabase, porphyrite, basalt, andesite, dacite, and liparite (quartz-porphyry). Although these intrusives are evidently later than the propylite series, not all of them were formed contemporaneously. The basic intrusives (including diabase, porphyrite, basalt, and andesite) are mostly older, all being altered in the same way as the propylite series in which they are found, whereas the more acid intrusives are mostly somewhat younger, being probably correlated with the acid volcanics that overlie unconformably the propylite series.

The lower Miocene volcanism was followed, probably during upper Miocene, by submarine eruptions of liparites and dacites, with subordinate andesites, all of which are distributed mostly in south Idu and rather locally in north Idu. As just mentioned, some of the minor intrusives in the propylite series, especially those of acid rocks, might be the feeders of the upper Miocene volcanics. In contrast with the propylite series, these upper Miocene volcanics are either quite fresh or are but little altered.

The foregoing phase of volcanism was succeeded, most probably during lower Pliocene, by a subordinate phase of activity characterized by minor intrusions (dikes) and extrusions of andesites. Regarding volcanism during this period, however, we are largely in the dark as only a few rocks in Idu have been identified with that period.

In the uppermost Pliocene, eruptions of basalts, dacites, and andesites, occurred only locally in Idu, and these were again exclusively submarine.

At the close of the Tertiary or the beginning of the Pleistocene, Idu peninsula was subjected like the other regions in the fossa magma to crustal movement, generally in the sense of uplift, and it was not until some time after this movement, which raised so much of the Tertiary sea-floor into land, that Pleistocene volcanism became vigorous. This volcanism was concentrated mainly in the northern part of the peninsula, while in the southern part, Tertiary volcanism was succeeded by that relative quiescence which marked the Pleistocene aud Recent epochs.

The first phase of lower Pleistocene volcanism is thus represented by eruptions of basalts, andesites, and dacites, all occurring in the forms of tuff and tuff-breccia that now occupy the bulk of the lacustrine deposits (Ono beds, Simo-Hata beds, and Simo-Tanna beds) accumulated during that period on the erosion reliefs of the Tertiary formations. It was followed at the end of lower Pleistocene and in the upper Pleistocene, when the lower Pleistocene deposits had been more or less deformed, by eruptions of central volcanoes. The volcanoes Tensi, Usami, Taga, Yugawara, Asitaka, Amagi, Hakone, and others in the northwestern part of the Idu peninsula yet unstudied, as also the dacitic masses in the vicinity of Atami, are all products of this phase of activity, with however certain differences in the times when the activities began and in the period for which they lasted. The basaltic Omuro-yama group represents the last volcanism in the peninsula, which probably occurred some time later when the older volcanoes Tensi, Usami, Taga, etc., were subjected to more or less dislocation and dissection; while the numerous hot-springs there represent a stage of post-volcanic thermal activity. So far as its visible part is concerned, Huzi may date from a much later age, probably Recent. That one of the earliest lava-flows from the volcano is younger than the older somma of Hakone has been definitely proved by field evidence.

All the insular volcanoes of the Seven Idu Islands and the Southern Islands are undoubtedly products of Quaternary volcanism, whatever may be the history of their foundation. Of these, the dissected basaltic volcanoes Utone-sima, To-sima, Mikura-sima, Higasi-yama (Hatizyo-sima), Tori-sima, and Kita Io-sima probably date to Pleistocene. With the exception of Tori-sima[111], we have no record of eruption of any of them. The basaltic volcanoes O-sima, Miyake-sima, Nisi-yama (Hatizyo-sima), and Aoga-sima have been active in Recent times, all displaying lava out-flows in historic times. The liparitic volcanoes Nii-sima and

111) The only recorded activity of this island is a mere paroxismal explosion of phreatic origin that occurred in 1902.

Kodu-sima, according to records, also have had one eruption each.

With the exception of the rarer alkaline rocks (potash-liparite and trachyandesite), the rocks that erupted in the course of the volcanism just outlined above have all several characteristics in common, mineralogical as well as chemical, with however certain differences due to local peculiarities. Whether chemically or mineralogically, there seems to be no systematic difference between the Tertiary and Quaternary series, excepting that the former usually has a higher water-content than the latter. A petropraphic similarity in the Ogasawara rocks to allied rocks from Idu is quite apparent.

Of the various rock-types represented, the basalts and basaltic andesites are most predominant besides being regional in distribution, while the others are rather local. These regional rock-types are usually characterized by phenocrysts of calcic plagioclase (anorthite to calcic labradorite) and pyroxenes (augite or hypersthene or both), with or without olivine, in a groundmass containing less calcic plagioclase (bytownite to sodic labradorite), pigeonite, magnetite, and one or more of silica minerals (cristobalite, tridymite, and quartz). It is notable that most of the young lavas from Miyake-sima, Hatizyo-sima, Aoga-sima, etc., are poor in phenocrysts or almost aphyric, while the old lavas from these volcanoes are sometimes strongly porphyritic with large phenocrysts of anorthite. Like the latter, most of the lavas from the Pleistocene basaltic volcanoes (Kita Io-sima, Tori-sima, Mikura-sima, etc.), as also the basalts in the Tertiary series, are strongly porphyritic, sometimes with large phenocrysts of anorthite, the less porphyritic or almost-aphyric rocks being rarely met with.

The variation diagram of the aphyric and aphanitic rocks (magma variation diagram) from both the Tertiary series and the Quaternary volcanoes shows smooth curves for all oxides, showing the probable variations in the magmatic liquids from which most of the volcanic rocks of the present region seem to have been derived.

The variation diagram of type-averages of the Tertiary porphyritic rocks is identical with the same diagram of the Quaternary porphyritic rocks. The two are again similar to the variation diagram of the well-differentiated rocks of one volcano, namely, Amagi, with the result that either of these two diagrams will represent the chemical variation for rocks of the entire region. The variation on the whole follows that of type-averages of the Japanese volcanic rocks, thus showing the common characteristics that distinguish them from corresponding type-averages of the world's igneous rocks: namely, in containing higher lime, lower alkalies, and larger ratios of iron-oxides to magnesia. But, as compared with type-averages of the Japanese volcanic rocks, the corresponding type-averages of the present region are usually a little higher in soda but lower in potash. So also do the latter as compared with the rocks from the two other volcanic zones in Japan, namely, the medial volcanic zone of NE. Japan and the Ryukyu volcanic zone.

The rocks of the region studied, except a few alkaline rocks, may be treated as a connected suite, all belonging to what Peacock calls the "calcic series", with high alkali-lime index, 62·5 for the Tertiary series and 65·7 for the Quaternary series. If the entire suite has originated from a common magma, we would have to admit that acid rocks such as liparites were derived by processes of differentiation from a basaltic magma. During the whole period since the Tertiary, however, volcanism in the present region has been alternately basaltic (or andesitic) and liparitic (or dacitic). This recurrence of similar rock-types points to one of two explanations: (1) either a body of acid magna that had separated out during early Tertiary or before it had remained throughout succeeding ages as an available source of the acid rocks that erupted during several distinct epochs, or (2) that differentiation to an advanced stage had proceeded repeatedly along definite lines at wide intervals of time. Although, of these two alternatives, the former is the more simple, the latter process also must have operated at certain local centres in the region, seeing that well-differentiated rocks intimately related, structurally as well as petrologically, occur in certain central volcanoes such as Amagi.

Although the rocks of the so-called Huzi volcanic zone may be treated on the whole as a connected magmatic suite, we find certain differences among them due to local peculiarities, mineralogical as well as chemical. Thus the Huzi rocks differ from the allied rocks of Idu and the Southern Islands in that the former are distinctly higher in alkalies, especially potash, and lower in lime than the latter. So also do the rocks from the volcanoes Kayaga-take and Iiduna-yama compared with the allied rocks of Idu and the Southern Islands. Although these two volcanoes lie farther north of Huzi, they belong in a wide sense to the Huzi volcanic zone. From these facts in view, the writer believes that the Huzi volcanic zone may be divided petrologically into two subzones, namely, the northern inland zone referred to as the *Huzi Volcanic Zone proper*, and the southern oceanic zone referred to as the *O-sima Volcanic Zone*. The Huzi volcanic zone proper includes the inland volcanoes Huzi, Kayaga-take, Iiduna-yama Kurohime-yama, and many others (Myoko-zan, Yatuga-take volcano group, etc.) yet unstudied, all of which are linearly arranged in a NNW.-SSE. direction on the fossa magna, while the O-sima volcanic zone includes, in addition to the volcanoes of the Idu peninsula, the insular and submarine volcanoes of the Pacific—the Seven Idu Islands and the Southern Islands. To generalize, *although the rocks of the so-called Huzi volcanic zone, with the exception of a few alkaline rocks, belong on the whole to a calcic series, the rocks from its northern inland part—the Huzi volcanic zone proper—are higher in alkalies and lower in lime than those from the southern oceanic part—the O-sima volcanic zone.* Whether or not the chemical differences of these two sub-zones are in any way connected with some differences in the geotectonic structure and in the nature of rocks of their foundation is a question we have no means of answering at present.

The O-sima volcanic zone just proposed has two kinds of alkaline rocks, namely, potash-liparite (Manzo-yama and Kodu-sima) and trachyandesite (Io-sima). As to the genesis of the potash-liparite, a possible explanation was offered in an earlier paper[112]. As to the genesis of the trachyandesite, little can be said with certainty at present except that its local distribution in the Volcano Islands group and the occcurrence in it of porphyritic olivine and augite, both of which are similar in microscopic characters to the respective minerals in the basalts from the same group, make it possible that it is genetically related to these basalts. In this connection the distribution of the sites of volcanic vents in the Volcano Islands group calls for notice. Although the general trend of this group is from NNW. to SSE.—that is, the trend of the so-called Huzi volcanic zone—, Io-sima, besides being elongated in outline from NE. to SW., has numerous solfataras which are aligned on fissures running in the same direction. The trachyandesitic submarine volcano, "Sin-to Volcano", also lies on a line running NE.-SW. through the basaltic volcano, Minami Io-sima. Similar relation holds between the basaltic and liparitic volcanoes of the Seven Idu Islands[113]. Therefore, if the sites of volcanic vents were fixed by dislocation or lines of weakness in the earth's crust, these two trends—the NNW.-SSE. trend of the basaltic (or andesitic) volcanoes and the NE.-SW. trend of the liparitic (or dacitic) and trachyandesitic volcanoes—may be a surface manifestation of the underground structure of the region, the former representing a principal fracture (Daly's "abyssal fissure")[114] connected with deep-seated reservoirs of a regional basaltic magma, and

112) H. TSUYA, *Bull. Earthq. Res. Inst.*, **7** (1929), 313.

113) H. TSUYA, *Bull. Earthq. Res. Inst.*, **10** (1932), 255; *Proc. Third. Pan-Pacific Sci. Congr.*, Tokyo, **1** (1926), 2399.

114) R. DALY, Igneous Rocks and the Depths of the Earth. New York (1933), 242.

the latter a subsidiary fracture connected with shallow-seated reservoirs of local differentiates, either liparitic or trachyandesitic, from the basaltic magma.

In conclusion, a few remarks should be added here regarding the alteration through secondary changes of the Tertiary volcanics in Idu, although on this point the writer has not yet been able to gather much information. As already noted, the only rocks that are altered to any important extent are these of the propylite series and the minor intrusives in that series. The common secondary minerals in them are chlorite, calcite, sericite, epidote, limonite, haematite, pyrite, zeolite, albite, and quartz, with amorphous silica, two or more of these minerals always occurring together. The alteration, however, has not advanced to the same degree and in the same way throughout the series. In some parts of the series, most of the rocks are almost unchanged, although, as a rule, incipient alteration of the constituent minerals is found only to a very slight extent, while in many others the alteration is considerable, resulting in virtual disappearance of the original structure of the rock, whether viewed microscopically or in the field. We often find that complete recrystallization has occurred, showing a mosaic of quartz and feldspar, with occasional flakes of sericite and chlorite.

Since the alteration of the propylite series has advanced farther not only at and near the contacts with minor intrusives in the series, but also in the intrusives themselves than at distances away from the contacts, it could only have been caused by local and chemical effects, that is to say, by chemical reactions between the original rocks of the series and some hydrothermal solutions[115] that possibly generated in a post-magmatic stage subsequent to the minor intrusions rather than by regional and dynamic agencies. The metamorphic changes justifying the name, propylite, were probably caused by a sodiferous hydrothermal solution, possibly related to the basic intrusives (diabase, porphyrite, basalt, and andesite). The product of this intense mineralization which is so economically important and which has been worked in several parts of the propylite series in the region, was generated probably by a hydrothermal solution rich in silica generally related to the acid intrusives (dacite and liparite or quartz-porphyry). K. Sugi divided the metamorphism of the Misaka series of the Nakagawa district adjoining the northern part of Hakone, which is intruded by a large quartz-diorite mass, and which is a lower Miocene series correlated with the propylite series of Idu, into two stages: dynamic metamorphism caused by a

115) T. KATO, *Jap. Jour. Geol. Geogr.*, 6 (1928), 31.

mountain-building movement generated within a geosynclinal area before the intrusion of the quartz-diorite and contact metamorphism at the time of that intrusion[116]. The writer is of the opinion that the dynamic metamorphism, if it did occur, must have been due merely to local stresses that generated outside the boundary of the quartz-diorite mass at the beginning of the intrusion of that mass, seeing that the metamorphism is quite local in the Misaka series both at and near the contacts with the intrusive, and that such metamorphism is never met with in the propylite series of Idu, which belongs to the same geotectonic unit as the Misaka series.

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20. 富士火山帶の火山作用, 特に伊豆及び南方諸島の地質及び岩石に就いて

地震研究所　津　屋　弘　逵

此論文では富士火山，伊豆半島，南方諸島等の地質及び岩石に就いて，筆者が既に發表した研究に其後の研究結果を加へ，所謂富士火山帶特に其富士火山以南小笠原火山列島に至る地域に於ける第三紀及び其後の火山作用を地質學的並びに岩石學的見地より考察した．卽ち，先づ同地域に行はれた火山作用を古第三紀火山作用，新第三紀火山作用，及び第四紀火山作用に分ち，各期の代表的火山岩類を噴出順序及び種類に依りて細別記述し，次に全岩類の主要造岩鑛物の顯微鏡的性質を總括し，最後に其化學成分上の特質を説明し，所謂富士火山帶は岩石學的に見て第三紀及び第四紀の噴出物を通じて他の火山帶とは異なつた全般的特質を有するが，少くとも第四紀の火山のみに就いて見たる富士火山帶は富士火山及び以北の內陸火山を含む支帶と伊豆半島及び以南の海洋火山を含む支帶とに分たれ，各支帶は夫々岩石學的(特に化學成分上の)特質を示し，前者を狹義の富士火山帶，後者を大島火山帶と稱する事の至當なるを論じた．

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116) K. Sugi, *Jap. Jour. Geol. Geogr.*, **9** (1931), 87.