Volcano Ôshima, Idzu.

By

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With 6 Plates and 42 Text-figures.

I. Introduction.

The present paper embodies the results of the writer's geologic investigation of the insular volcano Ôshima, in the province of Idzu[1], conducted under the auspices of the Earthquake Investigation Committee and of the Imperial University of Tôkyô.

The field observations on which the present work is based were carried out chiefly during two months in the summer of 1916, and supplementarily by making two trips in 1917 and 1918. The laboratory study was performed during the writer's third year course in the Imperial University and in the year after graduation.

In its present state the work is still far from complete, but with the hope of contributing to the vulcanology of Japan the writer has decided to publish the results so far obtained, deferring the making up of deficiencies to a later opportunity.

Here the writer wishes to tender his hearty thanks to Professor B. Kotô for his great kindness in reviewing the manuscript and for the valuable advice he has constantly given.

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1) 伊豆大島

Geographic Sketch.

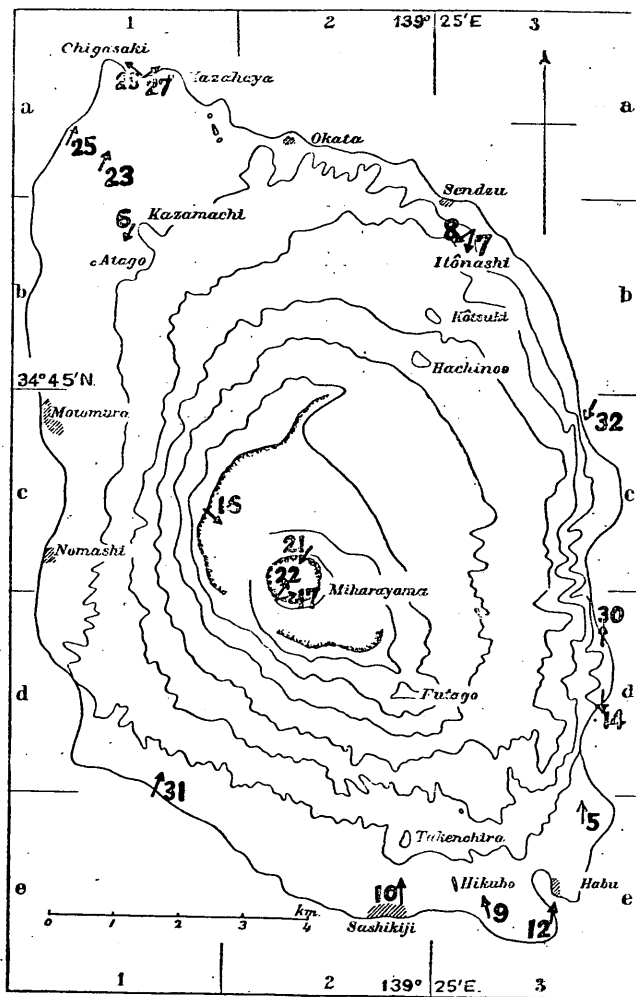Ôshima in the province of Idzu is the largest member of a

Fig. 1. Index map to scenic illustrations in the text.

    In the above index map, the thick numerals indicate text-figure numbers; the arrows indicate the direction in which the scenes given in the text were photographed. The squares, into which the map is virtually divided, will be referred to in the legends of those illustrations by the numerals and letters on its margin.

group of volcanic islands off the Idzu peninsula, commonly called Idzu Shichitô[1], or the Seven Idzu Islands, and lies in the sea of Sagami[2] about 110 km. S.S.W. of Tôkyô, extending over 34°40.5′–47′N. lat. and 139°21′–27.5′E. long.

The island is nearly elliptic in shape with a length of about 15 km. from N.N.W. to S.S.E., a breadth of about 8.5 km. from E.N.E. to W.S.W., and a circumference of about 50 km. It has an area of 103.8 sq. km. and a volume of 22.6 cub. km. (Calculated after Simpson's method.)

The coast line is simple, being indented only at the inlet of Habu[3] (3e) in the S.S.E. corner. The shore for the most part ends abruptly with precipitous cliffs whose elevations vary up to more than a hundred meters. Around the whole coast there are only two sandy beaches of any extent, one on the west, Yuno-hama[4] (1c), and the other on the south, Sonohama[5] (1e).

The island itself is a gigantic rheuclasmatic volcano elevated 755 m. above sea level or about 850 m. above the supposed base on the sea floor. It consists of a central homate called Mihara-yama[6] (2c), with an active crater at its summit, and a somma-separated by an extensive barren atrio, with such a dreary aspect that it is called " Sabaku "[7] (the desert) by the islanders.

The ring-wall of the somma is incomplete, lacking its north, eastern and southwestern sides; and from both these gaps barren strips of land extend toward the sea shores.

The outer slopes of the insular volcano vary greatly in differ-ent directions. On the western side, the slope is regular and makes a fine concave curve, the incliuation being about 25° near the summit and decreasing uniformly toward the foot; on the

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1) 伊豆七島   2) 相模灘   3) 波浮   4) 湯ノ濱   5) 砂ノ濱
6) 三原山   7) 沙漠

east it is abnormal, varying from 15° to less than 5°, and continuing from the top half way down, until, on approaching the shore, it becomes suddenly as steep as 40°. The skirt of the mountain is especially well developed on the northwestern side, whereas on the southeast it shows a complex irregular relief. The further continuation (submarine) of the mountain slopes is traceable far along the coast, inclining steeply toward north and east but gently in the opposite directions.

The relief of the cone surface is further diversified by a number of parasitic knobs on its flanks, but as a whole the shape of the island is that of a homate, and its outline viewed from a distance conveys a strong impression of the volcanic origin of the island (Fig. 2).
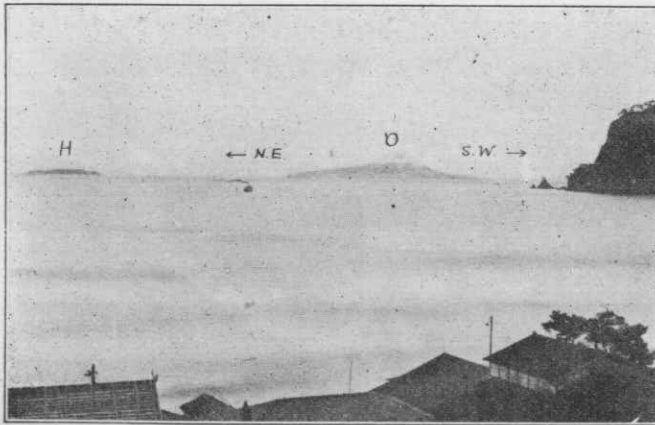

Fig. 2. The island of Ôshima (O), viewed southeastwards from Atami in the Idzu peninsula. Notice the asymmetric form of the volcano. H....Hatsushima, a small island near Atami.

The climate of the island is equable and rather moist, but the land being built up of loose materials, is dry and lacking in rivers and streams of any importance, as is usual in young volcanoes. Such being the case, rain water is generally used for drinking purposes.

The island was inhabited as early as in the prehistoric stone age by a people belonging to an unknown race whose remains are now found under a lava flow exposed on the precipitous cliff about 0.8 *km.* to the south of the village of Nomashi[1] (1c). It is not known when the island became inhabited by the Japanese, but history shews that it was a place of banishment from about the 7th century till the end of the 18th.

At present, the population of about 7400[2] is distributed in six villages—Motomura (1c), Nomashi (1c), Okata (2a), Sendzu (3a), Sashikiji (2e), and Habu (3e).[3] In the island peculiar customs are found in coiffures, dress, and the general mode of living, especially of the women.

Previous Work.

Ôshima has been celebrated in many respects from early times and studied by not a few whose works have been made use of largely.

The first geologist to visit Ôshima (twice in 1877) was EDMUND NAUMANN[4]. With him were TSUNASHIRÔ WADA[5] and JOHN MILNE[6]. The main object of their visit was to see the actual state of the volcanic eruption which had lasted from December 1876 to February 1877, at which time they also made a general geologic survey of the island.

According to NAUMANN, who also gave a brief petrography

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1) 野増

2) The population of the island was 7356 according to the statistics in 1918.

3) 元村　野増　岡田　泉津　差木地　波浮.

4) "Die Vulcaninsel Ooshima und ihre jüngste Eruption," *Zeitschrift der Deutschen geologischen Gesellschaft*, Bd. XXIX., S. 364, 1877.

NAUMANN's opinion was reviewed in the following works by WADA and MILNE:—

5) "Notes on the Volcano Ôshima," *Gakugei Shirin*, Vol. I., No. 1, 1877 (in Japanese).

6) "The Volcanoes of Japan," *Transactions of the Seismological Society of Japan*, Vol. IX., Part. II., 1883; *Geological Magazine*, Decade II., Vol. I., No. 5, 1887.

of the island, the whole history of the volcano may be divided
into three periods. (1) The first period is that represented by the
crater of Habu[1] (3c) which he considered to have been submarine
till the vent was completely congealed. (2) The second period is
marked by the extinction of the Habu crater and the birth of a
hypotbetical volcano at the northern part of the present Ôshima.
The supposed remains of this volcano he considered to have been
completely buried later. He assumed the existence of this northern
volcanic body to explain the abnormal topography of the island,
writing :—

" ....Die Convexität des nördlichen Abhanges lässt sich gewiss
nicht besser erklären, als durch Annahme einer älteren besonderen Erup-
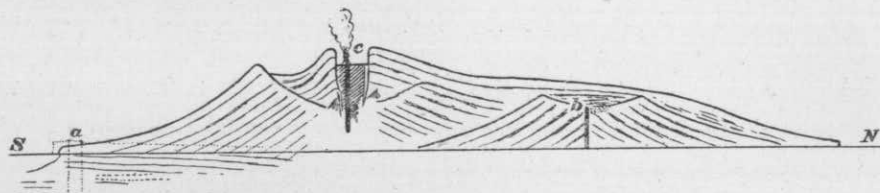tionsaxe für diesen Theil des Berges...."

Fig. 3. NAUMANN's ideal profile of Ôshima (N.-S.).
a····The crater of the first period.   b····The crater of the second period.
c··· The crater of the third period.

(3) The third period was represented by the present crater of
Mihara.[2]

In 1886, SHÔGO NISHIYAMA[3] wrote a brief note on the topo-
graphy of Ôshima and the state of the crater at that time ; but
the geology of the island was not studied further after NAUMANN's
visit until 1895, when NAOMASA YAMASAKI[4] made his trip.

He noticed the abnormal complex topography of the eastern

1) 波学 An inlet at the S.S.E. end of the island.
2) 三原
3) " Explanatory Text to the Geologic Sheet of Idzu." 1886 (in Japanese).
4) " Report on the Volcano Ôshima," Report Erthq. Invest. Com., No. 9, pp. 33—53, 1896.
in Japanese).

part of the island in contrast to the regular slope of the western part, and tried to explain this by supposing the existence of older volcanic bodies to the east of the present Ôshima. On this assumption, he divided the whole volcanic history into two stages: the first stage being represented by the hypothetical volcanoes which he considered to have been mostly submerged in water, so that only high parts of the crater wall were above the sea level as in the island of Santorin; the second stage being represented by the present volcanic body which consists of a somma and a central cone.

The harbour of Habu[1] (3e), according to him, was one of the craters in the first stage, the hills standing to the north of Habu being the remains of the older volcanic bodies.

He moreover recognized the tectonic line running through the island in the direction N.N.W.—S.S.E., along which the central crater and a number of parasitic cones are linearly arranged.

A brief description of the rocks was also given.

It is an interesting fact that some remains of the prehistoric stone age were discovered in 1901, under a lava flow (Pl. VI. BC 3) imbedded in a rugged cliff of Tatsunokuchi[2] (1d) not far from the village of Nomashi[3] (1c). YÔNOSUKE ÔTSUKI[4] and RYÔZÔ TORII[5] were sent at the time to examine these and to report on what they saw there.

Next year (1902), DENZÔ SATÔ and NOBUYO FUKUCHI[6] visited

1) 波浮   2) 龍ノ口   3) 野増

4) "Human Remains under a Lava of Ôshima in the Province of Idzu," *Jour. Geol. Soc Tôkyô*, Vol. VIII., No. 99, 1901 (in Japanese).

5) "Remains of the Stone Age under a Lava of Ôshima in the Province of Idzu," *Jour Geogr. Tôkyô*, Vol. XIV., Nos. 159 & 160, 1902 (in Japanese); *Jour. Anthropol. Soc. Tôkyo*, Vol XVII., p. 320, 1902 (in Japanese).

6) "Geological Notes on Ôshima, Idzu," *Jour. Geogr. Tôkyô*, Vol. XIV., Nos. 161 & 162, 1902 (in Japanese).

the island and made some geological observations. They pointed out that the harbour of Habu[1] (3e), which was thought by the earlier writers to be the crater of an old volcanic body, might be an explosion crater formed at the foot of the main cone of Ôshima ; and that Hikubo[2] (3e), a depression lying to the west of Habu and hemmed in by a horse-shoe shaped wall, might be also of like origin. They further attributed the formation of a great gap on the northeastern side of the ring-wall of the somma to an explosive action.

Cape Chigasaki[3] (1a), an elevated spot at the northwestern end of the island, was noticed by them for its peculiarity and was considered to be either a parasitic cone or an old volcanic body.
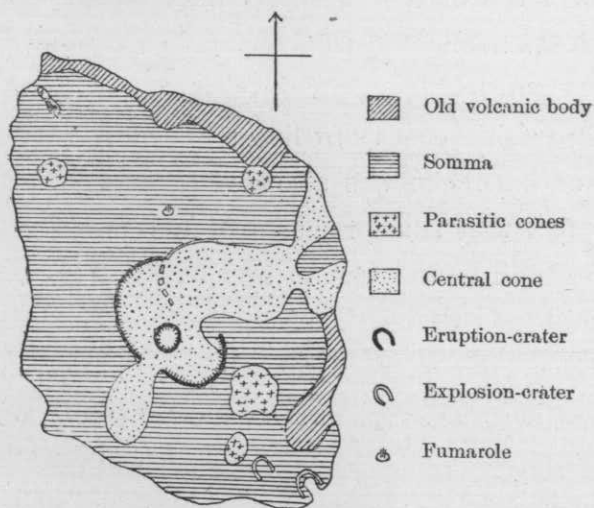
FUKUCHI[4] visited the island again in 1905, when a destructive earthquake occurred there. A geologic sketch map presented by him with his report shows the existence of old volcanic bodies lying to the north and to the east of the island (Fig. 4).

☒ Old volcanic body

▤ Somma

▨ Parasitic cones

▦ Central cone

☊ Eruption-crater

☋ Explosion-crater

⚑ Fumarole

Fig. 4. FUKUCHI's geologic sketch map of Ôshima.

In 1907, SEIJI NAKAMURA, TORAHIKO TERADA, and DEN'ICHIRÔ ISHITANI[5] studied the

1) 波浮   2) ヒクボ   3) 千ケ崎 or 乳ケ崎

4) " Geological Observation on the Earthquake of Ôshima in 1905," *Report Earthq. Invest. Com.*, No. 53, p. 87, 1906 (in Japanese).

5) "The Volcano of Ôshima, its Past and Present," *Proceedings of the Tôkyô Mathematico-Physical Society*, Vol. IV., p. 293, 1908 ; *Jour. Geogr. Tôkyô*, Vol. XX., Nos. 238-239, pp. 682 & 786, 1908 (in Japanese).

physical aspects of the volcano and made a topographic survey of the inside of the crater (Fig. 18, p. 33).

In 1909, IMMANUEL FRIEDLAENDER[1] spoke of the island as follows :—

(1) The volcanic activity began with the eruption of many craters along the east coast of the present Ôshima. The volcanoes of this stage are too old (probably of the Tertiary period) for the position of their craters to be pointed out now, but the hills in that part consisting of " andesite " must represent the remains of those volcanoes.

(2) In the next stage, the vulcanism was displayed along " the weak line " running in the direction N.N.W.—S.S.E. : a great cone of the somma was formed very gradually by successive extrusions of " olivine-bearing augite-andesite, very near to basalt"; Habu crater (an explosion-crater) (3e), Futago[2] (2d), and Itônashi[3] (2b) were then formed on the flanks of the main cone ; after that, the huge crater at the top of the present somma was formed either by explosion or by depression, while its northeastern quarter was blown away by explosion ; the central cone, Mihara[4], as well as the parasitic craters, Hikubo (3e) and Takenohira[5] (2e), were born in a later stage.

In 1909–'10, RYÔICHI ÔHASHI[6] denied the existence of any old volcanic bodies which all previous writers had supposed to underlie the present volcano.

He considered that the lavas exposed on the cliff opposite to Fudeshima[7] (3d) and those on the cliff west of Okata[8] (2a) be-

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1) " Ueber einige japanische Vulkane," *Mitteilungen der Deutschen Gesellschaft für Natur- und Völkerkunde Ostasiens*, Bd. XII., Teil 1, S. 49-59; 1909.

2) 二子   3) 伊東無   4) 三原   5) 岳ノ平

6) " On the Geology of Volcano Ôshima," *Jour. Geol. Soc. Tôkyô*, Vol. XVI., p. 519, 1909, Vol. XVII., pp. 15, 56, and 96, 1910 (in Japanese).

7) 筆島   8) 岡田

long to the earliest stage. Subsequently, at intervals, repeated extrusion of " black lavas " took place, followed by the ejection of ashes, sands, lapilli, etc. and the extrusion of " gray lavas ". In this way a great cone (the present somma) was built up, but a depression took place at its summit and a central cone appeared after repeated eruptions.

He divided the volcanic history into two stages : the *olivine-bearing* stage represented by " Fudeshima lava ", " Okata lava ", and " black lavas " ; and the *olivineless* stage represented by " gray lavas " and the lavas of the central cone.

Very recently the same writer[1] advanced the view that the area adjacent to the island is rising, or has risen, more rapidly in the east than in the west, thus explaining the asymmetrical form of the volcano,—that the eastern slope is gentler than the western.

During the eruption in 1912–'14, the island was visited by FUSAKICHI ÔMORI[2], SEIJI NAKAMURA[3], DENZÔ SATÔ[4], and YÔZÔ OKA-MURA[5], who reported on the volcanic eruptions.

KYÔTOKU FUJI[6] also visited the actual scene of activity and measured the temperature of flowing lava by means of the HOLBORN-KURLBAUM optical pyrometer and found it to be from 995°C. to 1048°C. in the red hot portion, and 857°C. in the dull portion.

1) R. ÔHASHI, " On the Asymmetrical Form of Ôshima," *Jour. Geol. Soc. Tôykô*, Vol. XXIV. No. 281, p. 72, 1917 (in Japanese).

2) " Preliminary Report on the Eruption of Volcano Mihara," *Report Earthq. Invest. Com.*, No. 81, 1915 (in Japanese).

3) " The Eruption of Volcano Mihara, Ôshima, Idzu," *Tôyô Gakugei Zasshi*, Nos. 368 & 369, 1912 (in Japanese).

4) " The Present Activity of the Mihara Volcano," *Jour. Geogr. Tôkyô*, No. 239, 1912 (in Japanese).

5) " Report on the Eruption of Volcano Mihara," *Report Geol. Surv. Japan*, No. 48, 1914)in Japanese).

6) " A Method of Determining the Melting or Solidifying Range of Temperatures of Lava by the Measurement of the Electric Conductivity," *Proceedings of the Tôkyô Mathematico-Physical Society*, 2nd Ser., Vol. VII., No. 14, 1914.

II.   Structure and Morphology.

Structural Outline.

A general structural idea of the volcano may be formed at a glance. In attempting, however, to discover the inner structure in detail, much difficulty arises as the mountain is covered with ejecta on its sides and is still young in dissection.

Such being the case there seems to be no other way than to conjecture the structure from the exposures on the sea cliffs which afford good natural profiles, as well as from the morphographic features which are so perfectly preserved in their original form, and are consequently so very intimately related with the geologic structure, that they aid us much in the structural investigation.

It is mainly from these two features that the history of the building up of the volcano has been traced, and the results will be stated in the following chapters. Before the detailed descriptions of the structure are given a general summary will be briefly outlined here.

The volcano is a composite stratified one consisting of double homates—a somma and a central one—and is built up of numerous layers, alternately accumulated of rheumatitica and clasmatica of basaltic nature, which have been extruded repeatedly without long intervals of rest between any two successive periods of extrusion.

The somma has several satellitic bodies. On the flanks of the main body of the somma there are many parasitic knobs: Atago[1] (1b), Kazamachi[2] (1b), Mitsumine[3] (1a), on the northwest:

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1) 愛宕   2) 風待   3) 三峯

Hachinoo[1] (2b), Kòtsuki[2] (3b), Itònashi[3] (2b), on the northeast and Futago[4] (2d), Takenohira[5] (2e), on the southeast. Two small explosion-craters, Habu[6] (3e) and Hikubo[7] (3e), are at the southeastern foot.

Besides these, there are, along the western half of the northern coast, small igneous bodies strikingly demolished which are considered to have been born in the middle of the volcanic history of the island and are now structurally separated from the main body of the somma.

The top of the somma is truncated with a ring-wall that surrounds a huge oval caldera. The wall is not completely closed but there are two gaps, a greater one on the northeastern and a smaller one on the southwestern side.

The active central homate Miharayama[8] (2c) stands in the caldera and its volcanic products not only cover the ground within the encircling wall but have also spread down to the sea shore through the gaps in the wall.

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

Volcano Ôshima

The main body
- The somma—A homate truncated at its top with a ring-wall surrounding a caldera, with parasitic cones and explosion-craters on its flanks.
- The central cone (Miharayama)—A homate with an active crater, standing in the caldera.

The demolished igneous bodies along the western half of the northern coast of the island.—The small satellitic igneous bodies which are considered to have been formed during the development of the somma.

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1) 蜂ノ尾   2) コオツキ   3) 伊東無   4) 二子
5) 岳ノ平   6) 波浮   7) ヒクボ   8) 三原山

Building Materials of the Somma.

The best opportunity for the structural study of the main part of the somma is afforded by the exposures on the sea cliffs. Those observed by the writer are shown in Pl. VI., from which one can see that the somma has been built up by many repeated eruptions. We can enumerate over a hundred lava flows separated by the layers of ejecta—ashes, sands, lapilli, etc. Undoubtedly some of those which appear to be separate flows may represent merely branches of one flow, but considering that what we see on the sea cliffs are only those parts of many lava flows that have been exposed by marine abrasion, their actual total number must be very great.

These lavas are of basic nature, and owing to their fluidity all of them are very thin, seldom exceeding 10 *m.* and ranging mostly from a few to several meters, sometimes even being less than half a meter in thickness.

Although all of these lavas bear close resemblance to one another in their petrographic characters, yet they may be distinguished into four rock-types.

Petrographic descriptions and intermagmatic relations will be dealt with later (pp. 67—125), but the general characteristics of each type are:—

(1) *Basaltic bandaite almost free from phenocrysts of mafic minerals.*

Lavas of this type predominate and are of the widest distribution.

Phenocrysts of bytownite, varying in amount, are scattered through the aphanitic groundmass, gray to black in colour, consisting of labradorite, augite, magnetite, and a small quantity of

glass. In the great majority of lavas of this type, small olivine phenocrysts are sporadically found in negligible amount, though in some they are lacking.

(2) *Hypersthene-basaltic bandaite.*

Lavas of this type are exposed only on the sea cliff marked *II* (1c) on the geologic map (Pl. V.), to the south of Motomura[1] (1c), and are intercalated by the lavas of the first type (Pl. VI. BC 2).

This type does not differ from the preceding in its essential characters but is characterized by the presence of hypersthene phenocrysts in moderate quantity.

(3) *Two-pyroxene-basaltic bandaite.*

This is seen only at Gyôja[2] (3c ; marked *III* on the geologic map; Pl. VI. FG 6), in three layers, each about 20 m. in thickness, intercalated by layers of ejecta. This type is marked by the presence of phenocrysts of both hypersthene and augite in moderate quantity, besides those of plagioclase, as well as by the entire absence of olivine crystals.

These lavas appear to have been extruded from a flank opening while the main one was pouring out lavas of the first type.

(4) *Hypersthene-bearing augite-olivine-bytownite-basalt.*

This occurs only at the locality marked *IV* (3d), on the geologic map (Pl. V.), on the east coast (Pl. VI. EF 5). The exposure shows clearly that the lavas of this type were discharged from a local vent during the extrusion of lavas of the first type (p. 77).

The characteristic feature is the presence of olivine and augite crystals in abundance.

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1) 元村   2) 行者

Of the above four types of the somma lavas, the first pre-dominates, being exposed almost at every part of the island, while the other types are very much limited in their occurrence, being found only locally and intercalated with lavas of the first type, and even so only on the sea cliffs and never on the ring-wall of the somma. This suggests that the lavas of the second to fourth types were discharged as the " effluent " flows in DANA'S term. Even the lavas of the first type may perhaps not all have come from the summit crater, but some may have been discharged from flank openings.

The question as to how these different rock-types were formed will be discussed later (pp. 118—120).

Fragmental materials are by no means less important than lavas in the building up of the somma. According to their origin they may be divided into two kinds: (*a*) those originating in the magma itself before its consolidation—*juvenile ejecta*, and (*b*) those coming from the disturbed and shattered portions of the preexisting rocks.

Most of the ejecta are juvenile ejecta (*a*), and are of all grades in size,—volcanic ashes, sands, lapilli, and bombs.

The blocks belonging to (*b*) are found imbedded in the layers of volcanic ashes and sands, forming agglomerate beds. Ejecta of various kinds are exposed in alternate layers on the sea cliffs, on the walls of valleys, on road cuttings, and on the crater walls. These appear, so far as observed, to be subaerial deposits, there being no trace of any sorting action by the water on the pieces of ejecta.

Of the various volcanic products, special mention must be made of scoriæ, which are brown to black, consisting almost wholly of glass, and having been formed by the sudden chilling

of the magma. The surface of the lava is often scoriaceous. Some of the scoriaceous lapilli may have originated from the dough in the crater ; but another origin is also probable. It is conceivable that as the lava flowed out its surface consolidated while the interior was still in the molten state, so that when the molten pieces were ejected they broke the surficial crust of the lava,—hence the formation of scoriæ. Scoriæ considered to have been formed in this way were often observed, being associated with the lavas or accumulating on them as small spatter cones. Examples of such accumulation of scoriæ are seen at Kagamihata[1] (1c) and at Akahage[2] (1b).   -

In short, the somma consists of many lavas and ejecta, the result of repeated volcanic actions, which accumulated in alternating layers. The effect of these and later ejections is, that the surface of the ground is so entirely covered that it is impossible to estimate the structure of the core of the volcano and the distribution of each lava flow.

Steep Slope along the East Coast.

A remarkable feature of the island is a belt of steep slope, about 40° in inclination, along the east coast running in the direction from north to south (Fig. 5). On examining this part it became clear that it does not represent the original slope, since the lavas and ejecta layers are cut by it, but the geologic explanation for this peculiar feature could not be found except by inferences based on its topography.

ÔHASHI[3] considered this steep slope to be the remains of the old sea cliff formed by marine abrasion. This explanation, however, does not seem to agree with some of the observed facts :

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1) 鏡端   2) 赤禿
3) "On the Geology of Volcano Ôshima," *Jour. Geol. Soc. Tôkyô*, Vol. XVI., 1909 (in Japanese),

(1) the steep slope has been formed only on the east shore and nowhere else, and there is no apparent justification for supposing
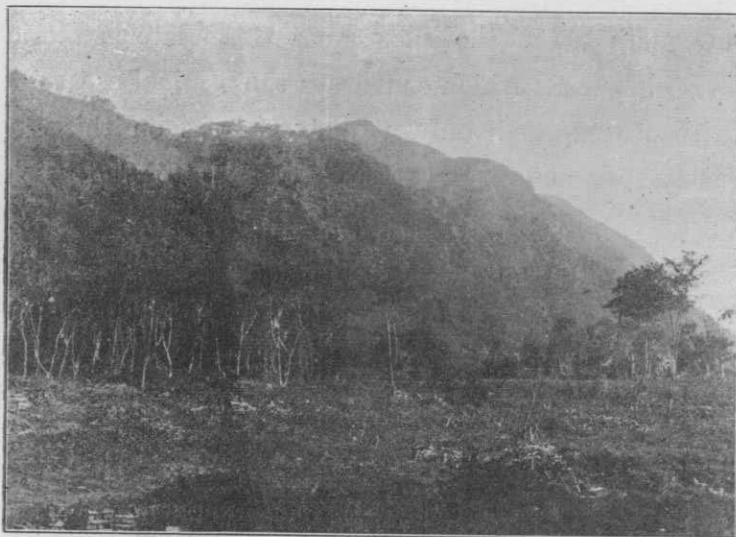

Fig. 5. The steep slope along the east coast of the island, viewed northwards from the flat land at the southeast end, consisting of overflowed lavas and ejecta (Fig. 1, 3e).

that this side of the sea coast has been specially subject to wave action; (2) there is no such platform on the sea bottom of the eastern side of the island as would be present if the steep slope in question had been formed by marine abrasion.

To explain these and other observed facts, the writer proposes another origin, which seems to be more probable, i.e., that this steep slope along the east coast of the island was formed by depression of the eastern part of the volcano along a weak line running in N.–S. direction.

As to the time of its formation, it was no doubt before the completion of the development of the somma, since many somma lavas have obviously overflowed on this steep slope. The flat land at the southeastern end of the island is a composite delta consist-

ing of alternate layers of overflowed lavas and ejecta. Pouring out of lavas and ejection of fragments from the local side vents have taken place at several points along the eastern foot of the steep slope so that for the most part these later materials have concealed the materials which constitute the original escarpment surface. These are exposed only at a few places on this steep side under consideration and on the sea cliff opposite to Fudeshima[1] (3d).

Vulcanism on the Flanks of the Somma.

Parasitic Cones.—On the flanks of the somma, there are a number of small elevations which are considered to be parasitic cones simply from their outer forms. Their morphographic features are :—

	Names of parasitic cones	Elevations above sea level (in m.)	Elevations above the surrounding area (in m.)	Basal extension (in sq. m.)	Inclination of the side-slope
The north-western flank	Atago (愛宕 1b; Fig. 6)	121.5	80	175,000	20°
	Kazamachi (風待 1b)	128	70	283,000	,,
	Mitsumine (三峯 1a)				
	The south-eastern-most hill	58	20	25,000	,,
	The middle hill	56	30	25,000	,,
	The north-western-most hill	43.4	30	18,000	,,
The north-eastern flank	Hachinoo (蜂ノ尾 2b; Fig. 7)	419	120 in N. 25 in S.	237,000	,,
	Kôtsuki (コオツキ 3b; Fig. 7)	315	65 in N. 20 in S.	138,000	,,
	Itônashi (伊東無 2b; Fig. 8)	128	90 in N. 40 in S.	138,000	,,
The south-eastern flank	Futago (二子 2d; Fig. 9)	With a double summit 617.9 & 640	250 in S E. 60 in N.W.	950,000	,,
	Takenohira (岳ノ平 2e; Fig. 10)	231.4	160	411,000	20°-23°

Unfortunately, most of these elevations are entirely covered

Fig. 6. Atago, a parasitic knob on the northwestern flank of the somma, as seen southwestwards from the foot of Kazamachi. (Fig. 1, 1b)
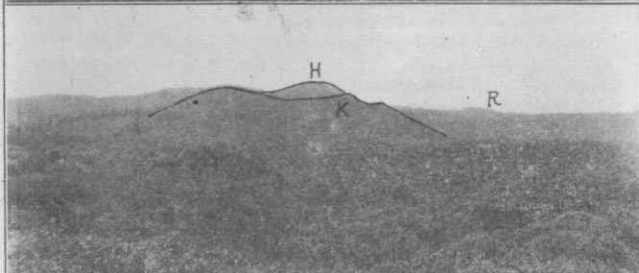
Fig. 7. Hachinoo (*H*) and Kôtsuki (*K*), parasitic knobs on the northeastern flank of the somma, as seen southwards. *R* - Ring-wall of the somma. (Fig. 1, 3b)
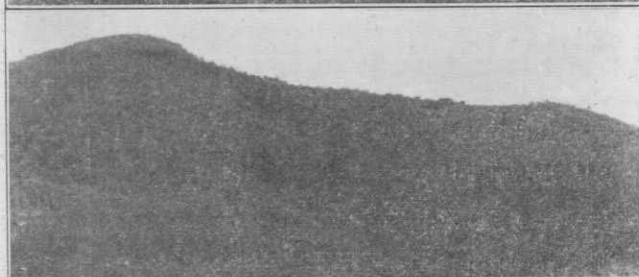
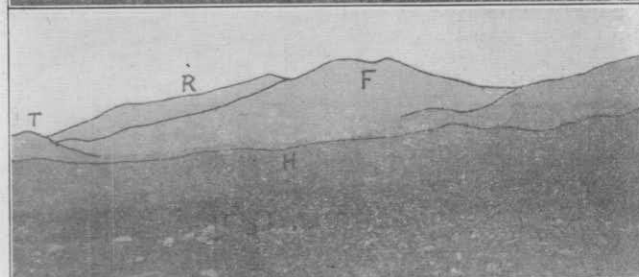Fig. 8. Itônashi, a parasitic knob on the northeastern flank of the somma, as seen southwestwards. (Fig. 1, 3b)

Fig. 9. Futago (*F*), a parasitic knob on the southeastern flank of the somma, as seen northwards, beyond the hemming wall of Hikubo (*H*). *R* - Ring-wall of the somma. *T* - Takenobira. (Fig. 1, 3e)

Fig. 10. Takenobira (*T*), a parasitic knob on the southeastern flank of the somma, as seen northwards from the village of Sashikiji. *F* - Futago. (Fig. 1, 2e)

by ejecta of later eruptions and are not yet dissected so that practically nothing is known of their geologic structure and re- lationship to the main body of the somma.   Three of the above, however,—the middle hill of Mitsumine[1] (1a), Futago[2] (2d), and Takenohira[3] (2e)—appear to be built up of scoriæ consisting of glass with some plagioclase phenocrysts.

Other knobs are entirely covered by later ejecta so that it is not evident of what they are composed; but it may not be un- reasonable to suppose that they are also constructed of scoriæ seeing they resemble the above three in morphographic features. as well as in other respects.

Mention has already been made (pp. 17–18) of the formation of spatter cones by the accumulation of scoriaceous lapilli on the lava surface.   It is not impossible that the knobs now under con- sideration originated in the same way as those spatter cones. But, so far as observed, the lavas are generally on too small a scale to account for such a comparatively large quantity of scoriæ as would be contained in these knobs.

On the other hand, some of the somma lavas are considered to have been discharged as effluent flows from flank openings. though the location of these cannot be pointed out at present.   It is possible that scoriæ would have accumulated on some of these openings from which the lava flows were extruded.   As a matter of fact, it was actually observed in the central crater of Mihara[4] (2c) on the eruptions in 1876–'77 and in 1912–'14, that a large quantity of scoriæ was spattered out from the vents through which the lavas were issuing.

The parasitic knobs on the flanks of the somma are considered to have been formed in this way by the accumulation of scoriæ

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1) 三峯   2) 二子   3) 岳ノ平   4) 三原

from the side vents which were afterwards buried under later
ejecta. Fig. 11 is a diagrammatic representation of the ideal
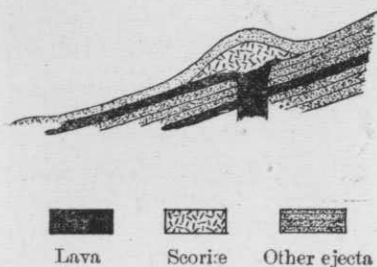structure of a parasitic cone according to this inference.

Lava   Scoria   Other ejecta

Fig. 11. Diagrammatic representation of the ideal structure of a parasitic cone.

As to the order of the forma-
tion of these parasitic cones no
reliable statement is possible, since
the geologic condition of each of
them and their mutual relation are
not known. Takenohira (2c) ap-
pears, however, to be the most re-
cent, for it is the least covered by
later ejecta and its original form is
nearly perfectly preserved with a bowl-shaped depression, to the
north of the highest point, which must represent the crater.

The parasitic cones are arranged mainly along the major axis
of the island, N.N.W.—S.S.E. This shows that the main flank
eruptions took place along the line running in the direction N.N.W.
—S.S.E., and that this afforded one of the factors for the exten-
sive development of the skirts of the somma on the northwestern
and southeastern sides.

Explosion-Craters of Phreatic Origin.—At the southeastern
foot of the somma there are two explosion-craters: Habu[1] (3e)
and Hikubo[2] (3e).

Habu (Figs. 12 & 13) is a harbour at the southeastern end
of the island (3e). Nearly circular in shape it is about 300 m.
broad, and is connected with the open sea by a narrow channel.

The surrounding wall is precipitous, with an average height
of about 50 m. On this wall, lavas and ejecta are exposed in
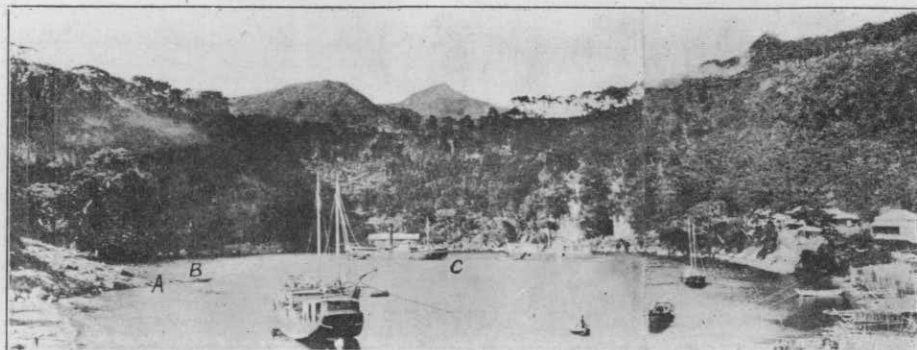alternate layers as shown in Fig. 13.

1) 波浮   2) ヒクボ

Fig. 12. The harbour of Habu (3e), a phreatic explosion-crater viewed northwards.
Reference letters, *A*, *B*, and *C*, correspond to those in Fig. 13. (Fig. 1, 3e)

Scale 1/10,000

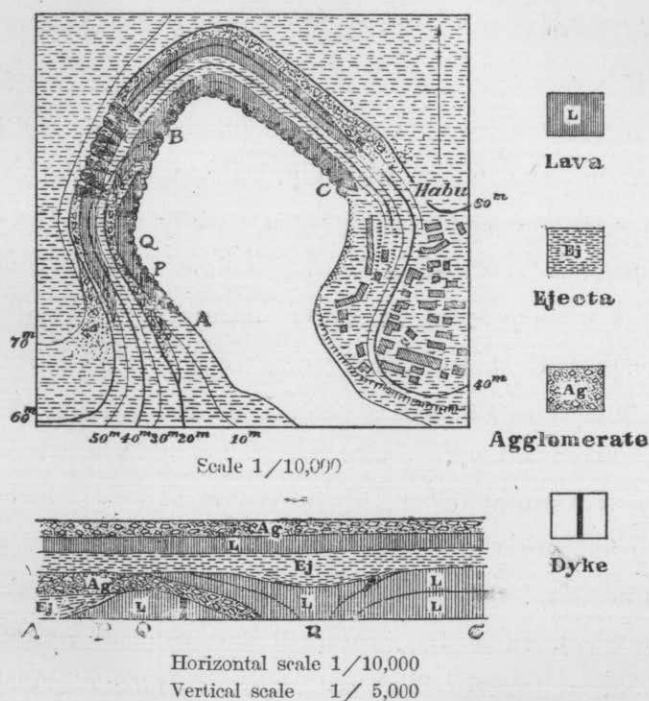Horizontal scale 1/10,000
Vertical scale   1/ 5,000

Fig. 13. Habu phreatic explosion-crater (3e).

The harbour was believed by some earlier authors[1] to be-

1) NAUMANN, "Die Vulcaninsel Ooshima und ihre jüngste Eruption," *Zeitschrift der Deutschen geologischen Gesellschaft*, Bd. XXIX., 1877.
YAMASAKI, "Report on the Volcano Ôshima," *Report Earthq. Invest. Com.*, No. 9, 1896 (in Japanese).

the oldest crater in Ôshima, but a close examination does not re-
veal any evidence for such a supposition.　No topographic feature
suggests that there was once a volcano having the present harbour
as its crater.　There are no such magmatic materials as one would
expect to have issued from this crater.　The lavas and ejecta ex-
posed on the encircling wall are nothing but those of the somma
as is clear from their dipping directions (generally toward the
southeast), as well as from their petrographic characteristics.

It would seem more probable that this Habu crater was
formed by a sudden blowing away of the surficial layers of lavas
and ejecta on the flat land at the southeastern foot of the somma
(pp. 17–18).

The probability of this inference is further strengthened by
the exposures on the crater wall.　In Fig. 13 the lava marked
Q shows a slaggy surface on the left hand side of P, while on
its opposite side a compact inner part is exposed.　The exposure
of the compact inner part is attributable to the removal of the
slaggy surficial part by explosive action thus leaving the latter on
the left side of point P.

This explosion was "*phreatic*"[1] following Suess's term, being
absolutely unaccompanied by any extrusion of incandescent ma-
terials, either fluent or pyroclastic.　Angular blocks of lava are
found scattered in the vicinity of Habu, and if these represent the
explosion products of the crater in question, as seems to be high-
ly probable, it follows that the Habu explosion must have taken
place at a very late stage of the volcanic history as these blocks
of lava are almost free from the covering of any later materials.

According to historic records, Habu harbour was once a

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[1]　Cited by Daly in his *Igneous Rocks and Their Origin*, 1914.

lake, but was afterwards connected with the open sea owing to the collapse of its southern wall under a seismic tidal wave that attended the earthquake on November 23rd, 1703 (the 12th year of the Genroku era).

Hikubo (3e) lies about 1 *km*. to the west of Habu. This is a spot hemmed in by a horse-shoe shaped wall open to the southeast. This wall, consisting of ejecta and having a height of about 50 *m*., may also be due to a phreatic explosion. As to the age of its formation, it must be very young, for its original form is preserved without any modification in spite of its easily destructible and loose structure.

If phreatic explosion is due to the heating of surface water by intrusive magma, as is generally believed, the presence of these craters, Habu and Hikubo, indicates that the magmatic intrusion came near the surface in this part of the island.

The Sea Cliff Opposite to Fudeshima.[1]—For about 1,000 *m*. along the coast opposite to Fudeshima (3d) in the south part of the east shore, there is a sea cliff about 170 *m*. high. This is the only cliff that was formed at the foot of that part of the fault escarpment along the east coast (p. 16), which remained uncovered by later volcanic materials. On the southern half of the cliff a thick accumulation of blocks of lava is exposed, with petrographic characters similar to those of the first type of the somma lava (p. 13) but free from olivine; while on its northern half a thick accumulation of red and brown scoriæ belonging to the same petrographic type is visible. Numerous dykes of olivineless basaltic bandaite (sempatic with phenocrysts of basic plagioclase scattered through the compact gray groundmass of comparatively high crystallinity

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1) 雛島

and granularity, consisting of plagioclase, augite, and magnetite) with various widths, ranging from a half to several meters, traverse the cliff in all directions (Pl. VI. EF).
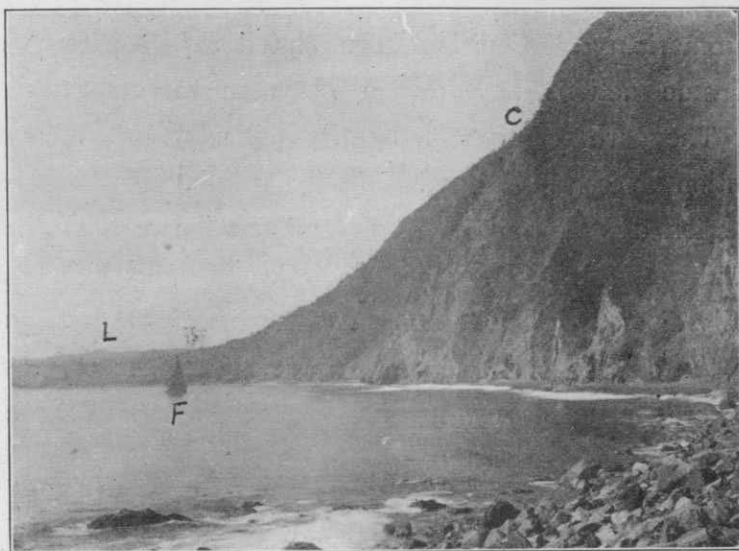

Fig. 14. Fudeshima (F), on the east coast and the 170 m. cliff (C) opposite to it, viewed southwards (Fig. 1, 3d). L····Flat land consisting of overflowed lavas and ejecta.

Scoriæ Accumulation on the Southeastern Flank. — In the southeastern part of the island an accumulation of brown scoriæ are seen. These are exposed on the walls of valleys and of cuttings along roads, being found in alternate layers with the somma lavas, as well as on the surface of the ground. The scoriæ accumulation exposed on the cliff opposite to Fudeshima (p. 24) is an example. That the scoriæ are far more abundantly found in this part than any other shows that these scoriaceous materials were discharged in all probability by local volcanic actions on this part of the flank, though the position of their centres cannot be determined exactly. No doubt these materials were not supplied by one continuous action only, but repeatedly

at intervals. Moreover, as is indicated by their occurrence in alternate layers with the somma lavas, the ejection of these scoriæ and the extrusion of the somma lavas must have succeeded one another.

Summarizing all that has been stated in the present chapter, the volcanic actions have taken place in various parts of the island. They are represented by the extrusion of effluent flows, the ejection of scoriaceous materials, the building of parasitic knobs, the injection of dykes, etc. Above all, the southeastern part of the island was especially subject to volcanic actions : scoriæ were repeatedly ejected in thick accumulation; magmatic intrusion came so near the surface as to cause phreatic explosions ; and numerous dykes were intruded, as we see on the sea cliff opposite to Fudeshima.[1]

The Caldera.

The somma is truncated at the top with a ring-wall surrounding a huge oval caldera, the major and minor axes of which are 3.2 km. from N.N.W. to S.S.E. and 2.5 km. from E.N.E. to W.S.W. respectively.

The crest line around the ring-wall is not uniform in its altitude. Its highest point is Shiroishi[2] (2d) on the southeast, attaining a height of 737 m. above sea level. The second highest, Kagamihata[3] (1c), lies on the northwest (604 m.). The rim of the encircling cliff is, as a rule, higher on the east (620–720 m.) than on the west (560–600 m.) (Fig. 15).

There are two possible explanations for the genesis of the caldera : (1) the blowing away of the apical part of the mountain by explosive action, (2) the depression of the summit.

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1) 筆島   2) 白石   3) 鏡端

If the former were correct we should naturally expect the presence of explosion products above the uppermost layer of lava exposed on the ring-wall encircling the caldera, but on examination no such products are to be found.
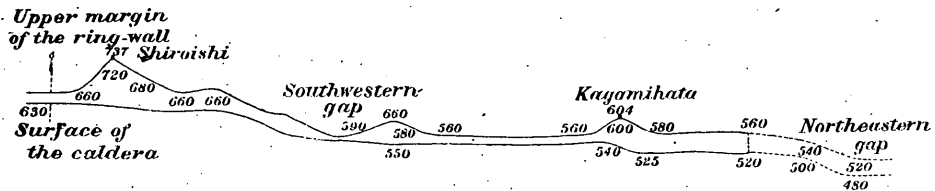

Fig. 15. Elevation of the crest line around the ring-wall.

On the other hand, the latter explanation seems to be preferable as it is highly probable that a hollow space would be formed below consequent on the withdrawal of magma from below the area, and that this hollow would induce the depression of the apical part of the volcano.

Moreover it would seem that the depression must have taken place with its centre somewhat to the west of the very top of the mountain, which supposition agrees with the observed features that (1) the ring-wall is higher on the east than on the west, and that (2) the distance from the margin of the ring-wall to the sea shore is longer on the east than on the west, the main volcano being considered as symmetrical.

There is a great gap in the ring-wall of the somma on its northeastern part, and the north side of this part is hemmed in by an arc-shaped wall.

Satô and Fukuchi[1] consider this great gap of the somma wall to be the result of an explosion, which formed, at the same time, that part of the wall which extends from due north of the central cone, Mihara,[2] northeastwards. They based this supposition on

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1) "Geological Notes on Ôshima, Idzu," *Jour. Geogr. Tôkyô*, Vol. XIV., 1902 (in Japanese).
2) 三原

a consideration of the morphologic features. NAKAMURA, TERADA, and ISHITANI[1] also support this view, stating :—

"...... (According to an old record,) detonations like thunder were repeatedly heard in Kyôto in an easterly direction, from October 19th, 1112 till the end of November, and the provincial government in Idzu reported that an eruption had taken place in an island. (The name of the island is not stated.)... Assuming that this eruption took place in Ôshima and the noises caused by it were heard in Kyôto, at a distance of about 180 miles from the supposed origin of the disturbance, we may estimate at least the degree of the eruption in question. By the explosion of Krakatoa, the limit of audibility of the noise was roughly speaking a circle with a radius equal to 2200 miles, when a circular area in radius of about 4 km. was blown away. In the eruption of Bandaizan in 1888, the limit of audibility was about 100 miles, and the corresponding linear dimension may be taken as 1 km. Without entering into a discussion on the masses exploded off, let us assume that the cube of linear dimensions of the masses blown away is proportional to the square of the distance which sound reaches. Then we obtain from the above data for Krakatoa that in Ôshima a crater with a radius of 0.75 km. must have been formed by this explosion, while from those of Bandaizan, we get 1.5 km. as the probable radius of the crater.

Now Messrs. SATÔ and FUKUCHI consider the large eastern gap of the old crater wall of the somma to be the result of an explosion, ... We consider this theory very probable, inasmuch as the theory of the destruction of the crater wall by a lava stream from the central cone is quite untenable, if we remember that a lava stream has generally not such a great velocity or momentum as to sweep before it an obstacle some fifty meters high. The radius of this supposed explosion-crater is estimated to be 1–2 km. on the map. Comparing this theory with the estimates given above, we may perhaps propose a hypothesis that the detonations heard in Kyôto in 1112, were due to that explosion which formed the eastern gap in the somma."

1) "The Volcano of Ôshima, its Past and Present," *Proceedings of the Tôkyô Mathematico-Physical Society,* Vol. IV, 1908 ; *Jour. Geogr. Tôkyô,* Vol. XX., No. 233, 1908 (in Japanese).

It seems to the writer, however, that the above is not a positive proof that the gap was formed by an explosion. That the momentum of a lava stream is insufficient to form such a gap as that in question is only suggestive that the gap was formed before the central cone lava flowed down to the east coast. Moreover, it is not sure whether the recorded detonation in 1112 resulted from the eruption in Ôshima or not.

ÔHASHI,[1] on the other hand, considered that this gap might have been formed by depression, basing his view on the absence of explosion products. But this also is not convincing as the later volcanic materials cover the ground so thickly on the eastern part of the island that the explosion products, if there are any, may well be hidden under these surficial deposits.

To consider the problem geologically is impossible at present as no data are available, so that in the absence of convincing proof that the gap was formed by an explosion, the writer is inclined to agree with ÔHASHI in regarding it as the result of simple depression induced by the formation of the caldera.

The Central Cone.

The central cone, Miharayama[2] (2c), stands somewhat to the south of the centre of the caldera. It is a perfectly preserved undissected homate. The highest point lies to the east of the crater-wall and rises 755 m. above sea level, or about 200 m. above the surrounding surface of the atrio. The sides of the homate averaging 20° in slopes are bare of vegetation and are covered by loose sands, lapilli, bombs, and lava-blocks.

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1) "On the Geology of Volcano Ôshima," *Jour. Geol. Soc. Tôkyô*, Vol. XVL, p. 530, 1909 (in Japanese).
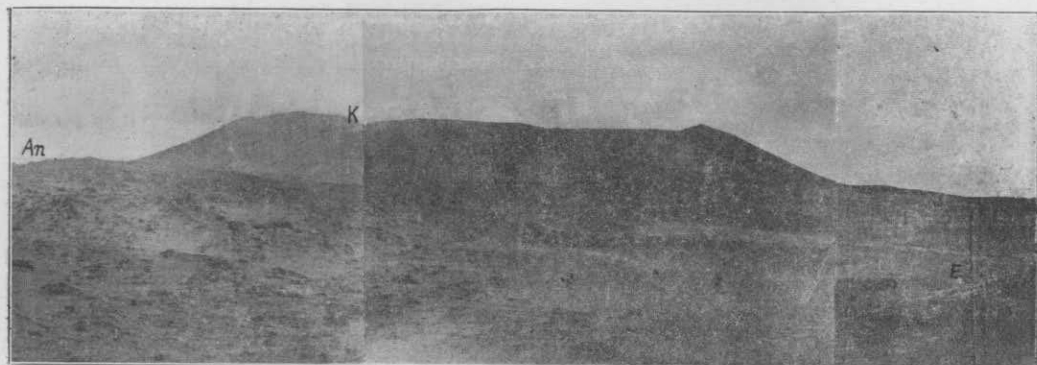
2) 三原山

Fig. 16. The central homate, Miharayama, viewed eastwards from the south of Kagamihata (1c). The lava seen on the left side (An) is that extruded in 1778 (An-ei era). K....Kawajiri, the lowest point of the crater margin. E ...Loose ejecta of the central cone. (Fig. 1, 1c)

The homate is very simple in its building up, being composed of superfluent lavas and ejecta the alternately accumulated layers of which may be well observed on the inner wall of the summit crater (Fig. 17).

The lavas of the central cone do not differ much from those of the somma, consisting mainly of basic plagioclase, augite, hypersthene (including clino-hypersthene), and magnetite. But *no trace of olivine* has ever been detected, in which point the central cone lavas afford a contrast to the somma lavas, in most of which olivine is meagrely present. Another distinguishing character of the central cone lavas from the somma lavas is that the plagioclase in the groundmass is more calcic in the former than in the latter. Chemically, the central cone lavas are poorer in SiO_2, Fe_2O_3, MgO, and Na_2O, but are richer in Al_2O_3, FeO, and CaO. As described in the petrography (p. 79), this rock is so peculiar in its compositi n as to deserve a new name, for which "*Miharaite*," derived from Miharayama, is proposed.

The volcanic products of the central cone, both lavas and ejecta, not only fill the caldera, but are also spread down to the

sea shores through the northeastern and southwestern gaps of the ring-wall of the somma. Especially on the eastern part of the island, the products of the central cone are so distributed over the surface of the somma body as to conceal its original slope.
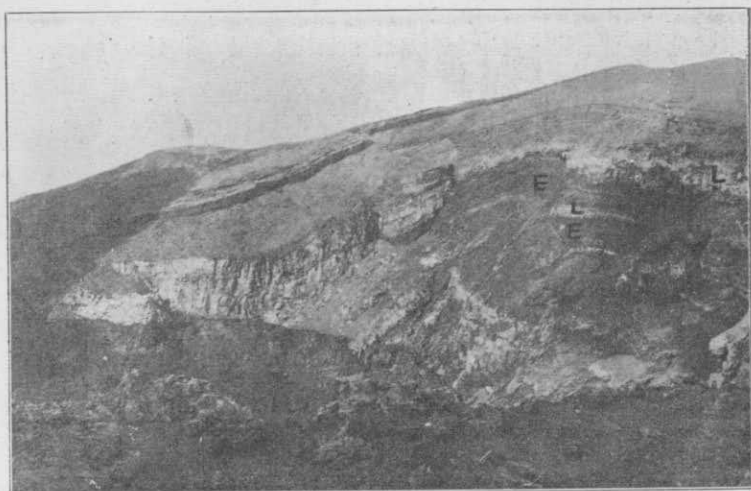
Fig. 17. The eastern inner wall of the Mihara crater, on which the alternately accumulated layers of lavas (*L*) and ejecta (*E*) are well observed (Fig. 1, 2d).

The summit crater of the central cone is nearly circular, the meridional and equatorial axes being about 700 *m*. and 800 *m*. respectively.

The crater seems to have attained its present size in 1684 according to historic records (p. 55).

It is surrounded by a ridge line as shown in Figs. 18–20 (p. 33), where *a* is the lowest point (665 *m*. above sea level) and *b* the highest (755 *m*.). The ground slopes gently on both sides of this line and the margin of the almost perpendicular cliff of the crater is obtained by descending a few steps toward the inner side. The lowest point of the upper margin of the cliff is Kawajiri[1] (647 *m*., *K* in Figs. 18–20) on the north side.

1) 川尻

The feature of the inside of the crater is always changing. It is habitual that when the vulcanism displays its full energy, lava fills the crater, and on declining, the layer of lava depresses more and more due to its own weight, leaving the peripheral parts in the form of terraces.

In 1874, according to MILNE, southwest of the centre of the crater-floor there was a deep hole, from which steam was issuing.

During the eruption of 1876–'77, lava poured out from this hole, and a miniature spatter cone, NAUMANN's cone (Nm in Figs. 18, 19, & 21), was formed on the crater-floor where the hole had previously been. This new cone seems soon to have been blown away on its northwestern side, for when NAUMANN, MILNE, and WADA visited the island during this eruption in January 1877 they found it in this demolished condition. At that time, molten lava is said to have been seen in the summit pit of NAUMANN's cone.

Nineteen years later, when YAMASAKI observed the Mihara crater (January 1896), he found that NAUMANN's cone lacked its northern half. There was an intermediate flat stage at the foot of the crater-wall, and at about the centre of this stage (i.e. to the east of NAUMANN's cone) he found a depression with steep walls, at the bottom of which, in a round hole (vent or crater-pit), red molten lava could be seen. Thus the vent or the crater-pit of NAUMANN's cone had gradually shifted to the east and had transformed itself into the main pit at the time of YAMASAKI's visit.

In the summer of 1907, NAKAMURA and his colleagues surveyed in detail the inside of the crater. Fig. 18 is a copy of the map they made. Comparing this map with YAMASAKI's descriptions we see that in the meantime (11½ years) topographic changes had again occurred. As shown in Figs. 18 and 21, NAUMANN's
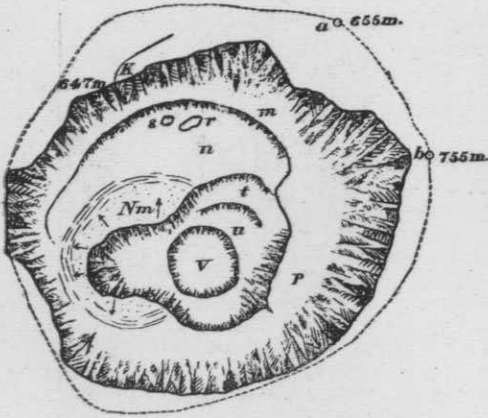
Fig. 18. The state of the inside of the Mihara crater in the summer of 1907. Scale 1/15,000.

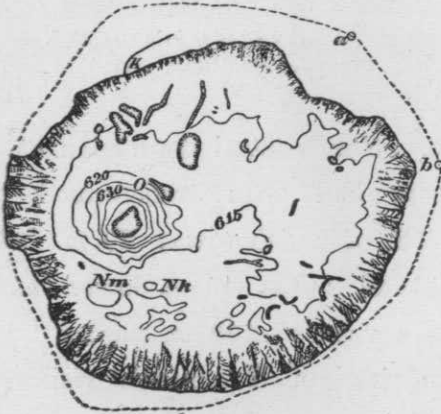(After NAKAMURA and others.)

Fig. 19. The state of the inside of the Mihara crater in the beginning of January 1 13. Scale 1/15,000.

(After OKAMURA.)
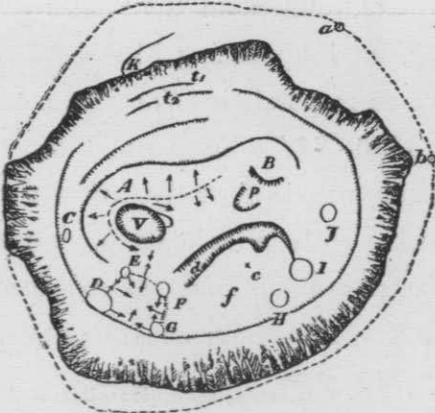
Fig. 20. The state of the inside of the Mihara crater in the summer of 1916. Scale 1/15,000.

Fig. 21.   The state of the inside of the Mihara crater in about 1907,
looking down southwestwards (Fig. 1, 2c).   The reference letters, Nm, V, p,
and m, correspond to those in Fig. 18.

cone, Nm, lacked its eastern side.   The central depression at the
crater-floor described by Yamasaki had been transformed into
rugged terraces, t and u in Fig. 18, of which t was 20 m. lower
than the flat part denoted by n[1], and u was 40 m. lower than t.
At the bottom of u there was a vent V, 160 m. across, which
was successor to the vent at the time of Yamasaki's visit.   At
the foot of the northern wall of the crater, there was a narrow
flat strip of land, m, about 20 m. broad, 500 m. in the total length,
30–40 m. higher than the bed n, and appearing like a gallery.
This gallery-like flat strip m must correspond to the crater-floor
immediately after the eruption in 1876–'77.[2]   From amid the flat
bed n, two prominences, r and s, projected abruptly, of which r
was a mass consisting of lava-blocks with a miniature craterlet
at the top, while s was a loose pyramidal mass of red brown

1) n was about 110 m. below the upper margin of the crater-wall and must correspond to
the flat stage observed by Yamasaki.

2) Though nothing is stated about the gallery m in Yamasaki's descriptions, it must have
existed at that time.

scoriæ the greater portion of which must have since been lost. The area denoted by p was covered with dense lava of gigantic dimensions in fantastic forms. The relief of the ground in the crater is shown in the map by means of arrows.

The Meiji-Taishô eruption (1912–'14) began with the out-pouring of lava from this vent (V in Fig. 18). During this interval, the extrusion of lava took place intermittently five times, of which the second and fourth can be considered as the after-effects of the first and third respectively. In the first period, during March–June 1912, the lava reached a level of 62 m. below Kawajiri[1], burying half of NAUMANN's cone and forming a new spatter cone, NAKAMURA's cone, somewhat to the southwest of the centre of the crater-floor. The second eruption, in July, was the squeezing out of a new molten lava due to the depression of the lava layer at the crater bottom and resulted in the breaking up of NAKAMURA's cone. In the third activity (September—October 1912), the extrusion of the lava took place from a new vent at the western part of the crater-bottom being accompanied by the formation of a new spatter cone—ÔMORI's cone—around the vent.

Fig. 19 is based on the map published by the Imperial Geological Survey, showing the state of the inside of the crater in the beginning of January 1913, i.e. after the third eruption but before the fourth. Here Nm and Nk are the apical parts of the two spatter cones, NAUMANN's and NAKAMURA's respectively, freed from the covering of new lava, and O is a newly formed (ÔMORI's) cone. The lava constituting the crater-floor is that extruded by the third eruption. The relief at the bottom was as indicated by the contour lines, each representing a vertical distance of 5 m.

This feature was modified by the fourth activity in January

1) 川尻 K in Figs. 18-20.

1913 which was an extrusion of lava due to the depression of the
lava layer at the crater-bottom. The fifth eruption, a magnificent
lava outburst in May 1914, strikingly changed the feature of the
inside of the crater. The lava came to a level of 14 m. below
Kawajiri, entirely burying the old cones under newly erupted
materials and forming several new ones on the crater-bottom.
Cessation of activity was immediately followed by the beginning
of the depression of the crater-bottom. After this eruption a very
small activity took place in 1915, but this did not much modify
the state of the crater.

Fig. 20 is a sketch map based on the writer's eye-measure-
ments in the summer of 1916, showing the feature of the inside
of the crater at that time. The bottom of the crater appears,
at first sight, to be almost horizontal, being filled with the
lavas (now broken into fragmental blocks) of the last eruption.
Along the foot of the encircling wall of the crater there is a
narrow strip of land (30 m. below K) which forms two terraces
(t_1 and t_2) at the foot of Kawajiri. This was formed by the
sinking of the ground due to its own weight, soon after
the last activity ; and t_1 corresponds to the level to which the
lava was raised in the last eruption. Ômori states that these
terraces were in existence on his visit a week after the eruption
of May, 1914. The surface of the dislocation wall is vertically
grooved and striated. There are, on the crater-bottom, several
elevations—spatter cones and their ruins—which are denoted in
Fig. 20 by A, B, C, D, E, F, G, H, I, and J ; of these, the
largest two, A and B, are combined in a long continued hill which
is pretty well preserved on the northwestern side but is in a state
of collapse on the opposite side. A is a spatter cone formed by
the last eruption, being elevated about 25 m. above the crater-

bottom or about 6 m. above Kawajiri (K) with a circular pit, about 70 m. across and facing to S.S.E., rather large for the size of the cone. At the southeastern foot of the spatter cone, A, there is a wide ditch, d. The other one of the two conspicuous elevations, B, is a dome-shaped lava-mass the top of which is about 4 m. below Kawajiri, K. At the southern foot of B is a hollow, p, which is probably the remnant of a pit. The area to the south of the ditch, d, shows very irregular relief, the point marked c, about 50 m. below Kawajiri, being the lowest.
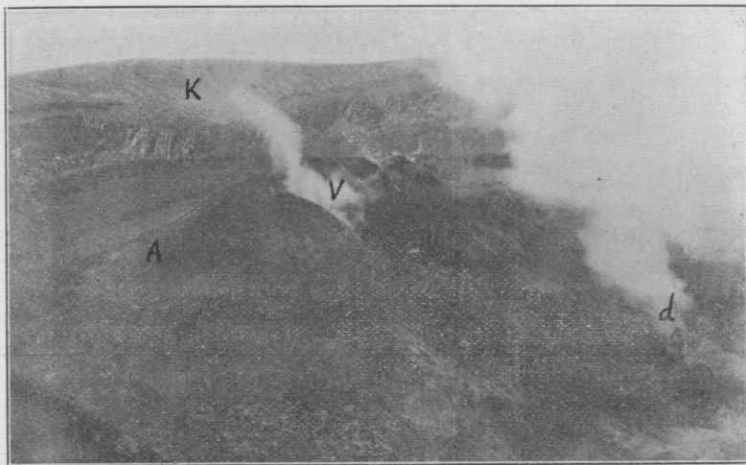
Fig. 22. The inside of the Mihara crater in the summer of 1916, looking down from the southwestern margin of the crater (Fig. 1, 2d). The reference letters, K, A, V, and d, correspond to those in Fig. 20.

The whole crater is at present a state of deep tranquility. No motion is seen and no sound is heard to cause any uneasiness. Activity is only indicated by fumes with a faint peculiar choking odour of sulphur dioxide, which is the characteristic gas at less active vents according to the law of variation in composition of volcanic gases, first established by SAINTE-CLAIRE DEVILLE, namely, that the nature of the gas evoluted depends upon the phase of volcanic activity. The fumes rise calmly at varying places, from

pits and clefts of the elevations on the crater-bottom and from
cracks and fissures traversing the lava which fills the crater-floor,
depositing sulphur in a yellow crust on any objects with which
they may come into contact.

Small Demolished Igneous Bodies along the Western Half of the Northern Coast.

From the cape of Chigasaki[1] (1a) at the northwestern end
of the island to the west of Okata[2] (2a), there lies along the sea
coast a row of hills elevated from the gentle skirt of the somma.
The surface of the hills is covered by the somma ejecta of a
comparatively late eruption, but they are underlain by the strikingly
destroyed small igneous bodies.
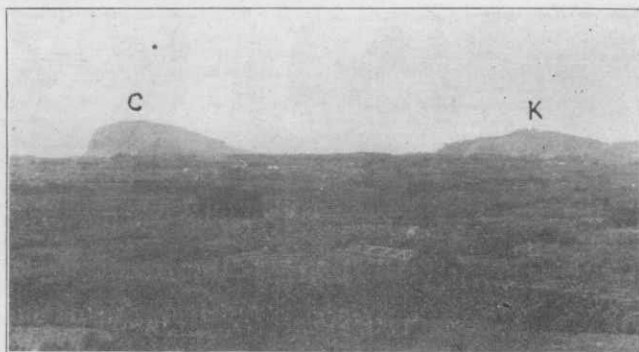
Fig. 23.   Chigasaki (C) and Kazahaya (K), remnants of sma'l
igneous bodies along the western half of the northern coast, now covered by
later volcanic materials of the somma, as seen northwards (Fig. 1, 1a).

The structure of these demolished igneous bodies as well as
their geological relation to the main body of the somma may be
clearly seen on the sea cliff where marine abrasion has afforded
an excellent opportunity to study them (Pl. VI. GA).

Chigasaki (Figs. 23–26) is an elevated spot, 95 m. above
sea level, projecting seawards as a cape, and commanding a splen-

1) 千ケ崎 or 乳ケ崎   2) 岡田

did view. The peculiar feature of this projection was noticed for
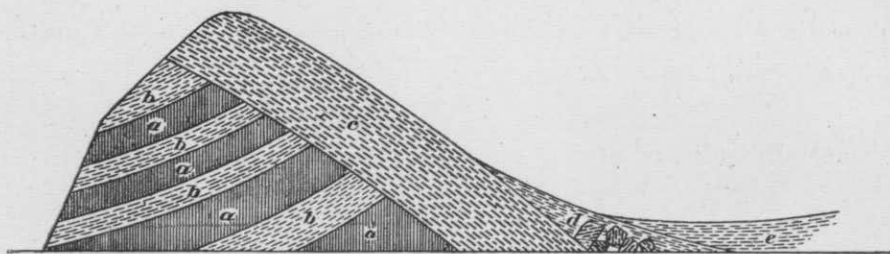
Fig. 24. A diagrammatic sketch showing the structure of Chigasaki.
a....Lavas of the igneous body of Chigasaki.
b....Ejecta of the same.
c....A layer consisting of small lava-fragments.
d....Talus accumulation of the blocks of c.
e ...Skirt of the somma.

the first time by D. Satô[1] who suggested that it might be either the remains of an old volcanic body or a half-destroyed parasitic cone. Ôhashi[2], on the other hand, is of opinion that it is merely nothing more than a part of the skirt of the somma. Fried-laender[3], on the other hand, considered it as a parasitic cone.

The structure being examined in detail, however, it becomes clear that Chigasaki is neither a mere part of the skirt nor a parasitic cone.

Fig. 24 represents a diagrammatic sketch showing the structure of Chigasaki. The hill is underlain by a demolished igneous body consisting of lavas (a) and ejecta (b) which dip northwards.

The lava is olivine-rich basaltic with large megaphenocrysts of anorthite, and differs from the most widely distributed somma lava. Over the abraded surface of this igneous body is a layer of

1) "Geological Notes on Ôshima, Idzu," Jour. Geogr. Tôkyô, Vol. XIV., No. 162, 1902 (in Japanese).

2) "On the Geology of Volcano Ôshima," Jour. Geogr. Soc. Tôkyô, Vol. XVII, No. 196, 1910 (in Japanese).

3) "Über einige japanische Vulkane," Mitteilungen der Deutschen Gesellschaft für Natur- und Völkerkunde Ostasiens, Bd. X., Teil 1, 1909.

small lava-fragments (c) with a southward dip of 40°, in a most pronouncedly discordant relation. The latter is covered at its southern foot with a talus deposit (d) formed by the accumulation of blocks of c that have fallen from its steep surface. It is over this old talus that the skirt of the main body of the somma (e) extends.
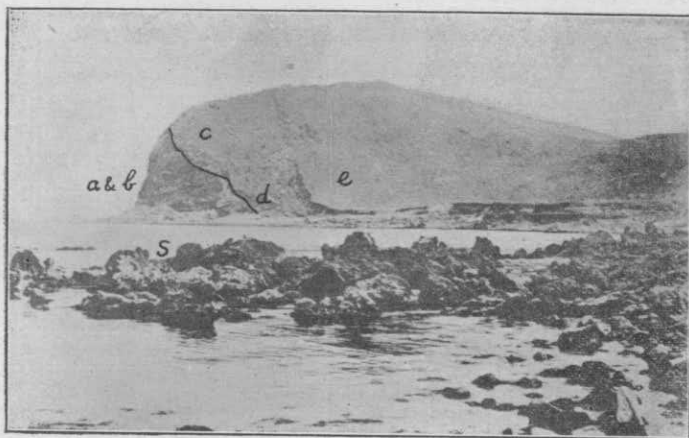
Fig. 25. Chigasaki as seen northwards (Fig. 1, 1a).
The reference letters, a, b, c, d, and e, correspond to those in Fig. 24.
S... Somma lava of the first type.

Fig. 26. Chigasaki as seen westwards from the north foot of Kazahaya (Fig. 1, 1a).
The reference letters, a, b, and c, correspond to those in Fig 24.

From the foregoing it is beyond dispute that what underlies the hill of Chigasaki is a demolished block of a small igneous body structurally independent of the somma body.
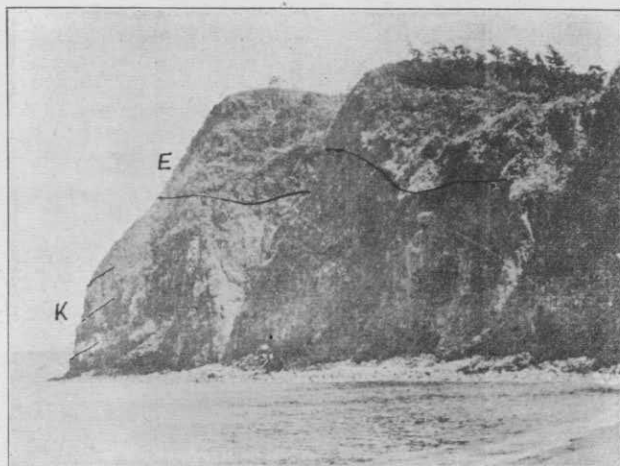
Fig. 27. Kazahaya, a remnant of small igneous body (K) covered by later ejected materials (E). (Fig. 1, 1a)

The easterly lying Kazahaya[1] (1a), a hill with a height of 108 $m.$, is also underlain by a demolished igneous body (Fig. 27). It consists of lavas (petrographically somewhat different from those of Chigasaki, but also rich in olivine) and ejecta, dipping also toward the sea, and having a structure like that of Chigasaki (Pl. VI. GA).

To the east of Kazahaya other small igneous bodies of olivine-rich basaltic and doleritic rocks in the form of lavas and intrusives are found (Pl. VI. GA 10—11). They are overlain by layers of contemporaneous ejecta, over the denuded surface of which later materials of the somma are again spread.

Another ruined igneous body (Pl. VI. GA 9) lies to the west of Okata[2] (2a). This consists of many thin layers of lavas (olivine-bytownite-basalt) and ejecta. What is considered

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1) 風早   2) 岡田

to be the centre of the igneous action is exposed on the cliff, the layers of lavas and ejecta inclining outwards (Fig. 28). The whole mass is highly disturbed, being traversed by many fissures, cracks, fractures and joints. Faultings, small in scale (vertical downthrows being $\frac{1}{3}$ m. in f_1, 1 m. in f_2 and f_3, and 5 m. in f_4), are also seen on this cliff, always with downthrows on the side of the igneous centre. The formation of these faultings seems to be attributable
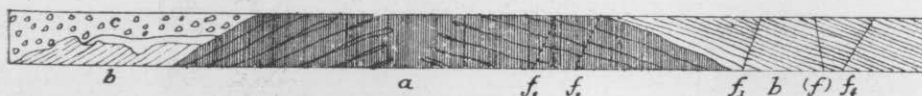
Fig. 28. Diagrammatic sketch showing the exposure on the sea cliff to the west of Okata.
a ......Lavas of the ruined igneous body.
b ......Ejecta of the same.
c ......Ejecta of the somma.
f_1-f_4..Faults. (f)....Fissure.

to the depression of the layers, due to their own weights, after the igneous agitations were over.[1] An ejecta bed of the somma body (c in Fig. 28) discordantly covers this demolished igneous mass.

From what has been stated in the foregoing pages, it may be claimed that the small demolished igneous bodies along the western half of the northern coast have no direct structural relation to the main body of the volcano Ôshima, and that the materials constituting them were supplied by local vents.

These igneous bodies must have existed, as their structure shows, before the skirt of the main body had developed to its present state, constituting at some time or other islets separated from the main body by the sea. It was not until marine abrasion

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1) Depression of lava layers due to their own weight is a phenomenon actually observed in some active volcanoes as Mihara (p. 32), Asama (Ômori, Bull. Earthq. Invest. Com., Vol. VII., No. 1; Report Earthq. Invest. Com., No. 81), etc.

had destroyed these igneous bodies that these islets were connected with the main body.

As to their probable birth-time, we have no direct evidence, but that such small igneous bodies as these still maintain their existence, though now in a highly demolished condition, in spite of the constant action of the sea, suggests that their birth was not at a very remote date. It would seem to be most reasonable to assume that they were born in the middle of the volcanic history of the main cone, soon after which they ceased to appear.

It is noticeable that the lavas constituting these igneous bodies are all comparatively rich in olivine and pyroxene, in contrast to the common somma lava in which these minerals are either absent or found only in a negligible amount.

Since these olivine-rich lavas are considered to have been discharged from the local vents while the main centre was pouring out olivine-poor lavas, the peculiar character of the former can not be attributed to what is called the magmatic cycle.

It appears likely that these olivine-rich lavas constituting the small igneous bodies were derived from the lower part of a local satellitic magma reservoir. On this supposition all the petrographic facts, especially the occurrence of olivine which the writer believes to be due to gravitational control, seem to be best explained. This point will be discussed fully on pp. 118—119.

The view, that the lavas of the demolished igneous bodies came from a local satellitic magma reservoir, explains the short life of the vents of these bodies. As to the persistence of vents in general, it is believed to be due to the action of " gas-fluxing " or " blow-piping "[1]; so if the vents now in question are

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1) DLAY, "The Nature of Volcanic Action," *Proc. Am. Acad. of Arts and Sciences*, Vol. XLVII., 1911.

supposed to have direct connection with the main magma reservoir, it is difficult to explain why they expired so soon in view of the high probability of a constant action of " gas-fluxing " or " blow-piping."

Explanation of the Present Features.

The topography is the end-product of structure, process, and stage, as Davis says, and all the present features of Ôshima are well explained when they are considered to be the combined results of the structure of the volcano and the agencies at work on it. The surficial agencies that are believed to have been acting on the island are winds, temporary streams caused by cloudbursts, and sea waves. No doubt these agencies must have been operating at every stage of the development of the insular volcano since it came into existence. But, on the other hand, repeated volcanic eruptions depositing juvenile products have covered the effects of these surficial agencies, whereupon the agencies have begun to act anew. Thus the surficial agencies have not yet had a sufficient opportunity to modify greatly the original topographic features dependent on the structure. In the following, an explanation for the more remarkable topographic features will be given :—

(I) *The Development of the Mountain Slopes.*

The development of the mountain slopes of Ôshima is not uniform in all directions.

(1) The *western* flank of the somma is very regularly developed showing a gradual slope with decreasing inclination downwards. This may be because no conditions have obstructed the natural development of the mountain slope in this part.

(2) The *northwestern* skirt of the somma is extensively developed with very gentle slope. This is attributable partly to the extrusion of the lavas from flank openings, the more striking of which are indicated by the scoriæ accumulations as Atago[1], Kazamachi[2], etc. (p. 20), and partly to the existence of small igneous bodies (p. 38) along the western half of the northern coast of the present Ôshima, which must have protected the new deposition from marine action, thus affording conditions specially favourable for the extensive development of the skirt.

(3) The *southeastern* part of the island is also extensively developed. This may be due to its having been the scene of frequent volcanic actions (pp. 25–26).

(4) The *eastern* slope of the mountain is abnormal, the gentle slope continuing from the summit to half way and becoming suddenly steep on approaching the sea shore. The profile of the island cut in an E.–W. direction through the centre shows a striking asymmetric form.

This asymmetric form has been noticed by previous writers, and various views have been suggested to explain it. YAMASAKI[3] tried to explain the abnormal feature of the eastern slope by supposing the existence of some older volcanic bodies in that part (p. 7), while ÔHASHI denied the presence of old volcanic bodies[4] and attributed the asymmetric form to the tilting of the ground[5] (p. 10). These are, however, hypotheses for which there is no direct evidence, while the latter may now be proved impossible.

1) 愛宕   2) 風待
3) "Report on the Volcano Ôshima," *Report Earthq. Invest. Com.*, No. 9, 1896 (in Japanese).
4) "On the Geology of Volcano Ôshima," *Jour. Geol. Soc. Tôkyô*, Vol. XVI., pp. 522–524, 1909 (in Japanese).
5) "On the Asymmetrical Form of Ôshima," *ibid.*, Vol. XXIV., p. 72, 1917 (in Japanese).

It is the writer's belief that the steep slope near the east coast is the remnant of a fault escarpment, as has already been stated (p. 17).

With regard to the cause of the abnormally gentle slope of the eastern flank of the mountain, the present writer differs from previous writers, considering it to be due mainly to an ununiform distribution of the volcanic materials. That this is not improbable may be illustrated thus :—

(a) In the first place, it is a fact often recognized that in some volcanoes[1], during their eruption, fine clasmatic ejecta fall more abundantly on the east than on the west, being transported by the upper atmospheric current (at least 4–5 km.) which is always travelling eastwards owing to the effect of the rotation of the earth; accordingly it is to be expected that in such volcanoes as Ôshima, where fine clasmatic ejecta take an important part in the building up of the volcano, the asymmetric form of the mountain was originally developed, though the writer has not yet found any direct evidence for this in Ôshima.

(b) As already stated (p. 27), the caldera is considered to have been formed with its centre somewhat to the west of the very top of the somma. The more extensive development of the slope on the east than on the west may be partly attributable to this eccentric depression.

(c) The ring-wall of the somma that surrounds the caldera must have checked the lavas of the central cone from flowing out of the caldera, but there is a great gap in the wall on the east,

1) B. Kotô, "The Great Eruption of Sakura-jima in 1914," *Jour. Sci. Coll. Imp. Univ. Tôkyô*, Vol. XXXVIII., Art. 3, p. 125, 1916.

F. Ômori, "The Sakura-jima Eruptions and Earthquakes II.," *Bull. Imp. Earthq. Invest. Com.*, Vol. VIII., No. 2, p. 115, 1916.

It is said that during the eruption of Asama in May 1911, ashes fell mainly on the east although the surface winds at the time were east or south.

consequently the lavas could flow out through this eastwards, thus affording an additional factor for the abnormal development of the eastern slope.

(d) Another cause for the development of the abnormal topographic features on the eastern flank may be wind action on the dry surface of the caldera. The effects of winds now in operation and actually recognizable are by no means small. The inside of the caldera is thickly covered by loose ejecta (volcanic ashes, sands, lapilli, bombs, lava-blocks, etc.) and by fragmental materials produced by friction or by other destructive actions. The effects of the winds on this dry surface is considerable. The sand-worn blocks, some of which are three faceted in the form of "Dreikanter", lying in the caldera, and various marks on the sandy surface show the abrasive effects of wind-blown sands. These marks indicate the direction of the prevailing wind in the caldera. Feather-like patterns marked on the surface of an aerial volcanic sand bed at the northeastern brim of the central crater show the direction of the wind to be N.E. to E. by N., while the patterns marked on the loose sandy surface at the northeastern part of the caldera by the sorting action of the wind (according to the size of the fragmental materials) show it to be N. by E. to due E. That the finer particles are found accumulated on the lee side of large blocks is an indication of the strength of the winds. The eastern slope of the volcano is thickly covered by sands and lapilli transported by the winds from the caldera through the great eastern gap of the encircling wall.

Although the effect of each of the above may be comparatively slight, yet the writer believes that taken together they may be sufficient to cause the abnormal feature of the eastern slope.

(II) *Surface Sculpture of the Mountain Slopes.*

There is no river in Ôshima, nor is it believed that there ever has been one. Meteoric water in flowing down the natural slopes of the ground as temporary streams (consequent streams) excavated shallow channels or gulches, but later volcanic products often filled these up. Exposures as shown in Fig. 29 are frequently met with on some road cuttings, for example, midway along the road from Nomashi[1] (1c) to Sembasaki[2] (1d).
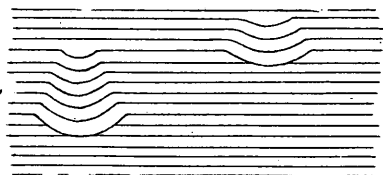
Fig. 29. Ejecta layers showing alternate excavation and deposition.

These reveal the alternately repeated accumulation and dissection.

As a whole, Ôshima is young in dissection, the radial gullies excavated as draining channels being mostly not deep.

In general, the depth of valleys depends on the thickness of the surficial deposit of ejecta overlying the solid lava, since the streams have excavated the ground till the underlying lava surface has become exposed. Most of the valleys in Ôshima (not all) have not yet reached a stage of development where the solid lava is excavated deeply.

Thus different parts of the island are variously dissected. The difference in dissection, however, will be understood when the geologic condition of the island and the surficial agencies acting on it are considered.

In the *northwestern* half of the somma, i.e. on the *northern* and *western* flanks, comparatively shallow radial valleys are rather regularly developed. This is quite natural as the inclination

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1) 野増   2) センバ崎

of the outer slopes of the somma is normal in this part and the layers of ejecta covering the solid lavas are comparatively thin.

On the *southeastern* flank, as the original relief is complicated owing to specially frequent volcanic actions on this side (p. 26), the development of the valleys is accordingly irregular. Moreover, as easily dissectible scoriaceous ejecta constitute the ground in this part, temporary streams have excavated it deeply.

The *eastern* slope of the volcano, continuing from the inside of the caldera toward the east coast through the great north-eastern gap of the ring-wall of the somma, is thickly covered by loose sandy materials. There the ground is almost undissected. This is due to the constant levelling action of the western wind in shifting the loose materials.

The part along the east coast of the island is deeply dissected, valleys being sometimes as deep as 200 *m.* These apparently incomprehensible sculptures may be well understood when the drainage in Ôshima is considered. The water that falls in the caldera, after soaking down through the sands and lapilli, by which the inside of the caldera is loosely covered, till the surface of the underlying lava is reached, runs off the natural slopes; accordingly a larger quantity of water is supplied to the eastern part of the island than to any other, since the ring-wall of the somma is greatly broken on the eastern side and the running down of temporary streams is uninterrupted. Moreover, the slope of the ground is especially steep near the east coast. Both of these conditions would naturally favour a greater dissection here.

(III) *The Coast.*

The island is constantly subjected to marine erosion at its margins. The waves that dash against the shore break up and

remove the rocks thus forming precipitous cliffs around the island.
So the shore of Ôshima ends for the most part abruptly with
cliffs. Their elevations vary in different parts. The cliff between
Nomashi[1] (1c) and the cape of Sembasaki[2] (1d) in the southern
part of the western shore, and that opposite to Fudeshima[3] (3d)
in the southeastern part, are especially high, attaining 100 m.
and 170 m. respectively. In other parts, the heights of the cliffs
usually vary up to some sixty or seventy meters.

Between Nomashi and Sembasaki the relief of the mountain
side as well as that of the sea bottom (notice the 100 fathom
line in Fig. 42, p. 140) suggest that this part once projected far
into the sea, and that the high cliff may have been formed by
the removal of this projecting part by wave erosion.
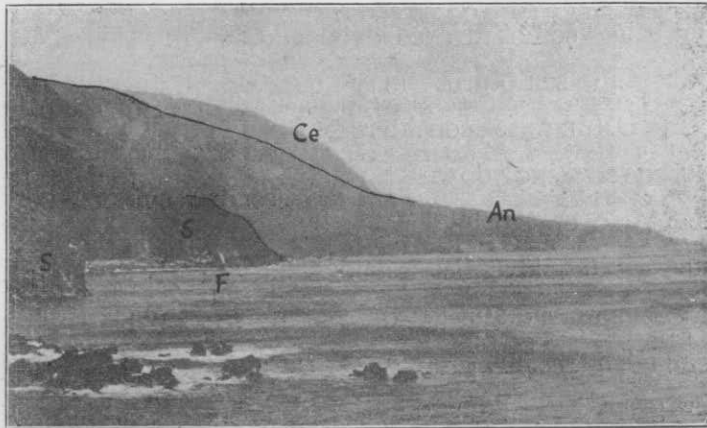
Fig. 30. The northward view of the east coast. S ...Somma rocks after the
formation of the escarpment along the east coast. F....Funô no Taki (a water-fall).
An....Central cone lava in 1778. Ce....Central cone ejecta. (Fig. 1, 3d)

The formation of the 170 m. cliff at the shore opposite to
Fudeshima (Fig. 14, p. 25) may be explained by the special con-
ditions of this part. This cliff is at the foot of the steep slope along

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1) 野増   2) センバ崎   3) 筆島

the east coast of the island. As already stated (p. 18), the original surface of this steep slope is covered for the most part by later lavas and ejecta, being protected from marine abrasion, while only at the part where the 170 m. cliff is now developed could no covering of later materials be seen. This part, then, must have been subjected to marine action for a long time and the high cliff must have consequently been formed. The steepness of the original slope may also have favoured the development of this high cliff.

The action of the waves has clearly been far more vigorous than the dissecting action of streams, for at every point where a valley ends it hangs high on the sea cliff. The sole, more or less permanent stream in Ôshima near the eastern shore flows down into the sea over a hanging valley in a water-fall called Funô no Taki[1] (3c; Fig. 30).

Fig. 31. Sanohama, a beach on the southwest coast formed by the accumulation of loose ejecta of the central cone blown down from the caldera. S....Sand-covered southern flank of the somma. C...Old sea cliff showing the stratification of ejecta. (Fig. 1, 1e).

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1) 不能ノ瀧

Angular blocks which have fallen from the cliffs are gradually rounded and reduced in size by the action of waves until at last they become sands. Every stage of this course, from large angular blocks to sands, is seen at different parts on the coast of the island. Large angular blocks are found at the foot of every precipitous cliff. Gravel beaches are found at several places, i.e., on the coasts of Chigasaki[1] (1a), of Nomashi[2] (1c), of Okata[3] (2a), etc., while a sandy beach, developed by wave action, is seen on the coast of Motomura[4] being called Yunohama[5] (1c).

Besides the above, there are two sand beaches, a small one, Gyôjahama[6] (3c), on the east coast, and a more extensive one, Sanohama[7] (1e ; Fig. 31), on the southwest coast. But these differ
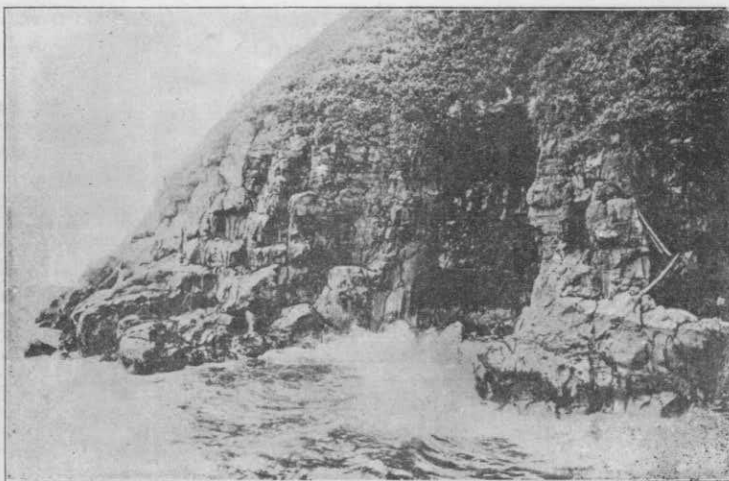
Fig. 32. Cave of Gyôja on the east coast excavated by wave action. The rock constituting the cliff is somma lava of the third type. (Fig. 1, 3c)

from the above in their origin as they were not formed by the action of the waves, but were developed by the accumulation of sands blown down by the wind from the caldera through the north-

1) 千ヶ崎 or 乳ヶ崎　　2) 野増　　3) 岡田　　4) 元村　　5) 湯ノ濱
6) 行者濱　　7) 砂ノ濱

-eastern and the southwestern gaps of the ring-wall of the somma. The former sea-cliffs, at the base of which the wind-blown sands accumulated, are now inland at distances of some 200–500 m. from the present strands, while from the tops of these cliffs to the inside of the caldera extend barren strips of sandy land.

Other effects of the sea waves are the excavation of caves on the precipices and the formation of sea arches and of detached islands of rocks or stacks. Caves are found at some places, i.e. at Gyôja (3c; Fig. 32), at the cliff opposite to Fudeshima[1] (3d), and at the cliff to the south of Chigasaki (1a). An example of sea arches is Neji no Iwaya[2] (3d), on the east coast. Many stacks are seen along the shores of the island. The most conspicuous of these is Fudeshima (3d; Fig. 14, p. 25), on the south part of the east shore.

III. Volcanic Activity in Historic Times.

ÔMORI[3] and NAKAMURA[4] have compiled historic records of the volcanic activity of Ôshima from many scattered and sometimes not readily accessible sources. The following succinct account of the eruptions of Ôshima in historic times is taken mainly from their records.

(1) 684 A.D. (天武天皇十三年)

On November 29, 684 (天武天皇十三年甲申年壬辰十月十四日), an eruption took place in Ôshima. This is the first eruption ever

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1) 筆島　　2) ネヂノ岩屋

3) "Preliminary Report on the Eruption of Volcano Mihara," *Report Earthq. Invest. Com.*, No. 81, 1915 (in Japanese).

"Notes on the Volcanic Eruptions in Japan," *ibid.*, No. 86, 1918 (in Japanese).

4) "History of the Eruptions of Volcano Mihara, Ôshima, Idzu," *ibid.*, No. 79, 1915 (in Japanese).

recorded in our chronology. The land increased by more than
300 *jô* (丈) on the western and northern sides of the island.[1]

Several authors are of opinion that the area now occupied by
the villages of Motomura[2] (formerly called Niijima[3]) and Noma-
shi[4] was formed by this eruption. For such inference, however,
there is no reliable basis, it apparently being merely etymological
as Niijima (the former name of Motomura) means " new island "
(*nii* new, *jima* island) and Nomashi means " field increase " (*no*
field, *mashi* increase).

(2) 1112 (天永三年)

An eruption of Ôshima ?

From November 18, 1112 (天永三年十月二十日) till the end of
the next month, detonations like thunder were repeatedly heard
in Kyôto from an easterly direction.[5]

Some authors consider that these were caused by an eruption
of Ôshima. It is this eruption that was assumed by NAKAMURA,
TERADA, and ISHITANI[6] to have resulted in the formation of the
great gap in the somma wall on its northeastern side (p. 28).

(3) 1416 (應永廿三年)

On September 2, 1416 (應永廿三年八月二日), an eruption of
Ôshima took place.[7]

(4) 1421 (應永廿八年)

On May 14, 1421 (應永廿八年四月四日), an eruption of Ôshima

1) 日本書紀   2) 元村   3) 新島   4) 野增
5) 中右記 (A diary written by MUNETADA NAKATOMI [中臣宗忠]).
6) "The Volcano of Ôshima, its Past and Present," *Proceedings of the Tôkyô Mathematico-Physical Society*, Vol. IV., 1908; *Jour. Geogr. Tôkyô*, No. 238, 1908 (in Japanese).
7) 野史   神明鏡

occurred. Noises like thunder were heard in Kamakura[1] and the sea water became so hot as to cause the death of many fish.[2]

(5) 1600-1601 (慶長五－六年頃)
1612-1613 (慶長十七－十八年頃)
1636-1637 (寛永十三－十四年頃)

In these years, small eruptions took place in Ôshima.[3]

(6) 1684-1690 (貞享元年－元禄三年)

On March 31, 1684 (貞享元年二月十六日), a violent eruption of Ôshima began, the activity continuing for seven years.[4] It is said that a crater measuring about 10 *chô* (町) in diameter was formed on the summit of Mihara[5]. This may probably mean that the central crater of Mihara reached these dimensions at that time.

On April 22, 1684 (貞享元年三月八日), lava flowed out from the foot of Kokamataki,[6] about 1 *ri* (4 *km.*) distant to N. 60° E. from the central crater of Mihara, and reached to the sea shore.

(7) 1777-1778 (安永六年－七年)

The eruption of the An-ei era was the most violent one ever recorded in the history of the volcanic activity of Ôshima. Many writings[7] mention this magnificent outburst.

The first eruption began on August 31, 1777 (安永六年七月二

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1) 鎌倉   2) 鎌倉大日記
3) 伊豆七島明細記 (This book tells of an official manuscript of eruptions.)
4) 分類年代記 甘露叢 近世東西略史 常憲院殿御實記 慶安元禄間記 大島山火記 伊豆七島明細記 伊豆海島志 纉日本王代一覽 伊豆七島志
5) 三原
6) 小釜瀧 (The locality is not known.)
7) 纉日本王代一覽 近世東西略史 後見草 武江年表 大島山火記 伊豆七島明細記 伊豆海島風土記 伊豆海島志 The most authentic and detailed descriptions are found in "Ôshima Sankwaki" (大島山火記), a collection of official reports concerning the eruption of the An-ei era.

十九日). At night, lighting flashes were seen and noises were heard from the summit of the mountain. The land was frequently shaken (probably airquake?), and ashes and Pele's hairs fell throughout the island. On September 29 (八月廿七日), the volcano became quiet, but again broke out in a violent eruption on October 1 (八月廿九日), culminating in the middle of February, 1778 (安永七年正月中旬), then gradually declining.

On May 27, 1778 (安永七年三月二十二日), lava flowed out from the Mihara crater to the northeast and crept down along Nakanosawa,[1] reaching a length of 1 *ri* (4 *km.*).

From October, 1778 (安永七年八月下旬), the volcanic activity again became violent, and on November 6 (九月十八日), lava flowed down to the southwest along Akasawa[2] for 1.5 *ri* (6 *km.*), while on November 15 (九月二十七日), another lava streamed along Gomisawa[3] for 2 *ri* (8 *km.*) falling intot he sea after the " Sawaiian type "[4] (Fig. 30, p. 50).

On December 18, 1778 (安永七年十一月二十一日), an eruption took place at Sôhajikama.[5]

The areas covered by the lavas of the An-ei era are indicated on the geologic map (Pl. V.). For the most part they can actually be traced. The locality of Sôhajikama is not known. At the place where a shrine called Hajikama[6] now stands (3b) there is no trace of any such eruption.

(8) 1803 (享和三年)

On November 14, 1803 (享和三年十月朔日), an eruption of

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1) 中ノ澤   2) 赤澤   3) ゴミ澤
4) B. Kotô. " The Great Eruption of Sakura-jima in 1914," *Jour. Sci. Coll. Imp. Univ. Tôkyô*, Vol. XXXVIII., Art. 3, p. 78, 1916.
5) 宗菓地釜   6) 波治釜

Ôshima took place, and on the next day ashes fell in Yedo (Tôkyô).[1]

(9)   1822   (文 政 五 年)

An eruption of Ôshima took place and ashes fell for two or three years.[2]

(10)   1846   (弘 化 三 年)

At about this date an eruption of Ôshima took place.[3]

(11)   1870   (明 治 三 年)

A small eruption of Ôshima lasted for four days.

(12)   1876-1877   (明 治 九 年―十 年)

A rather violent eruption took place in 1876–1877, being minutely described by NAUMANN[4], MILNE[5], and WADA[6]. The eruption began toward the end of December, 1876 (明治九年). On the 27th, an earthquake (airquake?) occurred, and at night a light on the top of the mountain was seen. The volcanic activity lasted till February 6 (forty days). Lava was poured out in the crater of Mihara[7] but it did not run over the brim of the crater. The result of this eruption was the formation of a miniature spatter cone, NAUMANN's cone, at the bottom of the Mihara crater.

(13)   1912-1914   (明 治 四 十 五 年―大 正 三 年)

This eruption lasted for two years and three months, from

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1)   續日本王代一覽 泰平年表   2) & 3) 大島明細記

4)   "Die Vulkaninsel Ooshima und ihre jüngste Eruption," *Zeilschrift der Deutschen geologischen Gesellschaft*, Bd. XXIX., 1877.

5)   "The Volcanoes of Japan," *Transactions of the Seismological Society of Japan*, Vol. IX., Part II., 1886; *Geological Magazine*, Decade II., Vol. I., No. 5, 1887.

6)   "Notes on the Volcano Ôshima," *Gakugei Shirn*, Vol. I., No. 1. 1877 (in Japanese).

7)   三原

March 1912 (明治四十五年) till May 1914 (大正三年). During this eruption, several experts[1] visited the island and reported in detail their observations on the actual state of the eruption.

Lavas were extruded in five periods with short intervals of quietude between each two successive periods. They did not run over the brim of the Mihara crater but they changed the state of the inside of the crater.

As a premonitory symptom, slight roarings were frequently heard as early as in 1910.

The first activity began with the pouring out of lava from a vent at the crater bottom in March 1912 and terminated on June 10. During this interval, lava was raised to a level of 62 m. below Kawajiri[2] (the lowest point of the upper margin of the crater wall of Mihara, K in Figs. 18–20), half burying NAUMANN's cone, while a small new spatter cone—NAKAMURA's cone[3]—was formed on the surface of the lava layer, somewhat to the south-west of the centre of the crater-bottom.

On July 27, a sudden depression of the consolidated lava layer took place, due to its own weight, leaving the peripheral part in the form of a terrace. This accompanied the breaking up of NAKAMURA's cone and the squeezing out of a new lava, from July 27 to 29, from the clefts and cracks that traversed the lava layer.

The volcano broke out again in a remarkable eruption on

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1) ÔMORI, " Preliminary Report on the Eruption of Volcano Mihara," *Report Earthq. Invest. Com.*, No. 81, 1915 (in Japanese).

NAKAMURA, " The Eruption of Volcano Mihara, Ôshima, Idzu," *Tôyô Gakugei Zasshi,* Nos. 368 & 369, 1912 (in Japanese).

SATÔ, " The Present Activity of the Mihara Volcano," *Jour. Geogr. Tôkyô*, No. 289, 1912 (in Japanese).

OKAMURA, " Report on the Eruption of Volcano Mihara," *Report Geol. Surv. Japan*, No. 48, 1914 (in Japanese).

2) 川尻   3) 中村山

September 16, 1912 (大正元年), which lasted till October 29 (forty-three days). During this interval the extrusion of lava took place from a vent newly formed at the western part of the crater-bottom. NAKAMURA's cone was buried under the new lava except at its apical part, and a new larger spatter cone—ÔMORI's cone[1] (O in Fig. 19, p. 33)—was formed on the bottom.

The layer of the lava extruded by the eruption in September—October sank owing to its own weight on January 14, 1913 (大正二年). This was accompanied by a new extrusion of lava which lasted till the 25th.

A magnificent lava outburst that began again on May 15, 1914 (大正三年) reached its climax of intensity during the next three days, thence becoming gradually weaker until on the 21st the continuous lava extrusion ceased, after which erupting intermittently several times in a day it stopped completely within a few days. The lava extruded in this eruption filled up the depressed part formed in January 1913, reaching a level of 14 m. below Kawajiri. Both NAKAMURA's cone and ÔMORI's cone were buried entirely under the newly erupted materials while several new spatter cones were formed on the crater-bottom (Fig. 20, p. 33).

(14)   1915   (大正四年)

On about the 10th of October, 1915 a light on the top of the mountain was seen at night. On 14th a small amount of black ash fell in Motomura[2] (1c), Sanohama[3] (1e), etc., and at midnight of the 16th strong roarings were heard and airquakes were felt at Motomura. The activity continued till the end of October but ceased without having poured out any lava.[4]

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1) 大森山   2) 元村   3) 砂ノ濱
4) *Tôyô Gakugei Zasshi*, No. 411, 1915 (in Japanese).

IV. Petrography.

Ôshima is built up wholly of volcanic rocks. A brief petrographic description of these was given for the first time by NAU-MANN[1] in 1877, then by YAMASAKI[2] in 1896, and somewhat more in detail by ÔHASHI[3] in 1910. Specially of the lavas erupted in 1912, brief notes were published by OKAMURA[4] who visited the scene of the volcanic activity and collected some specimens.

These descriptions, however, are not sufficiently detailed while some are not quite correct; moreover, there is still a wide field open for further study.

Of the previous writers, NAUMANN spoke of sanidine as one of the essential component minerals, citing in his petrographic description the result of the chemical analysis made by KORSCHELT which shews a very high percentage of alkalies (K_2O 6.28%, Na_2O 2.02%). This would be quite incomprehensible to any one who examined for himself the rocks of Ôshima, which are, in reality, characterized by specially high lime and extremely low alkalies. Nevertheless, this erroneous result has been reproduced in many later papers by MILNE[5], WADA[6], NISHIYAMA[7], BACHER[8], and STARK[9], and has become widely known among the petrologists of

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1) "Die Vulkaninsel Ooshima und ihre jüngste Eruption," *Zeitschrift der Deutschen geolog-ischen Gesellschaft*, Bd. XXIX., 1877.

2) "Report on the Volcano Ôshima," *Report Earthq. Invest., Com.*, No. 9, 1896. (in Japanese).

3) "On the Geology of Volcano Ôshima," *Jour. Geol. Soc. Tôkyô*, Vol. XVII., 1910 (in Japanese).

4) "Report on the Eruption of Volcano Mihara," *Report Geol. Surv. Japan*, No. 48, 1914 (in Japanese).

5) "Volcanoes of Japan," *Transactions of the Seismological Society of Japan*, Vol. IX., Part II., 1886; *Geological Magazine*, Decade II., Vol. I., No. 5, 1887.

6) "Notes on the Volcano Ôshima," *Gakugei Shirin*, Vol. I., No. 1, 1877 (in Japanese).

7) "Explanatory Text to the Geologic Sheet of Idzu," 1886 (in Japanese).

8) "Über die Laven der kleineren Idzu Inseln," München, 1914.

9) "Petrographische Provinzen," *Fortschritte der Mineralogie, Kristallographie und Petro-graphie*, Bd. IV., 1914.

the world.   Above all, the last two of these authors laid emphasis on the assumed alkaline nature of this rock, considering it as one of the examples of the sporadic occurrence of alkaline rocks in the region of calci-alkaline rocks, a fact which has an important bearing on the current discussion of the genetical relationship of these two branches of igneous rocks.

It is to be regretted that this erroneous report has led some petrologists to such an important but incorrect conclusion as stated above.   The writer hopes that the following petrographic decriptions will serve to eliminate this erroneous conception and to add to the meagre petrographic knowledge of the Idzu islands.

In applying names to our rocks, the definitions given by IDDINGS in his "*Igneous Rocks*," Vol. II. have been followed, partly because of the distinctness of his definitions but mainly because his terms seem to be better fitted to our present case than any others yet proposed.

The rocks of Ôshima may perhaps be called " basalt " according to the loose prevailing nomenclature.   In the typical basalt, however, the amount of silica is generally insufficient to form the higher silicates;[1] while in the main types of our rocks, the silica, in spite of its low percentage, is more than enough to form the highest silicates, leaving some of it still in free state, as indicated by the value of k in OSANN's formula ($k>1$) and by the presence of normative quartz.

What has been just stated is one of the common characteristics of the recent volcanic rocks which are so widely spread through the Japanese archipelago and are commonly called " pyroxene-an-

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[1]   The type-basalt, calculated by ROBINSON (*U. S. Geol. Surv.*, *Prof. Paper* No. 76, p. 101, 19:3) yields 9.7% of olivine in the norm.

·desites." IDDINGS's term " bandaite,"[1] which includes the quartzose aphanites characterized by normative labradorite, is not only suggestive of the intimate relation of our rocks with " pyroxene-andesites " but also clearly implies the oversaturation of silica with respect to other components.

The application of the term " basalt "[2] in this paper is restricted only to those rocks so rich in olivine that they are inferred to belong to the perfelic order.

To the rocks of the central cone, a new name " miharaite " has been given on account of their peculiar chemical compositions which will be given later (pp. 87–88).

Some Specially Devised Petrographic Methods.

For the exact identification of the rock-forming minerals, the writer wished to determine their optical properties as far as circumstances permitted. But, since few of the methods of optical measurement have proved to be applicable owing to the minuteness of the mineral grains, the writer has introduced some specially devised ones, of which brief notes are given in the following :—

Refractive Indices.—The refractive indices of the minerals were determined by the BECKE-line method, immersing the mineral grains in liquids of the known indices. With a biaxial mineral, observations were made twice on each grain above a nicol, placing first one of the vibration directions of the mineral grain and then the other parallel to that of the nicol. Repeating the process on a large number of grains of various orientation with different liquids, the highest and the lowest values of the refractive indices, γ' and a', were obtained, and then γ and a were expressed as fol-

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1) *Igneous Rocks*, Vol. II., p. 111, 1913.
2) *Ibid.*, pp. 196-193.

lows: $\gamma > \gamma'$, $a < a'$. For the determination of the limiting values of β, the following method was adopted.

The method is based upon the principle that the value of β lies always between the two values of the refractive indices to be observed on a crystal grain of any orientation.

To prove this principle, let N_1 and N_2 be respectively the greater and the smaller normal velocities in any direction N (Fig. 33) in a crystal, that makes the angles, φ and φ' (where $\varphi > \varphi'$ without any loss of generality), with the two poles of the optic binormals, A and B; and let a and c be respectively the greatest and the smallest principal velocities. Then N_1 and N_2 may be expressed by

$$
\left.
\begin{aligned}
N_1^2 &= \frac{1}{2}(a^2 + c^2) + \frac{1}{2}(a^2 - c^2)\cos(\varphi - \varphi'), \\
N_2^2 &= \frac{1}{2}(a^2 + c^2) + \frac{1}{2}(a^2 - c^2)\cos(\varphi + \varphi').
\end{aligned}
\right\} \quad \cdots\cdots\cdots\cdots(1)
$$

Since the values of the normal velocities are the reciprocals of those of the refractive indices, we have the relations
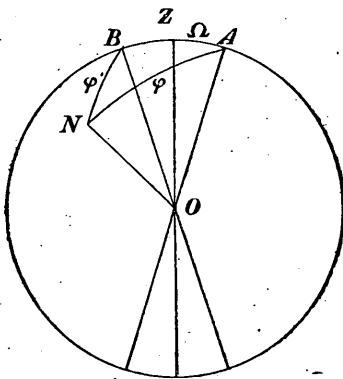
Fig. 33.

$$N_1 = \frac{1}{n_1},$$

$$N_2 = \frac{1}{n_2},$$

$$a = \frac{1}{\alpha},$$

$$c = \frac{1}{\gamma},$$

where n_1 and n_2 are the refractive indices for the faster and the slower waves respectively. From these relations we may transform (1) into

$$n_1{}^2 = \cfrac{1}{\dfrac{1}{2}\left(\dfrac{1}{\alpha^2}+\dfrac{1}{\gamma^2}\right)+\dfrac{1}{2}\left(\dfrac{1}{\alpha^2}-\dfrac{1}{\gamma^2}\right)\cos(\varphi-\varphi')} ,$$

$$n_2{}^2 = \cfrac{1}{\dfrac{1}{2}\left(\dfrac{1}{\alpha^2}+\dfrac{1}{\gamma^2}\right)+\dfrac{1}{2}\left(\dfrac{1}{\alpha^2}-\dfrac{1}{\gamma^2}\right)\cos(\varphi+\varphi')} . \qquad \cdots\cdots(2)$$

Specially when N coincides with B, we have

$$n_1 = n_2 = \beta$$

$$\varphi = 2\Omega \qquad \varphi' = 0°$$

where Ω is the angle between the Z-axis and one of the optic binormals, (2) may therefore be written as

$$\beta^2 = \cfrac{1}{\dfrac{1}{2}\left(\dfrac{1}{\alpha^2}+\dfrac{1}{\gamma^2}\right)+\dfrac{1}{2}\left(\dfrac{1}{\alpha^2}-\dfrac{1}{\gamma^2}\right)\cos 2\Omega} \qquad \cdots\cdots(3)$$

Now, as we have in the spherical triangle ABN (Fig. 33)

$$\varphi-\varphi' \leqq 2\Omega \leqq \varphi+\varphi'$$

it follows that

$$\cos(\varphi-\varphi') \geqq \cos 2\Omega \geqq \cos(\varphi+\varphi') \qquad \cdots\cdots(4)$$

for any values of $\varphi-\varphi'$, $\varphi+\varphi'$, and 2Ω, within the limit of $0°-180°$,[1] and accordingly from (2), (3), and (4) we have

$$n_1^2 \leqq \beta^2 \leqq n_2^2.$$

Moreover, as n_1, n_2, and β are positive, we have

$$n_1 \leqq \beta \leqq n_2 \qquad \cdots\cdots(5)$$

Applying the principle just proved, the limiting values of β were determined as follows :—

The finely crushed fragments of a biaxial mineral were im-

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1) We have here no necessity to consider any angles out of this limit.

mersed successively in liquids of different refractive indices and the determination was made on each fragment whether the refractive index of the liquid, p, was above, below, or lay between, the two values of the refractive indices of the fragment, n_1 and n_2. Getting the results $n_1' < n_2' < p'$ in any trial and $p'' < n_1'' < n_2''$ in another, β was determined from (5) as $p'' < \beta < p'$.

In the writer's practical work with refractive liquids, WRIGHT's solutions were used for feldspars, and mixtures of monobromnaphthalene and methyleniodide for the mafic minerals. The indices of refraction of these sets of liquid for sodium light were measured on a refractometer and their constancy was checked from time to time during experiments.

Optical Orientation.—Optical orientation of feldspar was determined with the cleavage piece parallel to M (010)—in which one of the optical binormals is visible through a conoscope—by the following method :—

Examining the section with a conoscope and putting the zero-isogyre parallel to one of the vibration planes of the nicols, the azimuth (φ) and the central angular distance (ρ) of the pole were measured with the screw micrometer ocular, ρ being reduced from the observed linear distance first to the apparent angle by means of MALLARD's formula and then to the true angle within the crystal, using the value of β obtained by the method described above. The position of extinction was then observed orthoscopically, and all the data obtained were plotted in stereographic projection as in Fig. 34 where O is the
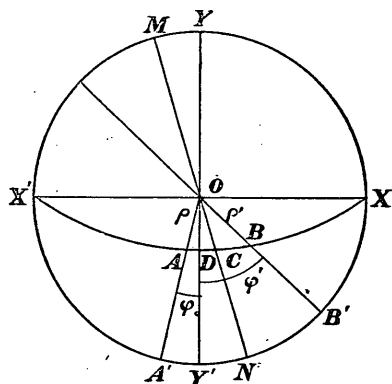
Fig. 34.

centre of the stereogram, XX' and YY' the vibration directions of nicols, A the position of the observed optic axis, XAX' the great circle representing the optical plane, and MN the direction of extinction. The straight line OA was then drawn to cut the stereographic circle at A', and taking the point B' on the same circle so that $A'N=NB'$ and connecting B' with O, the position of the other optic axis B was determined as the point of intersection of the straight line $B'O$ with the great circle XAX' (BIOT-FRESNEL's law).

The azimuth (φ') and the central angular distance (ρ') of the second pole were calculated as follows :—

$$\varphi' = B'ON + Y'ON = A'ON + Y'ON$$
$$= \varphi + Y'ON \times 2 \ldots\ldots\ldots\ldots(1)$$

In spherical triangles, OAD and OBD, we have the relations :—

$$\sin AD = \sin \varphi \sin \rho \ldots\ldots(2)$$
$$\tan OD = \cos \varphi \tan \rho \ldots\ldots(3)$$
$$\cot \rho' = \cos \varphi' \cot OD \ldots\ldots(4)$$
$$\tan BD = \sin OD \tan \varphi' \ldots\ldots(5)$$

and from the formulæ (1), (3), and (4), the values of φ' and ρ' were obtained.

The inclination of the optical plane with respect to the side pinacoid, i. e. $O.P. \wedge M(010)$, was determined by subtracting the value of angle OD from $90°$.

Optic Axial Angle.[1]—Calculating the values of AD and BD with the formulæ (2), (3), and (5), the optic axial angle was determined $(AD + BD)$.

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1) S. TSUBOI, " On the Methods of Measurement of the Optic Axial Angle of a Mineral in Rock Slice," *Jour. Geol. Soc. Tô'cyô*, Vol. XXIV., p. 149, 1917 (in Japanese).

Special Descriptions.

Special descriptions of the rocks of Ôshima will be given below in the following order :—

(A) Lavas of the Somma.

1) Basaltic bandaite almost free from phenocrysts of mafic minerals.

2) Hypersthene-basaltic bandaite.

3) Two-pyroxene-basaltic bandaite.

4) Hypersthene-bearing augite-olivine-bytownite-basalt.

(B) Lavas of the Central Cone.

5) Miharaite.

(C) Rocks constituting the Demolished Igneous Bodies along the Western Half of the Northern Coast.

6) Two-pyroxene-olivine-anorthite-basalt.

7) Olivine-bytownite-basalt (a).

8) Olivine-bytownite-dolerite.

9) Olivine-bytownite-basalt (β).

(D) Rocks occurring as Dykes.

10) Olivineless-basaltic bandaite (a).

11) Olivineless-basaltic bandaite (β).

(E) Ejecta.

12) Ashes, Sands, Lapilli, and Bombs.

13) Micro-allivalite.

14) Augite-micro-diorite.

(A) Lavas of the Somma.

1) Basaltic bandaite almost free from phenocrysts of mafic minerals. (The first type of the somma lava.) (Pl. I. Figs. 1–6.)

This type contains the lavas of more or less wide latitude. The characteristic feature which distinguishes this from the others

is meagreness of phenocrysts of mafic minerals.

Mode of Occurrence.—The somma lavas of this type are of
the widest distribution. They are found through all parts of the
island in numerous flows, both superfluent and effluent, alternated
by layers of clasmatic materials and constitute the main part of
the somma. The best exposures of these lavas are met with on
the precipitous cliffs that surround the island (Pl. VI.) and on the
ring-wall at the top of the somma.

Megascopic Characters.—The rock varies in megascopic char-
acters from only slightly to strongly porphyritic, plagioclase con-
stituting the most conspicuous phenocrysts. They are usually
equant in development, very often grouped in cumuloporphyric
fabric, and vary in diameter from 0.2 to 3 *mm*. In most lavas,
small sporadic phenocrysts of olivine are found, but in some, they
are wholly wanting. In rare instances, it happens that small
phenocrysts of hypersthene and augite occur in negligible amount.
These phenocrysts are scattered through the groundmass with no
trace of any regular arrangement.

The groundmass is megascopically of two types : (α) black in
colour and generally porous and slaggy, and (β) gray in colour
and rather compact or almost free from pores and vesicles ; the
two, however, are connected by intermediate types. The differences
between these types are attributable merely to the varying
conditions under which the rocks consolidated. As a rule, the
surficial part of each lava has the groundmass of α-type and the
inner part that of β-type.

Microscopic Characters.—Under the microscope, phenocrysts
of plagioclase are always seen, but those of other minerals rarely
appear in thin section.

Phenocrystic *plagioclase* is generally euhedral to subhedral,

and often forms a group of two or three individuals. The following optical properties were determined for sodium light :—

$$\alpha < 1.571 \quad 1.572 < \beta < 1.575 \quad 1.578 < \gamma \quad \gamma - \alpha > 0.007$$

$$2V \rightleftharpoons 82° \text{ supposing } \beta = 1.574 \quad \text{Optical characte} \cdots\cdots \text{negative.}$$

The three principal refractive indices were determined with a number of specimens from various localities. The optic axial angle, $2V$, was measured with a cleavage piece of feldspar parallel to M (010) taken from the lava exposed on the sea cliff to the south of Chigasaki[1] (1a ; Pl. VI. AB 1). From the above optical prop-erties, the mineral was identified as calcic bytownite with its chemical composition $Ab_{15}An_{85}$ according to BECKE.[2] Three types of twinning of this mineral were observed: those according to the Carlsbad, albite, and pericline laws. The former two are very common, while the last is only rarely met with. Albite-twinned lamellæ are generally thick and not numerous. Zonal structure due to a difference of chemical compositions is not noticeably exhibited. The mineral is generally poor in inclusions, but it sometimes contains uncrystallized or half-crystallized substance which seems to be rock mass imprisoned before consolidation.

Olivine, which is found in most lavas as phenocrysts though these are extremely small in number, is always subhedral to an-hedral, occasionally with a resorption-border. Sometimes olivine crystals are reduced to very small grains by magmatic resorption. With the grains of this mineral separated from the chemically analysed specimen, the following optical measurement was made :—

$$\alpha < 1.6906 < \beta < 1.7146 < \gamma \quad \gamma - \alpha > 0.024$$

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1) 千ケ崎 or 乳ケ崎

2) " Zur Physiographie der Gemengteile der krystallinen Schiefer," *Denkschriften der kaiserlichen Akademie der Wissenschaften*, 75 Band, S. 103, 1913 (Wien).

From these values of the refractive indices the composition of the olivine is inferred to be about $(Fe_2SiO_4)_{25-30}(Mg_2SiO_4)_{75-70}$ according to H. BACKLUND.

Pale light greenish *augite* and low double-refracting, weakly pleochroic *hypersthene* are extremely rare as phenocrysts. The former is in subhedral to anhedral forms, sometimes twinned on (100); the latter is always normal in optical orientation so far as observed. Sometimes the two occur in parallel intergrowth.

The *groundmass* consists of prismoid plagioclase, light greenish anhedral augite, and magnetite, usually with more or less interstitial glass. Plagioclase is here labradorite varying from $Ab_{50}An_{50}$ to $Ab_{35}An_{65}$ with the mean refractive index 1.558—1.565. Augite has the refractive indices $\alpha < 1.6836$ $1.6836 < \beta < 1.6869$ $1.6975 < \gamma$, and is comparable with the mineral described as diopside from Taberg in which the medium refractive index is 1.6836. Th texture of the groundmass varies in different parts. In its megascopically black part (α-type), it is docrystalline; and fine-grained irregularly shaped, often dendritic, skeletal crystals of magnetite disseminate among the plagioclase prisms and augite grains. The interstitial glass is colourless but sometimes appears brown in the vicinity of the vesicles owing to fine dusty inclusions. In its megascopically gray, compact part (β-type), the groundmass is nearly holocrystalline, granular intersertal, and the felsic and mafic components are present in equal amount. Here the magnetite crystals are generally large and show their own forms.

Chemical Characters.—A specimen from the uppermost lava (Pl. VI. DE 4) exposed on the south shore at the east end of Sashikiji[1] (2e) was chemically analysed by Mr. ÔHASHI of the Geological Survey through the kindness of Prof. KOTÔ, to both

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1) 差木地

of whom the writer is much indebted. The analysed specimen was nearly holocrystalline, consisting of calcic bytownite, labradorite, diopsidic augite, and magnetite, with a negligible amount of olivine. This specimen has been selected for analysis because it belongs to the most widely spread type of the somma lavas, while being nearly holocrystalline, as stated, it consequently affords a correlative comparison of its mineralogical and chemical characters.

The result of the chemical analysis is as follows :—

	Weight percentage.	Molecular ratio.
SiO_2	53.01	0.884
Al_2O_3	14.73	0.144
Fe_2O_3	3.38	0.021
FeO	9.42	0.131
MgO	4.97	0.124
CaO	9.09	0.162
Na_2O	2.09	0.034
K_2O	0.44	0.005
H_2O	1.22	0.068
TiO	1.03	0.013
ZrO_2	0.04	——
MnO	0.34	0.005
P_2O_5	0.11	0.001
Total	99.87	

Osann's formula.

$s=58.12$ $A=2.52$ $C=6.80$ $F=23.24$
            $a=1.55$ $c=4.18$ $f=14.27$
            $n=8.70$ $k=1.12$

Norm.

Quartz 9.6
Orthoclase 2.8

Albite 17.8

Anorthite................................29.2

Diopside 12.4

Hypersthene 19.7

Magnetite 4.9

Ilmenite 2.0

Apatite 0.3

Ratios.

$$\frac{\text{Sal}}{\text{Fem}} = 1.57 \qquad \text{Class 'III}$$

$$\frac{Q}{F} = 0.19 \qquad \text{Order 4'}$$

$$\frac{Na_2O' + K_2O'}{CaO'} = 0.37 \qquad \text{Rang 4}$$

$$\frac{K_2O'}{Na_2O'} = 0.15 \qquad \text{Subrang 4'}$$

According to the C. I. P. W. quantitative system, the rock belongs to 'III. 4'. 4. 4'., an unnamed subrang.

Name of Rock.—The characteristic feature of the present rock is well seen in OSANN's formula as well as in the norm. In the values of a, c, and f, the present rock accords with " plagioclase-basalt of the Royat type "[1], from which, however, it is decisively distinguished in the value of k.

Normatively, the present rock is characterized by labradorite $Ab_{39}An_{61}$ and contains quartz molecules in such quantities that it is classified in the quardofelic order in the quantitative system. The rock is, therefore, to be classed as " bandaite "[2] according to IDDINGS's term. But as the present rock is transitional to " basalt " in its less quaric and more femic characters, it may properly be called " basaltic bandaite."

1) OSANN, *Tschermak's Min. u. Petr. Mitth.*, Bd. XX., S. 451, 1901.

2) IDDINGS, *Igneous Rocks*, Vol. II., p. 111, 1913.

2) **Hypersthene-basaltic bandaite.** (The second type of the somma lava.) (Pl. II. Fig. 1.)

This type looks like the sempatic variety of the preceding one in its megascopic appearance, but is characterized by the presence of hypersthene phenocrysts in moderate quantity.

Mode of Occurrence.—The rock of this type occurs only as a small flow and is exposed on the sea cliff to the south of Moto-mura[1] (Pl. V. 1c *II*; Pl. VI. BC 2). As seen in Pl. VI., it is clear that lava of the present type was poured out in the middle of the outpouring of lavas of the first type, and accordingly that the petrographic difference between this type and the preceding one is not due to a difference in the time of its extrusion but must be attributed to another cause. This point will be discussed later (pp. 118–119).

Megascopic Characters.—Megascopically, the rock is strongly porphyritic, with numerous phenocrysts of plagioclase and moderate ones of hypersthene. They are scattered with no trace of any regular arrangement. The plagioclase is 2 *mm.* in average diameter and the hypersthene is of about the same size being dark green with resinous luster. The groundmass is grayish black and aphanitic, and has many small pores of rather irregular shape, averaging in diameter about 1.5 *mm.*, uniformly distributed through the whole parts of the rock, but is not slaggy.

Microscopic Characters.—Under the microscope, the rock is porphyritic and sempatic. The conspicuous phenocrysts are short prismatic crystals of calcic bytownite ($Ab_{15}An_{85}$). Its character is quite the same as that of the mineral in the preceding type and requires no special mention.

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1) 元村

Other phenocrystic minerals are pyroxenes, only in a subordinate quantity. Of these, subhedral prismatic crystals of *hypersthene* greatly predominate over those of light greenish *augite* in which $c \wedge Z \geqq 43°$. The latter are often found surrounding the former in thin shells in parallel intergrowth.

The following optical properties of hypersthene were observed :—

$$a < 1.6906 \qquad 1.6906 < \beta < 1.7146 \qquad 1.7014 < \gamma$$
$$2V \doteqdot 85° \text{ supposing } \beta = 1.7 \qquad \text{Optical character} \ldots \text{negative.}$$

Pleochroism is not strong :—

X ... light reddish brown
Y ... light reddish yellow
Z ... light bluish green.

The above optical properties of hypersthene are comparable to those of the mineral from Labrador containing 10% of FeO, which was studied by Lévy and Lacroix. The Labrador specimen has the refractive indices :—

$$a \doteqdot 1.692 \qquad \beta = 1.702 \qquad \gamma = 1.705$$

The *groundmass* is percrystalline and centimillimeter-grained, and consists of prismoid crystals of labradorite ($Ab_{50}An_{50}$), anhedral light greenish augite, and isometric magnetite, with only a trifling amount of interstitial glass pigmented into brown with very fine dusty inclusions. The felsic and mafic components are nearly equal in quantity and the texture is granular intersertal or typically basaltic.

3) Two-pyroxene-basaltic bandaite. (The third type of the somma lava.) (Pl. II. Figs. 2-3.)

The rock of this type is marked by the presence in moderate

quantity of phenocrysts of both hypersthene and augite besides those of plagioclase, and by the entire absence of olivine.

Mode of Occurrence.—The exposure of the lavas of this type is seen only on the cliff at Gyôja[1], on the east coast, in three layers, each about 20 m. in thickness, intercalated by layers of ejecta (Pl. V. 3c *III*; Pl. VI. FG 6). The geologic relation between lavas of this type and those of the first type could not be observed owing to the accumulation of sands and lapilli of the central cone blown down by the wind from the caldera through the northeastern gap of the ring-wall of the somma.

Megascopic Characters.—The rock is megascopically fine-grained, non-vesicular and is gray, sometimes with a purplish tone due to the partial hematitization of magnetite grains in its groundmass. It is megascopically dopatic, the phenocrysts being of plagioclase, usually less than 2 mm. in diameter, and of dark greenish pyroxenes, smaller and less abundant than the former but not negligible.

Microscopic Characters.—Microscopically, the rock is docrystalline in crystallinity and seriate porphyritic in fabric. The most conspicuous phenocrysts are of *calcic bytownite* near $Ab_{12}An_{88}$, as identified from its optical properties, commonly exhibiting the Carlsbad and albite twins but rarely the pericline, and with rather scanty inclusions of augite microlites, black glass, and fine dust, arranged irregularly or zonally. Sometimes the mineral is coated by a thin layer of less calcic plagioclase (labradorite) with a distinct boundary between them. The core part has the following optical properties :—

$$a < 1.571 \qquad 1.574 < \beta < 1.577 \qquad 1.578 < \gamma$$

$$2V \doteqdot 84° \text{ supposing } \beta = 1.576 \qquad \text{Optical character....negative.}$$

1) 行者

The subordinate phenocrysts are of *hypersthene*, rather low in FeO as may be inferred from its optical properties, and of light greenish *augite*, subhedral to anhedral and prismoid to equant, sometimes twinned after (100). The two are found in some cases in parallel intergrowth. Their optical properties are :—

Hypersthene

$$a < 1.6906 < \beta < 1.7146 < \gamma$$

$2E \doteqdot 89°$ $2V \doteqdot 82°$ supposing $\beta = 1.7$ Optical character .... negative.

Pleochroism :—

X .... light reddish brown
Y .... light reddish yellow
Z .... light bluish green

Augite

$a < 1.6869$ $1.6869 < \beta < 1.6906$ $1.7014 < \gamma$ $c \wedge Z \doteqdot 45°$

The angle $c \wedge Z$ was measured on a section of augite in parallel intergrowth with hypersthene whose interference figure shows that the section is cut parallel to (010).

The intersertal *groundmass* consists of plagioclase prisms, 0.05—0.3 *mm.* in length, light greenish augite grains ($a < 1.6836 < \beta < 1.6869 < \gamma$), and magnetite, subhedral to anhedral often showing dendritic skeletal crystals.

4) Hypersthene-bearing augite-olivine-bytownite-basalt.

(The fourth type of the somma lava.) (Pl. II. Fig. 4.)

Rock of this type is highly characterized by the presence of abundant olivine phenocrysts, and is decisively distinguishable from the preceding types in this respect.

Mode of Occurrence.—This type is a decidedly rare one, occurring only at the locality indicated on the geologic map (Pl. V.

3d) by *IV* on the east coast (Pl. VI. EF 5). The exposure at this locality is as shown in Fig. 35, where L_4 is the lava of the present type, and L_1 that of the first type, i. e. the most

Fig. 35. Ag............Agglomerate bed.
Ej............Other ejecta bed.
L_{1a} L_{1b} ....Lava of the first type.
L_4 ....Lava of the fourth type.

widely spread basaltic bandaite. There the present rock-type occurs in ten flows, each under $1 m$. in thickness and with thin layers of scoriæ and ashes between them. As may be seen from Fig. 35, lavas of the present type L_4 must have been discharged from a local vent during the extrusion of the lavas L_{1a} and L_{1b}, both of which belong to the first type.

Megascopic Characters.—Megascopically, the rock is strongly porphyritic with phenocrysts of plagioclase, olivine, and augite, scattered through the groundmass without a trace of any regular arrangement. Plagioclase phenocrysts, single or grouped, are most abundant and average about 2 *mm*. in diameter, the largest being over 5 *mm*. Olivine, though small in size (<1 *mm*.), is found abundantly and is conspicuous for its characteristic luster. The augite phenocrysts, mostly in groups of two or three individuals, are about 2 or 3 *mm*. in diameter, and vary greatly in amount in different flows. The groundmass is grayish and aphanitic and has pores of various size (<3 *mm*. in diameter).

Microscopic Characters.—Microscopically, the rock is sempatic. Single or grouped phenocrysts of *calcic bytownite* ($Ab_{15}An_{85}$) with the refractive indices $\alpha < 1.571$ $1.572 < \beta < 1.575$ $1.579 < \gamma$

are seen abundantly. They are generally subhedral, commonly twinned according to the Carlsbad, albite, and rarely pericline laws, and carry rather abundant inclusions (mostly augite grains, extremely few magnetite crystals, and a fine dusty substance), usually arranged zonally in thin bands parallel to the crystal outline. The zonal structure due to chemical difference is sometimes exhibited, especially in the peripheral part, though very faintly. In the simplest case, the less calcic plagioclase surrounds the more calcic, but in some cases the more calcic and less calcic zones alternate between the most calcic core and the least calcic outermost shell.

Phenocrysts of *olivine*, next to those of plagioclase in amount, are anhedral to subhedral, generally resorbed, often with deep indentation. The alteration products, iddingsite and magnetite, are often seen deposited along the cracks. Very poor inclusions of this mineral are colourless glass and trichites.

Subordinate phenocrysts of pyroxenes, of which *hypersthene* is negligible in quantity, show the usual characters. Of the *augite* phenocrysts the following refractive indices were measured[1]:—

$$\alpha' \doteqdot 1.6869 \qquad 1.6869 < \beta < 1.6906 \qquad 1.7014 < \gamma \qquad \gamma' < 1.7168$$

The *groundmass* is percrystalline, centimillimeter-grained, and granular intersertal, being built up of granular augite and prismoid plagioclase with euhedral magnetite scattered here and there and only a negligible amount of glass, very often appearing brown because of fine dusty inclusions. It is a remarkable feature of the groundmass that the mafic components nearly equal, and at times even exceed the felsic, in quantity as well as in size.

Name of Rock.—The present rock is so rich in olivine that it is inferred to belong to the perfelic order of the quantitative system,

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1) Here α' and γ' denote respectively the observed minimum and maximum refractive indices.

and is therefore classed as " basalt ", following the definition given by IDDINGS.[1]

(B) Lavas of the Central Cone.

5) Miharaite. (Pl. II. Figs. 5-6. Pl. III. Figs. 1-4.)

The central cone is built up of many lava flows intercalated by layers of ejecta, as has already been stated (p. 30). Though each of these has certain peculiar characters, both in magascopic and microscopic features, all agree so closely in their important petrographic characters that they are rightly treated as belonging to the same type.

It is a remarkable fact that no trace of olivine has ever been detected in the lavas of the central cone in contrast to the olivine-bearing somma lavas.

Older Lava (Pl. II. Fig. 5).—Older lavas of the central cone are exposed in layers on the inner wall of the crater. The specimen of which the following description is given came from the lowest exposed lava on the east wall of the crater.

Megascopically, phenocrysts of plagioclase, 2 or 3 *mm.* in diameter, are scattered moderately, and those of hypersthene, far smaller than the former, sporadically through the groundmass. The groundmass is gray to black, aphanitic, and varies from compact to more or less porous and slaggy.

Under the microscope, calcic plagioclase and hypersthene are found as phenocrysts; and less calcic plagioclase, augite, and magnetite, as the constituents of the groundmass. Interstitial glass is present in variable but generally in small quantities. The groundmass varies within a wide range both in granularity and

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1) *Igneous Rocks*, Vol. II., p. 196, 1913.

crystallinity, and the texture is accordingly from nearly hyalopilitic to granular intersertal.

An-ei Lava (1778) (Pl. II. Fig. 6).—The lava of 1778 is the most conspicuous now seen in Ôshima. As is shown in the geologic map (Pl. V.), extensive lava fields stretch from the top crater eastwards and southwards to the sea shores in almost uncovered condition. The field feature of this lava shows that it belongs to the "Pahoehoe" type. The vesiculation of the mass of the lava is rather evenly developed and uniformly disseminated as DALY[1] says, but the size of the pores is not always very small.

Megascopically, plagioclase phenocrysts, 0.5 — 3 *mm.* across, are sparsely scattered through the compact, aphanitic groundmass with abundant vesicles varying in diameter from a few *mm.* to 1 *cm.* They are mostly spherical, but some are elongated in one direction, even to such an extent that the length is ten times the breadth.

Microscopically, plagioclase phenocrysts are always seen. The groundmass consists of plagioclase, augite, magnetite, and brown glass. Its texture varies in different parts owing to the different conditions of consolidation. A specimen from the lava field on the northern flank of the central cone shows microporphyritic ground-mass (Pl. II. Fig. 6) with microphenocrysts (0.05-0.3 *mm.* across) of plagioclase, augite, and a few of hypersthene scattered in dopatic fabric through the black base which even in thin section is opaque owing to the fine dissemination of magnetite. Another specimen collected near the eastern end of the flow has its groundmass quite like that of *a*-type (p. 70) of the somma lava.

Meiji-Taishô Lava (1912-1914) (Pl. III. Figs. 1-4).—During the eruption in 1912-′14, the extrusion of lavas took place in five

1) *Igneous Rocks and Their Origin*, pp. 290-291, 1914.

"The Nature of Volcanic Action," *Proceedings of the American Academy of Arts and Sciences*, Vol. XLVII., No. 3, 1911.

periods. These lavas did not run over the brim of the crater but filled the bottom of it.[1]

Megascopically recognizable minerals are plagioclase and pyroxene. The former occurs abundantly as megaphenocrysts with a diameter varying mostly from 0.2 to 3 *mm.*, while the latter is only sporadically found and is far inferior in size. The colour of the groundmass varies in different parts. In its slaggy part it is jet-black, while in its more compact part it is dark gray. The surface of each lava is often coated with a thin scoriaceous film, brown in colour.

Microscopically, the rock contains abundant phenocrysts of plagioclase, a few of hypersthene and clino-hypersthene, and a negligible amount of augite. The texture of the groundmass varies. In the megascopically gray, comparatively compact part, it is percrystalline in crystallinity and decimillimeter-grained in granularity, consisting of prismoid plagioclase, augite grains, magnetite, and apatite (extremely rare), with only a negligible amount of interstitial glass, arranged in ophitic texture (Pl. III. Fig. 1); while in the black slaggy part, it is hyalocrystalline or docrystalline, plagioclase and augite swimming in the brown base, and is almost free from visible magnetite crystals (Pl. III. Fig. 2). In the part of the intermediate crystallinity, the groundmass is black and opaque in thin section owing to the dissemination of fine grains of magnetite (Pl. III. Figs. 3 & 4).

Characters of the Component Minerals.—*Plagioclase* occurs as phenocrysts and as a constituent of the groundmass. The phenocrystic one is euhedral and subhedral, and is developed in prismatic and nearly equant habits. Two or three individuals of

this mineral often form a grouped phenocryst. Twinning is usually present in simple and polysynthetic lamellæ according to the albite, Carlsbad, and rarely pericline laws. Zonal structure due to chemical difference is often very faintly exhibited. The mode of zoning is not always very simple, the more calcic and less calcic feldspars being often alternately developed in successive zones (Fig. 36). It is a general rule, however, that the outermost one coating each crystal in a very

1. Most calcic.
2. More calcic.
3. Less calcic.
4. Least calcic.

Fig. 36.

thin shell is the least calcic and the innermost one is the most calcic. The refractive indices measured with the isolated pieces are : $a < 1,572 < \beta < 1.578 < \gamma$, so the mineral was identified as calcic bytownite with its chemical composition $Ab_{13}An_{87}$ according to BECKE.[1] The optic axial angle was determined to be approximately $88°$ supposing $\beta = 1.575$. The mineral contains numerous inclusions of augite, feldspar, glass, and fluid bubbles. These are often arranged in distinct zones orientating themselves parallel to the outline of the host.

The plagioclase in the groundmass is too fine to be determined accurately, but as the mineral has its refractive indices near 1.57 in average it may be slightly less calcic (sodic bytownite) than the phenocrystic one. It is prismoid in crystal habit and is very commonly twinned in two or three lamellæ.

Another mode of occurrence of plagioclase which deserves special mention is as " rhombic lamellæ " (Pl. III. Fig. 2). These are found imbedded in brown glass and are often so extremely thin that their action on polarized light is scarcely recognizable.

1) "Zur Physiographie der Gemengteile der krystallinen Schiefer," *Denkschriften der kaiserlichen Akademie der Wissenschafte*, 75 Band, S. 103, 1913 (Wien).

They are more noticeably developed in more hyaline facies and make gradual transition to the plagioclase of common type. Most of them measur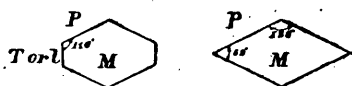e from 0.03–0.12 *mm.* along the longer diagonals of the rhombs. Well defined rhombs have angles measuring about 52°, 116°, and 128°, and thus seem to be bounded by the faces M (010), P (001), x (10$\bar{1}$), and T (1$\bar{1}$0) or l (110), as shown in Fig. 37, i. e. the lamellæ are very thin tabular parallel to M (010)."[1]

Fig. 37.

Hypersthene and *clino-hypersthene.*—Hypersthene occurs in subordinate amounts as phenocrysts of prismatic form measuring 0.2–1 *mm.* along the longest direction, being nearly euhedral to anhedral. Prismatic cleavage is sometimes noticeably exhibited and transverse cracks are often seen. Axial colours observed in thin section are :—

$\parallel c$ .... greenish $\perp c$ .... brownish

Conoscopic examination shows that the two forms of hypersthene are present—the normal one and that of the clino-form, with the trace of the optical plane parallel and transverse to the *c*-axis respectively. In properties other than the optical orientation the two behave quite alike and have no other characteristics to distinguish

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1) A similar occurrence of plagioclase is said to have been observed in the basaltic glass of Ogasawarajima (Bonin Islands), on which an account was given by the late Dr. Y. KIKUCHI ("On Pyroxenic Components in Certain Volcanic Rocks from Bonin Islands," *Jour. Sci. Coll. Imp. Univ. Japan*, Vol. III., pp. 70–73, 1889). There he observed that the "rhombic lamellæ" make gradual transition to the porphyritic crystal of plagioclase, as in the present case, and thus he confirmed that they are plagioclase (probably anorthite), as suggested by PENCK ("Studien über lockere vulkanische Auswürflinge," *Zeitschrift d. Deutschen geol. Gesellschaft*, Bd. XXX., S. 99, 1878), KREUTZ ("Ueber Vesuvlaven von 1881 und 1883," *Tschermak's Min. u. Petr. Mitth.*, Bd. IV., S. 139, 1885), and Doss ("Die basaltischen Laven und Tuffen der Provinz Hauran und vom Diret et-Tulûl in Sirien," *Tschermak's Min. u. Petr. Mitth.*, Bd. VII., S. 527, 1836). Crystal faces observed by him are as follows :—

F (001), M (010), y (20$\bar{1}$), o (11$\bar{1}$), p (1$\bar{1}\bar{1}$), x (10$\bar{1}$).

Twinning according to the albite and Carlsbad laws was also observed by him in the rock of Ogasawarajima.

them from each other. Polysynthetic twinning after (100) 'which is said to be very characteristic of clino-enstatite[1] is entirely absent in our clino-hypersthene.

Augite is a light greenish variety. It is found very rarely as microphenocrysts, but abundantly in the groundmass as one of the essential ingredients, and ranges from nearly euhedral to anhedral. Sometimes the mineral occurs in a thin rim around hypersthene in parallel intergrowth. The common type of twinning after (100) is often met with, while the intergrowth with plagioclase penetrating each other in cross is sometimes seen.

Magnetite occurs in rather large euhedral crystals in the more crystalline part, reaching as large as 0.06 *mm.* in diameter, while in the less crystalline part it shows very often dendritic skeletal forms.

Apatite is almost absent, its needle with characteristic negative elongation (0.02 *mm.* in length) was detected only in one instance in thin section from the percrystalline part of the recent lava.

Glass base is uniformly brown in thin section. Its index of refraction was measured with the powders from the more hyaline part of the recent lava to be $n = 1.593 - 1.596$. This high refractive index shows the basic nature of the glass.

Chemical Characters.—The chemical analyses of three of the lavas and one of the scoriæ of the recent eruption gave the following results :[2]—

	A	B	C	D	E
SiO$_2$	51.94	51.13	51.32	51.40	51.45
Al$_2$O$_3$	15.36	17.75	16.84	17.42	16.84
Fe$_2$O$_3$	3.11	0.45	0.65	1.74	1.49

1) O. ANDERSEN, "System Anorthite-Forsterite-Silica," *Am. Jour. Sci.* (4), Vol. XXXIX., p. 419, 1915.

2) These analyses were made in the Geological Survey and were published by OKAMURA in his report on the recent eruption (*Report Geol. Surv. Japan*, No. 48, 1914).

	A	B	C	D	E
FeO	9.81	11.58	12.14	10.26	10.95
MgO	4.93	4.40	4.22	4.36	4.48
CaO	10.54	10.83	10.85	10.51	10.71
Na$_2$O	0.77	1.30	1.52	1.44	1.23
K$_2$O	0.49	0.36	0.41	0.22	0.37
H$_2$O	0.43	0.95	1.00	0.49	0.72
TiO$_2$	1.53	1.01	1.01	1.44	1.27
P$_2$O$_5$	0.89	trace	trace	0.15	0.26
MnO	0.21	0.25	0.29	0.03	0.19
Total	100.01	100.01	100.25	99.46	99.96

A........Lava in April, 1912.

B........Lava in October, 1912.

C........Scoria in October, 1912.

D........Lava in December, 1912.

E........The average of the above four analyses.

Osann's formulæ.

	A	B	C	D	E
s	57.69	56.24	56.26	57.10	56.84
A	1.10	1.63	1.88	1.63	1.56
C	8.66	8.68	8.81	9.52	9.15
F	22.86	22.14	22.36	20.60	21.74
a	0.67	0.97	1.14	1.03	0.96
c	5.31	5.79	5.33	6.09	5.64
f	14.02	13.24	13.53	12.97	13.40
n	7.06	8.40	8.62	9.20	8.33
k	1.23	1.02	1.10	1.16	1.15

Norms.

	A	B	C	D	E
Quartz	14.2	6.1	5.3	9.2	8.8
Orthoclase	2.8	2.2	2.2	1.1	2.2
Albite	6.3	11.0	13.1	12.1	10.5

	A	B	C	D	E
Anorthite.	37.3	41.4	37.8	40.6	39.2
Diopside	8.4	10.3	13.6	9.1	10.3
Hypersthene	21.4	25.5	24.3	21.4	23.2
Magnetite	4.4	0.7	0.9	2.6	2.1
Ilmenite	2.9	2.0	2.0	1.7	2.4
Apatite	1.9	——	——	0.3	0.6

Ratios.

	A	B	C	D	E
$\dfrac{Sal}{Fem}$	1.55	1.58	1.43	1.79	1.57
$\dfrac{Q}{F}$	0.31	0.11	0.10	0.17	0.17
$\dfrac{Na_2O'+K_2O'}{CaO'}$	0.13	0.17	0.21	0.17	0.17
$\dfrac{K_2O'}{Na_2O'}$	0.42	0.19	0.16	0.09	0.20

Of the four analysed rocks, two (B and C) belong to *auvergnose* ('III. '5. 4. 4'.), one (D) to *bandose* (II'. 4'. 4'. 5.), and one (A) to an unnamed subrang ('III. 4. '5. 4.). The average of the four analyses places the rock at 'III. 4'. 4'. 4.

Name of Rock.—As is clear from the above description, the rock is basaltic, but is remarkable in its amount of silica relative to other components. This amount is not only sufficient to form the highest silicates but yields it to excess, which appears in the norms as occult quartz, so that the rock finds its position in average at the quardofelic order in the C. I. P. W. quantitative-system. The normative plagioclase, on the other hand, is as calcic as bytownite ($Ab_{16}An_{85}$ in A, $Ab_{22}An_{78}$ in B, $Ab_{27}An_{73}$ in C, $Ab_{24}An_{76}$ in D, and $Ab_{22}An_{78}$ in average). The rock is, therefore, *an aphanite belonging to the quardofelic order or very near to it, with the normative bytownite.*

The rocks with strongly calcic normative plagioclase usually

belong to the perfelic order with either a negligible amount of quartz or none, while those belonging to the quardofelic order are not yet known to have such calcic plagioclase as bytownite.[1] Thus, the rock now under consideration is quite unique in its composition.

Of the quardofelic aphanites characterized by lime-soda-feldspars, those with normative oligoclase, andesine, and labradorite are respectively called ungaite, shastaite, and bandaite. It is clear from the characters described above that the present rock must occupy the vacant position next to bandaite, or thereabout in the same group, being characterized by normative bytownite. Thus, it seems to be necessary, on account of its peculiar characters, to give a new name to our rock, for which "miharaite"[2] is here proposed, derived from the name of the central cone, Miharayama.[3]

In the following table, miharaite is compared with (i) the type-basalt given by ROBINSON,[4] (ii) the alboranite from Isla de la Nube, Alboran, described by BECKE[5], and (iii) the diabase from Barima District, British Guiana, described by HARRISON.[6]

     A...... Average composition of the present rock 'III. 4'. 4'. 4.

     B...... Type-basalt, calculated by ROBINSON from 246 analyses in II.
           5. 4. 3., III. 4. 3. 4., III. 5. 3. 4 & 5., III. 5. 4. 3., III. 5. 5.

     C...... Alboranite, 'III. 5. '4. 3(4). *auvergnose.*

     D...... Diabase, 'III. '5. '5. 5. *ouenose.*

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1) IDDINGS says, in a description of the phanerites belonging to the same group as the present rock, that the feldspars of any rock of this group almost never average as calcic as bytownite-anorthite (*Igneous Rocks*, Vol. II., p. 44, 1913).

2) "Mihara-gan" (三原岩) in Japanese.

3) 三原山

4) "The San Franciscan Volcanic Field, Arizona," *U. S. Geol. Surv., Prof. Paper* No. 76, p. 101, 1913.

5) *Tschermak's Min. u. Petr. Mitth.*, Bd. XVIII., S. 525, 1899.

6) *Rep. G. N. W. District*, II., p. 6, 1898. Reproduced in the following works:—

H. S. WASHINGTON, "Chemical Analyses of Igneous Rocks," *U. S. Geol. Surv., Prof. Paper* No. 14, p. 337, 1903.

IDDINGS, *Igneous Rocks*, Vol. II., p. 227, 1913.

	A	B	C	D
SiO_2	51.45	48.0	53.13	50.76
Al_2O_3	16.84	16.3	15.61	16.83
Fe_2O_3	1.49	4.0	2.33	4.16
FeO	10.95	7.6	8.23	4.45
MgO	4.48	7.3	5.80	10.09
CaO	10.71	9.9	11.75	11.30
Na_2O	1.23	2.8	1.86	0.97
K_2O	0.37	1.1	1.76	0.06
H_2O	0.72	1.4	0.73	0.14
TiO_2	1.27	1.4	——	0.46
P_2O_5	0.26	0.3	——	——
MnO	0.19	0.2	——	0.69
Total	99.96	100.3	101.21	99.91

Norms.

	A	B	C	D
Quartz	8.8	——	2.0	6.7
Orthoclase	2.2	6.7	10.6	0.6
Albite	10.5	23.6	15.7	8.4
Anorthite	39.2	28.6	28.9	41.1
Diopside	10.3	15.6	24.8	11.8
Hypersthene	23.2	5.9	15.7	23.8
Olivine	——	9.7	——	——
Magnetite	2.1	5.8	3.3	6.1
Ilmenite	2.4	2.7	——	0.9
Apatite	0.6	1.9	——	——

(C) Rocks constituting the Demolished Igneous Bodies along the Western Half of the Northern Coast.

The rocks constituting the ruined igneous bodies along the western half of the northern coast (pp. 38–44) contain a fair

amount of phenocrysts of olivine and other mafic minerals in contrast to the somma lavas of the first type (p. 67), in which these minerals are either entirely wanting or negligible as phenocrysts. A moderate quantity of olivine in the rocks of the ruined igneous bodies indicates that these may belong to the perfelic order of the quantitative system. From this character as well as from others described below, the rocks are to be classed as " basalt " following the definition of this term given by IDDINGS.[1]

6) **Two-pyroxene-olivine-anorthite-basalt.** (Pl. III. Fig. 5.)

Mode of Occurrence.—The rock occurs in several lava flows constituting the ruined igneous body of Chigasaki[2] (1a ; pp. 38–41 ; Pl. VI. GA 14).

Megascopic Characters.—The rock shows very conspicuous phenocrysts of plagioclase, equant, mostly 2 or 3 *mm.* but sometimes as large as 1 or 2 *cm.* in diameter. Phenocrysts of olivine, hypersthene, and augite are also seen but are far inferior both in size and quantity, to those of plagioclase, being commonly less than 1 *mm.* in diameter.

The groundmass is megascopically aphanitic, gray and rather compact.

Microscopic Characters.—The phenocrystic minerals seen under the microscope are anorthite, olivine, hypersthene, and augite, in quantitative order.

The large phenocrystic *anorthite* has the following optical properties :—

    (1) Extinction angle on M (010): $-34°8' \pm 32'$

    (2) Refractive indices: $a < 1.578 < \beta < 1.582 < \gamma$

    (3) Positions of the optic axes relative to M (010):

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1) *Igneous Rocks*, Vol. II., p. 111, 1913.

2) 千ヶ崎 or 乳ヶ崎

$$\begin{cases} \varphi = 53^\circ & \varphi' = 87^\circ30'^{[1]} \\ \rho = 23^\circ8' & \rho' = 80^\circ22' \end{cases}$$

(4) Inclination of optical plane to the side pinacoid:

$$\text{O.P.} \wedge M\,(010) = 75^\circ35'$$

(5) Optic axial angle: $2V = 81^\circ40'$

(6) Optical character......negative.

From the values of refractive indices, the mineral was identified as anorthite with its chemical composition Ab_5An_{95} according to BECKE.[2] Optical constants other than refractive indices-also show a close agreement with those of anorthite.

The mineral encloses small crystals of olivine, $(Fe_2SiO_4)_{13-19}$ $(Mg_2SiO_4)_{87-81}$, with the refractive indices $\alpha < 1.678 < \beta < 1.691 < \gamma$.

Plagioclase, as microphenocrysts, is also anorthite with refractive indices similar to the above, euhedral to subhedral, commonly twinned according to the Carlsbad and albite laws, but rarely to the pericline and Manebach laws. Some of the plagioclase crystals are almost free from inclusions, but most of them include rather abundantly anhedral grains of light greenish augite and uncrystallized or partly crystallized opaque masses (slag), which latter may have been imprisoned prior to crystallization. Olivine is only rarely found

1. Most calcic.
2. Medium calcic.
3. Least calcic.

Fig. 38.

as an inclusion. Zonal arrangement of inclusions is very well developed in some cases. Zonal structure due to chemical difference is almost lacking except that the less calcic plagioclase forms the shell of the anorthite phenocryst. In very rare cases a more complex zoning (Fig. 38) is extremely faintly exhibited.

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1) As to the meanings of φ, ρ, φ', and ρ' see Fig. 34, p. 65. The values in (3)—(6) were calculated by supposing $\beta = 1.578$.

2) "Zur Physiographie der Gemengteile der krystallinen Schiefer," *Denkschriften der kaiserlichen Akademie der Wissenschaften*, 75 Bd. S. 103, 1913 (Wien).

Olivine phenocrysts, next to those of anorthite in amount but far less numerous, range in diameter from 0.3 to 1 *mm*. These have irregular outlines with rounded corners and sometimes deep indentations, each being fringed with a resorption-border, consisting of magnetite grains, surrounded in turn by a specially fine-grained thin layer similar in composition to the groundmass. The refractive indices of olivine crystals were measured with the result: $\alpha < 1.678 < \beta < 1.691 < \gamma$. The mineral is therefore inferred to have the chemical composition $(Fe_2SiO_4)_{13-19}(Mg_2SiO_4)_{87-81}$. The mineral is fresh, but irregularly cracked, and is almost free from inclusions except fluid enclosures which are very rarely found.

Subordinate phenocrysts of hypersthene and augite are present. *Hypersthene* phenocrysts are subhedral and prismatic, the largest in thin section measuring 1 *mm*. along the *c*-axis, and are traversed by the usual cleavage lines and other cracks, of which those perpendicular to the *c*-axis are conspicuous. The mineral has the optical plane parallel to (010) and shows its characteristic pleochroism. As inclusions it often contains small plagioclase crystals.

Light greenish *augite* phenocrysts, 0.8 *mm*. across in the largest example are euhedral to anhedral, twinned sometimes on (100).

A parallel growth of two pyroxenes is commonly seen, the hypersthene being always enclosed by a very thin rim of augite.

The minerals in the *groundmass* are prismoid plagioclase which is at least as calcic as labradorite-bytownite with the maximum symmetrical extinction angle reaching 45°, light greenish anhedral augite, and euhedral isometric magnetite, with an extremely small amount of interstitial glass, light brown in colour, clouded by numerous globules. These component minerals vary from 0.01 to 0.1 *mm*. in diameter and build up the granular intersertal ground-

mass which is high in crystallinity (nearly holocrystalline) but low, in granularity.

7) Olivine-bytownite-basalt (*a*). (Pl. III. Fig. 6.)

Mode of Occurrence.—The rock occurs as lavas constituting the ruined igneous body underlying Kazahaya[1] (1a; p. 41; Pl. VI. GA. 13).

Megascopic Characters.—The rock is dark gray and is strongly porphyritic. The phenocrysts are mainly of plagioclase with diameters from 1 to 3 *mm.* Minute olivine phenocrysts are seen in smaller quantities. Irregular pores with diameters, mostly from 1 to 2 *mm.* and in maximum 5 *mm.*, are distributed through the rock mass.

Microscopic Characters.—Microscopically, the rock is dopatic. Phenocrysts of *plagioclase*, which is calcic bytownite ($Ab_{13}An_{87}$) with the refractive indices $\alpha < 1.572 < \beta < 1.578 < \gamma$, are generally subhedral, twinned as usual, and often carrying inclusions of augite, uncrystallized groundmass, and fine dusty substances. Zonal structure due to chemical difference is only very faintly developed or almost lacking.

The microphenocrysts of slightly greenish *olivine*, $(Fe_2SiO_4)_{13-19}$ $(Mg_2SiO_4)_{87-81}$ ($\alpha < 1.678 < \beta < 1.691 < \gamma$), averaging about 0.2–0.3 *mm.* in length, are anhedral often with deep indentations, remarkably traversed by cleavage lines and cracks perpendicular to the *c*-axis, and not infrequently surrounded by the alteration product, brownish yellow iron oxide.

These phenocrysts are scattered through the nearly holocrystalline, centimillimeter-grained, granular intersertal *groundmass*. The minerals that build up the groundmass are prismoid plagioclase

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(1) 風早

(labradorite-bytownite) which is simply or polysynthetically twinned, light greenish anhedral augite occasionally twinned on (100), and small isometric magnetite. Colourless glass enclosing a fine dusty substance is found very sparingly as the interstitial matrix.

8) Olivine-bytownite-dolerite. (Pl. IV. Fig. 1.)

Mode of Occurrence.—To the east of Kazahaya (1a), igneous bodies are exposed on the sea cliff in the form of lavas and intrusives (p. 41; Pl. VI. GA 10–11). The rock specimen here described was taken from the westernmost intrusive mass which appears to be a congealed vent (Pl. VI. GA 11).

Megascopic Characters.—The rock is megascopically fine-grained non-vesicular, and is gray in colour. Porphyritic components recognizable with the naked eye are plagioclase, 5 *mm.* in maximum diameter with nearly equant development, and olivine, less abundant and smaller than the former.

Microscopic Characters.—Under the microscope, the phenocrysts of *calcic bytownite*, $Ab_{15}An_{85}$ with the refractive indices $a < 1.571$ $1.572 < \beta < 1.575$ $1.577 < \gamma$, show the usual characters. They are generally subhedral, twinned, v e r y f a i n t l y exhibit zonal structure, and commonly carry inclusions.

Subhedral to anhedral *diopsidic augite*, occasionally twinned on (100), and anhedral *olivine*, $(Fe_2SiO_4)_{13-19}(Mg_2SiO_4)_{87-81}$ ($a < 1.678$ $> \beta \wedge 1.691 < \gamma$), with brown iron oxide deposited along the cracks that traverse the mineral, are seen as microphenocrysts, less than 1 *mm.* in diameter.

The nearly holocrystalline *groundmass* consists of sodic bytownite, light coloured diopsidic augite, and magnetite, with only a trifling amount of brown glass clouded with fine dust.

The characteristic feature of the groundmass is high granularity, being decimillimeter-grained and doleritic in texture.

9) Olivine-bytownite-basalt (*β*). (Pl. IV. Fig. 2.)

Mode of Occurrence.—This rock constitutes the igneous body to the west of Okata[1] (2a ; pp. 41–42 ; Pl. VI. GA 9).

Megascopic Characters.—Megascopically, the rock is sempatic with abundant phenocrysts of plagioclase, 1–4 *mm.* in diameter, scattered among the grayish, aphanitic, more or less porous groundmass. Olivine crystals are found far smaller in size and less in quantity.

Microscopic Characters.—Microscopically, the single or grouped phenocrysts of *calcic bytownite*, $Ab_{12}An_{88}$ ($a < 1.574 < \beta < 1.578 < \gamma$), are equant, mostly subhedral, and commonly twinned, often exhibiting a very faintly marked zonal structure. Inclusions, sometimes with zonal arrangement, are as usual.

Olivine phenocrysts, 0.05–0.7 *mm.* across in average, with rounded corners and indentations, are comparatively common. The refractive indices are $1.678 < \beta < 1.691$, so the composition of the mineral is inferred to be $(Fe_2SiO_4)_{13-19}(Mg_2SiO_4)_{87-81}$. Secondary iron oxide is seen along the margin of the crystal, and iddingsite along the cracks.

The *groundmass* is almost holocrystalline, centimillimeter-grained, and basaltic, being built up of prismoid plagioclase (extinction angle $> 30°$), anhedral light greenish augite, and small isometric magnetite.

(D) Rocks occurring as Dykes.

Dykes are seen at several places in the island. On the cliff opposite to Fudeshima[2] (3d), numerous dykes are exposed, as has

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1) 岡田   2) 筆島

already been stated (pp. 24–25 ; Pl. VI. EF). Dykes are also seen, one at the foot of the western wall of the crater-harbour Habu[1] (3e ; p. 22 ; Pl. VI. DE), and four on the ring-wall of the somma indicated by × on the geologic map (Pl. V. 1c and 2d). These are olivineless basaltic bandaite with characters similar to those of the first type of the somma lava. They are of two types :—

10) Olivineless basaltic bandaite (α). (Pl. IV. Fig. 3.)

The rock of dykes piercing the cliff opposite to Fudeshima is megascopically compact, non-vesicular and is sempatic with mega-phenocrysts of plagioclase, from 5 *mm.* downwards in diameter.

Microscopically, the phenocrysts of *calcic bytownite* $Ab_{16}An_{86}$ are mostly in euhedral to subhedral stout prismatic to equant forms, and usually exhibit very faintly marked zonal structure. The *groundmass* consists of light greenish augite, plagioclase, less calcic than the phenocrystic one, and magnetite, arranged in texture near the ophitic fabric. The characteristic feature of the groundmass is high crystallinity and high granularity, it being almost holocrys-talline and centimillimeter-grained.

11) Olivineless basaltic bandaite (β). (Pl. IV. Fig. 4.)

The rocks of the other dykes, of which the southernmost one on the western ring-wall of the somma is taken as representative, are gray, compact without any vesicles. The plagioclase pheno-crysts are very small, rarely over 1 *mm.* across, and are not conspicuous though they are fairly abundant. A few hypersthene phenocrysts are also seen.

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1) 波浮

Microscopically, subhedral phenocrysts of *calcic bytownite* (Ab_{15} An_{85}) with usual characters and a few anhedral ones of *hypersthene* are found. The *groundmass* consists of small plagioclase prisms, augite anhedrons, and magnetite grains, with a small amount of colourless glass as interstitial matter. Only one crystal of apatite was found in a thin section. These component minerals of the groundmass vary from 0.003 to 0.04 *mm.* in diameter and arrange themselves in granular intersertal texture.

(E) *Ejecta.*

12) Ashes, Sands, Lapilli, and Bombs.

Ejecta are not less important than lavas in the building up of the volcano Ôshima. They are found in many layers alternated with lavas.

In size they are of four grades—(1) ashes, (2) sands, (3) lapilli, and (4) bombs.

Ashes and Sands.—These are brown, black, or yellowish in colour; sometimes as red as rouge, having been scorched by the intense heat of the molten lava. Ashes and sands treated with HCl were observed under the microscope to consist mainly of splinters of glass and fragments of calcic bytownite with only a negligible amount of fine pieces of the minerals that constitute the groundmass of the lava. This fact indicates that these ashes and sands originated in the magma itself before the consolidation of the groundmass and did not come from the disturbed and shattered portions of the rocky walls through which the vent was drilled. These form what PIRSSON[1] terms " vitric

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1) " The Microscopic Characters of Volcanic Tuffs," *Am. Jour. Sci.* (4), Vol. XL., p. 191, 1915.

tuff" and "crystal tuff." Ashes occasionally form *cendre granulée* or *pisolite*, as was found interstratified on the ring-wall of the somma, some 500 *m*. southwest of Kagamihata[1] (1c).

Lapilli.—There are two kinds of ejecta of the lapilli grade, viz. fragments of the pre-existing rocks and juvenile ones. The latter which far predominate over the former are glassy and scoriaceous, and often contain phenocrysts of calcic bytownite. In most cases, lapilli form very thin beds, rarely exceeding 20 *cm*. in thickness, between the ash and sand layers, though they some-times form thick accumulations, as for example on the cliff opposite to Fudeshima[2] (3d ; pp. 25–26). The surfaces of the ground in the caldera and the apical part of the somma are loosely covered by the lapilli of the central cone.

Bombs.—The larger blocks of the pre-existing rocks are imbedded in ash and sand beds and form agglomerate beds, which are however very rare. Bombs that originated in molten lavas are scattered around the crater on the upper slopes of the central cone. They are multifarious in shape—spindle-shaped, subspherical, spheroidal, etc. Their size is also of wide range. A very large specimen found near Kawajiri,[3] the lowest point of the crater margin (*K* in Fig. 20, p. 33), has a diameter of over 1 *m*. Petro-graphically, the bombs do not differ from the lavas of the central cone, namely miharaite. Parallel arrangement of phenocrystic minerals which is said often to have been observed in the bombs of other volcanoes is not markedly seen in these. This may be due to the high fluidity of the molten lava. It is an interesting fact that bombs sometimes contain blocks of earlier lavas as nuclei around which new lava-materials are coated.

Pele's Hairs.—Among the ejecta of a peculiar form is black

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1) 鏡端   2) 筆島   3) 川尻

Pele's hair or glass cotton, found and collected by Nakamura in 1907 between narrow crevices of lava in the central Mihara[1] crater. This is the only specimen ever found in our country. History records the fall of Pele's hairs during the eruption on August 31, 1777 (p. 56).

13) Micro-allivalite. (Pl. IV. Fig. 5.)

At the foot of Kazahaya[2] (1a), imbedded in an ash layer (Pl. VI. GA 12) between the lavas of olivine-bytownite-basalt (p. 92) which constitute a small igneous body, the writer found a coarse-grained holocrystalline block, about 3 cm. across, which is petrographically identical to that ejected in the eruption of Sakurajima[3] in 1914, at the southern extremity of Kyûshû, described by Kotô[4] under the new name of " micro-allivalite." Specimens of similar motex were also collected by Tsujimura on Miyakejima[5], one of the Idzu Islands.

The block may be what Lacroix calls " enclaves homœogènes " or Harker calls " cognate xenolith." The writer's view on the genesis of this phanerocrystalline mass will be given later (pp. 121–122).

Our micro-allivalite consists of anorthite and greenish olivine, each grain ranging in diameter from 1 to 5 mm.

Anorthite has the refractive indices : $\alpha < 1.575$ $1.581 < \beta < 1.584$ $1.583 < \gamma$, so that the chemical composition of the mineral is inferred to be Ab_5An_{95}. It is twinned according to Carlsbad, albite, pericline, and Manebach laws.

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1) 三原   2) 風早   3) 櫻島

4) " The Great Eruption of Sakura-jima in 1914," *Jour. Sci. Coll. Imp. Univ. Tôkyô*, Vol. XXXVIII., Art. 3, p. 195, 1916.

5) 三宅島

Olivine is traversed by numerous cracks. It is $(Fe_2SiO_4)_{12-18}$ $(Mg_2SiO_4)_{88-82}$ with the refractive indices :—

$$a < 1.636 < \beta < 1.687 < \gamma$$

Observed maximum refractive index < 1.7185

Small interstices between the large individuals of the minerals are filled with a material containing hypersthene, similar to the groundmass of the lava.

14) Augite-micro-diorite. (Pl. VI. Fig. 6.)

An ejected block of rather acidic nature was found at the northern foot of Kagamihata[1] (1c) imbedded in the uppermost bed of agglomerate.

It is a holocrystalline, fine-grained (mostly 0.3–1.5 *mm*. in diameter) mass of hypidiomorphic granular texture, consisting essentially of plagioclase and augite with magnetite and apatite as accessories.

Plagioclase belongs to andesine-labradorite with chemical compositions ranging from $Ab_{65}An_{35}$ to $Ab_{45}An_{55}$, determined by the refractive indices (1.55–1.56). These plagioclases are twinned simply (Carlsbad law) and polysynthetically (albite law) and exhibit noticeable zonal structures. In the simplest case the innermost zone is the most calcic, successive ones become more and more sodic with gradual transition; while not a few show the more complex manner of zoning as shown in Fig. 39.
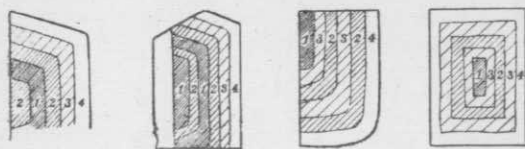

Fig. 39.

1. Most calcic.   2. Less calcic.
3. More sodic.   4. Most sodic.

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1) 鏡端

Augite is a greenish, high double-refracting one, traversed by characteristic cleavage lines parallel to (110) and often twinned on (100). It is noteworthy for its pleochroism. Pleochroism is noticeable in thicker sections, especially in those which extinguish nearly straight. It is as follows :—

$$X' \ldots \ldots \ldots \text{yellowish green}$$
$$Z' \ldots \ldots \ldots \text{deep green}$$
$$\text{Absorption} \quad Z' > X'$$

Here, X' and Z' respectively denote the vibration directions of the faster and the slower rays in section.

The observed refractive indices for sodium light of this unusual augite are given below. For comparison, those of the minerals from other localities which have like optical properties are cited in parallel columns.

	α	β	γ
Pleochroic augite, Ôshima[1]	$\begin{array}{l}\alpha < 1.698 \\ 1.691 < \alpha'\end{array}$	$1.701 < \beta < 1.716$	$\begin{array}{l}1.701 < \gamma \\ \gamma' < 1.715\end{array}$
Augite, Pojana	1.688	1.701	1.713
Augite, Renfrew	1.6975	1.7039	1.7227
Augite, Boreslau	——	1.70	——
Dark green diopside, Nordmarken	——	1.7047	——

Optical plane ‖ (010).

Augite sometimes includes small crystals of plagioclase.

Magnetite is found as an accessory ingredient in subhedral crystals and *apatite* is as usual in small needles with characteristic negative elongation.

The interstices of the component minerals are often filled with a colourless salic matter with somewhat lower refractive indices

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1) Here α' and γ' respectively denote the observed minimum and maximum refractive indices.

but similar double refraction to the afore-mentioned plagioclase, and show a micrographic fabric.

Of the many kinds of phanerocrystalline blocks found in the volcanoes of Japan, one somewhat similar to that described here was discovered by HIRABAYASHI[1] among the ejecta of Fuji[2], being especially abundant around the crater of one of its parasitic cones, Hôeizan.[3] It consists of anorthite, augite, hypersthene, and magnetite. He considered it as a fragmented block of a deep-seated dyke since a rock with similar petrographic characters was actually observed occurring as a dyke in the highly dissected Ashitaka[4], an older volcano adjacent to Fuji.

The genesis of our micro-diorite will be discussed on pp. 121–125.

V. History of the Magma.

In the foregoing pages, the various rock-types of Ôshima have been described in detail. Each of these rock-types has certain distinguishing characteristics, but all of them differ only slightly from one another, agreeing so closely in their essential features that they are considered to have originated from the same magma. What, then, is this original magma? How have the various rock-types and the petrographic characters as now seen been developed from it? The present chapter is an attempt to answer these questions and to discuss the history of the magma of Ôshima.

The more important rock-types, except those occurring as dykes and ejecta, are :—

1) "Volcanoes Fuji and Ashitaka," *Report Earthq. Invest. Com.*, No. 24, 1899 (in Japanese).
2) 富士
3) 寶永山
4) 愛鷹

	Names of rocks	Phenocrysts			Ground-mass
		Olivine	Plagioclase	Pyroxenes	
Rocks constituting the demolished igneous bodies along the northwestern coast	Two-pyroxene-olivine-anorthite-basalt	$(Fe_2SiO_4)_{13-19}$ $(Mg_2SiO_4)_{87-81}$	Anorthite Ab_5An_{95}	Hypersthene and augite / Comparatively abundant	Consisting of plagioclase (from sodic labradorite to sodic bytownite), augite, magnetite, and glass.
	Olivine-bytownite-basalt (α and β)	Comparatively abundant	Calcic bytownite near $Ab_{15}An_{85}$	Absent	
	Olivine-bytownite-dolerite			Augite / Slight	
Somma lavas	Basaltic bandaite (the commonest somma lavas)	$(Fe_2SiO_4)_{25-30}$ $(Mg_2SiO_4)_{75-70}$ Slight or absent		Hypersthene and augite / Slight or absent	
	Hypersthene-basaltic bandaite	Absent		Hypersthene: moderate / Augite: slight	
	Two-pyroxene-basaltic bandaite	Absent		Hypersthene and augite / Moderate	
	Hypersthene-bearing augite-olivine-bytownite-basalt	Comparatively abundant		Hypersthene: slight / Augite: moderate	
Central cone lavas	Miharaite	Absent		Hypersthene and augite / Slight	

The above table shows that the main difference between the various rock-types exists in the amount and character of the phenocrysts of olivine and pyroxenes, both of which are of comparatively high specific gravity. This fact suggests the importance of gravitative effects on these heavy crystals.

As to the effect of the separation and subsidence of crystals

in the magma, BOWEN[1] made a thorough consideration, based on the results of recent experiments with artificial silicate mixtures which are comparable to the natural magma.

It was seen in the rocks of Ôshima that the observed facts correspond, at least in a general sense, to what might be expected from BOWEN's theory.

Before a detailed petrologic discussion is given, the writer will here briefly outline the conclusion to which he has been led.

The original magma from which the rocks of Ôshima were derived was basaltic; from it the crystals of olivine, hypersthene (partly clino-hypersthene), augite, and plagioclase separated in the course of cooling before being extruded as lavas. Of these minerals, the former three, being much heavier than the magma, sank in the magma basin as they crystallized out; while the last mentioned, matching the magma closely in density, remained practically suspended in it. Thus, the heavy crystals relatively concentrated toward the bottom. The observed rock-types represent various parts of the magma basin differentiated as above, or different stages of the subsidence of the heavy crystals, but represent only one stage of the cooling of the magma.

Probable High Fluidity of the Magma of Ôshima.

The facility of the movement of crystals in the magma must be greatly influenced by the viscosity of the latter.

The data at hand suggest a probable high fluidity of the magma of Ôshima.

In the first place, it is known of various melts that their

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1) "The Later Stages of the Evolution of the Igneous Rocks," *Jour. Geol.* Vol. XXIII., Supplement to No. 8, 1915.

fluidity increases inversely their content of silica, and DOELTER instanced the magma of plagioclase-basalt as one of the most fluidal magmas. The strongly basic nature of our rocks (SiO₂ 51.13–53.01%) suggests that the magma from which they were derived was highly fluidal.

The behaviour of the magma in the intratelluric stage cannot be discerned, but its behaviour after being extruded as lavas can be inferred from observed facts. As already stated (p. 13), each of the lava flows is very thin, being mostly from a few to several meters, but the crystallinity of the groundmass is very high, percrystalline, in spite of the possible greater tendency to consolidate as glassy rocks owing to the rapid cooling in such thin lavas. This must be due to the high fluidity of the lavas.

The presence of volatile fluxes and a rise of temperature would naturally diminish the viscosity of the melts. Moreover, according to VOGT's researches on slags, the rate of diminution of viscosity with rise of temperature is greater for those of basic than for those of acidic composition. Thus the fluidity of the basic magma of Ôshima, which is very fluidal even in the effusive stage, must be still greater in the intratelluric stage when the temperature is far higher and an amount of volatile fluxes is present as is indicated by the vesicular nature of the lavas.

High fluidity of the magma of Ôshima is, then, most probable. In such fluidal magma, movement of the crystals is by no means a mere speculative process, but must be necessarily expected.

Separation of a Mix-Crystal Series.

Crystallization of the magma of Ôshima involves the separation of mix-crystal series as olivine, plagioclase, and pyroxenes.

BOWEN's[1] discussion on the crystallization of melts of any system involving a mix-crystal series under various conditions may be summarized as follows :—

(I) *Crystallization with Perfect Equilibrium.*—Let A and B be respectively the higher- and lower-melting components of the mix-crystal series. When the cooling of the melt is extremely slow and perfect equilibrium prevails, the crystals first separated from the melt are rich in A, but as the cooling proceeds, the crystals, not only those in the act of separating but also those which have previously separated, continually change in composition as a result of the interchange of material between liquid and crystals, becoming richer in B. The crystals formed in this manner would be homogeneous throughout.

(II) *Crystallization with Great Undercooling.*—When the cooling of the melt is extremely rapid, the liquid may be undercooled to a certain temperature before crystallization begins, whereupon the crystals of uniform composition (without zonal structure) will separate out.

(III) *Crystallization with Zoning.*—When the cooling is moderately rapid, there may be only a limited opportunity or none at all for a change in composition of the crystals already separated, but the composition of crystals in the act of separating would change toward the enrichment of B, so that the resultant crystals would show a zonal structure due to difference in composition varying from one rich in A to one rich in B. There is a certain rate of cooling which gives maximum zoning, in which case, the outermost zone of the crystal has the composition of pure B, whatever the total composition of the original

1) " The Later Stages of the Evolution of the Igneous Rocks," *Jour. Geol.,* Vol. XXIII., Supplement to No. 8, 1915.

material may have been. With a rate of cooling, somewhat quicker or slower than that which gives maximum zoning, the range of zoning is not so great on account of either a moderate degree of undercooling or a partial adjustment of composition between various zones.

(IV) *Crystallization with Local Collection of Crystals.*—In the foregoing discussion, sinking or floating of the crystals has been left out of consideration. The results as outlined above are to be obtained only when the relative movement of the crystals in the melt from which they are separated is prevented. In the case of slow cooling, if the separated crystals differ from the melt in density, sinking or floating of the crystals would take place whereupon a local collection of them would be accomplished. In this case, in the part where many crystals have accumulated, only a small amount of liquid is available for the interchange of material between liquid and crystals, so that the crystals would not be subject to a continual indefinite change in their composition toward enrichment in B, but would remain rich n A.

Crystallization of the Component Minerals.

The separation of the component minerals of our rocks took place in two distinct generations—before and after the extrusion of the magma. The phenocrysts of olivine, plagioclase, hypersthene (and clino-hypersthene), and augite belong to the intratelluric separation, while the groundmass constituents, plagioclase, augite, and magnetite, are of the effusive stage. A discussion on the course of the crystallization of these component minerals follows :—

Olivine.—Olivine, which contains no other mineral as inclusion, appears to be the earliest separated mineral.

There is reason for believing that the magma of Ôshima closely matches in density calcic plagioclase crystals (p. 109). Olivine crystals are therefore of much higher specific gravity than the magma from which they were separated; consequently the importance of their subsidence in the highly fluidal magma during the course of crystallization may be reasonably assumed.

Olivine forms a mix-crystal series belonging to Type I of Roozeboom's classification[1] composed of forsterite (Mg_2SiO_4, the higher-melting component with the melting point $1890° \pm 20°C$.[2]) and fayalite (Fe_2SiO_4, the lower-melting component). Following the discussions given on pp. 105–106, the net result of the separation and subsidence of olivine crystals, when the magma cools uniformly throughout the whole mass, would be: (1) at a given portion of the magma basin, the earlier the stage is, the richer the olivine crystals there present are in forsterite, and (2) at a given stage, the lower the portion of the magma basin is, the more abundant the olivine crystals are, and the richer they are in forsterite. Thus, there must be a stage where the forsterite-rich crystals are concentrated in the lower portion of the magma basin, and where only a few olivine crystals less rich in forsterite are in the upper portion. If the subsidence of the olivine crystals goes on still further, the upper portion of the magma basin will at last become entirely free from olivine.

The olivine in the lavas rich in this mineral is rich in forsterite, $(Fe_2SiO_4)_{13-19}(Mg_2SiO_4)_{87-81}$; while that in the olivine-poor lavas is less rich in forsterite, $(Fe_2SiO_4)_{25-30}(Mg_2SiO_4)_{75-70}$ (p. 102). This can be explained by supposing that the olivine-rich lavas were

1) Harker, *The Natural History of Igneous Rocks*, p. 372, 1909.
2) Bowen and Andersen, "The System MgO–SiO₂," *Am. Jour. Sci.* (4), Vol. XXXVII., p. 487, 1914.

discharged from the lower portion, and the olivine-poor ones from the upper portion of the magma basin.

Moreover, the separation of the olivine crystals from the magma should bring about an excess of silica in the residual liquid. That this inference is justified from observed facts, will be shown elsewhere (p. 120).

Plagioclase.—Plagioclase also forms a mix-crystal series of Roozeboom's Type I,[1] consisting of albite ($NaAlSi_3O_8$, the lower-melting component with the melting point 1100°C.) and anorthite ($CaAl_2Si_2O_8$, the higher-melting component with the melting point 1550°C.). The positions of both solidus and liquidus were accurately determined and the exact composition of solid and liquid in equilibrium with each other in the binary system became known.[2]

The crystallization of plagioclase takes place in one of the four manners given on pp. 105–106.

The plagioclase phenocrysts in the rocks of Ôshima show no noticeable zonal structure due to chemical difference, though very faint examples are frequently seen. This fact must be construed as meaning that *the cooling of the magma of Ôshima in the intratelluric stage was extremely slow, approaching the rate required to produce perfect equilibrium.* The crystals with only very faint zoning would be formed also by very rapid cooling, but, if so, the centres of crystallization about which plagioclase is precipitated must have been much more numerous, and the plagioclase crystals accordingly would not be so large as they are.

Such slow cooling as is considered to have prevailed in the magma of Ôshima may have afforded an opportunity for the

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1) Day and Allen, " The Isomorphism and Thermal Properties of the Feldspars," *Carnegie Institution of Washington, Publ.* No. 31, 1915.

2) Bowen, " The Melting Phenomena of the Plagioclase Feldspars," *Am. Jour. Sci.* (4), Vol. XXXV., p. 583, 1913.

movement of the crystals in the magma ; consequently if the plagioclase crystals had differed decisively from the magma in density, the movement of the growing crystals and their local accumulation must have taken place in the magma. The inevitable result would be that the plagioclase crystals in different layers in the magma basin would differ in composition, and accordingly the plagioclase phenocrysts in various lavas would not be uniform in their composition. But when we turn to the plagioclase phenocrysts of the Ôshima rocks, we find that they are calcic bytownite, $Ab_{15}An_{85}$ or very near to it in chemical composition, throughout all the lavas with the only exception that anorthite (Ab_5An_{95}) occurs as phenocrysts in the lavas of Chigasaki[1] (1a ; pp. 89–90). Putting aside for a while this exceptional case,[2] the fact that all the plagioclase phenocrysts are nearly of the same composition could be realized only if no appreciable movement of the plagioclase crystals had taken place in the intratelluric stage *during the crystallization* of plagioclase. From the above fact, we can here reasonably deduce that *the magma of Ôshima (basaltic magma) closely matches the crystals of calcic plagioclase in density.* This conclusion as to the density of the basaltic magma is noteworthy in connection with BOWEN's statement that "laboratory determination of densities of calcic plagioclase crystals and of molten gabbro place them very close together,...."[3]

The degree of porphyricity with respect to the plagioclase phenocrysts is quite variable, from only slightly to strongly porphyritic, but there is no regularity in the variation which is great even in one flow. Variation in the quantity of the olivine phenocrysts in the lavas can be explained as due to a gravitative

1) 千ケ崎 or 乳ケ崎
2) With regard to this exceptional case, an explanation is given later (p. 110).
3) "The Problem of the Anorthosites," *Jour. Geol.*, Vol. XXV., p. 211, 1917.

effect (pp. 107–108). In the case of plagioclase phenocrysts, however, the variation in porphyricity is too irregular to be explained in the same manner, but it may be due in some way to varying conditions at the time of extrusion.

Anorthite phenocrysts in the lava of Chigasaki enclose small crystals of olivine, about $(Fe_2SiO_4)_{3-19} (Mg_2SiO_4)_{87-81}$ in composition (p. 90). This may be interpreted as indicating that *the crystallization of the plagioclase began as early as in the middle of the separation of the olivine crystals when they were still very rich in forsterite.* Such being the case, it is reasonable to consider that there was an opportunity for the sinking of the early formed anorthite crystals in company with the olivine crystals which were separating at the same time, though the anorthite crystals themselves would be very close in density to the magma, and that these accumulated toward the bottom in such a way that no change of composition involving an increase of albite (the lower-melting component) in crystals could be accomplished. The presence of anorthite as phenocrysts in the rock of Chigasaki may be explained as a result of the processes above mentioned. The bytownite phenocrysts in other rocks are considered to be, in the main, of later separation from the less calcic residual liquid after removal of the early formed anorthite crystals.

The results of experimental investigations on the equilibrium of various melts in the system involving the crystallization of the plagioclase show that the residual liquids are always very much richer in albite than the plagioclase crystals with which they are in equilibrium." If, in the middle of the slow crystallization of

1) Bowen, " The Melting Phenomena of the Plagioclase Feldspars." *Am. Jour. Sci.* (4), Vol. XXXV., p. 583, 1913.

Bowen, " The Crystallization of Haplobasalic, Haplodioritic and Related Magmas," *ibid.*, Vol. XL., p. 161, 1915.

plagioclase, the residual liquid happened to cool very rapidly, it would consolidate into a crystalline mass with composition corresponding to that of the residual liquid, uninfluenced by that of the crystals present in contact with the liquid, there being no opportunity for the adjustment of the equilibrium.

. In the rocks of Ôshima crystals of sodic bytownite or labradorite occur as a constituent of the groundmass, and often in a thin layer coating phenocrysts of calcic bytownite. These less calcic crystals are no doubt products formed by the sudden cooling of the residual liquid at the time of extrusion. This indicates that *at the last intratelluric stage the bytownite crystals ($Ab_{15}An_{85}$ or near to it) were in equilibrium with the liquid in which the less calcic plagioclase was one of the components.*

If the magma had cooled slowly further from this stage in the intratelluric reservoir, the plagioclase crystals would have changed their composition, becoming more sodic than $Ab_{15}An_{85}$. On the other hand, if the last intratelluric temperature had been higher, the phenocrystic plagioclase would have remained more calcic. Hence, from the fact that all the plagioclase phenocrysts in the rocks of Ôshima which are considered to have been suspended in the magma have nearly the same composition (near $Ab_{15}An_{85}$), it is inferred that *throughout all the stages in the history of the volcano, so far as represented by the exposed lavas, the magmatic temperature has not changed so much as to affect appreciably the composition of the plagioclase crystals suspended in the magma.* In other words, *the long volcanic history of the pouring out of the observed lavas is represented by a very limited interval in the cooling history of the magma.*

As to the temperature of the magma at this stage, we are able to estimate it roughly from the experimental results with

artificial plagioclases. The temperature at which the crystals $Ab_{15}An_{85}$ are in equilibrium with the residual liquid in the binary system albite-anorthite ($NaAlSi_3O_8 — CaAl_2Si_2O_8$) is about 1470°C., the composition of the liquid being $Ab_{40}An_{60}$; while in the ternary system diopside-albite-anorthite ($CaMgSi_2O_6 — NaAlSi_3O_8 — CaAl_2Si_2O_8$), it is about 1250°C., far lower than in the binary mixture, the composition of the residual liquid being then about 54% of $Ab_{36}An_{64}$ and 46% of diopside. The natural magma is a very complex polycomponent mixture, so that the temperature at which the crystals $Ab_{15}An_{85}$ are in equilibrium with the residual liquid must be far lower than that in the binary mixture. From this it can be asserted that *the intratelluric temperature of the magma of Ôshima at the last stage was decidedly lower than 1470°C., and may possibly have been as low as 1250°C. if not still lower.*

Pyroxenes.—Pyroxenes in the rocks of Ôshima are hypersthene (and clino-hypersthene) and augite. From studies on artificial melts[1] it is expected that pyroxenes may belong to a later crystallization than olivine. In agreement with this, no close association of olivine and pyroxene has been observed, in contrast to the frequent association of olivine and plagioclase,[2] suggesting that the durations of the crystallization of olivine and pyroxene have not overlapped. Accordingly, it is also inferred that plagioclase preceeded pyroxene in beginning the crystallization.

Hypersthene occurs only as phenocrysts and never as the constituents of the groundmass in the Ôshima rocks, indicating that

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1) BOWEN and ANDERSEN, "The System $MgO–SiO_2$," *Am. Jour. Sci.* (4), Vol. XXXVII., p. 487, 1914.

BOWEN, "The Ternary System Diopside-Forsterite-Silica," *ibid.*, Vol. XXXVIII., p. 207, 1914.

ANDERSEN, "The System Anorthite Forsterite-Silica," *ibid.*, Vol. XXXIX., p. 407, 1915.

2) A close association of olivine and plagioclase is seen in the Chigasaki lava (p. 90) and in micro-allivalite (p. 98).

its crystallization was restricted only to the intratelluric stage.

Hypersthene phenocrysts are often surrounded by augite crystals in parallel intergrowth. From this it is inferred that augite is a later crystallization product than hypersthene.

Augite is found both as phenocrysts and as a constituent of the groundmass, showing that its separation took place both in the intratelluric and effusive stages.

Summarizing what has been stated above the following con-- clusion is deduced as the most probable course of crystallization of pyroxenes :—

The hypersthene crystals began to separate from the magma after the crystallization of olivine was completed and in the middle of the crystallization of plagioclase. The duration of the separation of hypersthene was comparatively short, and after the cessation (?) of its crystallization, augite began to separate and continued to do so even in the effusive stage.

Pyroxenes form mix-crystal series, and the change in their composition during the course of crystallization is expected to have been accomplished as in the cases of olivine and of plagioclase. The data at hand, however, are insufficient for a discussion on this subject. The only point bearing on it is that in one of the somma lavas, two-pyroxene-basaltic bandaite exposed at Gyôja[1] (3c ; p. 74), the phenocrystic augite has the refractive indices : $a < 1.6869$ $1.6869 < \beta < 1.6906$ $1.7014 < \gamma$, while the mineral constituting the groundmass has the refractive indices : $a < 1.6836 < \beta < 1.6869 < \gamma$ (p. 76). From this, it is imagined that the augite crystals whose refractive indices are $a < 1.6869$ $1.6869 < \beta < 1.6906$ $1.7014 < \gamma$ would, by a change in chemical composition, approach those whose refractive indices are $a < 1.6836 < \beta < 1.6869 < \gamma$, if the crystallization

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of augite were to proceed further.

Since the specific gravity of the pyroxene crystals is believed
to be much higher than that of the magma from which they were
precipitated (p. 109) and the cooling of the magma to have been
very slow (p. 108), a sufficient opportunity must be allowed for the
sinking of the pyroxene crystals. Pyroxene phenocrysts are very
scarce in most of our rocks. This fact was also noticed by YAMA-
SAKI[1] who regarded it as one of the characteristic features of the
rocks of Ôshima. This scarcity of pyroxene phenocrysts is under-
stood when it is considered that most of the Ôshima rocks represent
the upper portion of the magma basin from which the heavy
pyroxene crystals had been removed by their subsidence effected
by gravitation.

Magnetite.—Magnetite is, for the most part, a product of the
period after the magma was extruded as lavas. The probability
of this inference is supported by :—(1) Magnetite occurs only as
very small grains constituting the groundmass and never as pheno-
crysts or as inclusions in other phenocystic minerals. (2) The
form of magnetite varies with the crystallinity of the ground-
mass ; thus, the glassy groundmass of some rocks (for example,
the hyalocrystalline part of miharaite, p. 81) is almost free from
visible magnetite crystals ; in the groundmass with a little higher
crystallinity, it disseminates in very fine, often skeletal crystals ;
while it is in euhedral crystals in the groundmass of high crys-
tallinity. If the magnetite crystals belonged chiefly to the intratel-
luric separation, they would be found in euhedral forms in every
rock, whatever the crystallinity of its groundmass may be.

Groundmass.—The groundmass is the product of sudden cooling

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1) "Report on the Volcano Ôshima," *Report Ea thq. Invest. Com.*, No. 9, p. 50, 1893 (in
Japanese).

-of the residual liquid after the magma has been extruded as lavas.
At such a very rapid rate of cooling as prevailed at the time of
-consolidation of the groundmass, the liquid crystallizes quickly
uninfluenced by the crystals in contact with it, there being little
-opportunity or none for the adjustment of equilibrium between
liquid and crystals and for the sorting of the crystals separating.
The composition of the groundmass as a bulk must therefore
-correspond to that of the residual liquid.

This residual liquid in the magma basin is thought to have
been practically constant in composition, since its temperature is
-supposed to have remained nearly the same throughout the whole
volcanic history so far as represented by the observed lavas (p. 111);
-accordingly it is expected that no very appreciable variation will
be seen in the composition of the groundmass of our rocks.

What has been actually observed is in harmony with the
-above expectation as to the composition of the groundmass, though
there is a rather wide variation in its texture—crystallinity,
-granularity, and fabric—, which may be merely due to varying
-conditions at the time of extrusion.

A difference has been seen, however, in the composition of
the plagioclase microlites in the groundmass, from sodic labradorite
to sodic bytownite. This would appear to be at variance with
what has been stated above, but it must be recalled that, on the
separating out of mix-crystals from the liquid, the composition of
these differs according to the proportion of the whole liquid that
-consolidates as crystals, even if the composition of the original
liquid was the same. This may account for the difference in the
composition of the plagioclase crystals in the groundmass.

Summary on the Cooling History of the Magma.

The original magma of Ôshima was basaltic, highly fluidal and nearly equal in density to calcic plagioclase.

The magma proceeded to cool extremely slowly. Its cooling history discussed in the foregoing pages is summarized as follows :—

(I) *The First Stage.*

Olivine.—The olivine began to crystallize. The first crystals were rich in forsterite, but they had a tendency to change their composition toward enrichment in fayalite, due to the molecular interchange between liquid and crystals. The high specific gravity of olivine crystals, the high fluidity of the magma, and the very slow rate of its cooling collectively afforded ample opportunity for the sinking of the olivine crystals in the magma.

(II) *The Second Stage.*

Olivine.—The separation and the subsidence of the olivine crystals continued to take place. The early separation of the forsterite-rich crystals resulted in the enrichment in fayalite of the residual liquid, accordingly, the later separated crystals became richer and richer in fayalite. The olivine crystals that subsided accumulated toward the lower portion of the magma basin, and the comparatively small amount of liquid there available deterred the crystals from continual indefinite change in composition toward enrichment in fayalite. The crystals therefore remained there rich in forsterite.

Plagioclase.—The plagioclase crystals began to separate. The earliest ones were very rich in anorthite. Since they closely match the magma in density, they remained practically suspended in the liquid where their composition became more and more sodic. Some

-of the crystals, however, had an opportunity to sink in company with the olivine crystals.
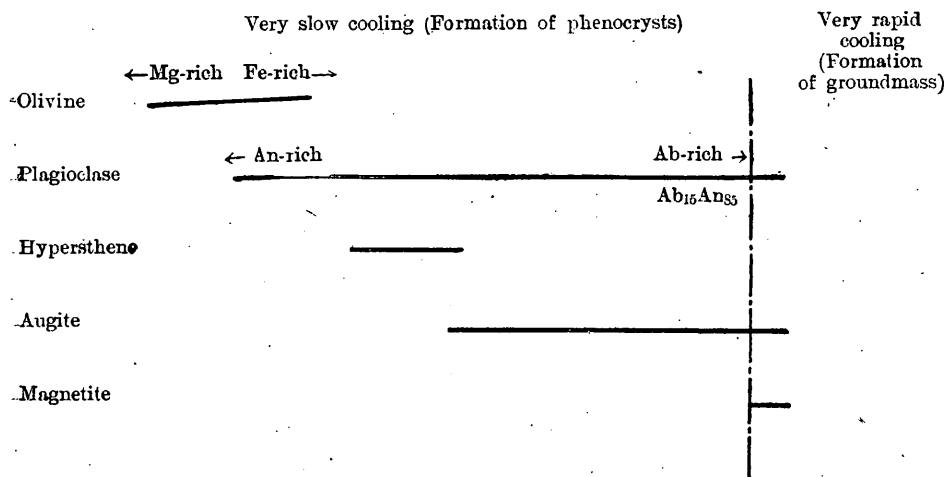
Very slow cooling (Formation of phenocrysts)   Very rapid cooling (Formation of groundmass)

←Mg-rich Fe-rich—→

-Olivine

←An-rich   Ab-rich →

Plagioclase

$Ab_{15}An_{85}$

Hypersthene

Augite

Magnetite

Fig. 40. Diagram showing the order of crystallization.

(III) *The Third Stage.*

Olivine.—The separation of olivine was completed and the later formed crystals comparatively rich in fayalite were in the act of sinking. As a result of the removal of olivine from the magma, an excess of silica was brought about in the residual liquid.

Plagioclase.—The plagioclase crystals were separating and their composition was becoming gradually sodic.

Pyroxenes.—The crystals of hypersthene appeared, but the duration of their crystallization was brief whereupon augite began to separate. Hypersthene and augite being heavier than the magma, sank in it.

(IV) *The Last State in the Magma Basin.*

The crystallization of the magma in the intratelluric stage proceeded as above, while the magmatic temperature became deci-

sively lower than 1470°C. and possibly as low as 1200°–1300°C. At this stage, bytownite crystals $Ab_{15}An_{85}$ were suspended in the residual liquid.

In *the lower portion* of the magma basin heavy mafic minerals accumulated and also some of the early separated plagioclase crystals which had sunk in company with the olivine crystals. There these minerals remained rich in higher-melting components owing to the small amount of the available liquid.

In *the upper portion* only a few crystals of mafic minerals of later separation, comparatively rich in the lower-melting components, were in the act of sinking.

All the observed lavas of Ôshima belong to extrusions after this last state of the magma was reached. The residual liquid in the magma reservoir consolidated after extrusion as the ground-mass, consisting of plagioclase, augite, magnetite, and a small amount of glass.

Development of the Various Rock-Types.

The development of the features seen in every rock-type can be explained by supposing that the rocks of different types were extruded from various portions of the magma basin, where differences in amount and character of the heavy intratelluric crystals were effected by gravitative action.

(1) **Rock-Types Comparatively Rich in Phenocrysts of Mafic Minerals.**—Rocks of these types are :—

(*a*)   Two-pyroxene-olivine-anorthite-basalt (p. 89).

(*b*)   Olivine-bytownite-basalt α (p. 92) and β (p. 94).

(*c*)   Olivine-bytownite-dolerite (p. 93).

(*d*)   Hypersthene-basaltic bandaite (p. 73).

(*e*)   Two-pyroxene-basaltic bandaite (p. 74).

(*f*)   Hypersthene-bearing angite-olivine-bytownite-basalt (p. 76).

The main distinguishing characteristics of these types are : (1) they are comparatively rich in phenocrysts of mafic minerals ; (2) the olivine crystals, when present, are richer in forsterite $(Fe_2SiO_4)_{13-19} (Mg_2SiO_4)_{87-81}$, than those in the commonest type of the somma lavas.

These lavas are considered to have been extruded from the lower portion of the magma basin where the heavy crystals accumulated, remaining rich in the higher-melting components owing to the small amount of liquid present. In some of them, phenocrysts of each of the three minerals, olivine, augite, and hypersthene, are present ; while in others they are found only singly or in pairs. This may be ascribed partly to there being an opportunity for the separate collection of these minerals, the durations of their crystallization being remote.

As to the occurrence of anorthite phenocrysts in the lava of Chigasaki[1] (1a), an explanation has already been given (p. 110).

(2) **Common Type of the Somma Lavas** (basaltic bandaite). —This type is characterized by scarcity in phenocrysts of olivine and pyroxenes. Sometimes these are even lacking. When the olivine crystals are present, they are less rich in forsterite than those in the rocks of the preceding types, about $(Fe_2SiO_4)_{25-30}(Mg_2SiO_4)_{75-70}$ in composition.

The lavas of this type do not differ from those of the preceding types in the times of their extrusion. They are believed to have come from the upper portion of the magma basin where the later formed crystals comparatively rich in the lower-melting components had sunk halfway. At the time of eruption, these crystals happened to come out by chance with the lava flows. That the distribution of the mafic phenocrysts is very irregular in these lavas and that

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1) 千ケ崎 or 乳ケ崎

they are scarce can be explained on the above supposition.

(3) **Central Cone Lavas** (miharaite).—The central cone lavas are entirely free from olivine. These must represent the upper portion of the magma basin in later stages when the subsidence of the olivine crystals in the remaining liquid had progressed so far that they were remote from the extruded lavas.

Pyroxene crystals occur sparingly since they are of later separation than olivine crystals and accordingly their subsidence was less extensive.

In connection with the above proposition that the somma lavas of the common type as well as the central cone lavas originated from the upper portion of the magma basin from which the olivine crystals had subsided, it is a noteworthy fact that chemical analyses made of the rocks of the somma and the central cone (pp. 71 & 85) gave an excess of silica with respect to other oxides, as shown in the following table :—

	Normative quartz	Values of k in OsANN's formulæ
A	9.6	1.12
B	14.2	1.23
C	6.1	1.02
D	5.3	1.10
E	9.2	1.16
F	8.8	1.15

A ...A typical somma lava exposed on the south shore at the east end of Sashikiji[1] (2e ; Pl. VI. DE 4).

B .... Central cone lava in April, 1912.

C .... Central cone lava in October, 1912.

D .... Scoria of the central cone in October, 1912.

E .... Central cone lava in December, 1912.

F .... The average of the four B—E.

1) 差木地

That the early separation of olivine would bring about an excess of silica in the residual liquid was already pointed out on p. 108.

(4) **Micro-allivalite.**[1]—A small ejected block of micro-allivalite was found imbedded in a volcanic ash bed (Pl. VI. GA 12) inter-calated with layers of the lavas of Kazahaya[2] (1a ; p. 92). It is a holocrystalline mass consisting of anorthite Ab_5An_{95} and olivine $(Fe_2SiO_4)_{12-18}(Mg_2SiO_4)_{88-82}$ with a small quantity of interstitial matter (p. 99). Both plagioclase and olivine constituting the micro-allivalite belong to the varieties richer in higher-melting components than those in common lavas. This fact is, according to the writer's belief, directly connected with the genesis of this ejected block.

There was a period when only anorthite and olivine (rich in forsterite) were crystallizing from the magma (the second stage, pp. 116–117), so that these had an opportunity of sinking together in the magma reservoir and accumulating in such a manner that no change in their compositions toward enrichment in the lower-melting components could be accomplished owing to the small amount of liquid available for the interchange of material between liquid and crystals. Thus, the mass formed at the lower portion of the magma basin would have just the characters now seen in micro-allivalite. The block now under consideration may be a piece broken off and ejected from the mass formed by the above process at the lower portion of the reservoir.

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1) Phanerocrystalline ejecta are very common both in our country as well as abroad, and various views on their geneses have been suggested by different writers. Especially on those from the volcanoes of Japan, we have HIRABAYASHI's and FUKUCHI's studies respectively on those of Fuji ("Report on the Geology of Volcanoes Fuji and Ashitaka," *Report Earthq. Invest. Com.*, No. 24, 1889. in Japanese) and of some of the Idzu Islands other than Ôshima ("On the Phanero-crystalline Bombs from Some of the Idzu Islands," *Jour. Geol. Soc. Tôkyô*, Vol. VIII., No. 95, 1901, in Japanese).

2) 風早

Another fact to corroborate this inference is that it is closely related to rocks of Kazahaya which are believed to have been extruded from the lower portion of the magma basin.

(5) **Augite-micro-diorite.**—This is an ejected block, about 3 $cm.$ across, found in an agglomerate bed at the northern foot of Kagamihata[1] (1c). It is a holocrystalline mass consisting of zonal structured plagioclase ranging from $Ab_{65}An_{35}$ to $Ab_{45}An_{55}$, uncommon augite which is greenish and slightly pleochroic, and acidic interstitial matter with micrographic fabric, with magnetite and apatite as accessory constituents (pp. 99–101).

This is a mere block showing no relation to any lavas, but its petrographic characters are just what might be expected to form at the upper portion of the magma reservoir if the cooling of the magma proceeded at a moderate rate.

As already stated (pp. 117–118) the magma of Ôshima is believed to have reached the stage at which it was in the middle of the crystallization of plagioclase and augite, and the temperature was that at which bytownite crystals $Ab_{15}An_{85}$ were in equilibrium with the residual liquid. This state of the magma has been maintained throughout the whole volcanic history so far as it is now traceable.

If the cooling of the magma proceeds further from this state at a very slow rate the results would be as follows :—

Plagioclase and augite, which were crystallizing till the above-mentioned state of the magma was reached, would continue to crystallize, and magnetite would soon begin to crystallize. The plagioclase and augite crystals in separating would become richer in the lower-melting components as time goes on. Even the crystals already separated, if there is a sufficient amount of the available

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1) 鏡端

liquid in contact with them, would change their compositions toward enrichment in the lower-melting components. But slow cooling affords a great opportunity for the continual movement of the growing crystals with respect to the residual liquid unless they match the liquid closely in density. The augite crystals being much heavier than the magma, their subsidence in it is beyond dispute. The plagioclase crystals are nearly equal in density with the magma, so that they must remain suspended in the liquid and accomplish a change in composition, becoming more and more sodic. In the meantime, the separation of these crystals would bring about in the residual liquid a relative concentration of silica (pp. 108 & 120–121) and the liquid would become gradually lighter as crystallization proceeded and at last decisively lighter than the plagioclase crystals. Then the plagioclase crystals hitherto suspended would begin to sink."[1]

If the cooling of the magma is rather more rapid, the sinking of the crystals would be somewhat restricted. In this case the plagioclase which does not differ much from the surrounding liquid in density would have only a limited opportunity for sinking, and the zoning of plagioclase would result. The augite crystals being heavier than the plagioclase crystals, the former would subside from the liquid in the upper portion before the newly separated crystals could deposite around them, so that the augite crystals in the upper portion would be only those rich in lower-melting component. Then the resultant mass would consist in the upper parts mainly of zonal structured plagioclase, lower-melting augite, and magnetite, with the latest crystallization product as the interstitial matter.

In our micro-diorite; the plagioclase is from labradorite to

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1) Such a process was supposed also by BOWEN when he discussed the anorthosites (*Jour. Geol.* Vol. XXV., p. 213, 1917).

andesine with zonal structure; the interstitial matter is acidic micrographic material, and the augite is of an unusual type. If this augite is interpreted to be one rich in lower-melting component, then the petrographic characters of the micro-diorite are just those which might be expected to be formed by the above mentioned process from the residual liquid of the magma of Ôshima when cooling at a moderate rate.

From what has been said, the genesis of the micro-diorite may be as follows :—

The magma of Ôshima cooled at a moderate rate in some portion of the reservoir and proceeded to crystallize following the course mentioned above, and consolidated into a mass with petrographic characters as seen in micro-diorite. The block now under discussion is a fragmented piece of this mass, which was ejected at the time of eruption.

By the above, the development of the general features of the micro-diorite can be accounted for; but to explain some of the more minute features, further assumptions are necessary.

That the zoning of plagioclase is not always simple in that calcic and sodic plagioclases often occur in alternate zones (p. 99) may be ascribed to a temporary rise of temperature due to the heat evolved by crystallization in the course of cooling of the magma.

As already stated, the absence of zonal structure in the augite crystals in contrast to the noticeable one in the plagioclase crystals may be due to the former outstripping the latter in their sinking down. In spite of this process the augite crystals are not very much inferior to the plagioclase crystals either in size or in amount. This may be explained by supposing that the augite crystals grew more rapidly than the plagioclase crystals. This supposition is

. necessary also to explain that the interstitial matter of the latest crystallization is strongly salic, for otherwise it must be far more femic.

In concluding the present chapter, the writer will remark on the change in the composition of the magma which is expected to be brought about by the cooling. All the rocks of Ôshima represent only one stage of the cooling of the magma, so that the difference between the various rock-types does not correspond to the difference in the course of cooling. The cooling history can only be inferred from the observed features of the component minerals. The past course of the magmatic change was summarized on pp. 116–118. The salic interstitial matter in the micro-diorite suggests the future state of the residual liquid after the cooling of the magma has proceeded sufficiently far. Summarizing, it is seen that the composition change of the local magma due to cooling would be from basic to acidic.

IV. The Geologic Position.

Nearly along the meridian of 138°E., an important tectonic line—the so-called " fossa magna " or " Fuji line "—traverses the main island of Japan, or Honshû, dividing it into two tectonically very distinct halves, North and South Japan. The line is prolonged in the direction of S. 10° E., being represented by a submarine ridge with a depth of less than 1,000 m. in the deep of the Pacific Ocean. To the east of this ridge a trench runs parallel with it, to which it may be genetically related (Fig. 41).

Ôshima rests on the above-mentioned submarine ridge with the other members of the Idzu Islands—Toshima, Udoneshima, Niijima,[1]
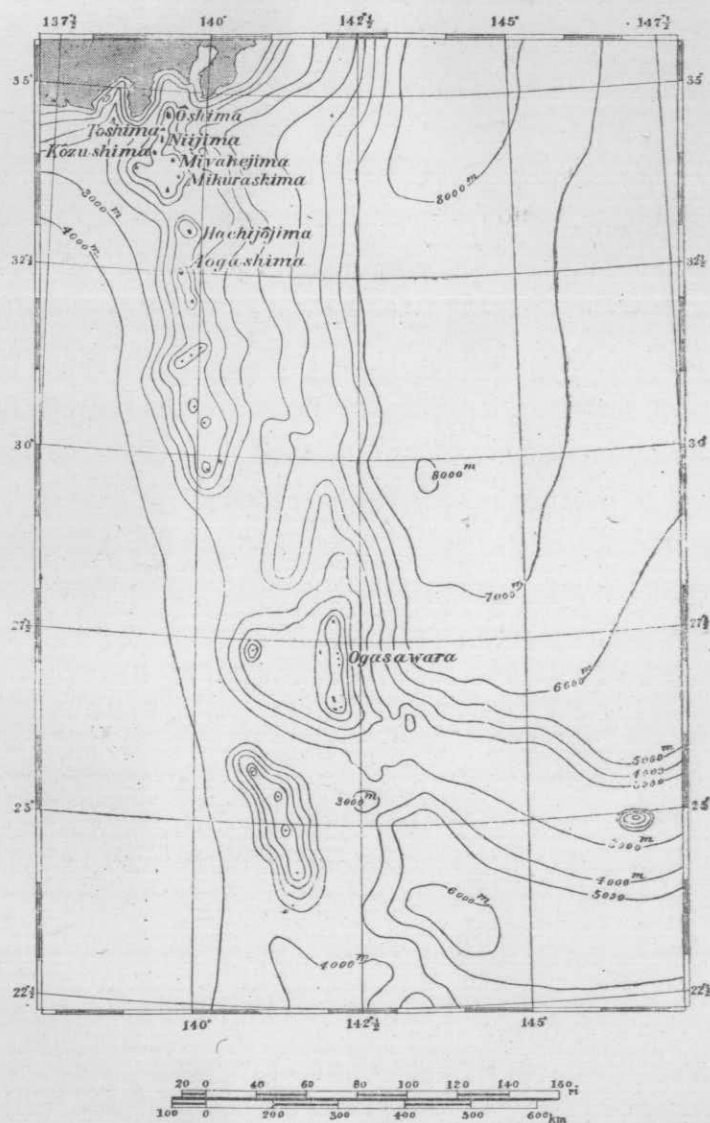
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1) 利島 鵜渡根島 新島

Fig. 41. Bathymetric map of the environs of the Idzu islands.

Shikineshima, Kôzushima, Miyakejima, Mikurashima, and Hachijô-
jima.[1] All of these islands are volcanic, and are grouped by some
as belonging to the "Fuji volcanic chain."

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1) 式根島 神津島 三宅島 御蔵島 八丈島

This term " Fuji volcanic chain " has, however, been variously
defined by different authors. In its widest sense it includes all the
volcanoes along the above-mentioned tectonic line, starting from
the Myôkô[1] volcanic group, passing through Yatsugatake[2], Fuji[3],
Ashitaka[4], Hakone[5], and then through the volcanoes of the Idzu
peninsula and the insular and submarine volcanoes of the Pacific—
Shichitô[6], Ogasawara[7], Sulphur Islands, etc,—to the Mariana Islands.
These volcanoes are arranged linearly in the same way as those be-
longing to one volcanic chain, but petrographically the nature of their
lavas is indefinite, being variously represented by many kinds of
rocks, and the forms of the volcanoes are multifarious[8]; according-
ly it is doubtful whether all of these volcanoes can be reasonably
grouped in one volcanic chain. Putting aside for a while a general
discussion on the problem of the so-called " Fuji volcanic chain " as a
whole, the volcanic lineage of the Idzu islands will be first considered
so far as this directly bears on the geologic position of Ôshima.

The insular volcanoes of Idzu are to be divided into two groups
in their arrangement and morphographic features, as well as in the
nature of the rocks which constitute them. Ôshima, Toshima,
Udoneshima, Miyakejima, Mikurashima, and Hachijôjima arrange
in the direction N.N.W.—S.S.E. and are conical (homate or konide),
being built up of basaltic rocks; Niijima, Shikineshima, and
Kôzushima arrange in N.N.E.—S.S.W., to the west of the former
group and are flat with comparatively steep sides in their forms
(tholoids), being constituted of rhyolitic rocks.

That the Idzu islands should be classed in two groups was
suggested by YAMASAKI[9] as early as in 1896, for he stated that

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1) 妙高   2) 八ヶ嶽   3) 富士   4) 愛鷹   5) 箱根   6) 七島   7) 小笠原

8) B. KOTÔ, " The Volcanoes of Japan," *Jour. Geol. Soc. Tôkyô*, Vol. XXIII., p. 6, 1916.

9) " Report on the Volcano Ôshima," *Report Earthq. Invest. Com.*, No. 9, 1896 (in Japanese).

there are two branches in what is commonly called " the Fuji volcanic chain "—one comprising the volcanoes of basic rocks as Ôshima, Miyakejima, Hakone[1], etc. and the other including those of the acidic rocks as Niijima, Kôzushima[2], etc. having a close relation to the dacitic volcanoes of the Idzu peninsula ; and that the recent activity of some of the former is known, while of the latter there are, according to him, no historic records of eruptions.

Later, in 1902, FUKUCHI[3] gave a fuller account on the distinction between these two groups of insular volcanoes. He considered that the basaltic islands belong to the same volcanic system as the volcanoes of Fuji, Hakone, Amagi[4], etc. which are constituted of similar rocks, and to this group of volcanoes he confined the application of the term " Fuji volcanic chain," excluding the rhyolitic islands. · As to the age relation between these two groups of volcanoes, he supposed that the rhyolitic islands are older than the volcanoes of " the Fuji chain." He was led to this belief by the fact that basaltic ejecta cover the rhyolitic rocks at the northern part of the island Niijima, and that the rhyolitic rocks of the Idzu islands are correlative to similar rocks at the southern extremity of the Idzu peninsula which are of the Tertiary period.

FUKUCHI's view on the age relation between the rhyolitic and basaltic islands was later endorsed by TAK. KATÔ[5]. Kôzu[6] also pointed out that the rhyolitic rocks of the Idzu islands are petrographically similar to the plagioliparite of the middle Tertiary which occurs in the southern part of the Idzu peninsula.

1) 大島　三宅島　箱根　　　2) 新島　神津島
3) "Geology of Niijima." Report Earthq. Invest. Com., No. 39, 1902 (in Japanese).
4) 天城
5) "The Land Slides in Kôzushima," Report Earthq. Invest. Com., No. 63, 1909 (in Japanese).
6) "Geology of the Southern Part of the Idzu Peninsula," Jour. Geol. Soc. Tôkyô, Vol. XIX, p. 97, 1912 (in Japanese).

Thus, the previous writers agree on the time relation between the rhyolitic and basaltic islands, and are inclined to consider, with varying emphasis, that the former are older than the latter, being correlative to the Tertiary rhyolitic bodies in the Idzu peninsula.

The sequence of the lavas as above being harmonious with that in North Japan, where pre-andesitic vulcanism is represented by plagioliparite mostly of the Tertiary period[1], the above view has been generally admitted by geologists.

Very recently, Tsujimura[2] opposed this generally accepted view. He noticed that Niijima and Kôzushima are too young in their morphographic aspect to be Tertiary volcanoes, and came at last to doubt if they are really so old as has been generally supposed.

On the other hand, Ômori and Nakamura enumerate in their historic records volcanic eruptions which they consider to mean those of Kôzushima in 838[3] and of Niijima in 886[4].

1) B. Kotô, " Volcanoes of Japan," *Jour. Geol. Soc. Tôkyô*, Vol. XXIII., p. 5, 1916.

2) " Kôzushima and Niijima," *Report Earthq. Invest. Com.*, No 89, 1918 (in Japanese).

3) Zoku-Nihon-Kôki (續日本後記) records that from August 15, 838 (承和五年七月癸酉十八日) for more than two months, some minute powders like ash fell in the provinces of Kawachi, Mikawa, Tôtômi, Suruga, Idzu, Kai, Musashi, Kazusa, Mino, Hida, Shinano, Echizen, Kaga, Etchû, Harima, and Kii. Some authors consider this as an eruption of Ôshima, while Ômori pointed out that this must mean an eruption of Kôzushima for in the same book are found the following lines : —

承和七年九月。伊豆國言。賀茂郡有造作島。本名上津島。‥‥上津島本體。草木繁茂。東南北方巖 峻嶰峰。人船不到。繞西面有泊宿之濱。今成燒崩。與海共成陸地并沙濱。二千許町。其島東北角。 有新造神院，其中有壟，高五百許丈，其周八百許丈，其形如伏鉢，‥‥自餘雜物。燎談未止。不能 具注，去承和五年七月五日夜出火，上津島左右海中燒。炎如野火。十二童子相接取炬，下海附火， 諸童子履潮如地，入地如水，震上大石。以火燒摧。炎燄逢天，其狀朦朧，所々燄飛。其間經句。雨 灰滿都，

" 上津島 " in the above description must mean Kôzushima (神津島); " 西面有泊宿之濱 " corresponds to the village, Kôzushima-mura, on the west coast of the island; and " 其島東北角。 有新造神院。其中有壟。高五百許丈，其周八百許丈，其形如伏鉢，" is a description of Tenjô-yama (天井山) standing at the northeastern part of the island.

4) Sandai-jitsuroku (三代實錄) records that on July 3, 886 (仁和二年五月十四日), there was observed in the province of Awa, toward the south, a very thick dark cloud, in which lightning flashes were seen, thundering noises and earthquakes continuing all night. The sky did not clear up till the morning of July 5 (五月二十六日), when the earth was covered with ashes two or three inches thick. On the other hand, it is told, according to Nihonkiryaku (日本紀略) and Fusôryakki (扶桑略記), that in 887 the provincial government of Idzu presented the central

Thus, the almost settled opinion as to the the age relation between the rhyolitic and the basaltic Idzu islands has become doubtful, and an interesting problem, which is of first importance in the geology of the Idzu islands, has presented itself for study.

It is true that the basaltic islands afford many records of recent eruptions, among which those of Ôshima in 1876–'77 and in 1912–'14, and of Miyakejima in 1874 are still fresh in our memory ; while the rhyolitic islands have not erupted, at least in very recent times. But it is problematical whether the rhyolitic islands are really so very old as has been hitherto generally supposed and whether their activity had been brought to an end before the basaltic ones appeared.

In the summer of 1918, the writer visited Niijima, one of the rhyolitic islands, with the object of solving the above question if possible. The following is only a very brief statement on this particular problem.

The rhyolitic rocks of Niijima are readily grouped in three main types—pyroxene-rhyolites[1], hornblende-rhyolites, and biotite-rhyolites, in order of extrusion. Besides these there is in the north of the island a basaltic ejecta bed which caps the masses of pyroxene- and hornblende-rhyolites. It is this fact which led FUKUCHI to the conclusion that the rhyolitic islands are older than the basaltic ones. This fact, however, only indicates that the

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government with a map of a newly created island, and so NAKAMURA considered that the record of the eruption above cited probably related to this new island. Unfortunately the name of the island is not stated, but from the descriptions "神明放火以朝听燒 則如銀岳," ÔMORI and NAKAMURA are inclined to consider this as meaning an eruption in a rhyolitic island, probably in Niijima, for "銀岳", or the "silver mountain", may mean white rhyolitic mountain.

1) Here the rocks are called under the field names. The rocks of Niijima were described by FUKUCHI ("Geology of Niijima," Report Earthq. Invest. Com., No. 39, 1902) as "rhyolites"; while BACHER ("Über die Laven der kleineren Idzu Inseln," München, 1914) pointed out that they are "dacites" and not "rhyolites"; as they contain no sanidine. The rocks are very low in crystallinity so that to what rock species they belong cannot be determined by microscopic investigation only.

ejection of the basaltic blocks took place after the extrusion of the particular lavas of pyroxene- and hornblende-rhyolites that constitute the masses underlying the basaltic ejecta, and not necessarily that all the rhyolitic rocks are older than the basaltic rocks. On the contrary the ejection of the basaltic blocks seems to have been antecedent to the extrusion of the biotite-rhyolites. For, while this basaltic ejecta bed also contains a few blocks of pyroxene- and hornblende-rhyolites, none of biotite-rhyolites are known to be imbedded; and it is also not known that the basaltic ejecta cover a biotite-rhyolite mass. Moreover, the rhyolitic ejecta bed, "Shiromama" bed, bears a few basaltic blocks among others. The homatholoid of Mukaiyama[1] of biotite-rhyolite in the south of the island rests on the "Shiromama" bed, and shows a very young morphographic aspect. Thus, it has become clear that rhyolitic and basaltic vulcanism displayed activity alternately in Niijima, accordingly at least some of the rhyolitic rocks must be as young as the basaltic ones.

All the rhyolitic bodies in Niijima, even the oldest, show far younger morphographic features than those on the main land, and the rocks constituting the former are very fresh with no trace of alteration in contrast to the more or less altered nature of the rocks of the latter; thus the volcanic activity of rhyolites in Niijima seems to have begun far later than that in the Idzu peninsula. Tradition, indeed, speaks of an eruption of Mukai-yama that occurred about 800 years ago. Oral tradition does not constitute very strong evidence, but here it must be noticed that tales of the eruption are told only of the newest volcano and not of the others, which makes us consider the tradition in this case all the more credible.

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1) 向山

Kôzushima also shows very young morphographic features. There is no good reason for doubting that the record on the vulcanism in 838 (see the foot-note on p. 129) refers to the eruption in Kôzushima.

From the above the rhyolitic insular volcanoes in Idzu appear to be quite young, and it is very probable that their eruptions took place even in historic times.

It will not be out of place here, to call attention to the geology of the Idzu peninsula which is closely related to that of the Idzu islands, for it is necessary in discussing the geology of isolated districts to correlate them with the geologically connected main land.

The geology of the Idzu peninsula was studied by ISHIWARA[1], and the southern part in particular by Kôzu[2]. The present writer also had an opportunity of making a hasty journey through the peninsula in January of 1918, and to secure some acquaintance with the rocks there exposed. The time available, however, was too limited for more than an observation confined only to a few parts along the eastern shore and the small area near Shimoda[3].

So far as is known to the writer principally from books and only to a limited extent from brief personal observation, the geology of the Idzu peninsula is as follows :—

The peninsula is built up largely of volcanic rocks. According to Kôzu, the rocks constituting the southern part of the peninsula are, in the order of their eruption : plagioliparite, potash-liparite, propylite, liparite, dacite, and pyroxene-andesite ; all but potash-liparite accompanying the tuffs and breccias besides the solid lavas. In his opinion the extension of these rocks began in the

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1 " Volcanoes in the Idzu Peninsula," *Report Earthq. Invest. Com.*, No. 17, 1898 (in Japanese).

2) " The Geology of the Southern Part of the Idzu Peninsula," *Report Imp. Geol. Surv.*, No. 38, 1913 (in Japanese).

3) 下田

middle Tertiary and lasted toward the end, with repeated renewal and decay in activity.

How these rocks are magmatically related to one another is a matter needing further investigation, yet it seems but natural to consider them as of two distinct lineages—rhyolitic and andesitic. It is to be noted that *the rocks of these two lineages erupted alternately in the Idzu peninsula in the Tertiary period.*

This order of eruption of these two rock-types being very important, the writer made a special point of confirming it during his trip. The youngest pyroxene-andesite covering the other rocks is seen in almost every part of the peninsula. There is, besides this, an older pyroxene-andesite underlying a liparitic rock. This older andesite was included by Kôzu in his "propylite" though the rock is, as he himself says, sometimes quite fresh. The age relation of this older andesite to a liparitic rock was observed by the present writer at two localities: near Nagata[1], a small village 4 km. (or 1 ri) northeast of Shimoda, where a liparitic tuff bed containing blocks of pyroxene-andesite was seen; and at the boundary of Asahi-mura[2] and Chikuma-mura[3], on the north side of the main road that runs westward from Shimoda through Kisami[4], where an altered andesitic rock is overlain by a bed of liparitic tuff some 4 m. thick.

Of the andesitic and rhyolitic rocks, the former continued to extrude in the Quaternary period in the Idzu peninsula and its environs. The Quaternary volcanoes, Amagi, Ashitaka, Fuji, Atami, Hakone[5], etc., are all built up of rocks belonging to the andesitic lineage which are considered to have descended from the Tertiary andesitic rocks of the southern part of the Idzu peninsula.

As a whole, the nature of the lavas of these volcanoes appears

1) 長田　　2) 朝日村　　3) 竹麻村　　4) 吉佐美　　5) 天城 愛鷹 富士 熱海 箱根

to have changed along the line from acidic to basic as time passed. Thus, according to ISHIWARA[1], the main body of Amagi[2], a volcano of the early Diluvium, consists of rather acidic " pyroxene-andesite " with 61% of SiO_2, while its parasitic cones which were formed in the late Diluvium are constituted of " basalt " with 56% of SiO_2.[3] HIRABAYASHI[4] also concluded that the lavas became more and more basic, not only locally but also regionally : from " pyroxene-andesite " to " olivine-pyroxene-andesite " in the volcanoes Hakone, Atami, and Ashitaka[5], and from " olivine-pyroxene-andesite " to " plagioclase-basalt " with 50% SiO_2 in the volcano Fuji[6].

On examining the rocks of the andesitic lineage in the peninsula and its environs, it is seen that their petrographic characters approach more and more to those of the basaltic rocks of the Idzu islands in the course of time, while the lavas of Fuji, Ômuroyama[7], etc. bear a close resemblance to those of the basaltic insular volcanoes. It may be reasonably concluded, therefore, that the basaltic Idzu islands belong to the same volcanic lineage as the above-mentioned volcanoes in the main land, and that their lavas descended from the Tertiary andesitic rocks of the southern part of the Idzu peninsula.

On the other hand, the rhyolitic rocks are not known to have erupted in the Idzu peninsula in the post-Tertiary period. But the rocks of the rhyolitic Idzu islands are of the same petrographic lineage as those of the rhyolitic bodies in the main land, as already suggested by some previous writers ; and their extrusion took place, in all probability, even in historic times. It appears then that

1) " Volcanoes in the Idzu Peninsula," *Report Earthq. Invest. Com.*, No. 17, 1898 (in Japanese)..

2) 天城

3) B. KOTÔ, "Studies on Some Japanese Rocks," *Quarterly Journal of Geological Society*, Vol. XL., p. 451, 1884.

4) " Volcanoes Fuji and Ashitaka," *Report Earthq. Invest. Com.* No. 24, 1899. (Japanese).

5) 箱根 熱海 愛鷹   6) 富士   7) 大室山

the rhyolitic rocks of the Idzu islands must have descended from those of the Tertiary period in the Idzu peninsula.

As stated above, the insular group of Idzu comprises volcanoes of two different lineages—those of basaltic and rhyolitic rocks, descended respectively from the Tertiary andesitic and rhyolitic in the Idzu peninsula. The writer hereafter distinguishes these two groups of the volcanic islands as " *Ôshima group* " and " *Niijima group*."[1] In the age of the volcanic activity of these two groups there is no disparity, all the volcanoes being very young. Of these, the basaltic Toshima, Udoneshima, and Mikurashima[1], and the rhyolitic Shikineshima[2] are not known from historic records to have ever been in a state of eruption; while the basaltic Ôshima, Miyakejima, and Hachijôjima[3], and the rhyolitic Niijima and Kôzushima[4] have displayed activity in historic times.

The islands of the Ôshima group and the volcanoes Fuji, Ashitaka, Hakone, Amagi, Atami, etc. lie in the zone that trends in the direction N.N.W.—S.S.E., meeting the festoon islands at large angles, and on its southern prolongation the volcanoes Aogashima, Torijima, and Sulphur Islands[5], as well as the submarine ones near Bayonnaise Rocks, Smith Rocks, North and South Sulphur Islands, etc. are situated. All of these are young volcanoes with historic records of eruptions, and their lavas are auganitic or basaltic. The writer thinks it appropriate to define the term " Fuji volcanic chain " as meaning this row of the Quaternary auganitic and basaltic volcanoes.

The insular volcanoes of the Ôshima group form a sub-group in the Fuji volcanic chain in geographic contiguity, petrographic and morphographic resemblance (all konide or homate), and similarity in mode of eruption. Of the volcanoes in the main

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1) 利島 鵜渡根島 御藏島 　2) 式根島 　3) 大島 三宅島 八丈島
4) 新島 神津島 　5) 青ヶ島 鳥島 硫黄島

Table I.

Abbreviations.

Lab. ..... labradorite. Byt. ..... bytownite. An. ...... anorthite.

+ .... present. — ...... absent. ± .... sometimes present, sometimes absent.

	Ôshima			Toshima			Udoneshima		Miyakejima			Mikurashima			Sambondake	Fuji
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plagioclase	Byt.	Byt.	Byt. to An	Lab. to Byt.		Byt.	Lab. to Byt.	Byt.	Byt.	An. to Byt.		Byt.	An.	Byt. to An.	Byt.	Basic
Phenocrysts { Augite	±	±	±	+	+	+	+	—	+	+	+	+	—	—	+	±
Hypersthene	±	+	±	—	—	+	—	—	+	+	+	—	—	+	+	±
Olivine	±	—	+	+	+	+	+	+	+	—	—	—	—	+	+	+
Biotite (very few)	—	—	—	—	—	—	—	—	—	—	—	—	+	—	+	—
Magnetite }	—	—	—	+	—	—	—	—	—	—	—	+	+	+	+	±
Groundmass				Consisting chiefly of plagioclase, augite, magnetite, and glass.												
SiO$_2$	53.01	51.45		49.91			50.79		54.55	53.35						49.77
Al$_2$O$_3$	14.73	16.84		18.13			16.61		16.26	15.62						20.57
Fe$_2$O$_3$	3.38	1.49		3.87			6.96		4.07	4.21						6.06
FeO	9.42	10.95		5.48			3.51		8.02	8.12						5.11
MgO	4.97	4.48		6.16			7.63		3.66	4.44						5.00
CaO	9.09	10.71		9.90			10.03		8.91	9.68						10.37
Na$_2$O	2.09	1.23		2.33			2.58		2.44	2.18						1.08
K$_2$O	0.44	0.37		0.37			0.55		0.32	0.84						0.84
H$_2$O	1.22	0.72		2.78			0.38		0.29	0.40						0.73
TiO$_2$	1.03	1.27		0.87			1.01		1.19	1.18						—
ZrO$_2$	0.04	—		—			—		—	—						—
MnO$_2$	0.34	0.19		—			—		—	—						0.20
P$_2$O$_5$	0.11	0.26		—			—		—	—						0.16
CO$_2$	—	—		trace			0.19		0.24	trace						—

s	58.1	56.8	56.1	54.8	58.6	60.3	54.8
A	2.5	1.6	2.8	3.0	2.9	2.8	1.7
C	6.8	9.2	9.1	7.3	7.1	7.7	11.6
F	23.2	21.7	21.4	24.8	22.2	19.3	18.6
a	1.5	1.0	1.7	1.7	1.8	1.9	1.1
c	4.2	5.6	5.7	4.3	4.5	5.2	7.1
f	14.3	13.4	12.6	14.0	13.7	12.9	11.8
n	8.7	8.3	9.1	8.8	8.0	9.3	6.5
k	1.1	1.2	1.0	1.0	1.1	1.2	1.1
Q	9.6	8.8	4.3	4.4	9.6	13.4	9.1
Or	2.8	2.2	2.2	3.3	5.0	1.7	5.0
Ab	17.8	10.5	19.9	22.0	18.3	20.4	8.9
An	29.2	39.2	37.8	32.0	30.4	32.0	48.4
Di	12.4	10.3	9.1	13.8	14.6	8.0	2.0
Hy	19.7	23.2	16.4	12.7	13.4	14.6	16.2
Mt	4.9	2.1	5.6	8.4	6.0	5.8	8.8
Il	2.0	2.4	1.7	1.9	2.3	2.3	—
Ap	0.3	0.6	—	—	—	—	—
Hm	—	—	—	1.2	—	—	—

Ôshima.
1) The somma lava (basaltic bandaite).
2) The central cone lava (miharaite).
3) The rocks of the northwestern small igneous bodies (basalt & dolerite).

Toshima.
4) ⎫ Specimens from 60m. ⎰ Olivine-bearing feldspar-basalt.
5) ⎬ from the top. ⎱ Ditto.
6) ⎭ Hypersthene-basalt.

Udoneshima.
7) ⎱ Localities not mentioned (olivine-bearing feldspar-basalt).
8) ⎰

Miyakejima.

9) A specimen from the top (augite-andesite).
10) ⎱ Lava of 1874. ⎰ Olivine-bearing feldspar-basalt.
11) ⎰ ⎱ Hypersthene-basalt in transition to hyper- sthene-andesite.

Mikurashima.
12) ⎫ ⎰ Feldspar-basalt.
13) ⎬ Localities not mentioned. ⎨ Basalt.
14) ⎭ ⎱ Olivine-bearing feldspar-basalt.

Sambondake.
15) Hypersthene-bearing basalt.

Fuji.
16) Plagioclase-basalt, partly olivine-pyroxene-andesite.
The chemically analysed specimen was collected at the tod-crater.

Table   II.

Ôshima	Miyake-jima	Hachi-jôjima	Aoga-shima	Submarine eruption near Bayonnaise Rocks	Submarine-eruption near Smith Rocks	Tori-jima	Submarine eruption near North Sulphur Island	Submarine eruption near South Sulphur Island	Agri-gan	Submarine eruption off Idzu	Fuji
684											781
											800
											826
											864
											870
											937
											999
											1033
	1085										1083
1112	1154										
1416											1331
1421	1469										
		1487									
		1518									1511
	1535	1522									
	1595										1560
1600–1601		1605									
1612–1613										1606	
1636–1637	1643										1627
1684–1690			1652								
	1712										1700
	1763										1707
1777–1778			1780								1708
			1781								
			1783								
			1785								1792
1803	1811										
1822	1835										
1846											
1870										1870	
1876–1877	1874										
						1902	1880	1904		1905	
				1906							
1912–1914								1914			
1915				1915							
					1916						
									1917		

land, Fuji is most closely related to those of the Ôshima group in all respects. These volcanoes appear to form one petrographic province, and their lavas are closely comagmatic. In the accompanying tables (Tables I & II), the petrographic characters of the lavas and the time d'stribution of the outbursts in historic times of these and the related volcanoes are shown.

As to the birth-time of the volcanoes' of the Ôshima group, the writer has been led, by correlating. their lavas with the general course of change in the magma of andesitic lineage in the Idzu peninsula (pp. 133–134), to think that they might have been born at a late date, probably in late Diluvium, when the nature of the magma regionally became strongly basic. Structural and morphographic features of these volcanoes also suggest that they are very young. The injection of the basic magma appears to have been the first step in the igneous activity of the basaltic Idzu islands, and these insular volcanoes may have been formed on the injection fissure at the locations where the lava extrusion was specially favourable.

The above is the writer's present assumption as to the geologic position of Ôshima but it must be subject to further study.

In concluding this chapter the writer wishes briefly to remark on the data so far known concerning the bathymetric conditions of the environs of Ôshima (Fig. 42). The sea bottom near the island slopes outwards from it in all directions, steeply toward the north and east[1], and gently toward the south and west. A sea over 800 fathoms (about 1,500 m.) deep separates the island from the Bôsô[2] peninsula consisting chiefly of the

---

1) How long the belt of this steep slope is prolonged is not known, but the bathymetric map suggests that it runs in the direction S. by E. nearly in a straight line. It may perhaps have some geotectonic meaning such as folding or fault.

2) 房總半島
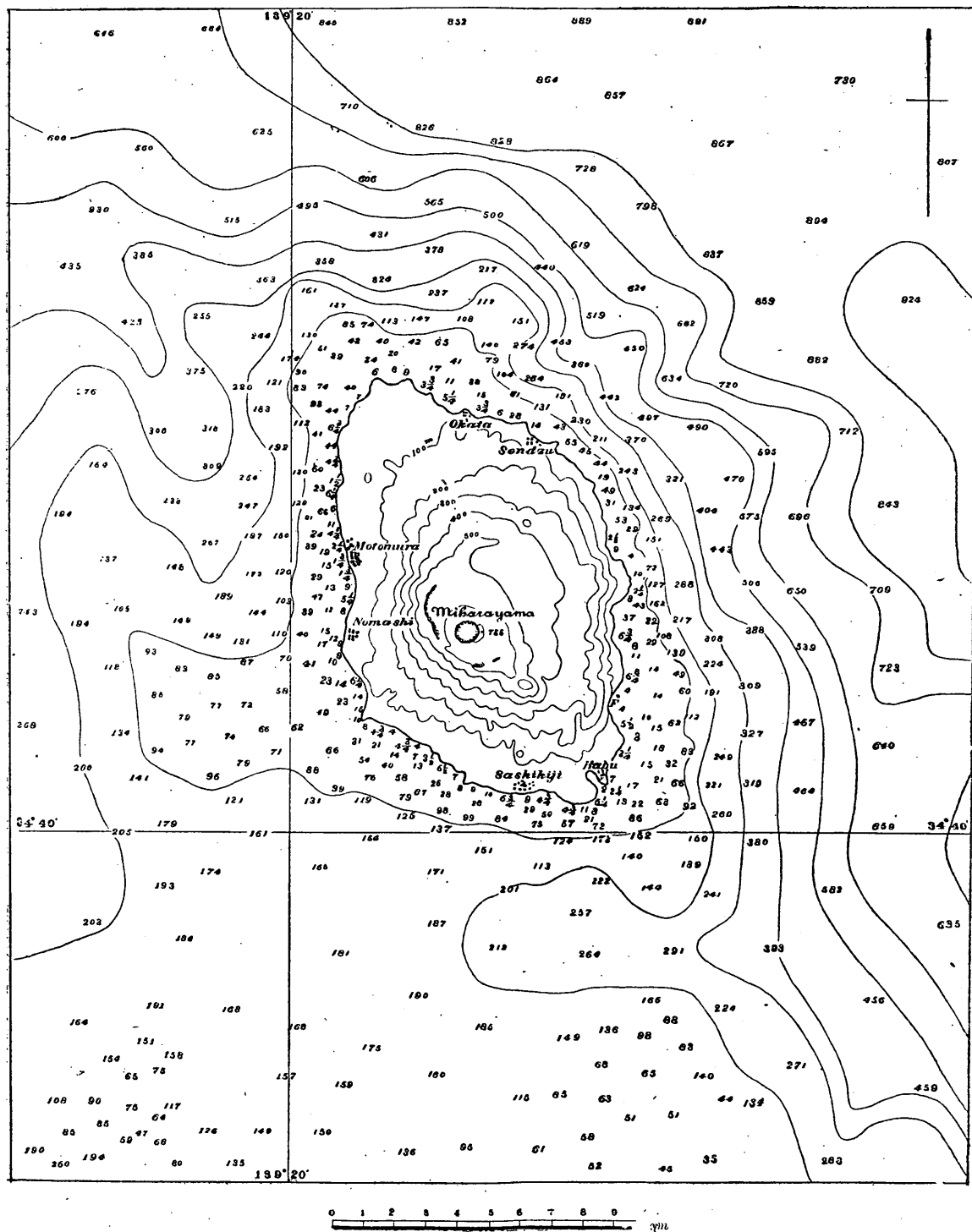
Fig. 42. Bathymetric map of the environs of Ôshima (after Naval Chart of Hydrographic Office, Imperial Japanese Navy). Soundings iu fathoms.

Tertiary sedimentary rocks, while a shallow floor under 300 fathoms (550 *m.*) connects the island to the Idzu peninsula which owes its existence to volcanic action. The materials which constitute the sea bottom near Ôshima are, according to YAMASAKI[1], fragments of volcanic glass with abundant microlites, pumices, and fine pieces of pyroxenes, and feldspars, mingled with the remains of Foraminifera, Radiolaria, etc., appearing in the main as green mud.

VII. General Summary.

(1) Both the position now occupied by the Idzu peninsula and its environs have been the scene of volcanic agitation since the Tertiary period. Here the vulcanism of the two different petrographic lineages—andesitic and rhyolitic—have displayed their activity, and built up the Idzu peninsula.

Lavas of these two lineages continued to be extruded down to the Quaternary period. The andesitic or basaltic lavas built up the volcanoes Fuji, Ashitaka, Hakone, Atami, Amagi[2], etc. on the main land and many insular and submarine ones in the Pacific Ocean, along the line that runs in the direction N.N.W.—S.S.E., conforming to the conspicuous "Fuji volcanic chain." The lavas descending from the Tertiary rhyolitic rocks formed the rhyolitic islands off the Idzu peninsula to the west of this volcanic chain. Contrary to the general opinion the writer agrees with TSUJIMURA that these rhyolitic islands are as young as the volcanoes of the Fuji volcanic chain.

What is commonly called "Idzu Shichitô"[3] comprises the

1) "Geology of the Bottom of the Pacific Ocean between the Tôkyô Bay and Ogasawara," *Jour. Gecl. Soc. Tôkyô*, Vol. XV., pp. 382–383, 1908 (in Japanese).
2) 富士 愛鷹 箱根 熱海 天城   3) 伊豆七島

Quaternary insular volcanoes of both of the above-mentioned lineages, and is to be subdivided into the Ôshima group and the Niijima group, consisting respectively of basaltic and rhyolitic islands.

The members of the former group are Ôshima, Toshima, Udoneshima, Miyakejima, Mikurashima, and Hachijôjima.[1] The rocks of these volcanic islands show a very strong resemblance to one another and appear to be closely comagmatic. By correlating these rocks and those in the related region in the main land, where the general magmatic change is from acidic to basic, it appears that the birth of the basaltic insular volcanoes was at a late date, probably late Diluvium, by which time the magma had become strongly basic.

(2) The insular volcano Ôshima consists mainly of double homates—a somma and a central cone—, and is built up of alternating lava-flows, both superfluent and effluent, and ejecta beds.

The somma has eight parasitic knobs and two phreatic explosion-craters on its flanks, and is truncated at the top with a ring-wall that surrounds a huge oval caldera, about 3 km. in diameter. The wall is not completely closed but has two gaps, a great one on the northeastern and a small one on the south-western sides.

The central homate, Miharayama,[2] standing in the caldera, has an active summit crater, 700 m. across. Its volcanic products cover the ground not only within the inside of the encircling wall but have also spread down to the sea shores through the gaps in the wall.

Besides the above, there are along the western half of the

1) 大島 利島 鵜渡根島 三宅島 御蔵島 八丈島   2) 三原山

northern coast, several small demolished igneous bodies now covered by the volcanic materials of the somma.

(3) The rocks constituting the volcano are of several types as already tabulated on p. 67, but they are readily grouped under three main headings,—basaltic bandaite, miharaite, and basalt.

Basaltic bandaite predominates amongst the lavas of the somma. In it, the phenocrysts of calcic bytownite are scattered through the granular intersertal groundmass consisting of labradorite, augite, magnetite, and a small quantity of glass. Most of the lavas of this type bear a negligible amount of small olivine phenocrysts, though in some this mineral is absent. Hypersthene and augite phenocrysts are either lacking or present only in small quantities.

The type which the writer describes under the new name " miharaite " constitutes the central cone. It does not differ much from the preceding in its petrographic characters but is characterized by an entire absence of olivine.

Basalt is a variety comparatively rich in phenocrysts of olivine and pyroxene. This constitutes the northwestern demolished igneous bodies, but is very rarely found as the lavas of the somma.

All of these rocks are strongly basic. The chemical analyses made of the first two types of the above three—basaltic bandaite and miharaite—, which exceed the third in mass, show a remarkable character in that the amount of silica, in spite of its low percentage, is not only enough to form the highest silicates but it is present in excess. This is one of the common characteristics of the most widely spread recent volcanic rocks of Japan, but the rocks of Ôshima are peculiar in their more femic and less quaric natures.

(4) The physiographic history of the volcano since its birth

is summarized as follows :—

The body which now constitutes the somma is the earliest of those so far seen. It was very gradually built up by repeated volcanic actions without any prolonged intervals of quietude. During the development of the somma, but far before its skirt reached the present state of development, extruded lavas comparatively rich in olivine formed small igneous bodies in the northwestern part of the present Ôshima, isolated at that time from the main body by the sea. These soon expired and were destroyed by the marine erosion. When the development of the somma was nearly completed, the steep slope running in the direction N.-S. along the east coast of the island was formed by the depression of the ground. Vulcanism displayed its energy not only at the centre of the volcano but also on the flanks of the somma at several-spots during various but comparatively later stages in the volcanic history. The products of these flank eruptions are especially abundant in the southeastern part of the island. The depression of the summit of the somma resulted in the formation of a huge caldera whereupon the encircling wall was badly broken in its northeastern quarter. The central homate appeared in the caldera and its products not only filled the inside of the caldera but spread down to the sea shore, especially abundantly in the east through the northeastern gap of the ring-wall. In historic times the volcano continued frequently to display its activity, and eruptions in the following years are on record: 684, 1112, 1416, 1421, 1600–1601, 1612–1613, 1636–1637, 1684–1690, 1777–1778, 1803,-1822, 1846, 1870, 1876–1877, 1912–1914, and 1915.

(5) Turning to the problem of the magma, the original magma is supposed to be basaltic, highly fluidal and with a specific gravity nearly equal to that of the calcic plagioclase crystals. The magma

cooled gradually, separating out the crystals of olivine, plagioclase, and pyroxene, in order as shown in Fig. 40 (p. 117), its temperature becoming at last decisively lower than 1470°C. and probably as low as 1200°–1300°C. During the course of the cooling of the magma, the separated crystals were affected by gravitation. Thus, plagioclase, matching the magma closely in density, remained practically suspended in the magma basin; while olivine and pyroxene, being much heavier than the magma, subsided in it toward the bottom as they crystallized out. As a result of the separation and the subsidence of the crystals the originally homogeneous magma became heterogeneous as time passed, the heavy crystals being relatively concentrated at the bottom. All the rocks of Ôshima represent, according to the writer's belief, certain stages after the above-mentioned magmatic temperature had been reached and the subsidence of the heavy crystals had gone on to a fair extent. The rock-type rich in phenocrysts of mafic minerals—basalt —may have been extruded from the lower portion of the magma basin where the mafic minerals were relatively concentrated; while most of the somma lavas in which olivine crystals are either absent or only very sparingly found—basaltic bandaite—are believed to have come from the upper part of the magma basin at the stage when the olivine crystals had half sunk; the central cone lavas which are entirely free from olivine—miharaite—are probably of a still later stage when the subsidence of olivine crystals had progressed still further so that they had no opportunity of entering the lavas as they were extruded.

The effect likely to be brought about by the cooling of the magma was considered and it was concluded that the magma would change from basic to acidic if the cooling proceeded. All the lavas of Ôshima now seen represent only one stage of the above course,

—in other words, the long physiographic history of Ôshima, so far as it can be traced back from structural study, is represented by only one stage in the cooling history of the magma.

(6) Future activity of the volcano Ôshima. The volcanic activity may depend upon many factors, of which the temperature condition of the magma is no doubt most important. Other conditions being equal, a rise of the magmatic temperature would naturally bring about a rise in the volcanic activity, while a fall in temperature would lead to its decay. In the volcano Ôshima, as already stated, the magma appears to have maintained the same temperature throughout all the stages in the physiographic development so far as is traceable. Moreover, the structural feature shows that there has been no prolonged period of quietude in its life history, there being many historical records of violent outbursts, of which the latest one that lasted from 1912 to 1914 is still very fresh in our memory. All in all, the volcano shows no sign of decay in its activity and appears likely to retain for some time the same energy which it has displayed in the past.

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Imperial University of Tôkyô.

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Volcano Ôshima, Idzu.

Plate I.

PLATE I. (Microphotographs)

Lavas of the Somma.

Basaltic bandaite almost free from phenocrysts of mafic minerals
(the 1st type of the somma lava). See pp. 67–72.

Fig. 1.—Somma lava with the groundmass of α-type (pp. 68 & 70). Here the crystallinity and granularity are low, and anhedral magnetite disseminates finely among the other components. The specimen is from the lava delta of Okata on the north coast (Pl. VI. GA 8). ×70.

Fig. 2.—Somma lava with the groundmass of the same type as the above, but somewhat higher both in crystallinity and granularity. The specimen was collected from the uppermost lava exposed on the western ring-wall at the point 800 m. to S.S.W. of Kagamihata. ×70.

Fig. 3.—Somma lava with the groundmass of β-type (pp. 68 & 70). Specimen from the uppermost lava exposed at Tatsunokuchi (Pl. VI. BC 3). ×70.

Fig. 4.—Somma lava with the same groundmass texture as the above but with extremely fine granularity (0.008 mm. in average diameter of the component minerals). Specimen from the lava exposed at the point, about 1 km. to N.N.W. of Habu, marked $\otimes$ on Pl. V. 3e. ×70.

Fig. 5.—Somma lava with higher crystallinity. The size of magnetite is here as large as 0.08 mm. across. Specimen from the uppermost lava on the sea cliff to the east of Sashikiji (Pl. VI. DE 4). ×70. See. p. 70.

Fig. 6.—Somma lava with similar texture to the above, but with still larger magnetite crystals. The specimen was taken from the sea cliff to the west of Sendzu (Pl. VI. GA 7). ×70.
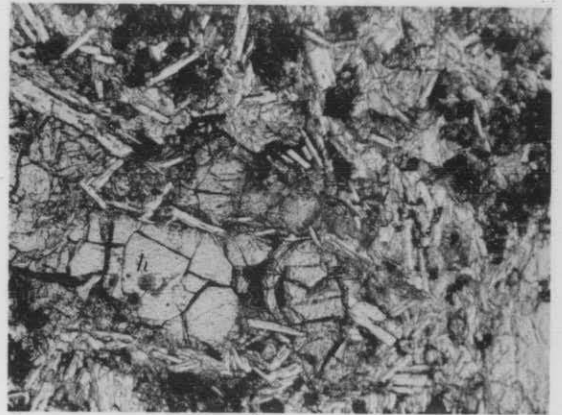
Fig. 1

Fig. 2
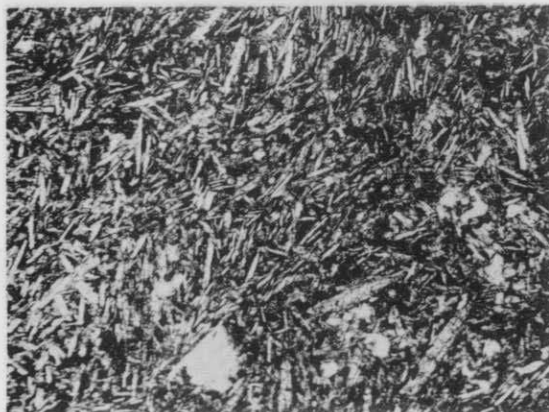
Fig. 3*

Fig. 4
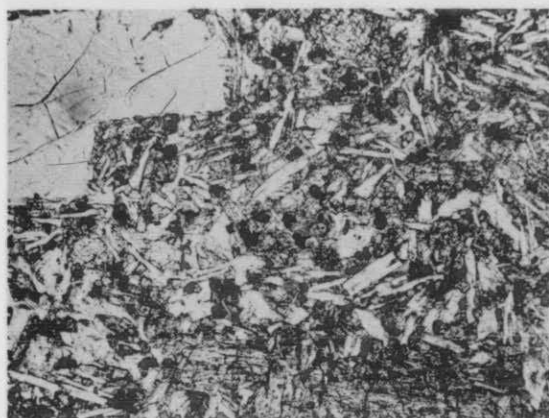
Fig. 5

Fig. 6
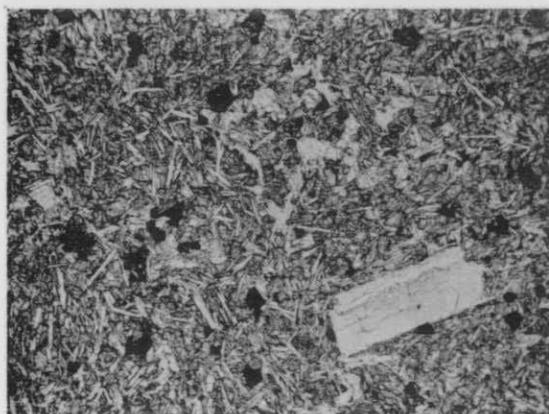
Tsuboi: Volcano Ôshima, Idzu.
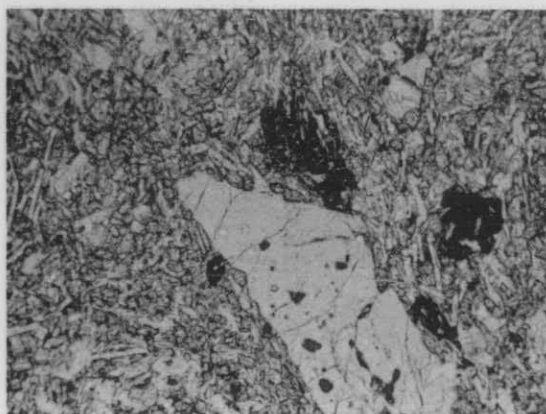
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Plate II.

PLATE II. (Microphotographs)

Fig. 1.—Hypersthene-basaltic bandaite (the 2nd type of the somma lava, Pl. VI. BC 2). ×70. See p. 73. p.... calcic bytownite, h ... hypersthene.

Fig. 2.—Two-pyroxene-basaltic bandaite (the 3rd type of the somma lava), from the lowest lava layer of the three on the sea cliff at Gyôja (Pl. VI. FG 6). ×70. See p. 74. h.... hypersthene.

Fig. 3.—The rock of the same type as in Fig. 2, from the uppermost lava layer of the three on the sea cliff at Gyôja (Pl. VI. FG 6). ×70. See p. 74. p.... calcic bytownite, a.... augite.

Fig. 4.—Hypersthene-bearing augite-olivine-bytownite-basalt (the 4th type of the somma lava, Pl. VI. EF 5). ×70. See p. 76. p.... calcic bytownite, o.... olivine.

Lavas of the Central Cone (Miharaite).

Fig. 5.—An older lava collected from the lowest exposed layer on the eastern crater-wall. ×70. See p. 79. p.... calcic bytownite.

Fig. 6.—Lava of 1778 (An-ei era), collected from the lava field on the northern flank of the central cone. ×70. See p. 80. p.... calcic bytownite, h.... hypersthene, a.... augite.

Fig. 1

Fig. 2

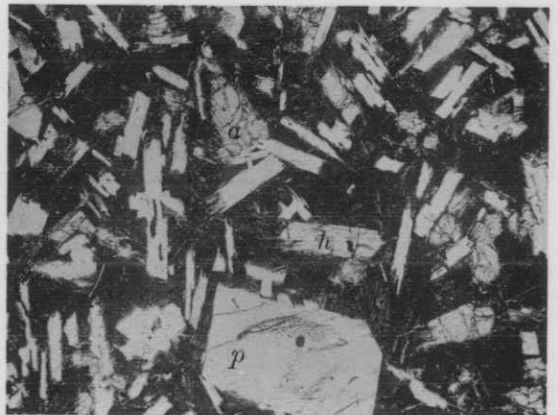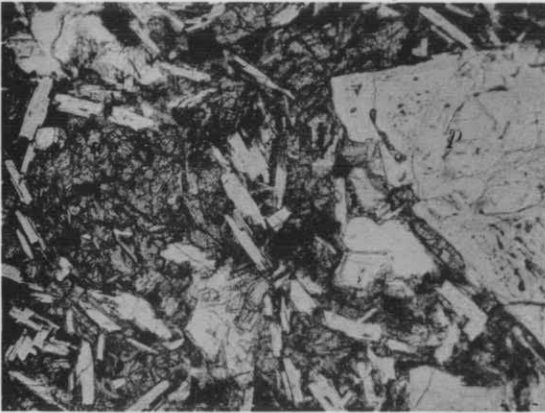Fig. 3

Fig. 4

Fig. 5

Fig. 6

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Plate III.

PLATE III. (Microphotographs)

Fig. 1.—The holocrystalline part of the lava of April 1912. ×70. See p. 81. p.... calcic bytownite, a.... augite.

Fig. 2.—The hyalocrystalline part of the same, with no visible magnetite crystals. ×70. See p. 81. p.... calcic bytownite, r.... rhombic lamella (p. 82), g.... brown glass.

Fig. 3.—The lava of September-October 1912, showing the groundmass of intermediate crystallinity. ×135. See p. 81. p.... calcic bytownite, m.... dendritic skeletal crystal of magnetite.

Fig. 4.—The lava of May 1914, now making the crater-floor. ×40. See p. 81. p.... calcic bytownite, $c.h.$.... clino-hypersthene.

Rocks of the Northwestern Demolished Igneous Bodies.

Fig. 5.—Two-pyroxene-olivine-anorthite-basalt, constituting the igneous body of Chigasaki (Pl. VI. GA 14). ×70. See p. 89. p.... anorthite, o.... olivine.

Fig. 6.—Olivine-bytownite-basalt (a), constituting the igneous body of Kazahaya (Pl. VI. GA 13). ×70. See p. 92. o.... olivine.
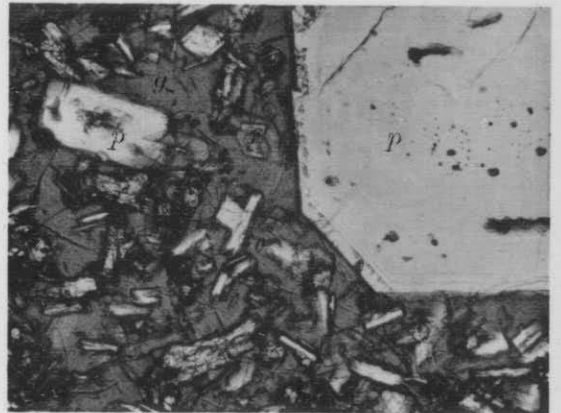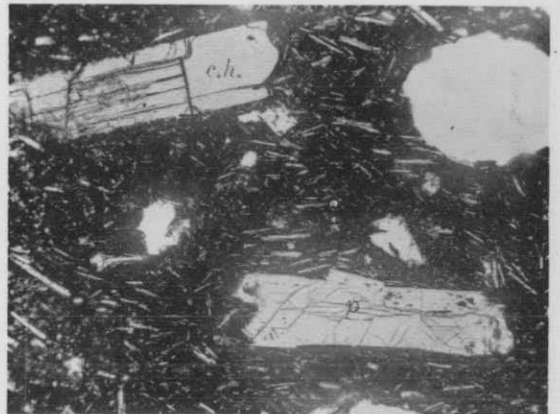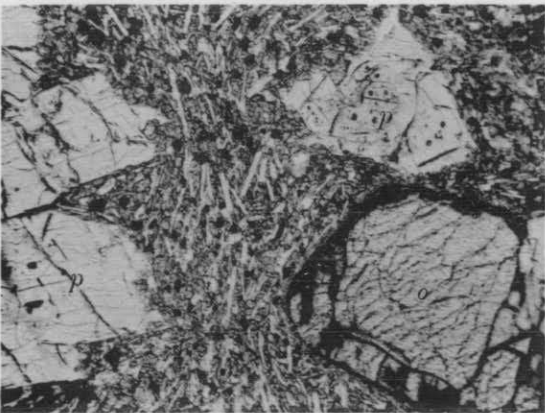
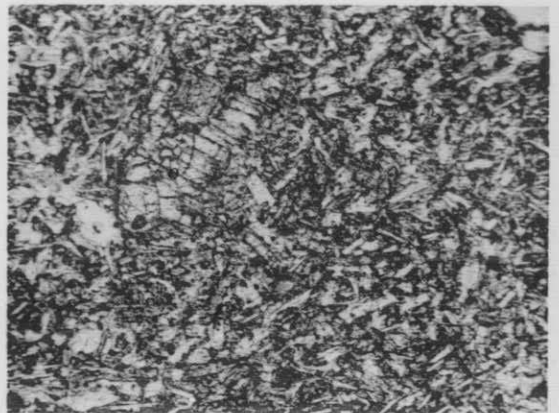Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

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Plate IV.

PLATE IV. (Microphotographs)

Fig. 1.—Olivine-bytownite-dolerite, constituting the igneous body (Pl. VI. GA 11) to the east of Kazahaya. ×70. See p. 93. *p* ... calcic bytownite, *a* ... augite, *o* ... olivine.

Fig. 2.—Olivine-bytownite-basalt (β), constituting the igneous body (Pl. VI. GA 9) to the west of Okata. ×70. See p. 94. *p* ... calcic bytownite, *o* ... olivine with brown iron oxide along the margin.

Rocks occurring as Dykes.

Fig. 3.—Olivineless basaltic bandaite (*a*), the rock of the dykes exposed on the cliff opposite to Fudeshima. ×70. See p. 95. *p* ... calcic bytownite, *a* ... augite.

Fig. 4.—Olivineless basaltic bandaite (β), the rock of the southernmost dyke of the three on the western ring-wall of the somma. ×135. See p. 95. *p* ... calcic bytownite, *a* ... augite.

Phanerocrystalline Ejecta.

Fig. 5.—Micro-allivalite. ×20. See p. 98. *p* ... anorthite, *o* ... olivine.

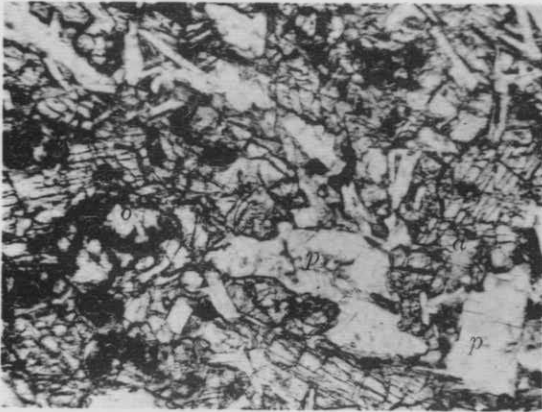Fig. 6.—Augite-micro-diorite. ×30. See p. 99. *p* ... andesine-labradorite, *a* ... unusual augite, *s* ... salic interstitial matter.

Fig. 1

Fig. 2

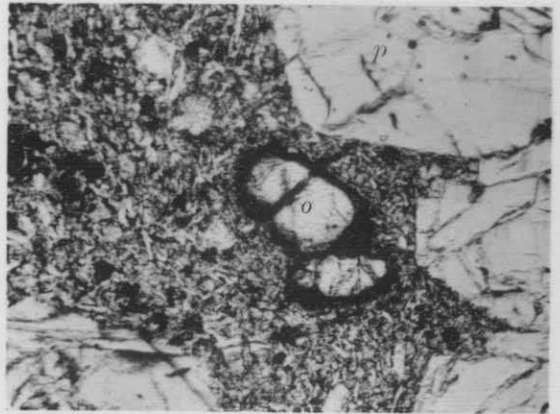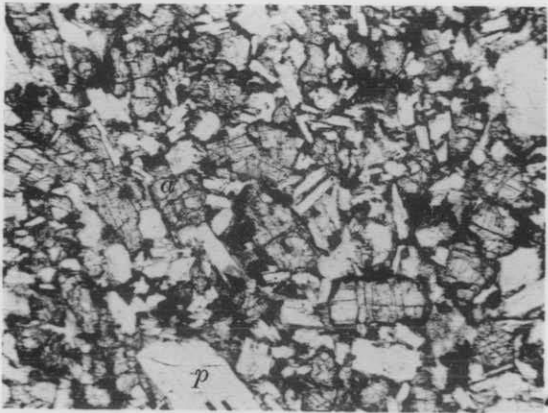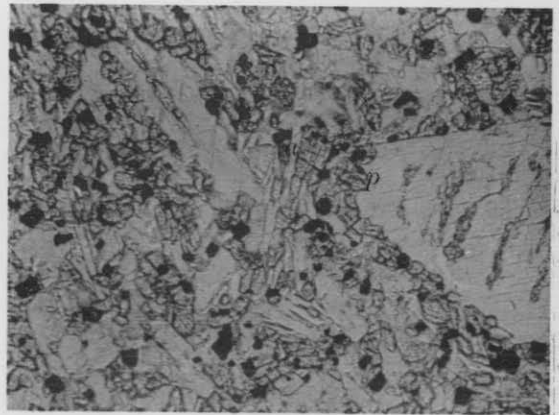
Fig. 3

Fig. 4

Fig. 5

Fig. 6

Tsuboi: Volcano Ôshima, Idzu.

S. Tsuboi:

Volcano Ôshima, Idzu.

Plate V.

PLATE V.

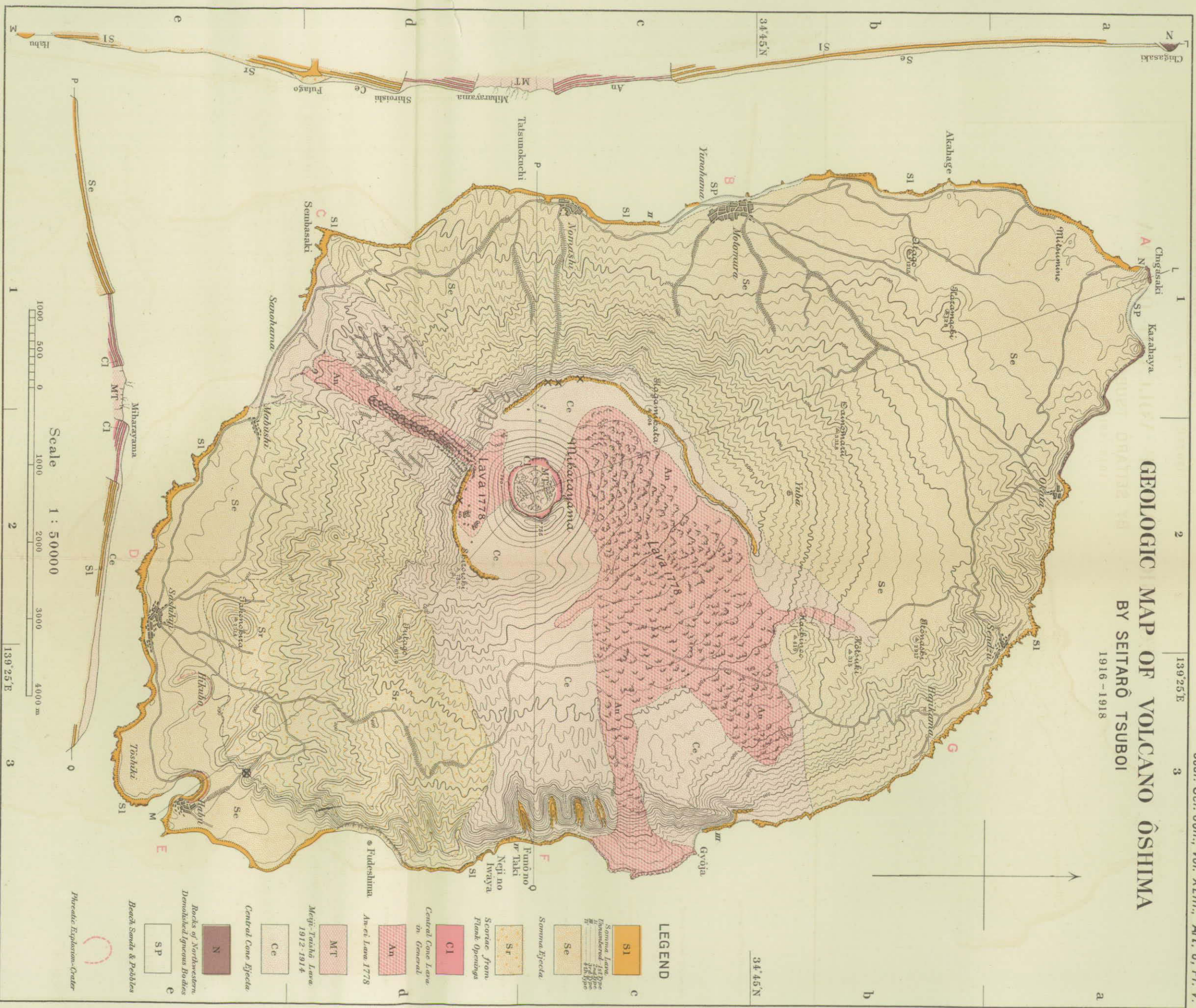## Geologic Map of Volcano Ôshima.

The geologic map of this plate is virtually divided by vertical and transverse lines into squares, which are referred to by the numerals and letters on the margin. Reference indices in the text, following locality names, indicate the square in which those names are to be found. Red reference letters, A B C ... G, around the coast, correspond with those in Pl. VI.

GEOLOGIC MAP OF VOLCANO ÔSHIMA

BY SEITARÔ TSUBOI

1916~1918

139°25'E

34°45'N

34°45'N

139°25'E

Cross-section (top):
W · Iidbu · Sl · Se · Sl · Sr · Ce · Futago · Sl · Shiraishi Ce · Mihorayama · MT · An · Sl · Se · Sl · Chigasaki

Cross-section (left):
Se · Cl · MT · Cl · Miharayama · Ce · Sl · P

Map labels: Chigasaki · Kazahaya · Akahage · Midomine · Sl · Se · Sl · Se · Nomaki · Motomura · Se · Sl · Tatsunokuchi · SP · Yanohama · Sembasaki · Sl · C · Sanohama · Mdobshi · Se · Se · Sl · Ce · Miharayama · Lava 1778 · Mihacayama · Ce · Lava 1778 · Ce · Ce · An · Yuba · Se · Sl · Nōji no Taki · Negi no Iwaya · Sl · Fudeshima · Gyōja · Sl · Sl · Ce · Sr · Sosuka · Hikata · Ce · Sl · Tōshiki · Se · M · E · F

LEGEND

Sl	Somma Lava
Se	Somma Ejecta
Cl	Central Cone Lava in General
Sr	Scoriae from Flank Openings
An	An-ei Lava 1778
MT	Meiji-Taishô Lava 1912~1914
Ce	Central Cone Ejecta
N	Rocks of Northwestern, Demolished Igneous Bodies
SP	Beach Sands & Pebbles

Phreatic Explosion-Crater

Scale 1 : 50000

1000 500 0 1000 2000 3000 4000 m.

1   0   1   2   3

Scale

S. Tsuboi:

Volcano Ôshima, Idzu.

Plate VI.

PLATE VI.

Diagrammatic Sketch of the Exposures on the Coastal Cliff.

Red reference letters, A B C....G, correspond with those in the geologic map of Pl. V. Arabic figures, 1 2 3....14, refer to the text and explanations of plates as follows :—

DIAGRAMMATIC SKETCH OF EXPOSURES ON THE COASTAL CLIFF

Horizontal Scale 1/20000   Vertical Scale 1/5000

LEGEND

- Somma Lava 1st Type
- Somma Lava 2nd Type
- Somma Lava 3rd Type
- Somma Lava 4th Type
- Somma Ejecta
- Scoriae from Flank Openings
- An-ei Lava 1778
- Central Cone Ejecta
- Lava of Northwestern Demolished Igneous Bodies
- Ejecta of Northwestern Demolished Igneous Bodies
- Dyke