Bulletin of the Earthquake
Research Institute
Vol. 40 (1962), pp. 767-804

43. *Geological and Petrological Studies of Volcano Fuji (VI).*
6. *Geology of the Volcano as Observed in Some Borings on its Flanks.*

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(Read May 22, 1962.—Received Sept. 30, 1962.)

Introduction.

Mt. Fuji, which is a dormant basaltic volcano, 3387 m in height above sea level, covers an area of about 900 km^2, extending over Shizuoka and Yamanashi prefectures in central Japan. Morphologically, it is a typical cone encircled with very gentle and extensive skirts on all sides except for a small section on the southeast where the extinct Ashitaka volcano stands close at hand.

In the course of his studies on the geology and petrology of the volcano, the writer has ascertained that it consists structurally of three parts, Komitake, old Fuji, and new Fuji, erupted successively in the order mentioned. Komitake (Fig. 1.), a prominent shoulder projecting from the northern flank of Mt. Fuji, is the ruin of an old andesitic volcano called Volcano Komitake.[1] Morphological and geological characteristics of this volcano show it to be probably of early Pleistocene age and contemporaneous in eruption with the Ashitaka volcano. Old Fuji, the precursor of the present Fuji, is represented principally by the volcanic mud-flows and other pyroclastics of basaltic nature that are distributed on the southwestern and southeastern foot of Mt. Fuji.[2] Being more or less deeply eroded and locally dislocated by faulting, these deposits are not conformable with the overlying earliest lava-flows of the new Fuji volcano. Therefore, it is inferred that the old Fuji volcano had become extinct some time before the beginning of eruption of the new Fuji volcano, probably in late Pleistocene or early Holocene age. The centre of eruption of old Fuji must have been on the southwest side of the Komitake volcano and not very far from the center of eruption of new Fuji. The result is that old Fuji does not stand

1) H. Tsuya, *Bull. Earthq. Res. Inst.*, **16** (1938), 452.
2) H. Tsuya, *Bull. Earthq. Res. Inst.*, **18** (1940), 419.

anywhere on Mt. Fuji as a distinct body, being buried for the most part beneath the ejecta of new Fuji.

The new Fuji volcano, which is represented by the present gigantic cone of Fuji, is composed largely of basaltic lava-flows, besides a

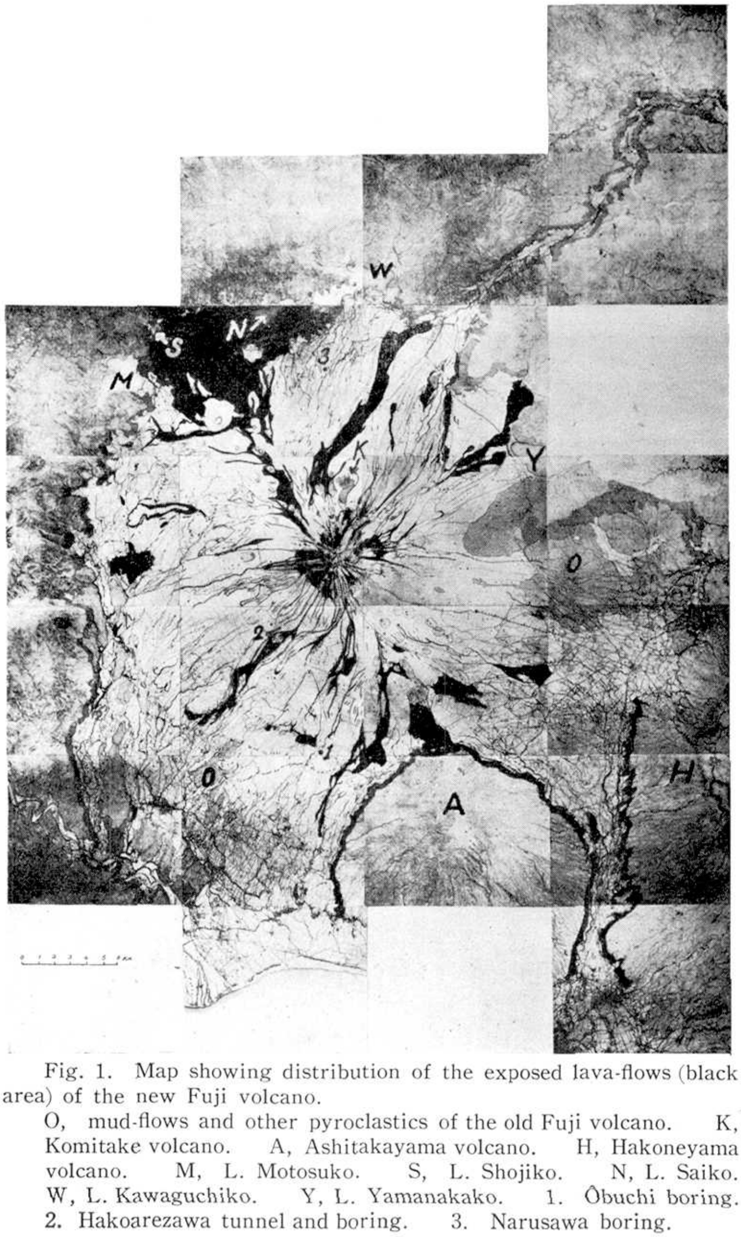


Fig. 1. Map showing distribution of the exposed lava-flows (black area) of the new Fuji volcano.

O, mud-flows and other pyroclastics of the old Fuji volcano. K, Komitake volcano. A, Ashitakayama volcano. H, Hakoneyama volcano. M, L. Motosuko. S, L. Shojiko. N, L. Saiko. W, L. Kawaguchiko. Y, L. Yamanakako. 1. Ôbuchi boring. 2. Hakoarezawa tunnel and boring. 3. Narusawa boring.

relatively small amount of pyroclastic ejecta, such as volcanic ash, sand, breccia, and pyroclastic flows. Ejected not only from the central main crater of the volcano but from a number of its lateral vents, the lava-flows may be counted by the thousand in all. Most of the lava-flows ejected in the early stages of eruption of the volcano are characterized by carrying large-sized phenocrysts, occasionally more than 1 cm in diameter, of calcic plagioclase. They are extensively distributed on the lower flanks of the mountain, resting on the ejecta of the old Fuji volcano. Starting with these lava-flows and subsequently ejecting basaltic lava-flows of various petrographic characters, such as aphyric basalt, olivine-basalt, augite-olivine-basalt, and two-pyroxene-olivine-basalt, the valcano has risen to the present height during the last several thousand years. The lava-flows are all, with a few exceptions, less than five meters in thickness, and some of them are as thin as 10 cm. Therefore, when ejected, they must have been highly fluid, although most of the "marubis"[3] have solidified as block (aa) lavas. A volcano mainly composed of basaltic lava-flows normally has the form of a shield like the Hawaiian volcanoes Mauna Loa and Kilauea. Unlike these, however, Mt. Fuji has grown up into an almost pure cone, probably because the new Fuji volcano has erupted almost co-axially with the underlying old Fuji which, attended by a large amount of pyroclastic ejecta, must have shown itself as a conical mountain. In other words, the eruption of new Fuji has remodelled its predecessor, old Fuji, into a new cone by covering with its lava-flows almost all parts of the latter. The Komitake volcano, which before the birth of Fuji must have been a lofty independent cone, has also contributed to the growth of Fuji, being buried deep beneath the ejecta of the latter to all but a small part of its summit.

As a large water reservoir, Mt. Fuji provides a number of underground springs at its foot, but as is usual on a young volcano, it lacks much running surface-water at all times except for a short time immediately after torrential rain. Therefore, although the lower slopes of the mountain have been covered for the most part with forests, natural and artificial, they have been left unsettled. In order to develop these slopes for new settlements and other purposes, prospectings for underground water have been carried out by borings and other means at several places on the slopes. But they have not yet brought out

3) Local name for the recent lava-flows left uncovered by pyroclastic ejecta on the lower slopes of the volcano.

clearly the mode of behaviour of the underground water, and none of the borings, except a few on the slopes near the foot of the mountain, has yet succeeded in striking water-bearing stratum or a water-slip extremely useful as a source of water supply. Some of the borings, however, provide us with a lot of core specimens of rocks, which unexposed on the surface are quite useful for detecting the geological structure of the volcano. The writer has been able to examine some of the borings with the result that his conception of the triple structure of the volcano is verified by actual observation.

This paper presents an outline of the geology of the borings carried out at Ôbuchi, Hakoarezawa and Narusawa on the south, west and north slopes of the volcano respectively. (Fig. 2.) The writer is indebted

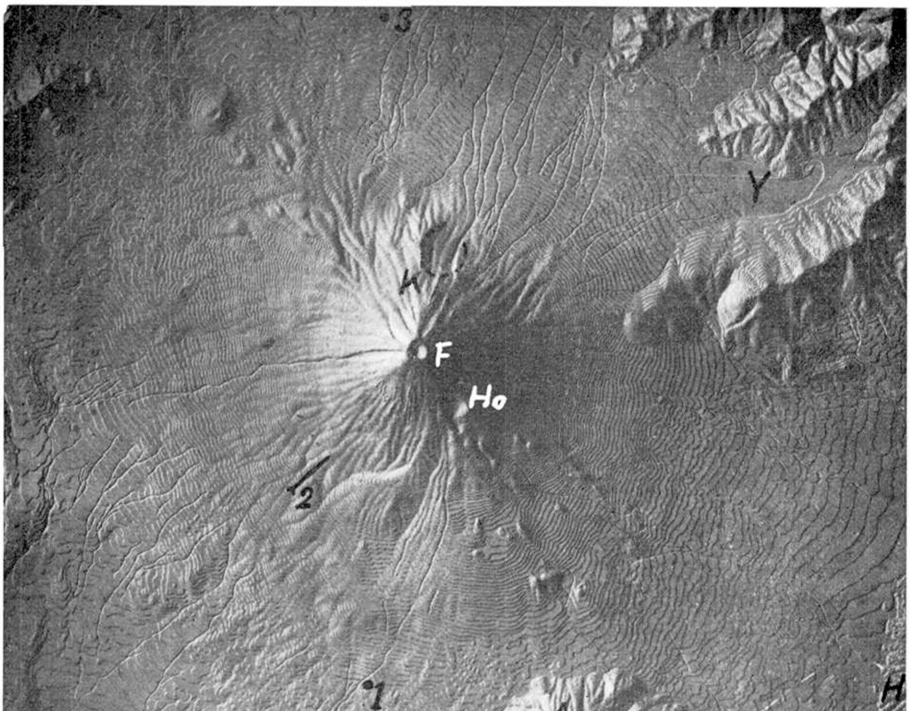


Fig. 2. Photograph of a plaster model of the Fuji volcano, showing location of the borings described in the text.
1. Ôbuchi boring. 2. Hakoarezawa tunnel and boring. 3. Narusawa boring No. 11. F, Summit of Mt. Fuji. Ho, Hôeizan (1707) crater. A, Ashitakayama. H, Hakoneyama. K, Komitake. M, L. Motosuko. Y, L. Yamanakako.

to Dr. W. Muroi of the Tokyo Chishitsu Kogyo K. K. for giving him the opportunity to examine the boring cores. He also wishes to thank the officials of the Fuji Sogokaihatsu K. K. and the Agricultural Land Bureau, Ministry of Agriculture and Forestry, for presenting him with written data and core specimens of the borings for free use in this investigation, and for allowing him to make public the results of this investigation.

The Ôbuchi Boring.

Location and History. This boring is located at a height of about 700 m above sea level in the village of Ôbuchi and by the mountaineering trail on the south slope of the volcano. It was bored in the early 1930 s by a private mining enterprise, the Iwakura Mine, for the purpose of prospecting the region for petroleum and not for underground water. It may now be said without giving offence to anyone that the work was done with the backing of an investor who, strange to say, believed in the false saying of a witch that petroleum was preserved in the rocks beneath the volcano. There is no scientific reason, however, for inferring that the basement complex of the volcano is, partly at least, oil-bearing. Thus it is represented, for the most part, by the Quaternary and Neogene Tertiary formations that, distributed in the hills and mountains surrounding the foot of the volcano, have yielded little oil. Therefore, it was a logical conclusion that the enterprise should be discontinued without fulfilling its purpose after costly borings lasting several years and attaining a depth of about 1000 m below the surface. But the boring must have been quite valuable to those interested in the study of the geologic structure of the volcano, because it enabled them to examine the rocks in all depths down to about 1000 m. When the boring was under way, the writer obtained a number of the boring cores, although unfortunately a complete columnar diagram of the boring was not available.

Geology of the Boring-site. The mountain side on which the Ôbuchi boring is located shows an average inclination of about 10° to the south, and is overgrown for the most part with bushes and forests. It is undulated with ridges, dales and hollows, most of which are not due to erosion, but represent the primary topography of the lava-flows that cover the area. Even gullies are quite few, to say nothing of erosion valleys, the most notable one being Garansawa and its tributary Fudôsawa.

As is usual with gullies on mountains, the Garansawa and Fudôsawa gullies vanish before reaching the foot of the mountain and have a stream of water only during heavy rains.

The surface of the ground adjacent to the boring-site consists for the most part of volcanic ash, sand and breccia, but the thickness of deposits of these ejecta is relatively thin, and the underlying lavas are exposed here and there, especially where the slope is relatively steep as on the side of a lava coulee. Some of the lavas are well exposed in the Garansawa and Fudôsawa gullies too. According to their distribution and petrographic characters, the lavas are classified in descending order of succession as follows:

1. Asagizuka parasitic cone lava (augite-hypersthene-olivine-basalt).
2. Nishiusuzuka parasitic cone lava (augite-olivine-basalt).
3. Garansawa lava (augite-olivine-basalt).
4. No. 2237 lava (olivine-basalt).
5. Nanairoishi lava (olivine-basalt).
6. Yorisaka lava (olivine-basalt).
7. Kiwadakubo lava (olivine-basalt).

These lavas are distributed in the vicinity of the boring-site as shown in Fig. 3.

The Asagizuka lava is a large flow erupted from the parasitic cone, Asagizuka, located at 1574.7 m above sea level, half way up the southeast side of the mountain, and on the east side of the upper course of the Garanzawa gully. It is extensively distributed on the slope adjacent to and outside of the eastern part of the area shown in Fig. 3. Except where covered by several younger "marubi" lava-flows, the lava forms the surface of its area of distribution with a thin veneer of volcanic ash. Petrographically, it is an augite-hypersthene-olivine-basalt, carrying a large amount of medium-sized phenocrysts of plagioclase, olivine, hypersthene, augite and magnetite, in a groundmass composed of minute grains of pyroxene and magnetite, plagioclase laths, and a little interstitial glass. The phenocrystic hypersthene is superior to augite in quantity as well as in size. The plagioclase phenocrysts are mostly lath-shaped and microscopically show a well-defined, rectangular form, as one of the characteristic features of the rock.

The Nishiusuzuka lava is a flow erupted from the parasitic cone, Nishiusuzuka, located at 1292.6 m above sea level, half way up the south side of the mountain, and at a distance of about 2 km east of the 1.5th station on the Fujinomiya trail. From the cone downwards, the lava is spread fanwise, the eastern wing of its front reaching as far as the slope, about 700 m above sea level, in the area now concerned, as shown in Fig. 3. In this frontal part, the lava is exposed here and there with a thin veneer of volcanic ash, but on the upper slope it is covered for the most part with a thick bed of volcanic ash and partly by younger

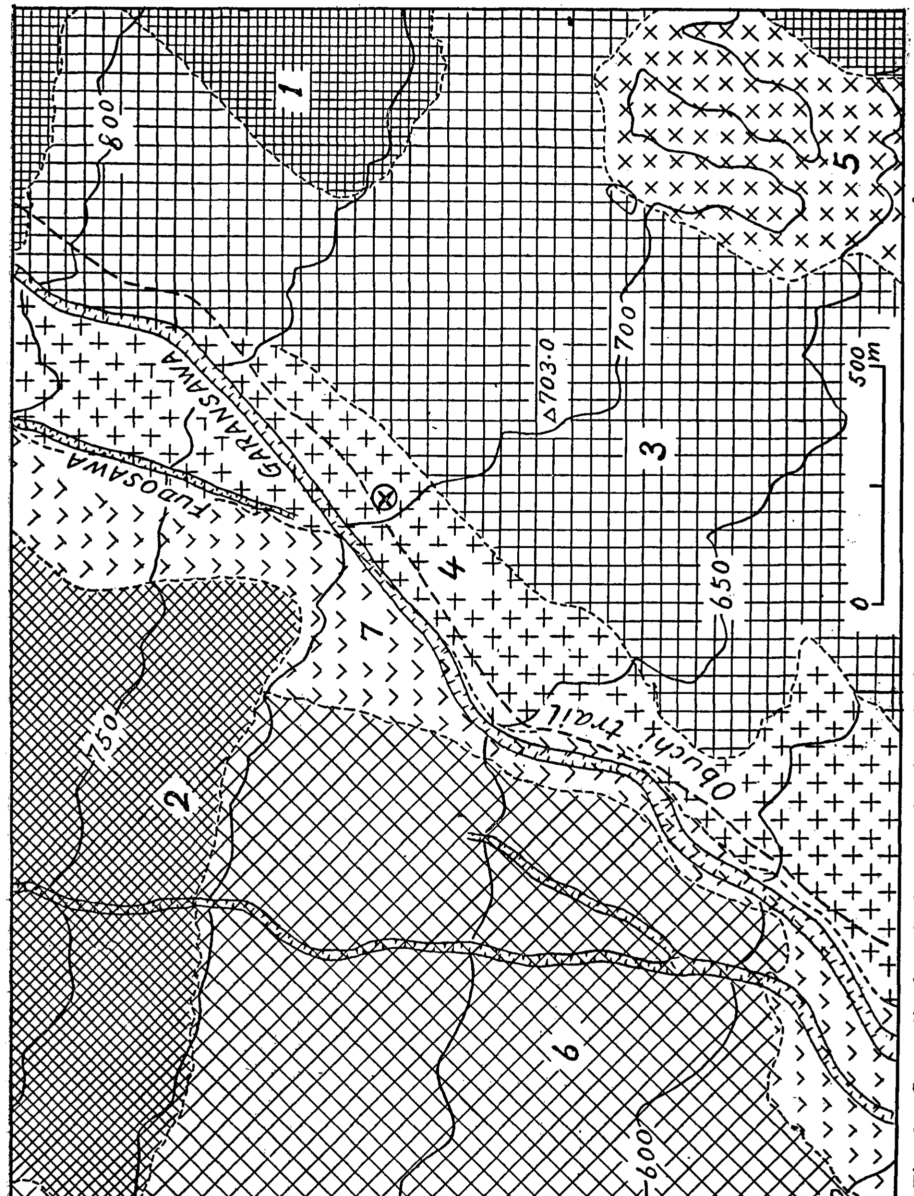


Fig. 3. Generalized geologic map showing distribution of lava-flows in the vicinity of the Ôbuchi boring. 1. Asagizuka parasitic cone lava. 2. Nishiusuzuka parasitic cone lava. 3. Garansawa lava. 4. No. 2237 lava. 5. Nanairoishi lava. 6. Yorisaka lava. 7. Kiwadakubo lava.

lava-flows. Petrographically, it is an augite-olivine-basalt, carrying a large amount of medium-sized phenocrysts of plagioclase, olivine, augite, and a few magnetite, in the groundmass consisting of plagioclase laths, pyroxene and magnetite grains, and a little interstitial glass. The augite phenocrysts are smaller in quantity as well as in size than the olivine.

The Garansawa lava is extensively distributed on the slope east of the Garansawa gully and below the front of the Asagizuka lava, with its farthest front on the slope east of Sobina and at a height of about 450 m above sea level. In the middle course of the Garansawa gully, between 800 m and 1200 m in height above sea level, the lava occurs in two sheets overlain by the Asagizuka lava. On the west side of the third of the Hôei (1707) craters, which is in the direction of the the upper course of the Gransawa gully, is exposed a lava of a like kind, although its direct connection with the Garansawa lava cannot be traced. This lava is probably one of the lavas erupted at a middle stage of the activity of the volcano. Petrographically, it is an augite-olivine-basalt carrying a large amount of small phenocrysts of plagioclase, olivine and augite, in the groundmass composed of plagioclase laths, pyroxene and magetite grains, and a little interstitial glass. The olivine is nearly equal to the augite in size as well as in quantity, and the former sometimes occurs in the latter as a relict mineral.

The No. 2237 lava occupies the narrow zone along the Garansawa gully between 800 m and 570 m in height above sea level, being overlain on the east side by the Garansawa lava and resting on the west side on the Kiwadakubo lava to be mentioned later. Covered with volcanic ash and breccia, it is exposed only locally in gullies, cliffs and road cuttings. As one of the lavas erupted at an earlier stage of the activity of the volcano, it is characterized by large and conspicuous phenocrysts of plagioclase. Thus petrographically, it is an olivine-basalt carrying olivine phenocrysts, besides the plagioclase, in a groundmass composed of plagioclase laths, pyroxene and magnetite grains, and a little interstitial glass. The olivine phenocrysts are mostly inconspicuous, occurring as microscopic grains embedded in the groundmass. The presence of large-sized plagioclase phenocrysts, more than 5 mm in diameter, is one of the distinguishing characteristics of most of the lavas erupted at the earlier stage of the volcano's activity.

The Nanairoishi lava is distributed on the slope about 1.5 km east of the Garansawa gully and between 700 m and 200 m in height above sea level. As shown in the map (lower right, Fig. 3), the top of its distribution area has a topography suggestive of a parasitic volcano. Thus, in the geologic map (1: 75,000, Numazu) published by the Geological Survey of Japan (1953), it is represented as a parasitic volcano. But there is no positive evidence to justify it as such; rather it may be a part of the lava coulee locally piled up to take the form of a mound. The lava is older in eruption than the Garansawa and Asagizuka lavas that surround it on the northwest and east respectively, while it is younger than the Kiwadakubo lava to be mentioned later. Petrographically, the lava is an olivine-basalt somewhat similar in megascopic feature to the No.

2237 lava, but is distinguishable from the latter in having a larger amount of plagioclase phenocrysts in a coarser and more granular groundmass. Some of the plagioclase phenocrysts are more than 5 mm in diameter. Besides a few phenocrysts, about 1 mm in diameter, of olivine, smaller grains of the mineral occur in the groundmass, together, with plagioclase laths, pyroxene and magnetite grains, and a little brown glass. Of the pyroxene grains, larger ones usually show a distinct wavy extinction.

The Yorisaka lava is extensively distributed on the slope west of the Garansawa gully, extending southwestwards as far as Senganmatsu located outside the area shown in the map (Fig. 3.) and at a height of about 200 m above sea level. The lava rests directly on the Kiwadakubo lava to be mentioned next, while on the slope higher than 700 m above sea level, it is covered partly with the Nishiusuzuka lava. The sequence of eruption of this lava and the above-mentioned two lavas (the No. 2237 and Nanairoishi lavas) is not known, because they are not in contact with each other, but they may be nearly of the same age, being somewhat similar in petrographic character to each other. Thus the Yorisaka lava is an olivine-basalt carrying conspicuous phenocrysts of plagioclase, some of which are larger than 5 mm in diameter. Olivine mostly occurs as microcrysts less than 0.1 mm in diameter in the groundmass consisting of plagioclase laths, pyroxene and magnetite grains, and a little interstitial glass.

The Kiwadakubo lava is the oldest one in the area shown in the map, Fig. 3, and is exposed in a narrow zone along the Garansawa gully and is below 700 m in height above sea level. Petrographically, it is an olivine-basalt carrying only a few phenocrysts, 0.5~1.0 mm in diameter, of plagioclase and olivine in a groundmass composed of plagioclase laths, olivine, pyroxene and magnetite grains, and a little interstitial glass. On the downward slope adjacent to the southwest side of the map, the lava is contiguous to the aphyric lava (Imaizumi lava) with which it is either contemporary or successive in eruption. Aphyric lavas like this also are one of the characteristic types met with among the earlier lavas of the volcano.

Core Rocks of the Ôbuchi Boring. Of the core rocks collected from the Ôbuchi boring, the specimens examined by the writer are as follows :

	Depths from the pit mouth in meters	Rock type
1	29.90—36.10	Olivine-basalt.
2	36.10—51.30	
3	51.30—52.40	
4	56.25—56.65	Two-pyroxene-olivine-basalt.
5	66	Aphyric olivine-basalt (altered andesite)
6	73.36—76.07	Hypersthene-augite-olivine-basalt.
7	86.95—87.06	
8	91	

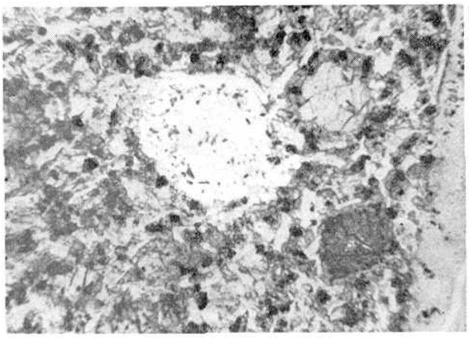
	Depths from the pit mouth in meters	Rock type
9	122.75—125.55	Hypersthene-augite-olivine-basalt.
10	147.10—148.00	
11	154.70—157.20	
12	276.00—279.00	Olivine-hypersthene-augite-basalt.
13	328.60—340.00	Augite-bearing olivine-basalt.
14	350.00—351.40	Hypersthene-augite-olivine-basalt-
15	413.00—424.00	Olivine-hypersthene-augite-andesite.
16	483.11—484.10	
17	619.50 (top)	Decomposed tuff.
18	619.50—620.50	Clay and decomposed tuff.
19	637.50—638.10	Altered andesite.
20	643.00—643.70	
21	726.00	
22	746.00	
23	760.00	
24	769.00	Fine sandstone.
25	885.00	

As the Ôbuchi boring is located in the area covered with the No. 2237 lava, together with some surface deposit of volcanic ash and breccia, it is natural that this lava is the first one met in the boring.

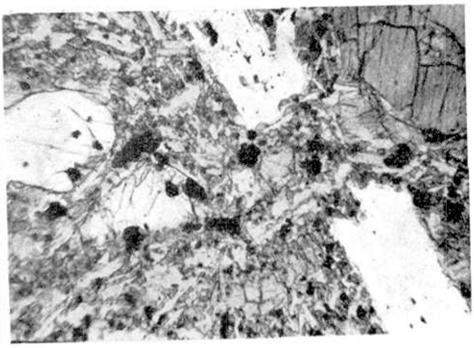
The rock (1) lifted from the depth between 29.90 m and 36.10 m is an olivine-basalt petrographically identical with the No. 2237 lava. (Fig. 4 a.) Therefore, it is inferred that this lava is a little more than 30 m in thickness at the boring-site, although it may not be a single flow-sheet.

The rock (2) at depths between 36.10 m and 51.30 m is an olivine-basalt petrographically quite different from any one of the lavas found in the vicinity of the boring-site. It contains not a few conspicuous phenocrysts of plagioclase, more than 5 mm in diameter, together with olivine, in a relatively coarse groundmass, more or less doleritic in structure and consisting of plagioclase, monoclinic pyroxene, olivine, magnetite, and a little interstitial glass.

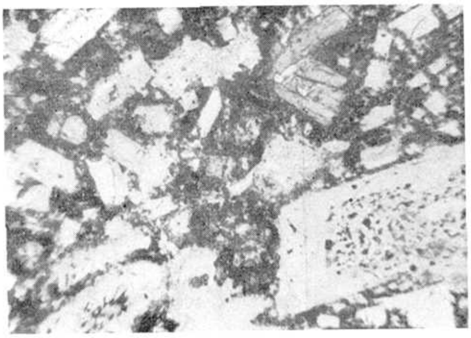
The rock (3) at depths between 51.30 m and 52.40 m is an olivine-basalt somewhat similar to either the Nanairoishi lava or the Yorisaka lava, but not identical with either of these. The rock (4) at depths between 56.25 m and 56.65 m is a two-pyroxene-olivine-basalt crowded with relatively small phenocrysts, 0.2~1.0 mm in diameter, of plagioclase, augite, hypersthene and olivine, in a groundmass consisting of plagioclase laths, minute grains of pyroxene and magnetite, and glass. Rocks of this petrographic type never occur in the lavas



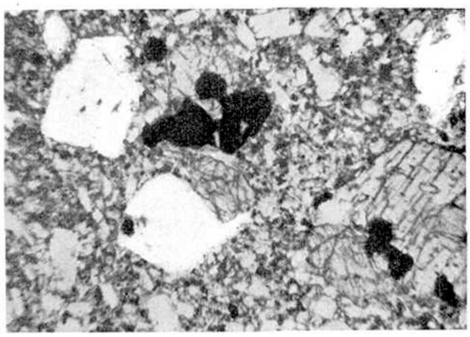
a. Olivine-basalt. [−29 m]



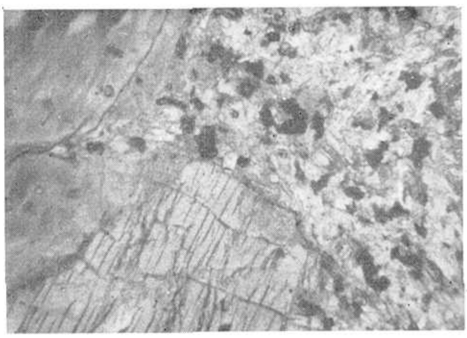
b. Hypersthene-augite-olivine-basalt. [−125 m]



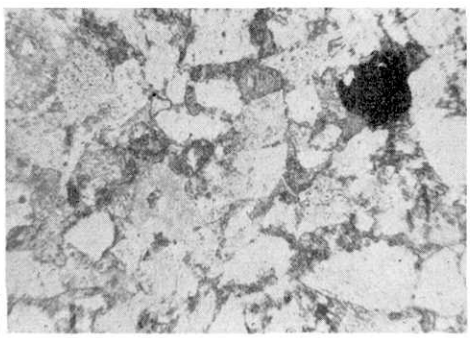
c. Hypersthene-augite-olivine-basalt (a lava block in the volcanic breccia of the old Fuji volcano). [−350 m]



d. Olivine-hypersthene-augite-andesite (a lava of the Ashitakayama volcano). [−483 m]



e. Altered andesite (Tertiary). [−726 m]



f. Sandstone (Tertiary). [−769 m]

Fig. 4 a∼f. Microphotographs of the rocks from the Ôbuchi boring. [×60] of the new Fuji volcano, but are found abundantly among the pyroclastic ejecta of the old Fuji volcano. Of the two specimens labelled as collected at the depth of 66 m, one is almost aphyric olivine-basalt consisting of plagioclase laths, olivine, monoclinic pyroxene and magnetite grains, and a little interstitial glass, besides a few inconspicuous plagioclase phenocrysts, and the other is an altered porphyrite impregnated with such secondary minerals as chlorite and epidote.

The aphyric basalt is somewhat similar to the Kiwadakubo lava, except that the former is poorer in olivine than the latter, while the altered porphyrite is quite foreign to any of the juvenile ejecta of the Fuji volcano. From the appearance of the four rock-specimens (3, 4, 5 a, b) and their various petrographic characters, it is inferred that the wall of the boring between the depths of 51.50 m and 66.00 m is largely composed of a volcanic breccia or an agglomerate nearly contemporaneous in eruption either with the Kiwadakubo lava or the Nanairoishi lava.

The rocks (6, 7, 8, 9, 10, 11) collected at various depths between 73.36 m and 157.20 m are a hypersthene-augite-olivine-basalt of the same general type, although they are not uniform both in the size and amount of the phenocrystic minerals and in the crystallinity of the groundmass. (Fig. 4 b.) They usually contain a lot of conspicuous prismoidal phenocrysts of plagioclase, besides hypersthene, augite, and olivine, in the groundmass, which is composed of plagioclase laths, monoclinic pyroxene and magnetite grains and a very little interstitial glass.

They are petrographically similar to none of the lavas distributed on the surface in the vicinity of the boring-site; instead they are identical with the Iwabuchi lava[4] which, distributed extensively on the south-southwestern foot of the volcano, represents one of its earliest flows. At Sobina on the lower course of the Garansawa gully, this lava is hidden under an olivine-basalt lava similar to the Kiwadakubo lava.

The rock (12) collected at the depths between 276 m and 279 m is an olivine-hypersthene-augite-basalt carrying a large amount of phenocrysts, less than 1 mm in diameter, of plagioclase, augite, hypersthene, magnetite and olivine, in the groundmass composed of a very minute aggregate of plagioclase, pyroxene and magnetite. Among the phenocrysts, the augite and hypersthene are more conspicuous and larger in amount than the olivine. It is not clear whether this rock is of a lava flow or not, although petrographically it is somewhat similar to certain lavas of the new Fuji volcano.

The rock (13) collected at the depths between 328.6 m and 340.13 m is also

4) H. TSUYA, *Bull. Earthq. Res. Inst.*, **18** (1940), 419.

a basalt, but petrographically it is quite different from the rocks mentioned above. Thus the rock is closely packed with crystals, 0.1~1.0 mm in diameter, of plagioclase, olivine, and a little augite; the groundmass is rather interstitial, consisting of a minute aggregate of plagioclase, pyroxene, and magnetite, besides cristobalite usually developed in the vesicular cavities.

The rock (14) collected at the depths between 350.00 m and 351.40 m is almost similar in microscopic structure to the above-mentioned one, but it contains not a little hypersthene and augite, besides plagioclase and olivine. (Fig. 4 c.)

From their petrographic characters, it is inferred that both of these rocks (13, 14) belong to the old Fuji volcano. If so, the wall of the boring between 328.60 m and 351.40 m in depth must be a portion of this volcano, and the boundary between the two Fuji volcanoes, old and new, must be at a depth between 328.60 m and 279.00 m, although its exact situation is quite unknown.

The rock (15) collected at a depth between 413.0 m and 424.0 m is a basaltic or basic andesitic rock somewhat different from the rocks of both the old and new Fuji volcanoes, and contains a lot of plagioclase phenocrysts, 0.5~2.0 mm in length. Hypersthene, augite and olivine are present mostly as microcrysts, less than 0.2 mm in diameter, embedded in the groundmass composed of plagioclase laths and minute grains of pyroxene and magnetite.

The rock (16) collected at a depth between 483.11 m and 484.10 m is similar in mineral composition to the foregoing, but more or less differs in microscopic structure from the latter.

Unlike any of the lavas of the Fuji volcano, new and old, these two rocks (15, 16) rather show a close petrographic resemblance to the rocks of the Komitake volcano. One of the most characteristic features of the rock (16) is that, like the rocks of the Komitake volcano, its groundmass is rather granular, consisting of square and rectangular crystals of plagioclase, grains and rods of monoclinic pyroxene with a lamellar twinning, magnetite grains, and interstitial glass and some cristobalite. (Fig. 4 d) Judged from the position of the boring-site, the rock seems to be outside the range of distribution of the ejecta from the Komitake volcano; rather its source may be attributed, together with the foregoing rock (15), to the near-by Ashitaka volcano which, being contemporaneous in eruption with the Komitake volcano, has some ejecta petrographically similar to those of the latter.

The rock (17) collected at the depth of 619.50 m is a tufaceous mudstone, grayish-yellow in color and brittle, when dried. It contains angular to sub-angular fragments of plagioclase, 0.1~0.5 mm in diameter, and grains of various altered andesitic rocks in a matrix disseminated with epidote, chlorite, and dusty materials. The rock (18) collected at a depth between 619.50 m and 620.50 m is similar in composition to the foregoing, but it is finer in the size of the components than the latter, and occasionally contains small fragments of augite.

From their petrographic characters, these two rocks are regarded as detrital sediments more or less subjected to weathering; probably they are of a Tertiary age, together with the underlying rocks next to be mentioned.

The rocks (19, 20, 21, 22 and 23) collected at depths between 637.50 m and 760.00 m are an altered pyroxene-andesite, all being petrographically similar to each other. Thus they contain phenocrysts of plagioclase and augite, partially or wholly replaced by secondary minerals, such as epidote and calcite; the groundmass has nothing primary but some plagioclase laths. Besides, they sometimes contain spots of epidote and veins of calcite and epidote. (Fig. 4 f.)

The similarity of the petrographic characters of these rocks suggests that the wall of the boring of these depths is composed of either one and the same lava sheet or some multiple sheets of similar lavas.

The rock (24) collected at a depth of 769 m is a light grayish, fine-grained sandstone consisting of angular to subangular fragments, less than 0.5 mm in diameter, of plagioclase and grains of altered andesitic rocks, together with secondary minerals such as chlorite, epidote and calcite, and some unidentified particles. The secondary minerals are not only disseminated but also occur as veinlets in the rock.

The rock (25) collected at a depth of 885 m is also a sandstone similar to the foregoing in mineral composition as well as in microscopic structure.

As above mentioned, the wall of the boring at depths between 619.50 m and 885.00 m is composed of altered rocks, namely, tufaceous mudstone, andesite and sandstone in the order of descending succession. As a matter of course, these rocks are not of the Quaternary, but of a much older age, belonging to the basement complex on which the Quaternary Ashitaka and Fuji volcanoes rest. They may be of the lower Miocene, seeing that the altered andesite shows in particular a petrographic similarity with some of the volcanics which, distributed extensively in the mountains about the Fuji volcano and in the Izu peninsula, are dated as being of that age.

Inferred from the rock succession as revealed by the Ôbuchi boring, the vertical geologic section in the NW.-SE. direction through the boring-site is as shown in Fig. 5. Thus, at the boring-site, the ejecta

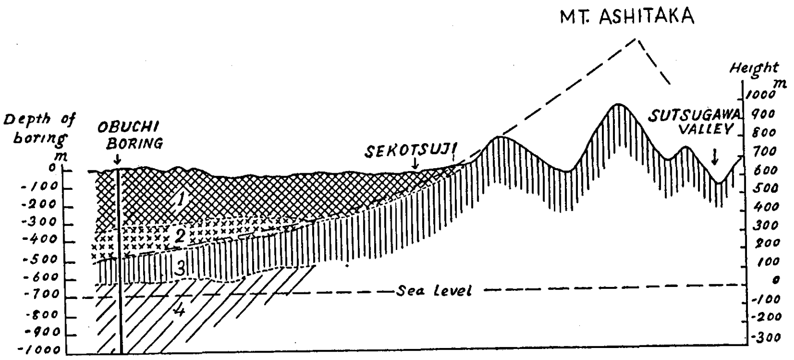


Fig. 5. Vertical geologic section in the NW.-SE. direction, passing through the Ôbuchi boring-site. 1. New Fuji volcano. 2. Old Fuji volcano. 3. Ashitakayama volcano. 4. Basement complex (Tertiary).

of the new Fuji volcano rest on those of the old Fuji volcano at the depth of about 300 m; the latter in turn rest on those probably of Ashitaka volcano at the depth of about 500 m. This depth of the boring-site is nearly on the curve extended northwest from the slope of the Ashitaka volcano, on the assumption that the slope of the southeast side of this volcano is applicable to its opposite side (*cf.* the broken curve in Fig. 5). The ejecta of the Ashitaka volcano rest on the surface of the basement Tertiary formation at the depth of about 600 m, that is, about 100 m above the present sea-level. At the boundary between the Quaternary volcanics and the Tertiary, nothing like a marine deposit seems to be present; on the contrary, the tufaceous mudstone at the top of the Tertiary appears to have been subjected more or less to weathering. Therefore, it is inferred that the Ashitaka and Komitake volcanoes have grown up on land from the beginning of their eruption, although they now stand, together with the younger Fuji mountain, within a basin-like depression at the bottom of the Bay of Suruga.

The Hakoarezawa Tunnel and Bore-holes.

Location and History. The Hakoarezawa bore-holes and tunnel are located on the southwest flank of Mt. Fuji, at a height of about 1000 m above sea level and near the 1st. station of the Fujinomiya mountaineering trail. The drilling of the tunnel and wells was started there a few years ago by a private exploitation enterprise, the Fuji Sôgôkaihatsu K. K., with the object of getting an underground watercourse useful for the water service to the communities to be developed on the nearby skirt of the mountain. The work had already advanced by the beginning of this year to excavate a tunnel about 2000 m long, together with several bore-holes within it, and extension work is still going on as no useful underground watercourse has yet been hit.

Geology of the Boring-site. The southwest flank of the mountain is cut rather deep at the middle heights between 2600 m and 1000 m above sea level with a number of radial valleys and gullies, and decreases its inclination downwards from about 20° to less than 10° rather abruptly at a height of about 1500 m. The site of the excavation is on the lower and gentler slope, just below the turning point of its inclination, lying near the middle course of the valley called Hakoarezawa.

The surface of the ground about the boring-site is covered for the most part with a bed of volcanic ash and breccia, more than 5 m in thickness, except where occupied by younger "marubi" lava-flows. The pyroclastic deposits are especially thick on and about the parasitic cones, Hinokizuka and Shiratsuka, which face each other across the Hakoarezawa valley. But in the area covered with the pyroclastic deposits, the underlying lavas are exposed here and there in the valleys that run across the area. Thus in the vicinity of the Hakoarezawa excavation site, more than six kinds of lavas are distributed as shown in Fig. 6. They are as follows in descending order of eruption.

1. Aosawa lava II (two-pyroxene-olivine-basalt).
2. Aosawa lava I (two-pyroxene-olivine-basalt).
3. Hakoarezawa lava (olivine-basalt).
4. Nishikurabone lava (olivine-basalt).
5. Higashikurabone lava (augite-olivine-basalt).
6. Lavas in general.

The Aosawa lava II, which is the youngest of all those mentioned, runs through the Aosawa valley for a distance of more than 6 km, from its upper course at a height of about 2600 m above sea level, down to its lower course at a height of about 900 m. It is a long, but small lava-stream, a few meters in width and less than a meter in thickness, suggesting that, when flowing, it was highly fluid and ran through the valley like running water. The lava lies directly on the Aosawa lava-flow I which also flowed down through the same valley,

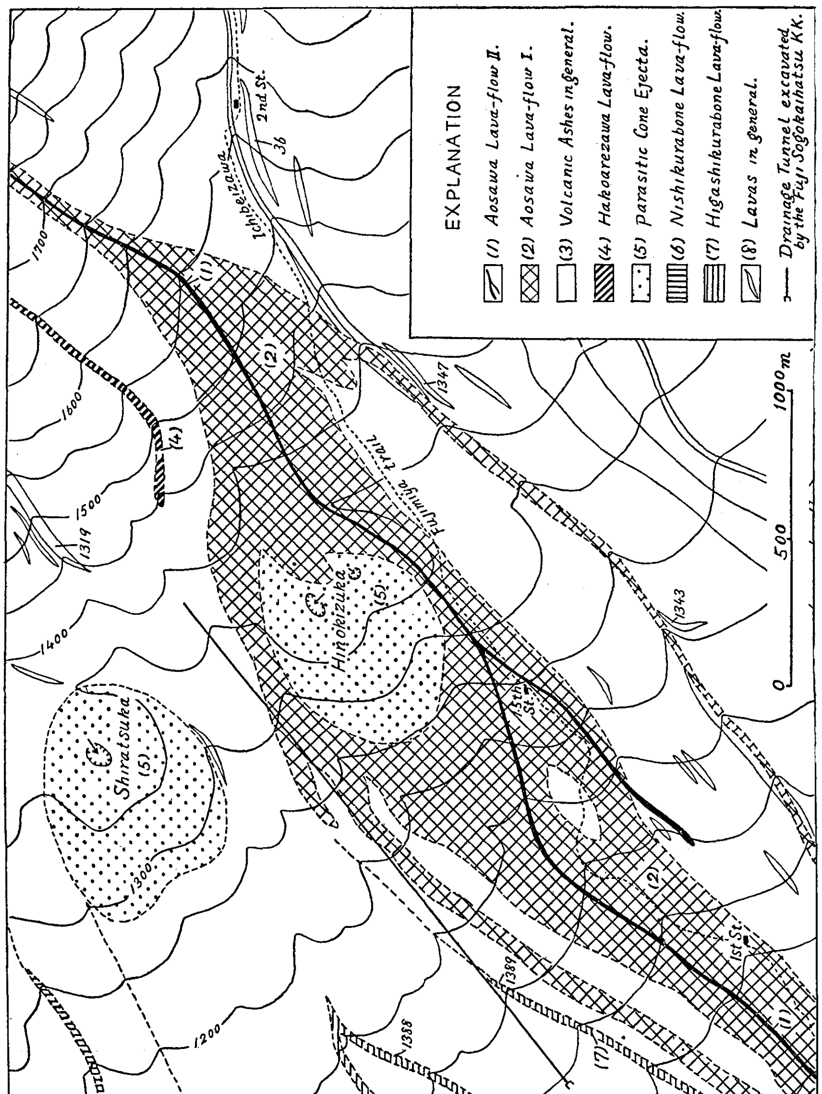


Fig. 6. Geologic sketch map showing distribution of main lava-flows in the vicinity of the Hakoarezawa tunnel.

but both are of different periods of eruption, seeing that the former followed the course of the gully cut through the latter.

The lava is a two-pyroxene-olivine-basalt carrying a moderate amount of plagioclase phenocrysts, 0.5~1.5 mm in diameter, together with scattered micro-phenocrysts of olivine, augite and hypersthene. These colored minerals are imbedded in the groundmass composed of rectangular plagioclase 0.1~0.2 mm long, very minute grains of pyroxene and magnetite, and a little interstitial glass.

The Aosawa lava I, which also runs through the Aosawa valley, is only a little larger in thickness as well as in width than the foregoing in the upper course of the valley, while it becomes thicker and wider downwards, sending out several branch flows. Thus in the vicinity of Hinokizuka, where the flow surrounds but leaves uncovered this parasitic cone, it shows the maximum width of about 1 km; a branch flow falls into the Ichibeizawa valley, and another into the Hakoarezawa valley as shown in Fig. 6. The farthest front of the flow reaches as far as Yamamiya on the Fujinomiya trail, 370 m in height above sea level.

This lava also is a two-pyroxene-olivine-basalt, but is fewer in the phenocrysts of olivine, augite and hypersthene than the foregoing. Its groundmass is clearly different in microscopic structure from that of the latter, consisting of fine needle-shaped plagioclase, very minute grains of pyroxene and magnetite, and a little interstitial glass.

The Hakoarezawa lava is the small "marubi" that starts from the slope above 2500 m in height and runs along the floor of the Hakoarezawa valley down to a level of about 1400 m.

This lava is an olivine-basalt carrying only a few megascopic phenocrysts of plagioclase and olivine. Microscopically, it has a large amount of plagioclase laths 0.1~0.5 mm long and olivine grains 0.1~0.3 mm across in the groundmass composed of minute plagioclase, pyroxene, magnetite, and a little interstitial glass, beside some clots of cristobalite in the vesicular cavities.

The Nishikurabone lava is exposed below a pyroclastic bed several meters thick in the Kurabonezawa valley which passes southweswards along the northwestern side of the Shiratsuka parasitic cone. At Nishikurabone (or Akayake), a settlement in the lower course of the valley (outside the map of Fig. 6), the lava occurs as a surface flow covered by a thin veneer of pyroclastics, forming a flat, fan-shaped ridge about 1 km wide at its front.

This lava has medium-sized phenocrysts of plagioclase and olivine in the groundmass in which plagioclase laths, grains of olivine, monoclinic pyroxene and magnetite are more or less interlocked with each other in a doleritic structure.

The Higashikurabone lava is exposed below a pyroclastic bed several meters thick in the lower courses of the Hakoarezawa and Fukazawa valleys which run southwestwards through the slope between the Hinokizuka and Shiratsuka parasitic cones. In the region adjacent to the southwest of the area of Fig. 6., the flow runs around the Futagoyama parasitic cone, reaching the lower part of the settlement of Higashikurabone, about 550 m above sea level, on one hand and near Yamamiya on the other. From its distribution, the lava is considered to have been erupted from the Shiratsuka parasitic cone, although this cone itself is entirely covered with pyroclastic ejecta.

The lava is an augite-olivine-basalt having megascopic and microscopic phenocrysts of plagioclase and olivine, and microscopic phenocrysts of augite and magnetite in the groundmass composed of needle-shaped plagioclase, granular monoclinic pyroxene and magnetite, and a little interstitial glass.

Besides the above-mentioned lava-flows, there are a number of lavas denoted altogether as lavas in general in Fig. 6. Most of them are exposed locally as sheets in the valleys, but a few younger lavas occur as such continuous flows as those exposed in the Ichibeizawa valley and on the ridge southeast of it. The Hinokizuka parasitic cone is entirely covered with pyroclastic ejecta, and none of the lavas exposed thereabout appears to have been erupted from this cone.

Geology of the Hakoarezawa Tunnel and Bore-holes. The Hakoarezawa tunnel has its mouth on the ridge near the Hakoarezawa valley and at a height of 1045 m above sea level. It runs from the mouth northeastwards in the direction of the centre of the volcano and in a straight line with a constant up-grade of 1 in 300; its cross-section is about 2 m × 2 m and its walls are left bare for all but a small part where the crumbly walls are lined with logs. In the spring of this year, when the writer visited the site twice, the main tunnel was 2017 m long from the mouth to the bottom, accompanied by several shorter branch tunnels and test bore-holes.

The geological structure of the walls of the tunnel is diagrammatically as shown in Fig. 7., and it is represented by the rocks, mentioned in descending order, as follows.

	Depths from the mouth (m)	Rocks
1	0	Aosawa lava I (two-pyroxene-olivine-basalt).
2	A few meter	Volcanic ash and breccia.
3	— 150	Higashikurabone lava (augite-olivine-basalt).
4	150— 330	Manno-fuketsu lava (olivine-basalt).
5	330— 550	Lava and agglomerate (hypersthene-augite-olivine-basalt).
6	550— 600	Lava (olivine-basalt).
7	600— 700	Lava (olivine-basalt).
8	700—1035	Lava and agglomerate (hypersthene-augite-olivine-basalt).
9	1035—1300	Alternation of lavas, agglomerates and breccias (lavas a to g).
10	1300—1350	Lava (olivine-basalt).
11	1350—1420	Lava (augite-bearing olivine-basalt).
12	1420—1500	Lava and agglomerates (lavas a to c) (augite-bearing olivine-basalt).
13	1500—1525	Volcanic ash and breccia.
14, 15	1525—1690	Lava and agglomerate (augite-olivine-basalt).
16	1690—1740	Lava (olivine-basalt).
17	1740—1890	Volcanic breccia.
18	1890—1925	Lava (augite-bearing olivine-basalt).
19	1925—2000	Volcanic sand and breccia.
20		Lava (hypersthene-olivine-basalt).
21		Lava (augite-hypersthene-olivine-basalt).

The numbers in the first column of the above table correspond to those bracketed in Fig. 7. The Aosawa lava I (1) lies within a striking distance of the Hakoarezawa tunnel, and a short branch of the flow passes the surface slope just above the middle of the tunnel, but it does not reach close to the mouth of the tunnel, where the ground is covered with volcanic ash and breccia few meters thick.

The rock first met inside the mouth of the main tunnel is the same as the Higashikurabone lava (3) above mentioned. It continues to appear along tne tunnel, together with some intercalating agglomerates, for a distance of little more than 100 m and its total thickness is estimated to be about 25 m.

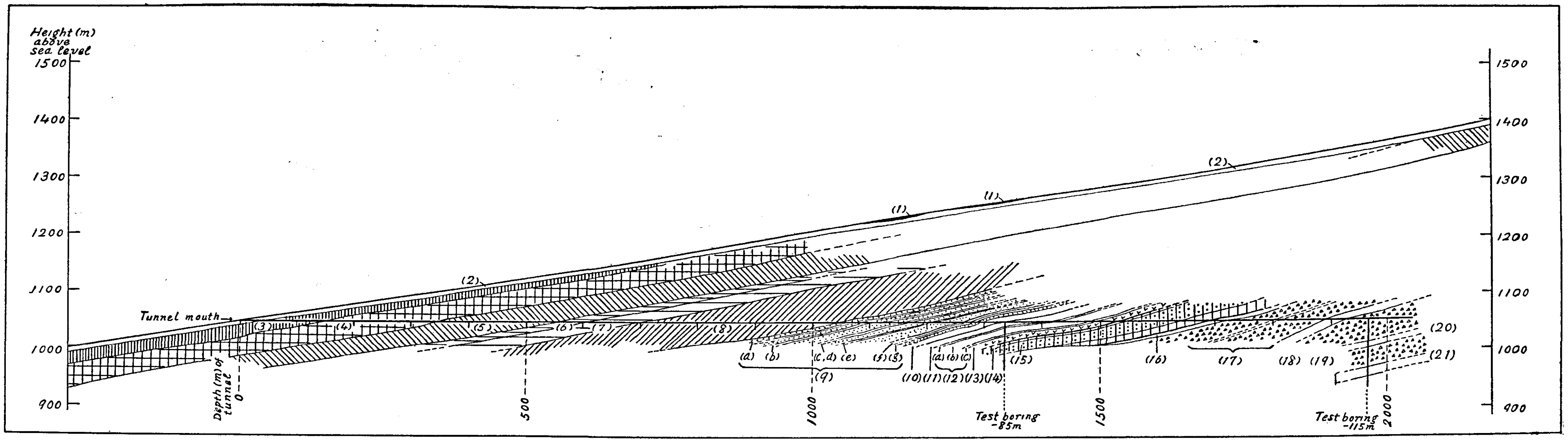


Fig. 7. Geological vertical section along the Hakoarezawa tunnel. For explanation, see text.

Directly below the foregoing is the lava (4) which, intercalated with some agglomerates, continues to be exposed for a distance of about 180 m.

It is an olivine-basalt, sporadically carrying conspicuous phenocrysts, 2~3 mm in diameter, of plagioclase, besides microscopic phenocrysts of plagioclase and olivine. The groundmass is relatively coarse-grained, consisting of plagioclase, monoclinic pyroxene, magnetite and olivine, more or less interlocked with each other in a doleritic structure, besides some interstitial glass covered with an opaque dust material. (Fig. 8 a.)

The lava is petrographically quite identical with and geologically capable of correlating with the lava-flow that is distributed in Manno and vicinity, the northeastern suburb of the town of Fujinomiya and the locality of a group of natural lava-tunnels (fuketsu); so the name of the lava is determined by this.

At depths between 330 m and 550 m are met some lava layers which, together with intercalating agglomerates, are all identical in petrographic character, representing successive flows of one and the same lava (5).

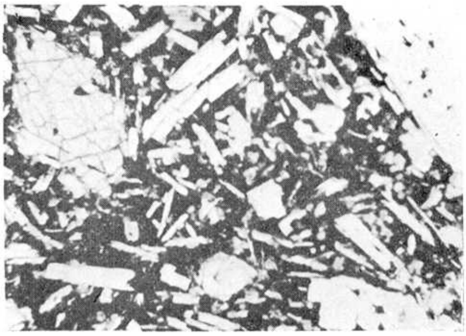
This lava is hypersthene-augite-olivine-basalt characterized particularly by a large amount of columnar plagioclase phenocrysts, 0.5~2.0 mm in length, which are sometimes are arranged in a flow structure. Hypersthene and augite also are conspicuous phenocrysts, besides olivine, although most of them are microscopic in size. The groundmass is composed of slender laths of plagioclase, minute grains of monoclinic pyroxene and magnetite, and a little interstitial glass. (Fig. 8 b.)

As shown in Fig. 7., this lava is regarded as a continuation of similar lava which occurs as several layers in the walls of the Hakoare-zawa valley No. 2 to the east of Shiratsuka and at a height of about 1400 m above sea level (Fig. 6, Loc. 1319).

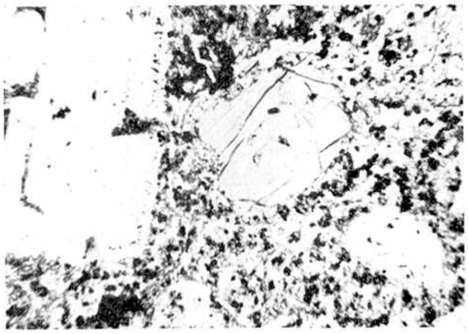
Below the foregoing is exposed a single lava sheet (6) about 15 m thick at depths between 550 m and 600 m.

It is an olivine-basalt carrying sporadical but conspicuous phenocrysts, 0.5~1.0 cm in diameter, of plagioclase, besides microscopic phenocrysts of plagioclase and olivine. The groundmass as usual, consists of plagioclase laths, pyroxene and magnetite grains, and some interstitial glass. The olivine occurs not only among the phenocrysts but as smaller grains embedded in the groundmass.

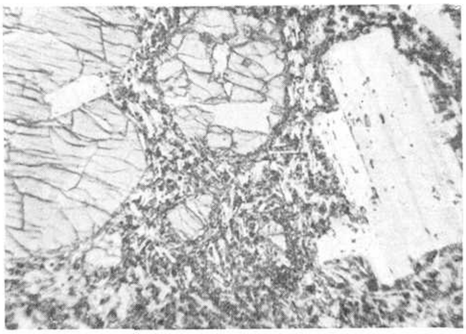
This lava is exposed nowhere on the surface of the ground roundabout,



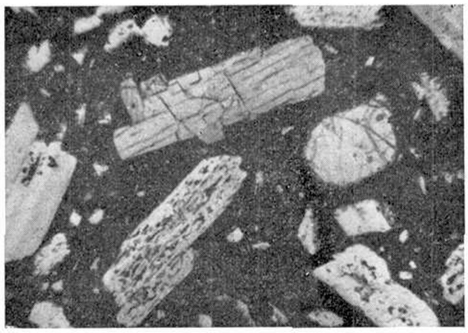
a. Olivine-basalt (Manno-fuketsu lava). [170 m]



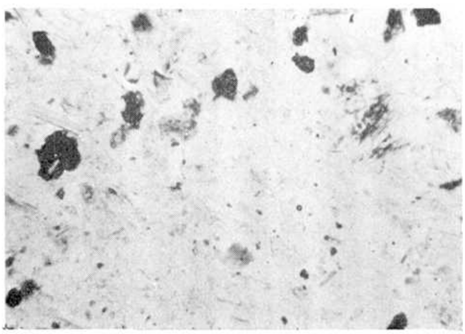
b. Hypersthene-augite-olivine-basalt. [360 m]



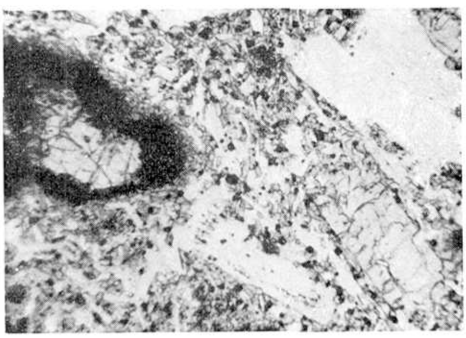
c. Augite-olivine-basalt (the lowest lava of the new Fuji volcano in the tunnel). [1640 m]



d. Two-pyroxene-olivine-basalt (a lava block in the volcanic breccia of the old Fuji volcano). [2000 m]



e. Dacitic pumice ash. [1940 m]



f. Two-pyroxene-olivine-basalt (a lava of the old Fuji volcano). [-75 m of the *boring 100 m deep, near the bottom* of the main tunnel].

Fig. 8 a~f. Microphotographs of the rocks from the Hakoarezawa tunnel. [×60] but it is somewhat similar to the Fujinomiya lava-flow which, covered by volcanic ash and breccia, is distributed in the town of Fujinomiya and vicinity.

The lava (7) exposed at depths between 600 m and 700 m is also an olivine-basalt, but it is easily distinguishable from the foregoing, megascopically as well as microscopically.

Thus, megascopically, it has a number of medium-sized plagioclase phenocrysts scattered in a black or dark-gray groundmass; microscopically, not a few olivine phenocrysts are present, besides the plagioclase, and the groundmass is composed of plagioclase laths, monoclinic pyroxene and magnetite grains, and a little interstitial glass.

At depths beween 700 m and 1035 m there occurs a lava (8) in layers intercalated with agglomerate. These lava and agglomerate layers are petrographically altogether uniform throughout that section of the tunnel, being hypersthene-augite-olivine-basalt.

Like the foregoing, this rock contains a lot of medium-sized plagioclase phenocrysts, most of which show long-columnar outlines under the microscope, but it differs from the foregoing in carrying a few but conspicuous phenocrysts of hypersthene and augite, besides olivine. The groundmass shows nothing special in the mineral composition nor in the structure.

It is possible that the two rocks (7) and (8) are the products ejected consecutively in one and the same phase of volcanic eruption. They form an underground lava-sheet amounting altogether to about 100 m in thickness, without being exposed anywhere on the neighbouring ground. None of the lavas lying below this also has its equivalent exposed on the neighbouring ground.

Below the rock (8), at depths between 1035 m and 1300 m, there is an alternation of lavas, agglomerates, and breccias (9). The lavas of this section are not petrographically identical with each other, but comprise the following varieties of basalts, (a) to (g) mentioned in descending order.

(a) Olivine-basalt.
(b) Olivine-basalt.
(c) Augite-hypersthene-bearing olivine-basalt.
(d) Augite-bearing olivine-basalt.
(e) Olivine-basalt.
(f) Augite-olivine-basalt.

(g) Olivine-basalt.

These lavas show their own microscopic structures, but have one common characteristic in that they are covered with small glistening phenocrysts of plagioclase. They usually accompany their own agglomerates and moreover, some of the lavas hold volcanic breccia and gravel beds between them. Thus those sandwiched in between the lavas (c) and (d) are the largest of all in thickness, consisting of fragments of basalts various in size as well as in petrographic characteristics. The rock fragments in some parts of these beds are mostly subangular and are accummulated in like manner to a bed of water-worn gravels.

The section between 1300 m and 1350 m in depth is composed of an olivine-basalt lava (10), which is evidently different in the microscopic structure from the overlying No. 9 (g) lava. Two test borings were run through this lava; one (A) of them reaches a depth of 85 m below the floor (1048.9 m in height above sea level) of the tunnel at 1333 m, and the other (B) is 30 m deep, located only 5 m away. The core specimens lifted by these borings have their equivalents exposed in the walls of the tunnel at depths more than 1350 m.

At depths between 1350 m and 1420 m of the tunnel is exposed an augite-bearing olivine-basalt (11), which contains a lot of small to medium-sized plagioclase and olivine phenocrysts and a few augite microphenocrysts. The groundmass is composed of plagioclase laths, monoclinic pyroxene and magnetite grains, and a little interstitial glass. The extension of this lava is met together with its agglomerate, at depths between 1.7 m and 9.2 m of the above-mentioned bore-hole (A) and between 2.3 m and 3.8 m of the bore-hole (B).

At depths between 1420 m and 1500 m is exposed an augite-bearing olivine-basalt lava (12 b) in association with the agglomerates (12 a) and (12 c).

The lava evidently differs from the foregoing in having a lot of long lath-shaped microphenocrysts of plagioclase, besides small to medium-sized phenocrysts of plagioclase and olivine, and a few microphenocrysts of augite.

The extension of this lava is met at depths between 9.2 m and 16.0 m of the bore-hole (A) and between 10 m and 15 m of the bore-hole (B).

Below the foregoing, at depths between 1500 m and 1530 m, occurs a remarkable bed of volcanic breccia (13) composed of fragments of various basalts.

Some of these basalts are nearly aphyric with only a few phenocrysts of plagioclase and olivine, but with or without pyroxene (augite and/or hypersthene); the others are porphyritic with a goodly number of phenocrysts of the minerals, but most of the phenocrysts are microscopic and usually show a gradual transition of size to the groundmass crystals.

The volcanic breccias are exposed in the subsidiary tunnel, too, which runs from the 1500 m point of the main tunnel southwards for a distance of 80 m. An extension of the same breccia bed is met in the bore-hole (A) at depths between 28 m and 40 m. Moreover, at depths between 24.2 m and 28.0 m of the hole, is met a sheet of aphyric basalt lava, which petrographically is similar to some rock-fragments in the underlying breccia. The same lava occurs in the bore-hole (B), too, at depths between 25.9 m and 29.4 m.

Below the foregoing volcanic breccia, at depths between 1525 m and 1690 m of the main tunnel, there occur lava sheets (14, 15), together with intercalated agglomerate. Petrographically, both the lava and agglomerate are of one and the same augite-olivine-basalt which, however, differs evidently from either of the overlying augite-bearing olivine-basalts (11, 12).

Thus the present basalt contains a few but distinct phenocrysts, 0.5～1.0 mm in diameter, of augite, besides a number of small to medium-sized phenocrysts of plagioclase and olivine; the groundmass is composed of small plagioclase laths, minute grains of monoclinic pyroxene and magnetite, and a very little interstitial glass. (Fig. 8 c.)

The same lava appears in the bore-hole (A) at depths between 40 m and 54 m, being underlain by its agglomerate and sand as far as a depth of 66 m. Therefore, it is inferred that the lower sheets of this lava, which occur in the vicinity of a depth of 1650 m in the main tunnel, thin out before extending to the site of the bore-hole (A).

The section between 1690 m and 1740 m in depth of the tunnel is walled by an olivine-basalt lava (16), which is somewhat similar in microscopic structure to the overlying one (15), except that it has few augite phenocrysts. The lava is underlaid by a thin bed of reddish soil.

Next come thick beds of volcanic breccia (17) at depths between 1740 m and 1880 m. A similar bed of volcanic breccia occurs in the bore-hole (A) at depths between 66 m and 85 m. The correlation of the lava and pyroclastic beds (11 to 17) of the main tunnel with those in the bore-holes (A, B) proves that they have an average dip of about 10°W, which is in accord with the surface slops right above the tunnel.

The volcanic breccia (17) is quite heterogeneous in composition, carrying not a few fragments of more or less altered basalts, besides a large amount of fragments of fresh basalts.

So far as the microscopic observations go, the altered basalts have phenocrysts of either augite or hypersthene or both, besides plagioclase and olivine; the pyroxenes are usually fresh, while the olivine is represented partly or wholly by pseudomorphs of serpentine. Most of the vesicular cavities and interstices in the groundmass of these rocks are filled with a greenish or light brownish isotropic material. The fresh basalts exhibit much diversity both of micro-structure and mineral composition, comprising such kinds as olivine-basalts, hypersthene-olivine-basalts and two-pyroxene-olivine-basalts.

These rocks evidently differ in micro-structure from any of the overlying lavas, to say nothing of the microscopic characters of their constituent minerals; rather they show certain petrographic similarities to the pyroclastics of the old Fuji volcano; some of them are petrographically identical with the rock-specimens which, collected at depths between 350 m and 500 m of the Ôbuchi boring, are estimated to be of the old Fuji volcano. Omitting any wordy description of their petrographic characters, a representative one of the rock-fragments in the breccia is illustrated by the microphotograph Fig. 8 d.

At depths between 1890 m and 1920 m, there occurs a lava sheet (No. 18) about 10 m thick, which underlies the volcanic breccia (No. 17).

The lava is a two-pyroxene-olivine-basalt containing microphenocrysts of augite and hypersthene, besides larger phenocrysts of plagioclase and olivine; the groundmass is composed of plagioclase laths, minute grains of pyroxene and magnetite, cristobalite in vesicular cavities, and a little interstitial glass. Its microscopic structure shows it to be of the old Fuji volcano.

From a depth of 1920 m inward, there develops a thick bed of volcanic breccia as far as the bottom of the tunnel at a depth of about 2000 m. The breccia is for the most part a loose mixture of angular to subangular blocks, less than a few scores of centimeters in diameter, and sands of basaltic nature. But it is attended in places by thin lenticular beds of volcanic sands and ashes. The blocks in the breccia are petrographically classified into olivine-basalts, augite-olivine-basalts and two-pyroxene-olivine-basalts. (Fig. 8 d) So far as microscopic examination is concerned, they show certain structures peculiar to the basalts of the old Fuji volcano.

It is noticeable that the foregoing volcanic breccia is attended by a thin whitish bed of fine pumiceous ash, besides the black or dark gray basaltic sand and ash beds. Thus the pumiceous ash occurs as a distinct bed a few cetimeters thick in the breccia at a depth of 1940 m in the tunnel, where a branch tunnel runs southward for a distance of about 180 m.

It is composed largely of shreds of colorless glass, less than 0.2 mm in diameter, resulting from the breaking up of pumiceous glassy lava. Some angular fragments of plagioclase and pyroxene are present in the ash, together with a few small rock-fragments of basaltic nature. But none of these mineral and rock-fragements are found enclosed in the pumice glass. (Fig. 8 e.) The glass is very fresh and almost perfectly clear containing no minerals of recognizable size, except a few crystallites and minute tubular vesicles. The refractive index of the glass is 1.500 approximately; it is comparable with the refractive index of acid andesite or rhyolite glass. Thus, compared with the Hôei (1707) pumice,[5] which is dacitic in composition with 68% SiO_2 and the refractive index of glass 1.507, the present glass is inferred to be a little more acidic, assuming that the refractive index of volcanic glass decreases with the increase of the acidity.

The occurrence of the pumice ash shows that an explosive ejection of acidic magma occurred once in the course of the activity of the old Fuji volcano, although nothing is known about the centre (crater) of the ejection.

The subsidiary tunnel branched off to the south at a depth of 1940 m of the main tunnel exposes in its walls, throughout a major part of its extension, volcanic breccia, sand and ash beds similar to the foregoing. Near the bottom of the branch tunnel was found a piece of natural charcoal imbedded in the volcanic breccia. According to the mechanical analyses by I. Murai, the volcanic breccia in which the charcoal is imbedded is a pyroclastic flow deposit. Therefore, it is inferred that the charcoal was produced by the natural carbonization of the wood caught by the pyroclastic flow at the time of its eruption. A radiocarbon dating of the charcoal was carried out on Oct. 4–5, 1962, by Prof. K. Kigoshi, Chemical Institute, Gakushuin University, Tokyo, with the result that the charcoal is 21,200 (±950) years old. It follows, therefore, that the volcanic breccia in which the charcoal is imbedded, must have been ejected more than 20,000 years ago by the eruption of

5) H. TSUYA, *Bull. Earthq. Res. Inst.*, **33** (1955), 341.

the old Fuji volcano.

In the above-mentioned branch tunnel and at a distance of 115 m from the main tunnel, a vertical bore-hole was made down to a depth of about 100 m. The cores obtained in the bore-hole show that there occur several lava sheets, besides volcanic ash, sand and breccia beds.

Three lava sheets, 1.5 m, 5.5 m and 2.0 m in thickness, are met with at depths of 10 m, 15 m, and 21 m of the bore-hole respectively. Whether they all exist actually as such is uncertain, but the cores collected as their representatives are petrographically almost identical with each other.

Thus, they are a two-pyroxene-olivine-basalt crowded with a number of microphenocrysts of plagioclase, olivine and hypersthene, besides a few augite. The groundmass is composed of plagioclase, monoclinic pyroxene, magnetite, and a little interstitial glass and cristobalite.

So far as examined, the rock-fragments in the volcanic breccia at depths between 17.5 m and 19.5 m are also similar to the lavas just mentioned in mineral composition as well as in microscopic structure.

A lava sheet is met with at depths between 30 m and 43 m of the bore-hole. (No. 20, Fig. 7.) It is almost aphyric without any noticeable phenocrysts, consisting of crystals, less than 0.5 mm in diameter, of plagioclase, olivine, augite, hypersthene and magnetite, together with a little interstitial glass.

Another lava sheet occurs at depths between 75 m and 96 m of the bore-hole. (No. 21, Fig. 7.) It is a two-pyroxene-olivine-basalt containing the phenocrysts of plagioclase, olivine, hypersthene and augite. The olivine crystals are either surrounded with a rim of magnetite grains or entirely replaced by the latter. The groundmass of the rock is composed of plagioclase laths, monoclinic pyroxene and magnetite grains, and a little interstitial glass and cristobalite. (Fig. 8 f)

The above-mentioned lavas in the bore-hole are petrographically more or less different from each other, but they all possess, together with the intervening volcanic breccia, certain petrographic features peculiar to the ejecta of the old Fuji volcano.

In short, the superimposed structure of the new and old Fuji volcanoes has become more evident by the investigation of the Hakoarezawa tunnel. Here the ejecta of the new Fuji volcano occur mostly as effluent basalt lavas; these lavas, together with some intervening pyroclastic beds, are piled about 260 m thick, and have an average dip of 10° West, conforming to the surface slope of the ground above the tunnel. Any distinct boundary between the new Fuji ejecta and the underlying old Fuji ejecta has not been located anywhere in the walls of the tunnel; such an unconformity marked either by an appreciable erosional relief or by a sudden change in dip of the ejecta beds has not been found. But, based on the difference in petrographic characters between the new and old Fuji ejecta, the boundary between them has been put at a depth of about 1700 m of the tunnel. The old Fuji ejecta are represented mostly by the pyroclastics such as basaltic ash, sand and breccia, but they are attended by basalt lavas at several altitudes. The pyroclastic ejecta of the old Fuji occur partly as "fall" deposits and partly as "flow" deposits; a piece of natural charcoal was found imbedded in one of the flow deposits. Furthermore, a thin bed of fine pumice ash, presumably of dacitic composition, occurs among the pyroclastic deposits of the old Fuji, suggesting that an eruption of acidic magma must have taken place in company with the eruptions of this basaltic volcano, as in the case of the Hôei (1707) eruption.

The Narusawa Boring No. 11.

In recent years, boring has been going on, together with the geophysical prospectings, at a number of places on the skirt of Mt. Fuji, in order to explore the source of ground water useful for irrigation and other purposes. The Narusawa Boring No. 11 is a core drilling carried out by the Bureau of Agricultural Land, Ministry of Agriculture and Forestry, on the northern skirt of the mountain. Through the courtesy of the officials of the Bureau, the writer has been able to examine some of the cores lifted by the boring, with the following result.

Location and Geology of the Boring-site. The Narusawa Boring No. 11 is located at a height of 1000 m above sea level, in the lower part of the northern slope of the mountain, and about 1.5 km southeast of the village of Narusawa. The surface of the ground in the vicinity of the boring-site has an average inclination of 10° North, and shows an undulation representing the original topography formed by the piling of successive lava-flows. Thus several ridges stretch long, together with intervening valleys, in the SW.-NE. direction; the ridges represent

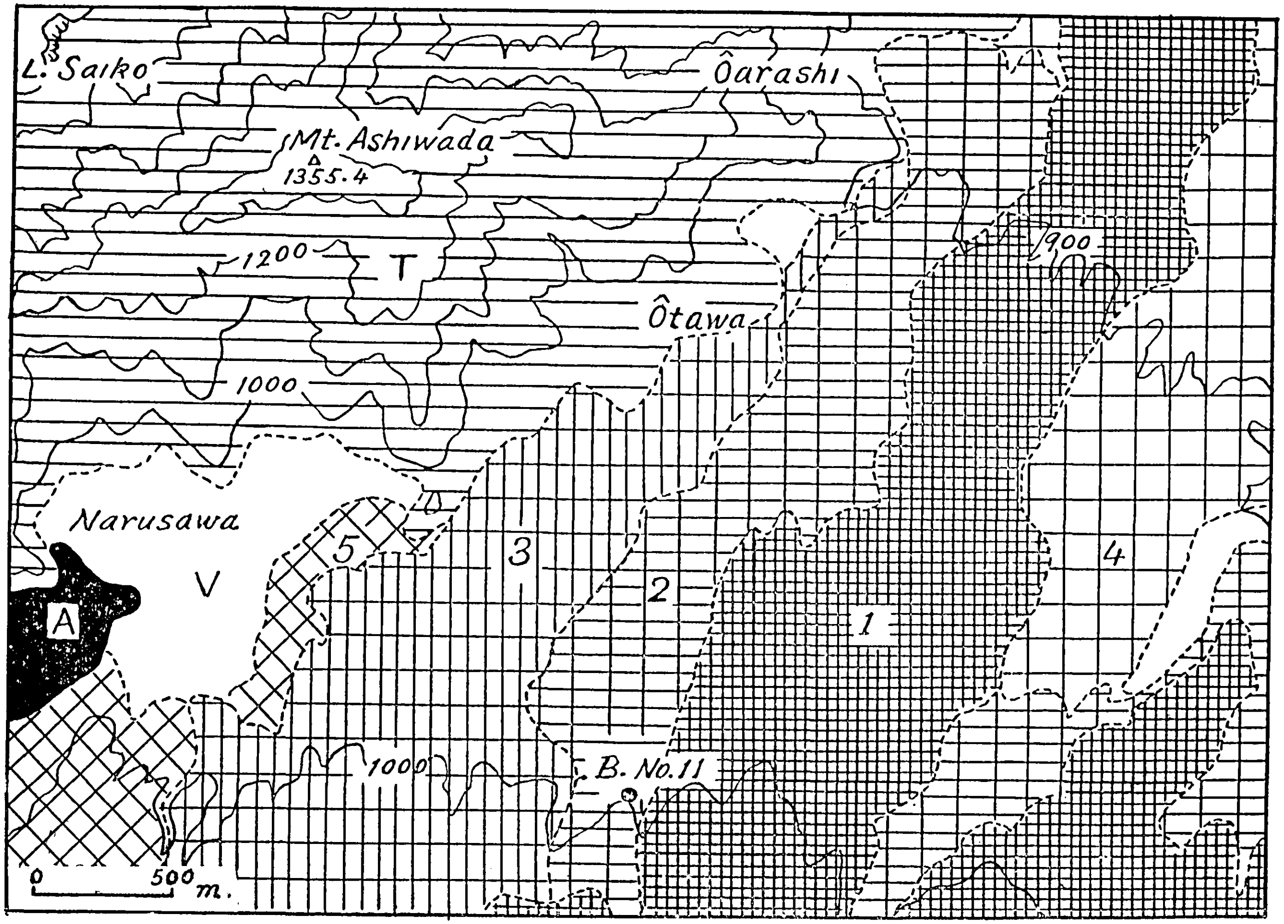


Fig. 9. Generalized geologic map showing distribution of lava-flows in the vicinity of the Narusawa boring No. 11 on the northern skirt of Mt. Fuji. 1. Higashiken parasitic cone lava. 2. Ôarashi lava. 3. Ôtawa lava. 4. Funatsu lava. 5. Narusawa lava, A. Aokigahara "marubi" lava (864 A.D.). V. Volcanic ash and detritus. T. Tertiary.

the coulees of the lavas that flowed down the northern slope of the mountain and the valleys the intervals between the lava coulees. There is no erosion valley worthy of mentioning, except a few dry gullies carved out by temporary running water.

Several lava-flows are distributed in the area surrounding the boring site, as shown in Fig. 9. Being covered with volcanic ash and sand beds, they are exposed only here and there particularly on the steep side and front slopes of their respective coulees. The following are the lavas discriminated geologically as well as petrographically.

1. Higashiken lava (augite-olivine-basalt).
2. Ôarashi lava (hypersthene-olivine-bearing basalt).
3. Ôtawa lava (olivine-basalt).
4. Funatsu lava (olivine-basalt).
5. Narusawa lava (two-pyroxene-olivine-basalt).

The Higashiken lava, the youngest of all the lavas mentioned, occurs as a coulee, about 600 m in width, on the slope east of the boring-site. From its extension on the slope outside of and adjacent to the southeast of the area concerned, the lava is considered to be a large flow erupted from the parasitic cone Higashiken, 1649 m in height above sea level, situated halfway up the northern flank of the main volcano. The farthest front of the flow has reached the southwestern shore of Lake Kawaguchi, one of the five lava-dammed lakes at the northern foot of the volcano.

The lava is an augite-olivine-basalt carrying some conspicuous phenocrysts of augite, besides plagioclase and olivine. These minerals occur abundantly as microphenocrysts, too. The groundmass is composed of minute lath-shaped crystals of plagioclase and monoclinic pyroxene, magnetite grains, and a little brownish glass base.

The Ôarashi lava forms the ridge on which the boring No. 11 is situated. It extends north-northeastward with a width of about 500 m, being bordered on its east and west sides by the overlying Higashiken lava and the underlying Ôtawa lava respectively. The farthest front of the lava lies in the village of Ôarashi near the southwestern shore of Lake Kawaguchi, where it rests on the Funatsu lava, and is barred from its further extension with the eastern tip of Mt. Ashiwada, one of the outlying Tertiary mountains.

The lava is an olivine-basalt devoid of any phenocrystic minerals other than plagioclase. The plagioclase phenocrysts are small in quantity, but are conspicuous by their presence, attaining a dimension of 5 mm in length. The groundmass is composed of plagioclase laths, olivine grains, very minute aggregate of pyroxene and magnetite, and a little interstitial brown glass.

The Ôtawa lava is exposed in the area adjoining the west of the foregoing, forming several ridges suggestive of lava-coulees. Towards the north and northwest, the lava abuts upon the older Narusawa lava, and its northern front is barred in the village of Ôtawa from its further extension with the Tertiary ridge of Mt. Ashiwada.

The lava is an olivine-basalt carrying phenocrysts of plagioclase and olivine. Some of the plagioclase phenocrysts are as large as 5 mm in diameter. The groundmass is composed of plagioclase laths, olivine and augite grains, and very minute aggregate of pyroxene and magnetite, besides a little interstitial glass. The augite grains in the groundmass usually show a very remarkable undulatory extinction.

The Funatsu lava, the oldest lava next to the Narusawa lava in the area concerned, is exposed in a small area to the east of the village of Ôarashi, but a similar lava is exposed extensively in the town of Kawaguchi (former Funatsu village) and vicinity on the southeast shore of Lake Kawaguchi, being separated from that of Ôarashi by the down-stream of the Higashiken lava-flow.

It is an olivine-basalt, almost black in color and crowded with large-sized phenocrysts of plagioclase, 3~8 mm in diameter. The olivine phenocrysts are present fairly abundantly, but they are all microscopic in size. The groundmass is composed of slender laths of plagioclase, minute grains of monoclinic pyroxene and magnetite, and interstitial glass base.

The Narusawa lava, the oldest of the lavas in the area concerned, is exposed on the hills that surround the southeast side of the village of Narusawa, representing a lava front bounded by the Tertiary mountains on the north of the village. On the east side, it is covered by the Ôtawa lava, and on the south and west sides, by the Aokigahara lava and others not mentioned in this paper.

Petrographically, the Narusawa lava is a two-pyroxene-olivine-basalt having conspicuous phenocrysts of hypersthene and augite, besides olivine and plagioclase. The hypersthene, up to 1.5 mm in length, is superior to the augite in size as well as in amount. A few magnetite phenocrysts are present usually associated with the pyroxenes. The groundmass is an aggregate of plagioclase microlites,

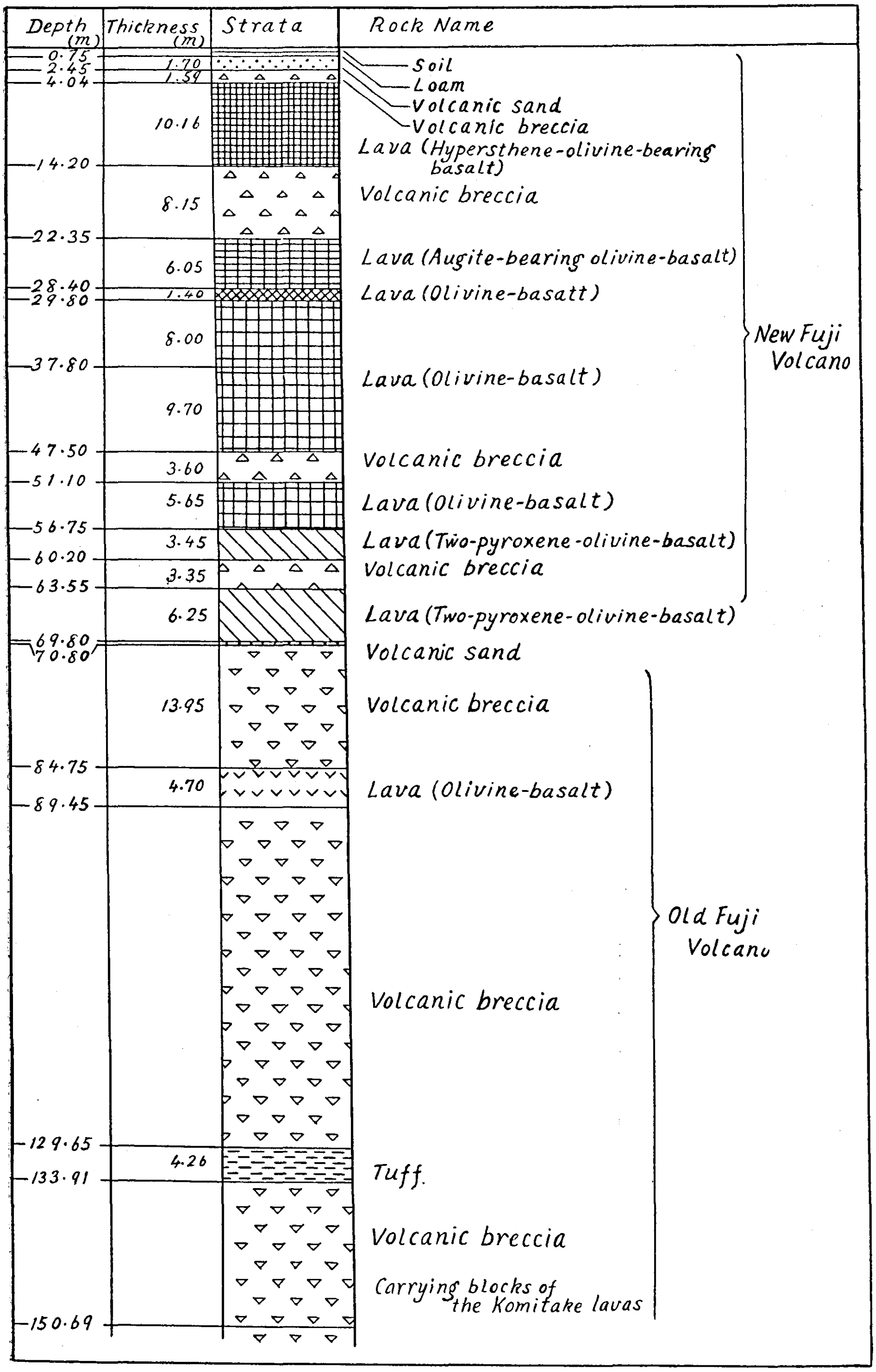


Fig. 10. Succession of lavas and pyroclastics as observed on the walls of the Narusawa boring No. 11.

minute grains of monoclinic pyroxene and magnetite, and a little glass base. This rock is quite similar both in mineral composition and microscopic structure to the lava (No. 8) exposed in the walls of the Hakoarezawa tunnel at depths between 700 m and 1035 m.

Geology of the Boring No. 11. The cores lifted from the boring No. 11 have revealed a succession of ejecta from its mouth to a depth of 150 m as shown in Fig. 10. The lava sheets that occur in succession with or without pyroclastic beds between them are as follows:

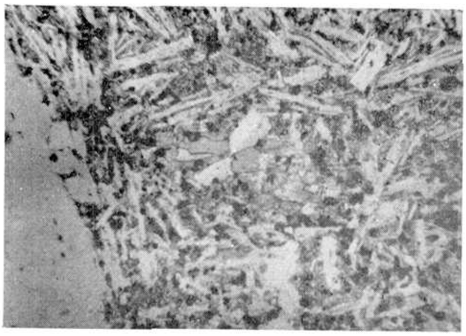
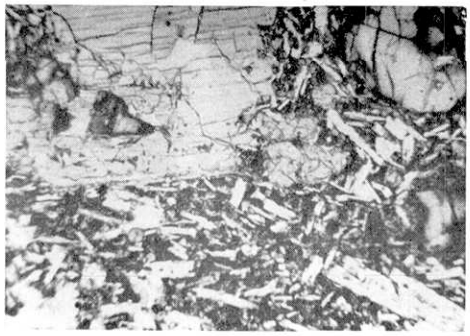
	Depths from the mouth (m)	Rocks
1	4.04—14.20	Hypersthene-olivine-bearing basalt (Ôarashi lava).
2	22.35—28.40	Augite-bearing olivine-basalt.
3	28.40—29.80	Olivine-basalt.
4	29.80—56.75	Olivine-basalt.
5	56.75—69.80	Two-pyroxene-olivine-basalt.
6	84.75—89.45	Olivine-basalt.

The first lava (No. 1), which occurs as a sheet, about 10 m in thickness, just below the uppermost pyroclastic beds about 4 m thick in all, is similar to the Ôarashi lava exposed here and there on the ground about the boring-site. (Fig. 11 a)

Below the foregoing and separated by a pyroclastic bed about 8 m thick, lies the lava (No. 2) that occurs as a sheet about 6 m thick. It is similar in megascopic appearance, to the Funatsu lava already referred to, particularly in having large plagioclase phenocrysts, but differs from the latter in bearing a few microphenocrysts of augite.

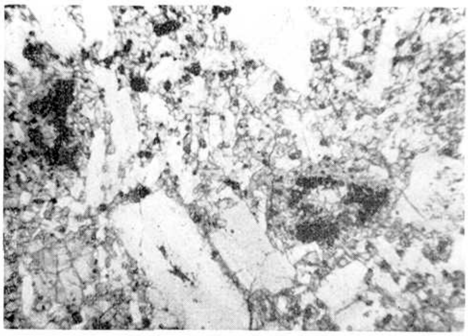
The core lifted from a depth of about 30 m, immediately below lava No. 2, is an olivine-basalt megascopically similar to the lava No. 1. But unlike the latter, microscopically, it is devoid of hypersthene and instead is rich in small olivine grains in the groundmass. The rock represents only a small part between depths of 28.4 m and 29.8 m of the boring, so that it is uncertain whether it occurs as a distinct lava sheet or as a block in a pyroclastic bed.

At depths between 29.80 m and 56.75 m of the boring lies an olivine basalt lava No. 4 with an intercalated pyroclastic bed 3.6 m thick at a depth of about 50 m. Several core-specimens collected from this part of the boring are petrographically identical with each other, being characterized by conspicuous phenocrysts of plagioclase, up to 1 cm in

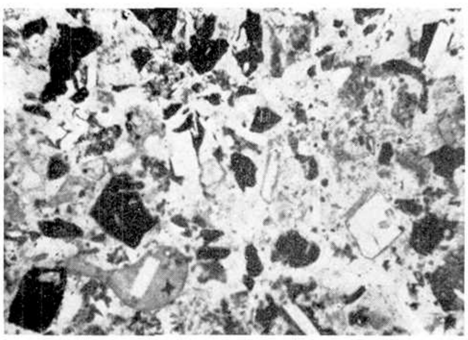
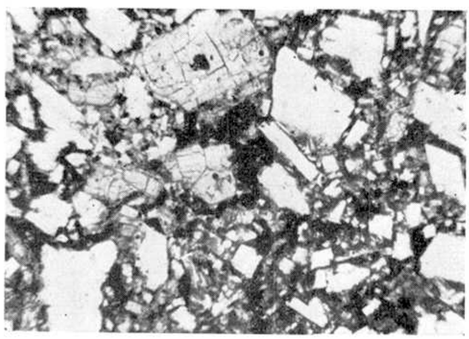
a. Hypersthene-olivine-bearing basalt (Ôtawa lava). [−6.9 m]

b. Two-pyroxene-olivine-basalt (Narusawa lava). [−58 m]




c. Olivine-basalt (a lava of the old Fuji volcano). [−89.45 m]

d. Augite-olivine-basalt (a lava block in the volcanic breccia of the old Fuji volcano). [−112 m]

e. Basaltic tuff. [−130 m]

f. Olivine-bearing two-pyroxene-andesite (a lava block in the volcanic breccia of the old Fuji volcano). [−140 m]

Fig. 11 a∼f. Microphotographs of the rocks from the Narusawa boring No. 11. [×60] diameter. Therefore they are considered to be of one and the same lava which however occurs in sheets, upper and lower, separated with a pyroclastic bed. In many respects, this lava is similar to the Funatsu lava already referred to, so that both may be of the same age in eruption.

Immediately below the foregoing, at depths between 56.7 m and 69.8 m, lies a lava of two-pyroxene-olivine-basalt No. 5 with an intercalated pyroclastic bed 3.35 m thick at the depth of about 62 m. This rock is quite similar in mineral composition as well as in microscopic structure to the Narusawa lava, suggesting that it represents the underground extension of the latter. (Fig. 11 b.)

Separated from the foregoing with pyroclastic beds (volcanic sand and breccia), a lava sheet of olivine-basalt No. 6 occurs at depths between 84.7 m and 89.4 m.

The rock has only a few megascopic phenocrysts of plagioclase, but it is crowded with a lot of microscopic phenocrysts of plagioclase and olivine. The olivine is usually surrounded with a black rim composed of minute magnetite grains. The groundmass is an aggregate of plagioclase microlites, minute grains of monoclinic pyroxene and magnetite, and a little interstitial glass and cristobalite. (Fig. 11 c.)

This rock differs in petrographic characters from any of the lavas ever examined of the new Fuji volcano; on the contrary, it is similar to some of the ejecta which occur either as lavas or as pyroclastics at depths more than 1700 m of the Hakoarezawa tunnel and which have been attributed to the old Fuji volcano.

From a depth of 89.4 m down to the bottom of the boring at a depth of 150.6 m, there occurs a continuous bed of volcanic breccias, intercalated with a tuff bed at the depths between 129.6 m and 133.9 m. So far as examined microscopically, most of the rocks lifted from various levels of the bed of volcanic breccias are similar to the ejecta of the old Fuji volcano. (Fig. 11 d.) But, it is remarkable that some of the rocks collected from the volcanic breccias at depths near the bottom of the boring are petrographically similar to the lavas of the Komitake volcano. (Fig. 11 f.) The tuff intercalated in the volcanic breccias at a depth of about 130 m is light gray in color and more or less indurated, cosisting of angular fragments of plagioclase, olivine, hypersthene and augite, together with basaltic rock-fragments. Of the rock-fragments, black scoriae and greenish-brown glass shards are predominant, suggesting the tuff to be a magma ash. (Fig. 11 e.)

From what has been stated above, it follows that the new Fuji volcano is underlain by the old Fuji volcano at the boring-site of Narusawa, too. Although the boundary between their ejecta has not been exactly located, it is presumably situated at a depth of about 70 m in the boring and immediately below lava sheet No. 5, where a thin bed of volcanic sand occurs as the top of the underlying thick bed of volcanic breccia. If so, in the vicinity of the Narusawa boring No. 11, the new Fuji volcano is only about 70 m in the thickness of its ejecta, and the Narusawa lava is the oldest of all the flows distributed thereabout. The ejecta of the old Fuji volcano, which are represented mostly by the volcanic breccias, have the thickness of more than 80 m at the site of the boring. Since the volcanic breccia near the bottom of the boring carry not a few rock-fragments similar to the ejecta of the Komitake volcano, it seems to show that the base of the old Fuji volcano is not very far below the bottom of the boring. This does not necessarily mean, however, that the ejecta of the old Fuji rest directly on those of the Komitake valcano situated underground at the boring-site. All that can be said with certainty is that the old Fuji volcano erupted somewhere on the pre-existing Komitake volcano, and that the pyroclastic ejecta from the former were deposited as the volcanic breccia, in company with the rock-fragments of the latter, in the vicinity of the boring-site.

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43. 富士火山の地質学的並に岩石学的研究 (VI)

6. 富士山腹の二，三の試錐孔及び坑道において観察された地質

地震研究所　津　屋　弘　逵

富士山南腹の大淵地内の海抜 700 m 余の地点において，今から 20 余年前に，同火山の基盤岩層の石油探査の目的で，深さ 1000 m 内外に達するボーリングが行われた．これを大淵ボーリングとよぶ．近年には，富士山腹の開発のために，地下水源を求めて各地でボーリングが行われている．その一つは富士総合開発株式会社が富士宮登山道一合目近くの箱荒沢の海抜 1050 m の地点において掘進中の長さ 2000 m 以上に達する水平坑道と数本のボーリングである．これを箱荒沢トンネルおよびボーリングとよぶ．また，富士山の北東および北麓近くの山腹において行われた数本のボーリングのうち鳴沢村地内の海抜 1000 m 余の地点には，農林省農地局によつて行われた鳴沢ボーリング No. 11 がある．

大淵ボーリングの地質については，かつて報告したことがあるが，筆者の手元に保存されているその一部の錐心を，新たに箱荒沢トンネルおよびボーリングの坑壁岩片および錐心，鳴沢ボーリングの錐心などと比較観察した．また，箱荒沢トンネルについて坑内の地質調査を行つた．この調査研究の結果，筆者がかねて提唱する富士火山の三部構造，すなわち小御岳火山，古富士火山，および新富士火山がさらに確認された．

大淵ボーリングにおいては，孔口から深さ約 280 m までは新富士の噴出物（橄欖石玄武岩，紫蘇輝石・普通輝石・橄欖石玄武岩など），深さ約 330～350 m 付近は古富士の噴出物（含普通輝石・橄欖石玄武岩，紫蘇輝石・橄欖石玄武岩など），深さ約 413～484 m 付近は小御岳火山の噴出物に類似するが，おそらく愛鷹山火山の噴出物（橄欖石・紫蘇輝石・普通輝石安山岩），深さ約 620 m 以下少なくも 885 m までは富士山周辺の山地や伊豆地方に分布するいわゆる御坂統（第三紀中新世下部）に類似する基盤岩層（変質凝灰岩，緑色安山岩，砂岩など）である．

箱荒沢トンネルにおいては，坑口から深さ約 1740 m までは新富士の熔岩，集塊岩，角礫岩など（橄欖石玄武岩，普通輝石・橄欖石玄武岩，紫蘇輝石・普通輝石・橄欖石玄武岩など）で，その全体の厚さは約 300 m，西方への傾斜約 10° である．その深さ約 1740 m から奥の 2000 m までは古富士の噴出物で，大部分玄武岩質の角礫岩層（火山泥流，火砕流堆積物を伴なう），火山灰砂層などであるが，二，三の熔岩層（含普通輝石・橄欖石玄武岩，紫蘇輝石・橄欖石玄武岩，普通輝石・紫蘇輝石・橄欖石玄武岩など）を挟む．火砕流堆積物の中には，まれに完全に炭化した天然木炭があり，これの C^{14} 年代測定によつて，古富士火山の噴火年代を知ることができるであろう．学習院大学化学教室の木越邦彦教授によって行われた測定によると，この木炭の年令は 21200 (±950) 年である．従って，古富士火山は今から約 2 万年前の時代に噴火活動を行っていたにちがいない．また深さ 1920 m から奥の角礫岩の間には，玄武岩質の火山灰砂層の他に，純白色乃至淡灰白色の軽石ガラスの砂の薄いレンズ層（厚さ 2～3 cm）が挟まる．この砂は玄武岩や長石，輝石などの破片を多少雑えるが，大部分無色透明の天然ガラスの破片で，その屈折率 ($n=1.500$) のきわめて低いことから，石英安山岩あるいは流紋岩質のものと考えられる．この酸性火山岩の軽石が古富士火山の噴出物であるかどうか明らかでないが，宝永 4 年の噴火のとき，玄武岩砂礫の噴出にさき立つて，石英安山岩質の軽石（そのガラスの屈折率 $n=1.507$）および黒曜石が噴出した事実から見ると，古富士火山の活動時代にすでに同様の噴火現象が起つたとも考えられる．箱荒沢トンネルの坑内では，古富士と新富士との噴出物は特に著るしい侵蝕面によつて境されず，構造的にも著るしい相異を示さないが，新富士の噴出物は大部分玄武岩熔岩層であるのに対して，古富士のそれは大部分火山灰砂および角礫岩層で，岩質上，富士宮市付近の山麓に分布する古富士噴出物にきわめてよく類似するものである．箱荒沢トンネルの坑内 1330 m の地点において掘られた深さ 85 m のボーリングの錐心はすべて新富士のもので，坑道の 1330～1700 m の熔岩層その他に相当する．また坑奥の枝坑内において掘られた深さ 115 m のボーリングの錐心はすべて古富士火山の噴出物である．

鳴沢ボーリング No. 11 においては，孔口から深さ約 70 m のところまでは新富士の噴出物（大部分熔岩層で，含紫蘇輝石・橄欖石玄武岩，含普通輝石・橄欖石玄武岩，橄欖石玄武岩，複輝石玄武岩など）である．これらは新富士の噴出物としてはむしろその活動初期に近いもので，ボーリング地点から鳴沢，大田和，大嵐などの部落付近に若干の火山灰砂層をかぶつて分布する大田和熔岩，船津熔岩，鳴沢熔岩などはそれらに当たる．ボーリングの深さ約 70 m 以下 150 m までは古富士火山の噴出物で大部分玄武岩質の角礫岩および灰砂層であるが，深さ約 84～89 m のところに橄欖石玄武岩の熔岩層があり，また深さ約 129～134 m のところに固化した凝灰岩層がある．ここでも新富士と古富士との境界に著しい風化侵蝕面は認められないが，深さ約 70 m 以下の角礫岩層は箱荒沢坑道内や富士宮付近の地表に見られる古富士噴出物と岩質上よく類似する．その上に，深さ 150 m の孔底に近い部分の角礫岩の礫には，小御岳火山の安山岩に近似するものが少なくない．このことは古富士火山の噴出が小御岳火山の山体上に起つて，後者の噴出物の破片を雑えたことを示すものであろう．