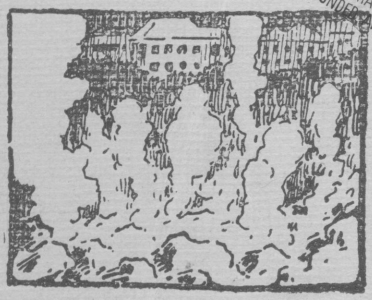
GUIDE-BOOK EXCURSION E—1,3,4

(Nov. 15th—19th, 1926)

UNZEN VOLCANOES



PAN-PACIFIC SCIENCE CONGRESS, 1926

JAPAN

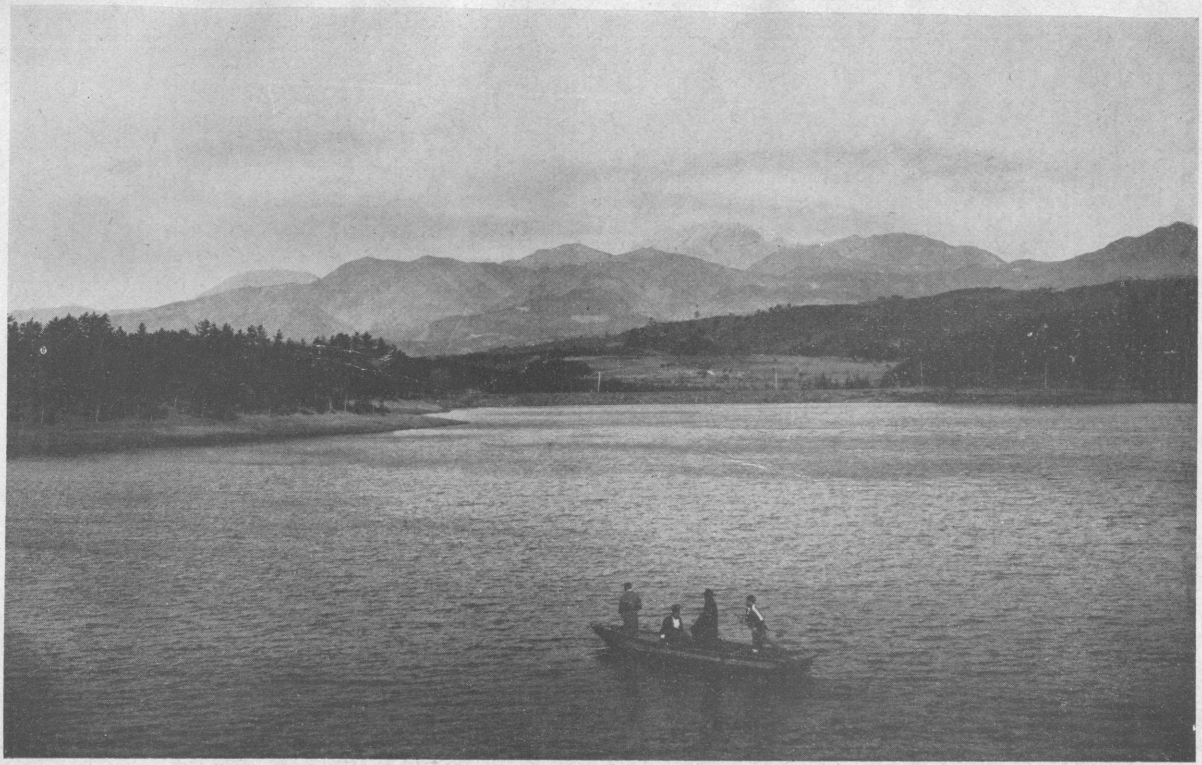


Fig. 1. Unzen Volcanoes observed from Suwano-Ike.

UNZEN VOLCANOES

CONTENTS

THE GEOLOGY OF THE UNZEN VOLCANOES

By Takuji Ogawa and Fujio Homma

The following notes are essentially founded on the paper published by the senior of the writers on the earthquake of Shimabara in 1922, but an important modification has been made by the junior writer in the description of the structure of the volcano, as a result of his trips in the spring and autumn of 1925. The geological map, here inserted, which has been prepared by the latter, is also based on one appended to the former paper, but adapted to a wholly new interpretation of the orographical and structural features and the successive stages of volcanic activity.

I. GEOGRAPHICAL AND GEOLOGICAL OUTLINES OF THE SHIMABARA PENINSULA

The peninsula lies on the western coast of Kyūshū Island, and stretches southeastward from the western part of Hizen Province. It has a length of 34 km. measured from NNE to SSW and an area of 465 sq. km. It lies in the midst of a flat sea basin on the western continuation of the Inland Sea, which occupies a depression between North and South Kyūshū. The peninsula has a comparatively simple elliptical outline, with the longer axis lying from NNE to SSW, except on the western side, which is encroached on by Chijiwa-nada or Tachibana-wan. The almost perfect elliptical curvature of its north and east coasts is due to the conical elevation of Mt. Unzen in the centre of the peninsula. The gentle slope here merges into a flat

plain and dives under the waves of the Ariake Sea. The south-western prolongation has a more crooked outline than the main part; and along the coast, we find a succession of cliffs of soft Pliocene beds which, undermined by the waves, have formed a narrow submarine platform exposed at low tide.

The group of Fugen-dake (1,360 m.), or Unzen-dake proper, consists of a central cone, Fugen-dake, and of a *somma* encircling the north, west and south of the same, with the peaks, Kunimi-dake and Myōken-dake, which are a little lower than the central cone. The whole conical mound, consisting of rather acidic and viscous lava, has a steep slope of 20° on all sides, and presents a very imposing aspect seen from the east and southeast foot.

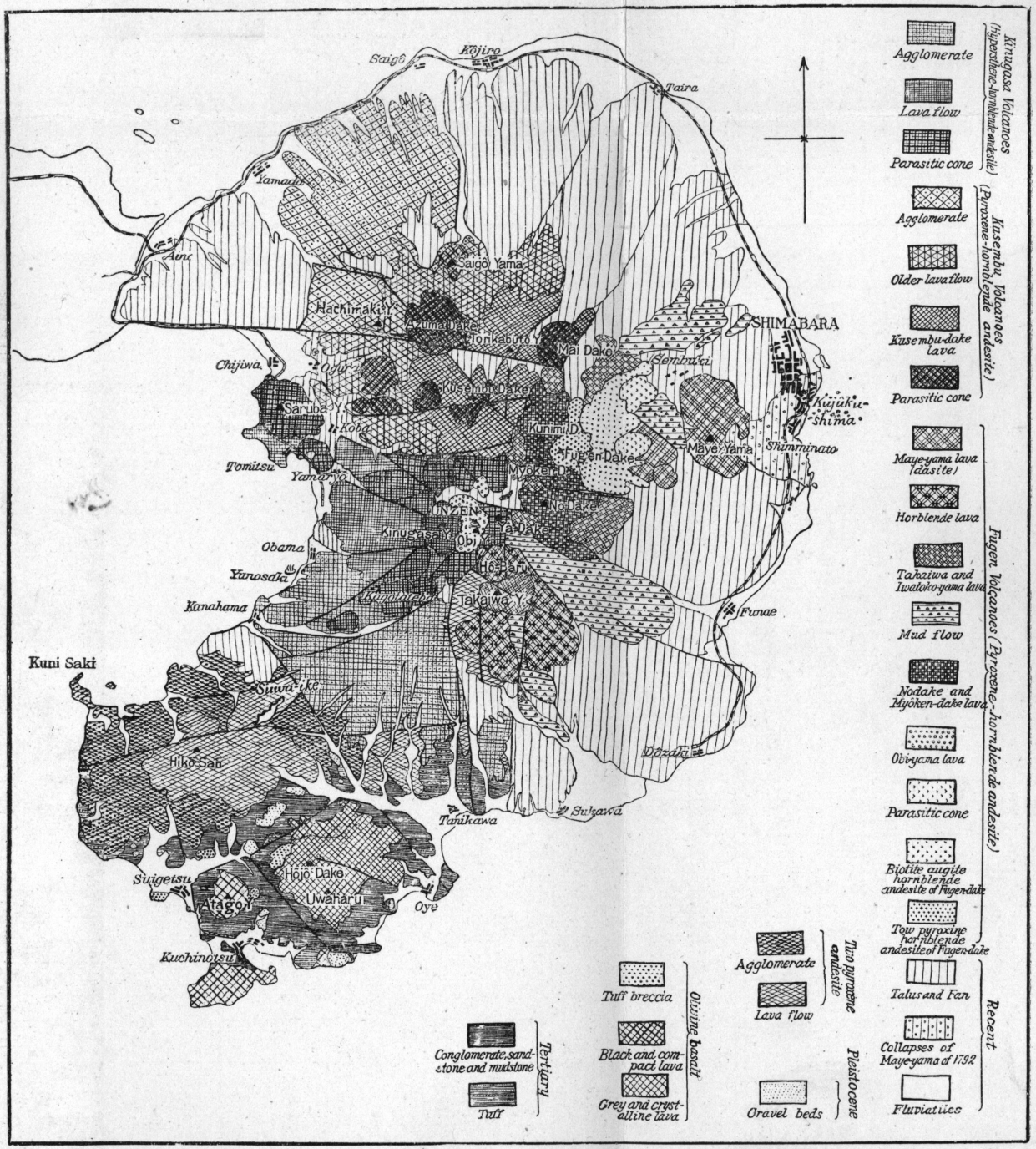
In order to have an insight into the geological structure of the volcanic district, we have to go back to a more remote geological past than the younger Tertiary epoch. Older formations building up the Northern Kyūshū Mountains are mostly metamorphic Palaeozoic sediments which include vast masses of granites and other plutonic rocks. Though we lack as yet a detailed investigation into the nature of the rocks, we are probably justified in assuming that they are homologous to rocks found in other parts of the inner zone of the Japanese Islands, and owe their highly metamorphosed petrographical character to the regional metamorphism which accompanied the orogenic process in building up the folded mountain system. Amphibolites and less metamorphosed basic tuffaceous rocks intercalated in normal sediments are most probably of the later Palaeozoic age, being older than the Rhaetic plant-bearing series of Nagato. They represent volcanic products made during the formation of a geosynclinal in that age.

The Palaeozoic terrain with intrusions of plutonic rocks seems to have been subjected in later times to a compression from the west, apparently in connection with the formation of the insular arc of Ryūkyū. The greatest disturbances must have happened simultaneously with the folding of the Idzumi Sandstone, which contains marine sediments deposited in a narrow longitudinal trough between the inner and outer zones of the older mountains.

Of the Tertiary deposits which occupy an extensive region to the north of the Cretaceous belt, the lowest horizon is represented by the Lower Coal Measure. It is worked in Miike, Amakusa, Karatsu and other basins, which have recently been studied very precisely by

GEOLOGICAL MAP OF SHIMABARA PENINSULA

Fig. 2.



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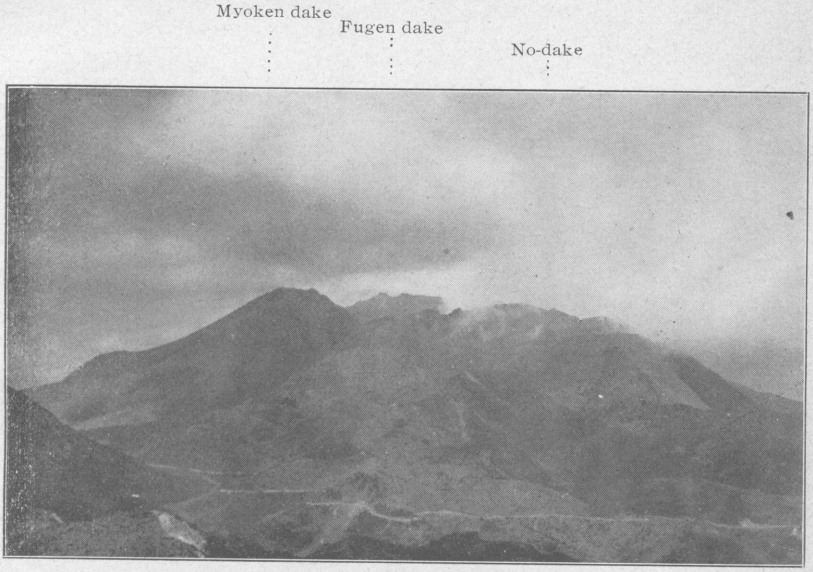


Fig. 3. Fugen Group of Unzen Volcanoes.

Mr. T. Nagao. The uppermost part of the formation is composed of basaltic rock materials, which mark an episode of the epoch throughout Northwestern Kyūshū and the coasts of the Japan Sea in Chūgoku. Then a new epoch, probably early Pleistocene, was opened by intense volcanic activity, which caused the accumulation of vast masses of basic andesites and their detrital materials on the basement of the volcanic district of Unzen-dake. The eruption of hornblende-andesite which succeeded the new subterranean convulsion, continued to a certain extent. Petrographically speaking, the sequence is therefore basalt, pyroxene-andesite and hornblende-andesite, that is, a cycle of magmatic differentiation with decreasing basicity.

The eruption of these volcanic rocks has no doubt a close relation to the dislocations which took place subsequent to the great orogenic movement. After the folding and bending of the Idzumi-sandstone strata, the mountains north of the newly built chain were transversed with numerous lines of dislocation in diverse directions.

Of the lineaments, two can be traced along lines drawn from Kumamoto to Moji and to Karatsu. They represent two sides of the triangular Tsukushi Mountains, which are again cut by less marked lines into separate blocks. These and the leading directrix, which runs from Sagano-seki to Misumi on the northern margin of the South Kyūshū Mountains, bound two sides of two depressed areas between two major blocks of mountains in the island. The one on the east has also a triangular outline, but is occupied on its western part by the extensive volcanic districts of Buzen, Bungo and Higo Provinces, and the other on the west is marked by Unzen, Tara and other small volcanic centres.

II. THE EVOLUTION OF THE UNZEN VOLCANOES

From the orographical outlines of the peninsula above given, it is clear that the first volcanic activity began with an extrusion of olivine-basalt which either piled up on the accumulation of breccia and tuff of the same rock or directly on the Tertiary formation, composed of conglomerate, sandstone and mudstone. This was soon followed by another eruption of agglomerate and lava of two-pyroxene-andesite, which took place on fissure lines running in a northeasterly direction, forming a plateau to the north of the former.

Then came a long interval of intermittent volcanic activity in the peninsula, this phase being accompanied in the upper part of the

Tara and Kimbo Volcanoes by the extrusion of hornblende-bearing hypersthene-andesite. The first period of the volcanic activity of the Unzen volcanoes began with the eruption of an agglomerate of hypersthene-hornblende-andesite, in which occur a few sheets of lava flows. It was accompanied by a general upheaval of the land to the extent of at least several tens of meters. The fact is attested by horizontal beds of gravels consisting of round or subangular-blocks of basalt, pyroxene-andesite and older sedimentary rocks found in the southern half of the peninsula. The gravel beds gradually merge into an agglomerate of hypersthene-hornblende-andesite in their upper horizon, the volcanic products increasing in quantity towards the southern foot of the Unzen Volcanoes.

The centre of this eruption is supposed to have been on a certain spot not far from Kinugasa-yama, and the eruption is thought to have produced in its later stage several parasitic cones and explosion craters, one of which we can now recognize in Kinugasa-yama. The parasites were not scattered in a haphazard manner, but were aligned in a southwesterly or west-northwesterly direction.

The first period of activity among the Unzen Volcanoes was closed by the formation of a set of orotectonic lines, of which the most striking is the fissure trending in a west-southwesterly direction from the west foot of Takaiwa-yama to Kanahama, while another is discernible in the fault which runs in a west-northeasterly direction with a depression on its north side, extending from the base of Myōken-dake to Chijiwa through Koba. The latter line has been partly buried in accumulations of pyroxene-hornblende-andesites belonging to later stages of eruption. We believe it convenient to call this time of volcanic action the Kinugasa volcanic period.

Upon the sinking of the northeastern half of the Kinugasa Volcanoes, followed the second period, giving rise to the majestic stratovolcano of Kusembu, which has been, however, highly dissected during the long run of later activities. The materials erupted at the second period are characterized by the presence of pyroxene-hornblende-andesite, an abundance of hornblende and augite, and a scarcity of hypersthene. During the last stage of this period, there were formed several lava domes with more or less steep declivities, as seen in the case of Azuma-dake. Saigo-yama, a parasitic cone at the north foot of Azuma-dake, was subjected to an interesting vicissitude, for the effusion of lava of the parasitic cone took place in an explosion

crater which had already been formed on the flank of the stratovolcano of Kusembu, and it was afterwards buried in lava coming from Azuma-dake on the south.

The main crater of eruption in the second period appears to have been situated at Tashirobaru, on the north side of the foot of Kusembu-dake. The volcanic mounds produced in this period were severely damaged by the formation of easterly and northerly faults; the most prominent one, running from west to east, passes the northern shore of Chijiwa-nada and the south foots of Mts. Hajimaki and Azuma, while traces of another are preserved to the north of Kunimi-dake and the south of Takaiwa-yama in a curve, convex toward the west. The equatorial line of fracture is the most prominent orotectonic lineament found in the peninsula, and its significance was felt in connection with recent earthquakes such as that of 1792, (the 4th Year of Kwansei). In contrast to the seismotectonic line, the meridional one is distinguished by volcanic activity.

Between the second and third periods of activity among the Unzen Volcanoes, we find another long interval of quiescence, as may be inferred from the facts that the eastern half still maintains quite young aspects of topography, while the western half of the Unzen volcanic group has been highly dissected by erosion, attaining almost to maturity, and that in spite of the rather slightly increasing basicity of the lava in the Unzen volcanic group, a copious amount of dacite lava was effused from Mae-yama and the base of Mt. Fugen at the beginning of the third period of volcanic activity. It is also interesting to observe here an abnormal type of andesite with a unique association of quartz, hornblende and olivine, all of which are characterized by fractured outlines seen under the microscope.

The first of the three facts is an evidence of the presence a long interval between the second and the third periods of activity; the second points to an extraordinary convulsion in the beginning of third period, causing the outwelling of an acidic product of differentiation through the newly formed vents; while the third suggests that the rejuvenation which can be naturally expected after a long lapse of time in quiescence, most probably was due to a new supply of magma in the lava basin affected by an unknown subterranean convulsion.

During the third period, occurred a succession of effusions of considerable quantities of lava, accompanied by violent explosions

and emanations of vapour, so that destructive and constructive works were repeated many times. Takaiwa-yama, No-dake, Myōken-dake, Kunimi-dake and Mae-yama represent partly shattered cones, produced during this period. Fugen-dake with records of eruption in recent times, is the only one intact, thanks to its having been formed during the latest phase of this period.

Apparently the centre of the most violent activity was at first situated at the base of No-dake, deviating afterwards to the north in the direction of Myōken-dake and Kunimi-dake to culminate in Fugen-dake, which was built up after the explosion of Myōken-dake. It is a striking fact that Takaiwa-yama is situated on the meridional fault, which was, as above stated, produced at the end of the second period. Obi-yama, another seat of eruption during this period, is situated far from the centre of the main activity and, instead of forming a lofty peak, its activity consists in a continuous feeble emission of fumaroles and hot springs, known as Unzen, one of the most delightful resorts in Japan.

The petrographical character of the volcanic rocks found in the Shimabara Peninsula is as follows:

Olivine Basalt:—The phenocrysts are chiefly colourless olivine, besides some augite. The groundmass is an aggregate of small laths of plagioclase (Ab_{26} An_{74}—Ab_{31} An_{69}) and small grains of augite, with a subordinate quantity of magnetite. The texture is either typically doleritic (macroscopically grey in colour), or typically basaltic (macroscopically black in colour). The rock forms a flat dome (grey type), plateau (mainly black type), or dikes and sheets (black type).

Two Pyroxene-Andesite:—Two types can be distinguished by the naked eye; one of them is porphyritic and bears phenocrysts of augite attaining the size of 3 mm. × 3 mm., and the other is almost aphanitic. The size of the phenocrysts is in both cases usually less than 1 mm. × 1 mm., except that of the large phenocrysts of augite as above stated. This characteristic of the two-pyroxene-andesite is important as distinguishing it from the pyroxene-hornblende-andesite of the Unzen volcanoes. Under the microscope, the types do not present any more marked differences than those observable by the naked eye. Among phenocrysts, plagioclase (Ab_{15} An_{85}—Ab_{35} An_{65}) is dominant, augite and hypersthene occur in nearly equal quantities, olivine and brown hornblende are occasionally present, and magnetite is always present in small quantities. The groundmass is hyalopilitic. The

two-pyroxene-andesites form either agglomerate or lava in the south-eastern part of the peninsula. The northern limit of their distributions is the western foot of Takaiwa-yama but due to transportation by running water previous to the eruption of the Unzen volcanic group, numerous blocks are also found on the south foot of Mae-yama, and around Takaiwa-yama.

Pyroxene-Hornblende-Andesite of the Unzen Volcanoes:—All the types of rock found among the Unzen Volcanoes are characterized by the presence of large phenocrysts of white plagioclase and black hornblende with a dimension of about 5 mm. × 3 mm. in section, accompanied by variable amounts of biotite and occasionally quartz and pyroxenes. The colour of the rocks ranges from black to reddish brown, though grey is usual.

Under the microscope, the large phenocrysts of plagioclase are seen to have a well developed zonal structure, with rounded outlines due to corrosion, and especially those in the rock on Fugen-dake, are divided into two zones; the core being separated from the unaffected outer zone by a dirty corona formed by magmatic reaction. This fact shows that the plagioclase underwent two stages of crystallization, in spite of the uniform chemical composition (Ab_{45} An_{55}) of the two zonos. In the rocks which have a fluidal structure, phenocrysts of plagioclase (Ab_{49} An_{51}) are found, crushed into angular fragments, although the groundmass has remained quite unaffected by this action. It is a singular fact that in this type of rock we find considerable quantities of small olivine phenocrysts and occasionally a few fragments of quartz. As already stated, they may have come together by an injection of the lower basic differentiate into the upper acidic portion at the beginning of the volcanic activity of the third period. This kind of rock is found along the south side of Akamatsu-dani, and near the base of No-dake. The plagioclase occurring in the dacite of the first period of activity on the southeastern foot of Saruba-yama, is sodic in the extreme, the composition being Ab_{60} An_{40}, while that of the dacite forming Mt. Mae, on the contrary, is more calsic, having the composition of Ab_{51} An_{49}.

Hornblende occurs in a greenish brown variety, showing a strong pleochroism; the pleochrosm is strongest in cases where the rock has been stained by ferric oxide produced by contact with free air during the consolidation of the lava, the colours ranging between brownish red and bright green. Without exception, the crystals of hornblende

have been strongly affected by magmatic reaction and have beeen replaced by opacite or an assemblage of magnetite and long prisms of augite, in parallel position. The time of the crystallization of the hornblende is not clear, but it may not be much later than that of the pyroxene. We may infer that the formation of the hornblende was attained only after the accumulation of mineralizer in the lava basin in the course of a magmatic differentiation and in spite of the high temperature, because the considerable dimensions of the phenocrysts must be the result in a magma having an extraordinary fluidity. But in the case of the Unzen volcanoes, the magma could be expected to maintain this characteristic only in the lava basin, since, having lost this peculiarity during the exhalation of gases in the explosions it was extruded as viscous lava flows with many steep cones.

Phenocrysts of biotite are almost always present to a greater or less degree in every type of rock found among the Unzen Volcanoes. The colour of the biotite is brown as usual. Augite occurs in greatest abundance in the lavas of the Kusembu Volcano, and in those on the northern part of the summit of Fugen-dake. The distribution of augite-hornblende-andesite is of considerable significance, for it is found in the northern half of the Unzen Volcanoes, while hypersthene-hornblende-andesite occurs in the southern half and an intermediate rock, in the intermediate zone, so that the occurrence of augite seems to be independent of the period of eruption. This fact suggests to us that the occurrence of angite is due to an assimilation of any kind of the country rock, for only a slight quantity in assimilation would suffice to cause the change. As pyroxenes never form large phenocrysts like plagioclase or hornblende, they can not as a rule be discerned by the naked eye. Augite has a pale green colour and is not pleochroic in thin sections, while hyersthene shows a weak pleochroism, varying between pale green and pale reddish brown. Hypersthene is found in the rocks of the Kinugasa district and in a few cones of the Fugen volcanoes, Takaiwa-yama, No-dake and Myōken-dake, but rarely in those of the Kusembu Volcanoes.

Olivine occurs in several types of rock which do not contain much quartz or biotite. It is, however, especially frequent in those rocks which were produced in the centres of violent activity, for instance, in extensive lava flows at the base of Kinugasa-yama and No-dake and on the summit of Mt. Fugen (Hatoana). Quartz also occurs in many types of rock, but it is extremely limited in quantity,

except in the dacite lavas on the southeast foot of Saruba-yama on the southeast foot of Fugen-dake and on Mae-yama. The structures of the groundmass of rocks among the Unzen Volcanoes are variable, but the more basic type is generally the more crystalline, except in the case of the cryptocrystalline dacite of Mae-yama.

Chemical analyses of the rocks above mentioned are as follows:—

	1	2	3
SiO_2	63.13	62.02	58.15
TiO_2	0.67	0.75	0.75
Al_2O_3	16.84	16.49	17.69
Fe_2O_3	1.94	2.66	2.72
FeO	3.40	3.73	4.41
MnO	0.09	0.11	0.11
MgO	2.44	2.98	3.45
CaO	5.49	6.30	7.20
Na_2O	2.82	2.30	2.52
K_2O	2.31	2.01	1.68
P_2O_5	0.12	0.06	0.12
H_2O+	0.68	0.40	0.34
H_2O-	0.29	0.18	0.60
Total	100.22	99.99	99.74

1. Hypersthene-hornblende-andesite of Kinugasa-yama.
2. Pyroxene-hornblende-andesite of Kusembu-dake.
3. Olivine-pyroxene-hornblende-andesite of Hatoana, Fugen dake.

In a word, the general tendency of the changes in chemical composition of lavas produced in the Unzen volcanic group is in a very slightly increasing order of basicity, as against the general tendency of the chemical changes in the course of the volcanic activity in western Kyūshū. Exception to the order is observed, however, at the commencement of each new period, marked by an eruption of a small quantity of more acidic rocks, which were most probably formed during a long lapse of time on the upper part of the lava basin.

The mode of activity of the Unzen Volcanoes as briefly sketched above is of a very complicated character. It represents the last stage of a long series of volcanic action, commencing with the eruption

of olivine-basalt at the close of the Pliocene epoch and followed by that of two-pyroxene-andesite in and around the Shimabara Peninsula. A quiescence of activity in the Shimabara Peninsula took place after the eruptions of two-pyroxene-andesite, and during this interval the Tara and Kimbo Volcanoes produced hornblende-hypersthene-andesite as already stated, but their activity ceased when that of the Unzen Volcanoes commenced. Thus the volcanic action of the district reaching its climax at the centre of these numerous volcanoes, the activity of Unzen represents the last acidic stage in the regional evolution of volcanism in the western part of Kyūshū.

III. HISTORICAL ERUPTIONS AND EARTHQUAKES OF THE UNZEN VOLCANOES

The first recorded activity of Unzen is the eruption which began in 1657 (3rd year of Myoreki) and continued for more than twenty years. The chronicler of this eruption says:

"About a hundred and thirty years ago (reckoned from about 1793), when Koriki-Sakonnoshogen was governor, Fugen-dake was in eruption. It glowed for several nights so intensely that people in the northern part could dispense with lanterns or torches. The black, burnt rock (lava) can still be seen on the right on the way leading to Fugen. At that time, a flood came down from the uplands of Antoku and Fukae to the villages, causing damage to the farms. It is said that the present waterless river-bed marks the course of that flood."

Toshiyuki Kanai, who compiled local documents and gathered information with unusually sound criticism and insight in connection with his personal researches in the field, says:

"The eruption of 1657 took place in the community of Mie. The lava is now known as Furuyake, 'Old lava', of which the site is found in the valley between Yemaru and Hando-iwa. The course of the coulée is marked by a ridge of rugged rocks raised from the ravine for some hundred metres. In the following year a flood from the upland (probably Akamatsu-dani) of Fukaye and Nakakoba overran the two villages, sweeping houses away and killing more than thirty souls. Antoku-gawara is said to have been its course."

The lava of 1657, which welled out from Hando-iwa on the northern foot, is estimated to be 1,200 m. long and about 100 m. wide. It is distinguished by its rugged relief from the surrounding rocks.

Two more eruptions are recorded as took place in 1663 and 1664. In March, 1663, Fugen-dake was in activity for five days. The Kuju-kushima or "Ninety-nine islands," which marked the site of the eruption, were situated in a depression east of the central peak of the volcano. The name indicates numerous mounds of mud or piles of ejected blocks which had an existence for a short time only and completely disappeared afterwards. Another eruption occurred between 4 and 5 o'clock in the morning on 27th January, 1664. It is said that a detonation was heard before dawn, and fumes were seen in the morning. Scanty as are the dacuments on the eruptions, yet it is probable that the volcano was in a state of constant activity for more than ten years after 1657, in which year there occurred an extrusion of lava from the northern flank of Fugen-dake.

After the last mentioned successive eruptions of the volcano, a century elapsed before fresh activity occurred, at which time, it was accompanied by earthquakes. It brought catastrophe to the district and the adjoining sea-shore of Higo Province. The activity commenced with earthquake shocks in the winter of 1792. It was followed by an eruption from the top of Fugen-dake which lasted for several months during the following year, when a considerable quantity of lava was poured out from the flank. Extremely severe earthquake shocks concurred with the eruption, and culminated in the collapse of a part of Mae-yama, causing a tidal wave which inflicted disastrous effects on the shores of the Ariake-Sea.[1)]

(1) Precursory shocks were felt from November of 1791 on. The first occurred on the 2nd of the month (8th October of the Old Calendar). It was accompanied by subterranean detonations. Such shocks were felt three or four times daily, increasing in intensity about 6th December (10th November), and causing landslips on the southeastern front of Mae-yama. At that time, however, the shocks seem to have been more severe in the neighbourhood of Obama on the western coast.

Towards the end of January, the detonations heard near the mountains west of Shimabara became very frequent and intense. The sound was likened to thunder or to the firing of artillery.

1) We find an interesting description of the volcanic eruptions of Asama in 1784 and Unzen in 1792 in Titsigh's Illustration of Japan (translated from A. Rémusat's compilation in French by Fr. Schoberl in 1822). The date of the eruption of Unzen (pp. 109-112) was referred erroneously to 1793, and the second illustration of Asama (Part 1, Pl. 3) to Shimabara. The mistakes have obviously arisen in the compilation of the author's posthumous manuscripts.

(2) Eruption of Fugen-dake. On the morning of 9th February 1792, particularly heavy shocks were accompanied by detonations originating from Fugen-dake. At about 7 o'clock in the morning, people at Kojiro found black smoke looking like piled rocks coming forth from the top of the mountain. This black smoke came down like rain during the whole day. Shocks felt at Shimabara were very severe during the night. On the next day the head man of the village at Kojiro was ordered to send a farmer on a tour of inspection, but he could not go further than Yazaemonyake, frightened as he was by the shaking of the whole mountain and the emission of muddy materials. Officials next sent by Nabeshima, however, reached the top. According to their report, a depression with a diameter of about 50 m. had been opened by an explosion in front of the temple of Fugen. Jets of boiling water gushed more than 30 m. high, and with them large blocks of rock and mud were hurled up. The mud formed a large mound at the bottom of the hill.

The eruption reached its maximum intensity on the third day. Smoke was thrown up high into the sky and darkened it. Ashes fell in the neighbourhood of Shimabara. It gradually subsided, and in March the emission of mud was only 2 m. high.

(3) Extrusion of Lava in Anasako-dani. On 25th February, fifteen days after the eruption of Fugen-dake, the ground at Biwa-no-bachi, up the valley of Anasako, began to tremble and shook off earth and rocks. The second site of activity lies on a steep declivity about 1 km. northeast from the top and 4 km. from Shimabara. Toward noon on the 27th, dust was hurled up. During the night of 1st March, a fiery light was seen at the spot. The consolidated blocks of lava, pushed out of the new vent, fell down to the bottom of the ravine with a tremendous noise.

The head of the new lava flow, or "Shin-yake-gashira," lies beneath Hando-iwa, which is a cliff formed by a sheet of lava and is separated from Yazaemon-yake or Furu-yake by a spur called Roggi-yama, running northeastward to the hilly tracts of Orihashi. The coulée crept down the valley and overwhelmed the hamlet of Semboki. Its serpentine course, 4 km. long, bears the most rugged aspect imaginable and dwarf pine trees are the only vegetation growing after the lapse of a hundred years. On both sides, ravines more than 100 m. deep mark the former course of Anasako-dani. Its

lower end in the mouth of the valley has the form of a cliff 200 m. wide and 50 m. high.

During the time when the lava was welling out, which seems to have lasted for many months, the region presented a scene of infernal aspect terrifying in the extreme to the inhabitants of the neighbourhood. Pushed out by the emission of fresh red-hot melt, consolidated blocks of lava tumbled down to the bottom with a crash. This sound, combined with roaring and trembling coming from underground, made a tremendous noise. The first terror soon vanished, however, and picnickers swarmed to the scene so that tea-houses were built for them on adjoining heights. Officials sent from Kojiro reported on 25th March a crowd of spectators on the spot numbering thousands. The governor of Shimabara had to issue an order prohibiting people from visiting the scene, with the exception of a male representative from each family for inspection.

(4) Other vents of eruption. Meanwhile the subterranean convulsion found other outlets near the top of Fugen-dake. One was opened on the afternoon of 21st March at Hachi-no-kubo, which lies also on Hando-iwa. It was followed on the 24th by the opening of seven more outlets 200 m. northwest of the same, on the side of Furu-yake or Yazaemon-yake, as it was called in the reports of Kojiro. All these vents having underground communication with the crater on Anasako-dani, the top of Hando-iwa was torn asunder into two masses by a rent measuring 1-5 m. in width.

The validity of the facts compiled by T. Kanai concerning these eruptions is confirmed by the report of Kojiro for 27th April. We find in the same documents an interesting record to the effect that the distance covered by the coulée in 60 days was estimated at 21 *cho* 15 *ken* (2,320 m.), i. e., the speed was approximately 40 m. per day.

The eruption was going on during this time in full activity. Clouds produced by the emission of vapours from these vents hung high up in the sky, glowing in the twilight and reddening to a more fiery hue during the night. The lava coming downward menaced the town of Shimabara, which was shaken by incessant shocks.

(5) Earthquake of 21st April (lst March). At 4 o'clock in the afternoon on this day, occurred the severest shock hitherto felt. With it, roaring noises came from Mae-yama. The sound was like the discharge of guns on a Dutch frigate. Sometimes it seemed to pass from the mountains in the centre to the sea and sometimes from

the sea to the land. Shaken by the shocks, masses of rocks and débris fell down from Mae-yama and set the trees below on fire through the heat of their friction.

The shocks were very severe and frequent for three days, more than 300 being counted during the night and more than 100 in each of the next two days. They were most intense from midnight to the morning of the second day. Six of the schocks on the first day and four on the second put doors out of place. However, the earthquakes subsided gradually after the third day, although another severe shock occurred on 29th April (9th March).

The destruction recorded at Shimabara a week after was 61 houses and store-houses, besides 288 stables and sheds completely collapsed or badly damaged. Two men lost their lives by a falling house. This time the shock was severest along the eastern shore between Shimabara and Fukaye. At Shimabara, the eaves of most buildings were shaken down and the stone walls of the castle were dislodged.

At Kojiro in the northernmost part of the peninsula, it was reported that the same shocks were felt and some ovoid gravestones, *Ishi-doro* ("stone lanterns"), and *Torii* ("stone gates") fell down, while at Shimabara all such stone works completely succumbed to the shocks. We may conclude from these facts that the intensity of the shocks was as a whole far greater than that of the earthquake of 8th December 1922, to which we shall refer later, and also that the area of the greatest intensity was in the central and eastern part of the district.

A fact of importance is the formation of crevices in consequence of the earthquake. According to T. Kanai, the earth was rent by quakes at several places between Shimabara and Antoku. Two of the crevices with a trend W by N to E by S and about 1 km. long are shown in an old map of the town copied by the author. They ran across the castle ground and were at first only a few inches wide, but widened with the increasing intensity of the shocks to more than a foot. It is said that the ground sank on the southern side of these crevices. In connection with the fracture, the course of the underground water was subjected to a change ; springs gushed forth on the east of the castle close to the shore, while on the west up the hill beyond the castle, the fountain-heads dried up for a time. A similar crevice was produced on the west between Orihashi and Roggi,

measuring 1 km. and extending in the same direction as those on the east.

We find in a report on 31st May (11th April) at Kojiro that a far more striking line of fracture was produced most probably by the same earthquake. It ran from Iwomi-dake to the southern slope of Azuma-dake, and thence to the north flank of Fugen-dake. The part of the crevice near Azuma-dake was visible from the road, its width being about 1 m. When we join the three lines of fracture, their trend and position coincide with the lineaments marked by the depression in the interior of the northern fault-scarp.

Another equally noteworthy fact is a landslip caused by the earthquake on the southeastern part of Mea-yama. The destructive proccess commenced at midnight, when the severest shocks were felt at Shimabara, and continued for a whole month with varying intensity. The violence with which the mountain was torn asunder and thrown downward frightened the inhabitants in the immediate vicinity, no less than did the red-hot lava flowing down from Fugen-dake. In the Diary on the 22nd, it is mentioned that the rumour of a coming *Yamashio*, (literally, "Mountain-flood" or landslip) was in vogue among the people in Shimabara, and put them to flight to the north, almost the whole population except the *samurai* abandoning their homes. The flight continued for a fortnight, until the shocks had become weaker and less frequent.

(6) Collapse of a part of Mae-yama. Towards the middle of May, although the lava was continuing its downward movement, both the eruption from vents on Fugen-dake and the shocks and detonations of the earthquakes sensibly subsided and appear to have lost almost all their destructive energy. People returned to their dowellings by and by. It a tragic circumstance that people who had settled down again were surprised by the worst catastrophe in the whole course of the volcanic activity. It was the sudden collapse of a considerable portion of Mae-yama, which took place on the evening of 21st May (1st April). About 8 o'clock that evening, the townspeople of Shimabara once more felt severe shocks, of which two are said to have been particulary violent. They were followed by a crash as if thousands of thunderbolts were united in a single stroke. After a short time, loud shrieks were heard in the streets towards the east and south of the town. The advancing front of a tidal wave was soon perceived by a sentinel at the gateway of the castle. Most of the

populous parts of the town were engulfed by waves which came from the south three times in rapid succession.

At Kojiro it is said that between 7 and 8 o'clock, a loud roaring was heard from the sea, the noise resembling that of the turning of the windlass of a seine ; people hastened to the shore, and saw the wave-front raised like the ridge of a hill. All the inhabitants of the villages on the sea-shore fled to the upland without the loss of a single life.

The scene in Shimabara after the retreat of the tidal wave was beyond all imagination. The night was moonless, and the townspeople who outlived the disaster could not know what was the natural force at work that produced the cursed waves. When the morning dawned, however, Tengu-yama which formed the southeastern third of Mae-yama and commanded a narrow coastal plain stretching southward from the town, was found to have lost its eastern half, and presented the aspect of a sheer wall cut in banded layers of white and red lava. The precipice measured some hundred metres.

The mass which made up about one-sixth of Mae-yama, equal to about half a cubic kilometre, was thrown down on the eastern foot in a fan-shaped hilly tract with its margin projecting far beyond the previous shore line. Two villages, Ima-myo of Shimabara-mura and Kita-myo of Antoku-mura, were wholly buried under a thick débâcle of the débris, besides the southern suburb of the town with its flourishing harbour, which was also devastated and converted to a desert with pell-mell heaps of the same detrital materials. Detached patches of them, " flowed mounds " as Mr. I. Komada calls them, were swept on to the sea, and gave rise to islets which numbered from two to three hundred at the time of their formation. Many of them still exist along the shore east and south of the town.

The tidal wave was evidently caused by the dashing of the vast mass thrown down from Mae-yama into the sea. A circumstance which made the effect more serious was its coincidence with the hour of spring tide which is $9^{h}\ 20^{m}$ at the roadstead of Shimabara, and of which the range is nearly 5 m.

As to the amplitude of the waves, exaggerated heights, above 30 m., were given in an official report of Shimabara. According to an estimate of the three waves by T. Kanai, however, the second, which was the highest, did not attain more than 10 m. at Shimabara.

According to the report of 12th October (27th September), the damage caused by the tidal waves in Shimabara alone amounted to 9,720 men dead, 700 wounded, 3,347 houses and 2,000 other smaller buildings swept away. The devastated shore measures 76 km. from Saigo to Oe. In Amakusa 343 men were drowned, and 373 houses and 439 sheds swept away. In the three districts of Udo, Akita and Tamano in Higo Province, 4,652 men were drowned, 811 wounded and 2,252 houses swept away. The total loss of life there was more than 15,000.

Concerning the nature of the catastrophe, opinions are divided between geologists and seismologists. Messrs. D. Sato and I. Komada seem to conclude from the external form of Mae-yama that the collapse was due to a volcanic explosion which tore the mountain and threw masses of débris into the sea, in a manner similar to the formation of the explosion craters met with in many volcanoes of Japan. Such horseshoe-shaped depressions are, however, not limited to craters formed by explosions alone.

As Prof. F. Omori has pointed out, there is no record of volcanic symptoms in the present case, like falls of ash or exhalations of vapours at high temperature, which ought not to have escaped the attention of eye witnesses at the time of the disaster. It seems not to be doubted that meteoric water played an important rôle in the process of demolition in this case, as is common in all landslips. A table of the mean monthly rainfall at meteorological stations in the surrounding region shows a maximum in April. After the formation of numerous crevices, of which many reached the core of the mountain, a copious quantity or meteoric water must have found its way to the depths, while the whole surface on the flank and foot sloping to the shore was, during the same interval of time, made pretty wet, so as to have attained a degree of plasticity which prepared the ground for the gliding of detached masses in the next severe shock of 21st May. The transportation of a whole farm in Ue-no-baru speaks eloquently for a rather gentle movement of a portion of the foot-hill slope during the downfall of the main masses of torn mountain.

The collapse of Mae-yama and the tidal wave in Shimabara Bay as its consequence have their common cause in one of the landslips following severe shocks of earthquake, which loosened the mass of

the mountain and facilitated the circulation and percolation of meteoric water into its core.

(7) Subsequent eruptions, earthquakes and landslips. Although the collapse of Mae-yama constituted the climax to the whole course of events caused by the activity of Fugen-dake, we have details of the later behavior of the volcano recorded by vigilant reporters at Shimabara and Kojiro. It is evident from the documents that the volcanic eruption did not cease until some years after the catastrophe.

Two more eruptions took place from the top of Fugen-dake. The one on 19th July (1st June) was so violent that ash was reported to have fallen on Sembuki, and stones of considerable size are said to have been hurled up. The diameter of the new crater measured 70m. across, and was widened southward by the next eruption of 15th August (28th June). The roaring and shaking of the mountain are said to have been very violent. In the latter eruption, a prodigious quantity of smoke was also emitted from vents on Hachi-no-kubo and Anasako.

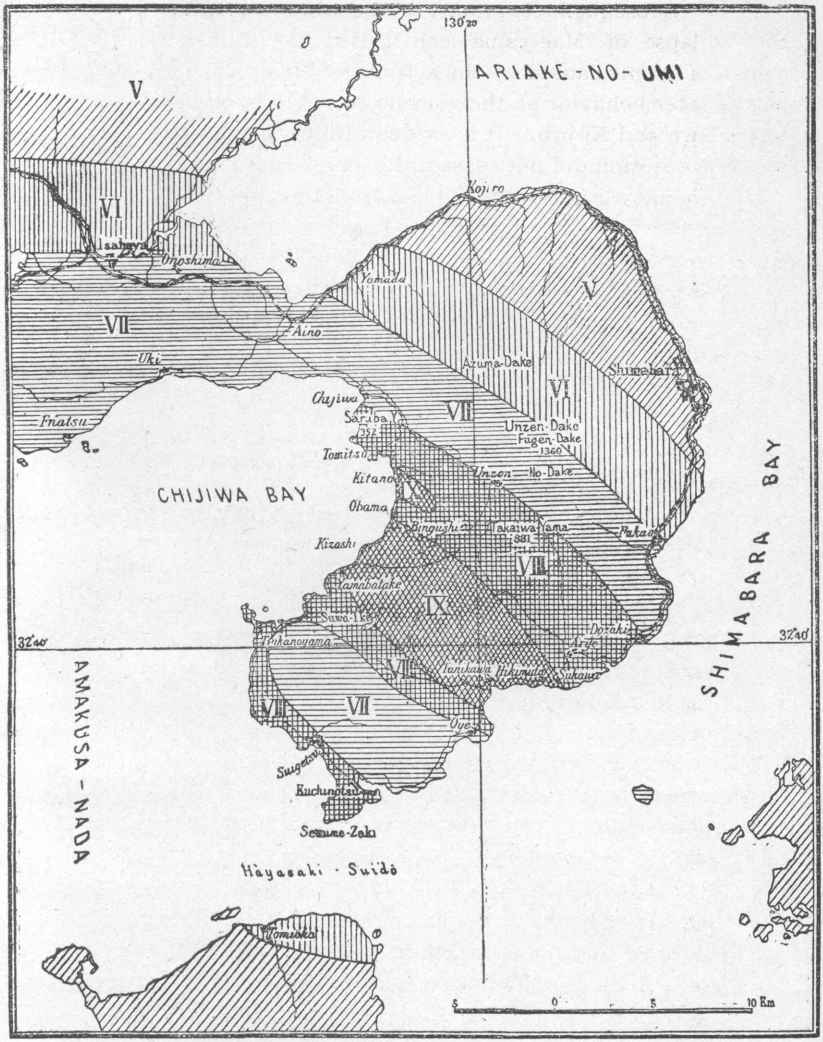
Accooding to the reports at Kojiro, the activity did not sensibly subside until September, and renewed its violence on 3rd February, 1793. The ashes accumulated so thickly near the top as to make it impracticable for officials sent on 24th March to approach the crater. The last report concerning the volcano, which is dated 8th April, states that the detonation of the mountain had not yet ceased.

Besides these records, T. Kanai mentions an eruption which is said to have taken place three or four years later. In "Odake-jigoku-monogatari", a work of doubtful authenticity, we find mentioned volcanic activity so late as 1799, in which year a violent eruption is said to have taken place between May and June. Two large craters opened on Odake (Fugen-dake), and mud and stones fell on Antoku and Koba. The lava-flow of Anasako had not come to a standstill at the end of August 1792, but it no longer menaced Shimabara.

The after-shocks of the earthquake of 21st May came to an end after ten days, and the detonations were reported to have ceased on 6th June. A shock, which occurred two days after, was not severe. Another on 27th June (9th May) seems to have been severer, for a crevice about one metre in width was produced on the southern slope of Mae-yama in the commune of Antoku, and the mountain itself was wholly shrouded in dust for some days.

Frequent shocks were further felt in Shimabara and Mie, during

Fig. 4.



Sketch map showing degrees of seismic intensity in the Shimabara Peninsula: V, pretty strong; VI, strong; VII, very strong; VIII, almost devastating; IX, devastating.

the violent eruption of 19th July. They did not cease for a fortnight. Another severe shock is said to have occurred on 1st August (15th July). On the afternoon of 31st January 1792, one more severe shock is recorded in the Kojiro report. Landslips of Mae-yama were several times mentioned during the whole interval up to the spring of 1793.

A retrospect of the volcanic and seismic phenomena which were manifested in the last eruption of Unzen in 1792, makes it evident that the activity had a character differing from that of eruptions of other Japanese volcanoes in the particular severity of the earthquakes in its whole course. This fact teaches us that the significance of earthquakes in the demolition and remodelling of a volcano in its later phase of activity is not to be overlooked. Question may indeed be raised about many so-called explosion craters shown as such in reports on Japanese volcanoes, in which traces of explosive avtivity are not clearly proved, provided seismicity is prevalent in the same phase in all of them as in Unzen.

IV. THE EARTHQUAKE OF 8TH DECEMBER 1922

The district had been comparatively free from subterranean disturbances for more than a century since the great volcanic activity of 1792, when in December 1922, occurred an earthquake shock of a grave character, almost equal in magnitude to that of Kumamoto in 1889. Of local shocks previous to this, that in 1909 was the only noteworthy one. The earthquake occurred early in the morning on 16th August, and was accompanied by 17 detonations in 24 hours. As two of them concurred with particularly sevère shocks, a panic among visiting foreigners resulted, but had no serious consequences.

The earthquake of December 1922 had also its precursors, of which one occurred one and a half months before, on 23rd October, and the other immediately before, on the afternoon of the 7th. The main shock, which caused considerable damage and loss of life in the peninsula, occurred at $1^h\ 50^m$ a.m., about 9½ hours after, several minor shocks occurring in the intervening time. Of after-shocks, a very strong one which occurred 5 minutes later, and another at $11^h\ 2^m$ were especially noteworthy.

The total number of macroseisms felt at Nagasaki was 110 and that of microseisms or tremors 1,798 up to 13th January. The maximum intensity of the principal shock seems to have attained in detached areas the IX grade ("devastating") in Mercalli-Sieberg's

scale, while most of the severely shaken region lay between the VII and VIII grades ("very strong" and "almost devastating").

As first pointed out by Professors T. Shida, M. Matsuyama and S. Sato in 1917 and 1918, the determination of the direction of the first motion of the preliminary tremor in a seismogram furnishes a valuable datum for the location of the centre and the determination of the nature of an earthquake. In a fracture-earthquake, the direction of the initial motion is found to be opposite in stations in alternate quadrants around an epicentrum, i. e. two opposite quadrants with the motion directed to, and the other two away from, the epicentrum. In a depression-earthquake, the motion is directed to the epicentrum in all stations in the immediate vicinity and beyond a nodal circle is directed away from it.

The following are Professor Saemontaro Nakamura's results obtained by the inspection of horizontal components:—

Nagasaki	8.8 (S)	64.8 (E)
Kumamoto	1.5 (S)	3.2 (W)
Kagoshima . . .	23.0 (S)	3.3 (E)
Miyazaki	5.5 (S)	10.5 (E)
Shimonoseki . . .	5.0 (S)	3.2 (E)
Oita	1.7 (S)	1.2 (W)

We find the direction of motion manifested in these records to be sufficiently consistent in pointing to the position of the epicentrum, except in the case of Oita, which markedly deviates from it. Moreover, it is directed toward the epicentrum in Nagasaki, Kumamoto and Oita, while it is away from the epicentrum in other stations. The initial motion is therefore that of a fracture earthquake. Professor Saemontaro Nakamura gives the following figures in seconds on the duration of the preliminary tremor:—

Nagasaki	2.9	Oita	17.8
Kumamoto . . .	7.7	Miyazaki	17.9
Fukuoka	12.0	Kagoshima . . .	17.0
Shimonoseki . .	19.4		

He calculated from these figures the distance from the stations of observation in two ways, the results of the first of which, calculated according to Professor F. Omori's formula, are:—

Distance from		Distance from	
Nagasaki	21.5 km.	Oita	132 km.
Kumamoto . . .	57.1	Miyazaki . . .	133
Fukuoka	89	Kagoshima . .	126
Shimonoseki . .	144		

To sum up the results obtained by Professor Saemontaro Nakamura, the earthquake was evidently of tectonic origin, and its epicentrum lay in Chijiwa-nada, some kilometres off the northwestern coast of southwestern Shimabara. As to the second and greater shock of $11^h\ 2^m$ p.m., its epicentrum was most probably located northward from that of the main shock of $1^h\ 50^m$ a.m.

We owe to Professor M. Matsuyama the interesting piece of information that in Kumamoto the initial motion of the second great shock was directed eastward in opposition to the first. This was ascertained also by Professor T. Shida on inspecting the seismogram of Kumamoto. The fact points to the second shock most probably being of a different nature from the first, for we see here the existence of a nodal circle having a diameter greater than the distance of Nagasaki from the epicentrum but smaller than that of Kumamoto from the same. It may be inferred that the second shock was a depression-earthquake.

This is a significant fact, giving an insight into the mechanism of the subsidence of the land in the zone of the Inland Sea and its continuations on the west and east. This fact is not limited to being a key for the interpretation of the formation in the surrounding sea floors of the peninsula only, but may be extended to the case of the whole region lying between the block mountains of the outer and inner zones of Southwest Japan. The process is evidently the formation, in the first place, of a fracture, naturally followed by the falling of blocks thus torn asunder. In the present instance, a landslide seems to have occurred on the north of the block forming the southwestern Pliocene plateau of the peninsula, subsequent to the formation of a fracture on its northeastern periphery.

The magnitude of the earthquake may be imagined from the following newspaper reports. In Nagasaki the main shock of $1^h\ 50^m$ a.m. was accompanied by a detonation and was so severe that many people fled from their houses in dismay. Several cases of small damage were reported in the city. At Isahaya, the plaster in the corners of the walls of most of the dwellings was cracked. At Onoshima, a village situated in a low alluvial plain, the damage was much more serious, for a dwelling wholly collapsed and another was partly damaged. The level of ground-water in the same village was disturbed by the shock for a week.

In the northern part of the peninsula, Aino-mura suffered most

severely, with one dwelling and 8 sheds knocked down, and at Yamada-mura, 4 sheds fell; but all the north and northeastern coastal villages from Moriyama to Fukae were exempt from devastation by the earthquake.

The limits of the violent shock in the peninsula are approximately conceivable from a report that the telegraphic lines were broken in the south of Ainotsu on the west and at Dōzaki on the east. Within these limits, the shocks at Chijiwa, Futsu, Fukae, Dōzaki and Kuchinotsu were of about the same degree of intensity. Disastrous effects are more strikingly manifest on the southeast from Higashiariie southwestward. But even here the sites of devastation are limited to particularly treacherous alluvial ground on stream beds. Most of the habitations lie on the margin of a plateau with substrata of volcanic accumulation or Pliocene tuffaceous sandstone, and there are desultory villages on an abraded platform of the same. The comparatively small number of buildings destroyed is therefore partly due to firmness of foundation and does not indicate that the shocks were of a lesser grade of intensity than those which ravaged regions of flat lands composed of paddy fields, as at Mino-Owari in 1891 or Northern Omi in 1909.

Among the effects of shocks on the surface, the visible fractures which revealed seismotectonic lines are the most important. Many examples have been reported in most of the great earthquakes which have occurred in the last fifty years in Japan.

From a survey of the facts, we may infer that the earthquake of 8th December was most intense on the northeastern periphery of the southwestern plateau, and the epicentral axis of the Kisashi-Tanikawa line may approximately represent the lie of the emergences of the subterranean convulsion. We may also presume that the adjoining northwestern and western peripheries were simultaneously affected by the same shocks, and seismotectonic lines parallel to the axis and on the northwest of it were equally intensely shaken by them, especially to the north of Obama.

The inferences obtained from the earthquake lead us to consider once more the catastrophe of 1792, in order to grasp the significance of seismicity as a factor of volcanic activity. The important rôle played by earthquakes before and during the paroxysmal outburst of a volcano was recognized in the case of the eruption of Vesuvius in 63 A.D. and again in the case of Sakura-jima in 1914. But it was not

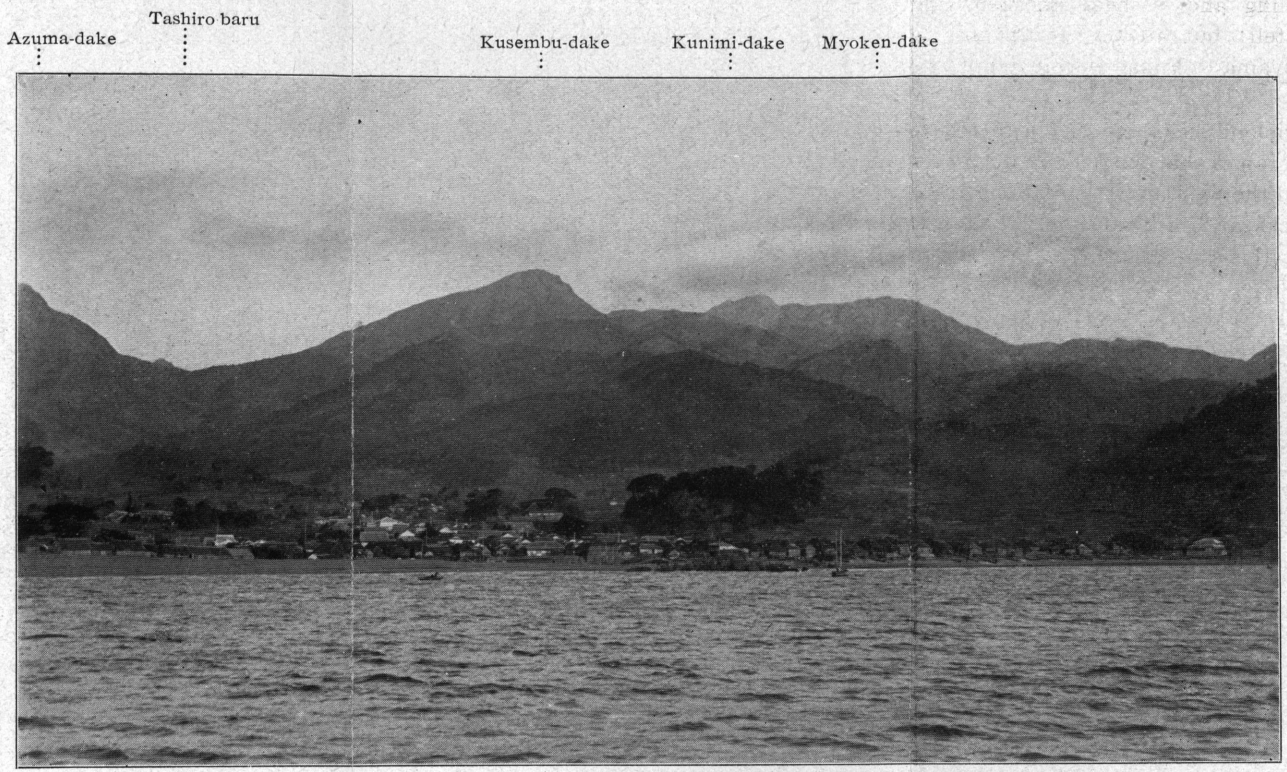


Fig. 5. Unzen Volcanoes observed from Chijiwa Nada.

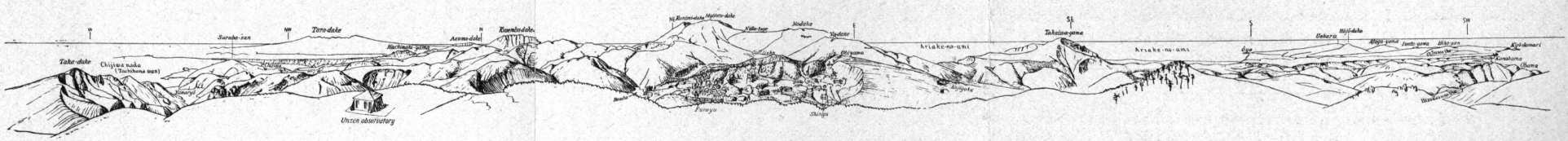


Fig. 6. Panorama of Shimabara Peninsula from Kinugasa-yama.

so recognized in the case of Unzen. The first precursory shocks felt in the winter of 1791 were most probably localized on the periphery of the Pliocene plateau, where those of 8th December, 1922, occurred. The coincidence suggests that those of 1791 were also due to a fracture, which originated in the substrata of the plateau. The substrata are nothing but a consolidated reservoir of basaltic magma, from which a more acid andesitic magma separated and was subsequently extruded further northeastward to form Unzen-dake. The precursory shocks may be looked upon as a manifestation of a released orogenic strain upon the upper portion of a magmatic reservoir which was in a state of almost complete crystallization. In other places further northeast, where the substrata were in a less degree of crystallinity, and contained a greater amount of residual magma, the same strain could not be manifested as purely seismic activity, but the pressure, being of a more or less hydrostatic nature, necessarily induced a disturbance in the magma. This view, which we may safely accept as a postulate from Bowen's researches on the differentiation of magma in its later stage of evolution, furnishes in the present case a key for a plausible interpretation of precursory shocks which are fracture earthquakes by nature, but which merge insensibly into purely volcanic or magmatic earthquakes in concurrence with outbursts of a volcano in its later phase.

The seismicity of the volcanic district of which we saw so much in the foregoing pages, evidently indicates that the present state of the activity is connected with a declining phase in the solidification of the magmatic reservoir, so that the earthquakes are losing their volcanic character even in the youngest centre of activity in Fugen-dake and the volcanic activity is approaching what can be best metaphorized as unsuccessful attempts at eruption (*veri tentativi falliti eruzione*). The earthquakes felt in the volcanic district in 1909 and 1922 are undoubtedly of the latter category, though we cannot say whether or not such convulsions may induce more serious consequences in the future.

V. A GUIDE TO THE UNZEN VOLCANOES

(1) The topography of the Unzen Volcanoes as observed at Chijiwa

Toward the northern part of Chijiwa, we find a characteristic topography which gradually rises from west to east, and on the south side, is abruptly cut in a distinct fault-scarp of the same trend. At the eastern end of this elevation are Hachimaki-yama (638 m.) and

Azuma-dake (860 m.) with craters on their summits. They were formed as adventive cones, before the dislocation.

Toward the eastern part of Chijiwa, we find a mountain mass of a far more complicated topography. The land, marked by numerous cones, gradually increases in altitude southeastward, forming the highest peaks of the Unzen Volcanoes in the cases of Kunimi-dake (north peak) and Myōken-dake (south peak). Kusembu-dake (1,162 m.) is another lofty steep peak towering five kilometers to the east of Chijiwa and Saruba-yama (392 m.) is found isolated from the mass to the south of this village. It is interesting to find here the highroad from Chijiwa to Obama, running along a gorge which does not coincide with the intermontane valley, but follows a line of more recent dislocation.

(2) Obama Hot Springs

About 7 km. south of Chijiwa, we find the Obama Hot Springs, gushing out where numerous saline springs, of which a few have their source at the sea-bottom. Many hotels, provided with accommodations for Japanese or foreigners, are built on a high stone embankment along the seashore. The source of the hot springs seems to be partially derived from the sea-water, while the heat is supplied by the emanation of hot vapour due to the post-volcanic activity of the hypersthene-hornblende-andesite of the Kinugasa Volcano.

The results of chemical analyses of the springs are given in the following table:—

Analyses of Obama Hot Springs
(Grams of 1 kilogram of mineral water)

Hot springs	Fukiage-yu	Meiji-yu	Hon-yu
Specific gravity	1.0065	1.0055	1.0055
Temperature	65°C.	59°C.	68°C.
Total residue	Ca. 8.84	Ca. 6.77	Ca. 6.80
KCl	0.3985	0.6029	0.4355
NaCl	5.4326	4.0030	4.0145
$CaCl_2$	1.2578	1.0046	1.0820
$MgCl_2$	0.9097	0.6029	0.6603
$CaSO_4$	0.4699	0.3769	0.2584
Fe_2O_3-Al_2O_3	0.0055	0.2623	0.0080
SiO_2	0.2200	0.2950	0.2400
NH_3	tr.	tr.	—
P_2O_5	tr.	—	tr.
Total	8.6940	7.1476	6.6987

(3) View at Kagotateba

About halfway from Obama to Unzen, there stands a tea-house commanding a splendid view. This place is called Kagotateba, because in the olden days bearers of *kago* (a kind of sedan chair) used to rest here. The road has been constructed on the basal agglomerate of the Kinugasa Volcano from Obama to Kagotateba, but from this place to Shinyu it passes over the flanks of lava domes, erupted on the agglomerate.

(4) Summit of Kinugasa-yama

On the summit of Kinugasa-yama, there is a meteorological observatory which is under the control of Nagasaki Prefecture and is provided with Omori's simple seismograph, barometers and anemometers. From the top of the observatory tower, we may enjoy a fine panoramic view as shown in the accompanying illustration.

Eastern View :—The "Jigoku", famous in Unzen since Kaempfer's time, emit sulphurous steam from numerous vents grouped in bleached craterlets. They constitute a post-volcanic activity of Obi-yama, which was opened in the form of a flat dome at the western foot of Ya-dake or the eastern foot of Kinugasa-yama. For a detailed description, reference may be made to the paragraph entitled "The Jigoku fumaroles".

Southern View :—The peak of Takaiwa-yama (880 m.), with a horseshoe-shaped crater at the west flank, stands on the gentle westerly slope of Ho-baru, of which the east side is steeply cut by a fault running from south to north, and from the northwest foot of this peak a remarkable tectonic valley runs to Kanahama, forming a beautiful curve with the convex side towards the south, bounding the northern limit of the extensive platform of agglomerate of the Kinugasa Volcano. The northern area of this valley, occupied by many adventive cones, shows a wavy aspect of young topography; while beyond the platform of agglomerate, we find a different topography extending through the southern half of the peninsula, where are found Tertiary formations, and old basic effusive rocks.

Western View :—A pond called Hirokawara-Ike, situated at the southwesten foot of Kinugasa-yama, has been artificially constructed

in the depression of an explosion on crater with a bank on one side, and another large explosion crater, opening toward Yamaryo, is seen on the west flank of Kinugasa-yama. The southern wall of this crater coincides with the fault-scarp formed between Kinugasa-yama and Yamaryo.

Northern View :—Thanks to the more or less flat ridges remaining on the limbs of the Kusembu mountain mass, we may restore in imagination its original undulatory topography, though it has been highly dissected by subsequent erosion, aided by volcanic explosions. The undulation of this mountain-mass was produced by the overlapping of numerous lava cones on the basement of the agglomerate of the Kusembu Volcanoes. Behind Kusembu-dake, there rise the peaks of Azuma-dake and Hachimaki-yama with horizontal bands caused by sheets of lava flow, and in the far distance, the dissected cone of the Tara Volcanoes.

Towards the northeast the beautiful young cones of Kunimi-dake, Myōken-dake and No-dake are seen standing near the base of the Kusembu Volcanoes, marking the highest part of the peninsula.

(5) The Jigoku Fumaroles

In its gigantic explosion crater, the recently erupted flat dome of Obi-yama preserves its post-volcanic activity and emits acid sulphurous steam and hot springs from numerous vents, which are called " Jigoku " by the Japanese. The vents of the fumarole group themselves in craterlets, arranged in a north-northwesterly direction, along three parallel lines, of which the eastern is the most active. Their distribution is given in the accompanying map. Near the fumaroles and hot springs, siliceous sinters and sulphur deposits are found and there are also two little mud cones at Shinyu. The resort of the Unzen hot springs consists of three groups, namely, Furuyu (the old not springs) Shinyu (the new hot springs) and Kojigoku (small hell). Among them, Shinyu, situated at the centre of the resort, is well provided with accommodations for foreigners. The nature of these copious hot springs is acidic and transparent with a moderate temperature. Analyses of the hot springs are given in the following table :

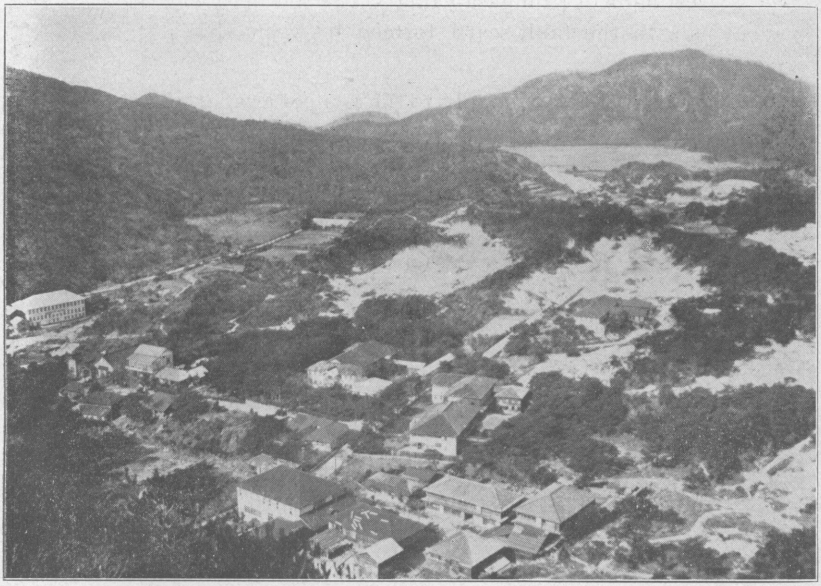


Fig. 7. Unzen Hot-Spring.

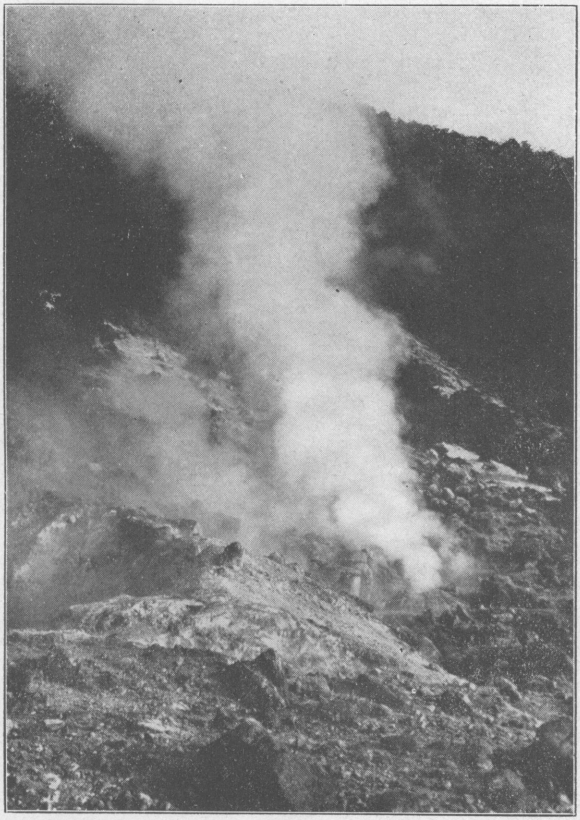
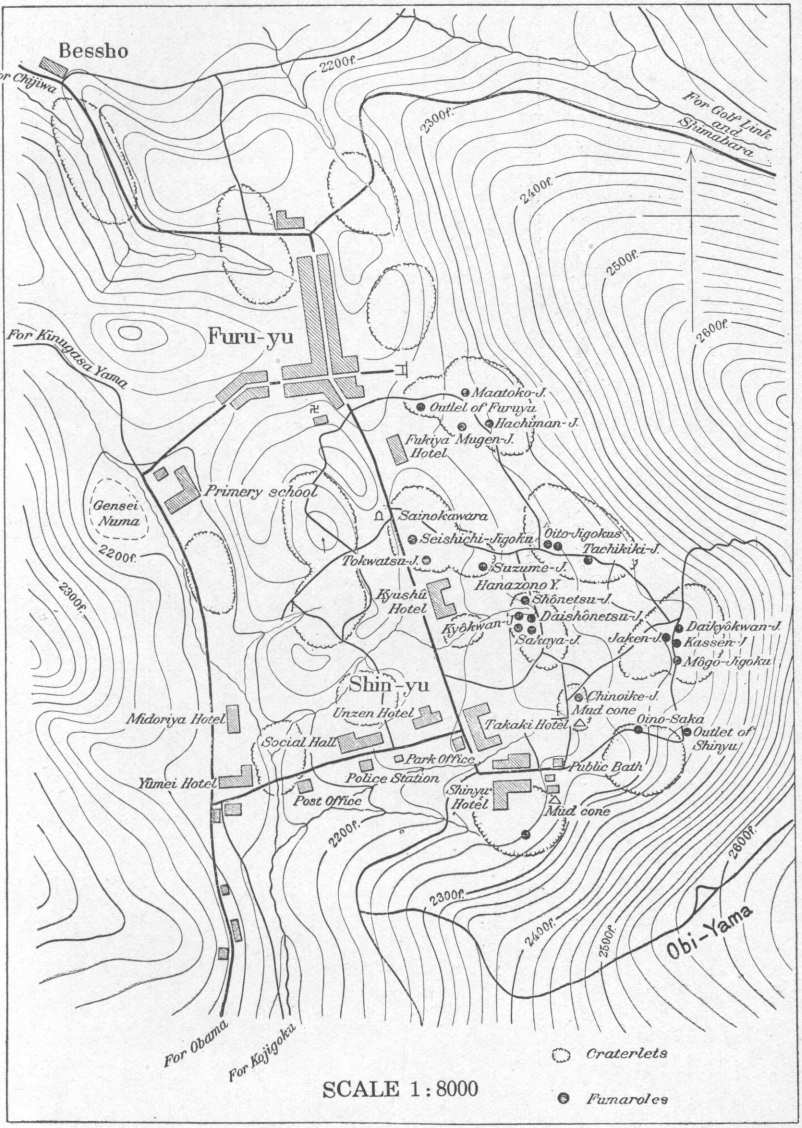


Fig. 8. Oyafuko Jigoku.

UNZEN HOT-SPRINGS. Fig. 9.



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Analyses of Unzen Hot Springs
(Grams in 1 kilogram of mineral water)

Hot spring	Enryakuyu	Nomiyu	Motoyu	Jaken-jigoku	Kojigoku
Temperature	74°C	61°C	42°C	56°C	84°C
Specific gravity	1.0017	1.0001	1.0005	1.0005	1.0007
Property	Strongly acidic	Acidic	Acidic	Weakly acidic	Weakly acidic
Total residue	1.1980	0.4490	0.3626	0.3590	0.3720
SH_2	0.0035	0.0012	0.0041	—	—
K_2SO_4	0.0172	0.0153	0.0131	0.0153	0.0183
Na_2SO_4	0.0613	0.0450	0.0489	0.0572	0.0917
$Al_2(SO_4)_3$	0.3986	—	—	0.0281	—
$CaSO_4$	0.0656	0.0946	0.0627	0.0727	0.0729
$FeSO_4$	0.2539	—	tr.	0.0149	—
$MgSO_4$	0.0516	0.0362	—	tr.	tr.
$Fe_2O_3+3AI_2O_3$	—	0.0220	0.0140	—	0.0150
$NaHSO_4$	0.0054	—	—	—	—
SiO_2	0.2450	0.1400	0.1070	0.1120	0.0920
SO_3	1.2887	0.1860	0.3817	0.1176	0.0735
HCI	tr.	tr.	tr.	tr.	tr.
P_2O_5	tr.	tr.	tr.	tr.	tr.
MH_3	tr.	tr.	tr.	tr.	tr.

Due to its altitude and its nearness to the sea, the temperature of Unzen even in midsummer is cooler than that at some of the resorts far to the north, and everything considered, Unzen is one of the most delightful hot spring resorts in all Japan.

(6) Golf Links

At two kilometers' distance from Shinyu, golf links have been constructed on the foot of Mt. Myōken. The links are bounded on the south by an easterly fault line, which was formed prior to the eruption of No-dake in an older volcano underlying No-dake and Ya-dake

The scenery about the golf links is of unfailing interest to visitors. Among the glories of Unzen, are the splendid azaleas which

bloom in May, the brilliant foliage of the maples in autumn, and in winter the celebrated "Silver Thaw," when the trees and shrubbery become coated with ice.

(7) Nida Pass

Situated about one kilometer above the golf links, Nida pass commands an extensive view of great beauty. The valley which runs east starting from the pass is called Akamatsu-dani. The south bank of the valley consists of a steep cliff of one hundred or more metres in height, formed by a fault in the direction of the east, while the north bank rises rather gently to the summit of Fugen-dake, plainly indicating that the eruption of Fugen-dake was later than the formation of the fault.

(8) Fugen-dake

An abstract of the historical records of the volcanic actions of Fugen-dake follows :

1657 A. D. (3rd Year of Meireki). The Furu-yake, or "Old lava flow", was effused from a spot between Emaru and Hando-Iwa.

1663, December 27th (3rd Year of Kwambun). An eruption of Kujūkushima on Fugen-dake began on this day and ended on the 29th. It was accompanied by a heavy rain.

1792, February 10th (4th Year of Kwansei). An eruption of Jigokuato on Fugen-dake took place at midnight.

1792, February 25th. A trembling of Anasako-dani.

1792, February 27th. An eruption of Anasako-dani.

1792, March 1st. The *Shin-yake*, or "New lava flow", was effused from the site of the eruption of Anasako-dani on 27th, February.

1792, March 21st. An eruption of Hachino-kubo.

1792, March 25th. An eruption at a spot 500 m. west of Hachino-kubo.

1792, April 21st. A severe earthquake from 3 P. M., 21st. to 6 A. M., 22 nd.

1792, April 29th. A great landslip at Nakakoba village.

1792, May 21 st. A severe earthquake and the tremendous landslip of Mae-yama took place, causing the disastrous tidal wave around the shore of Ariake Bay.

The new lava crept down at the rate of about 40 metres a day,

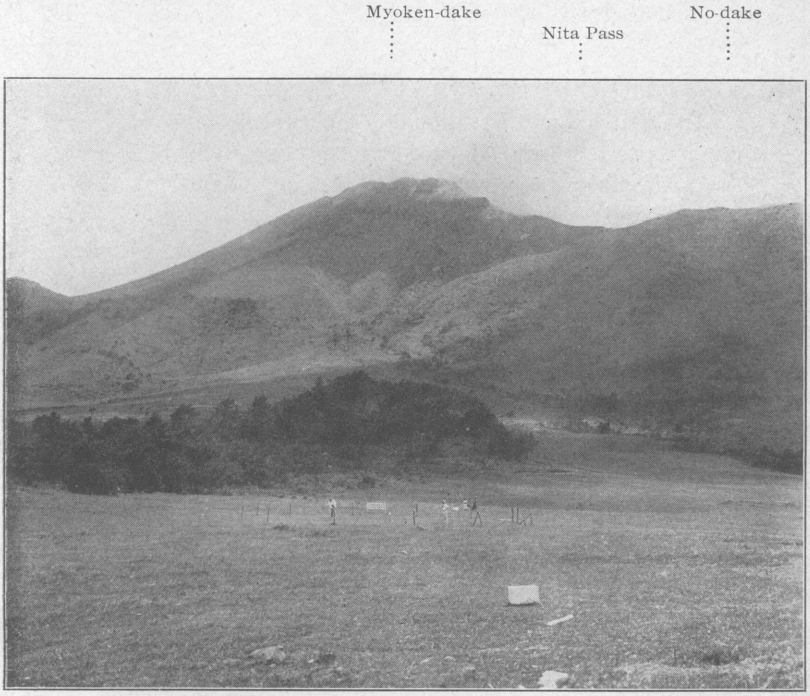
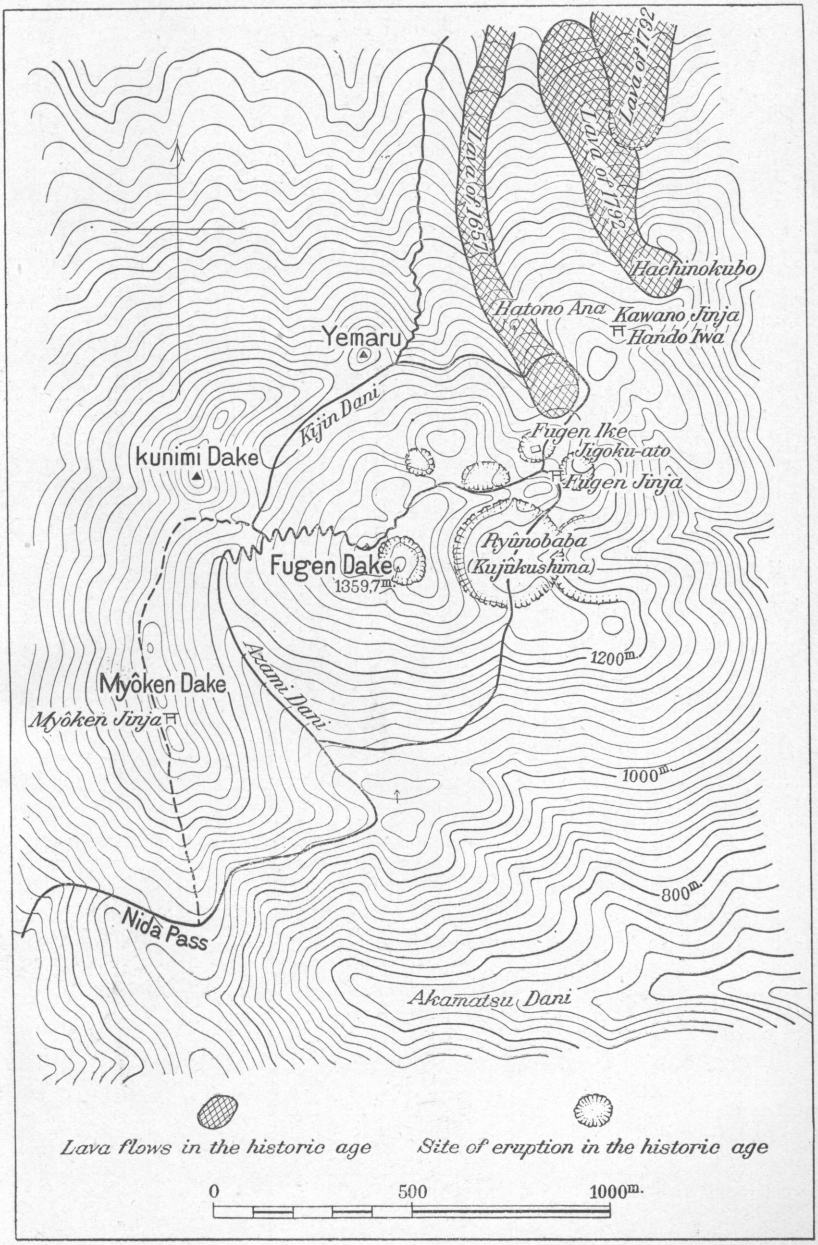


Fig. 10. Southwestern Foot of Myoken-dake with the Golf Links.

FUGEN-DAKE. Fig. 11.



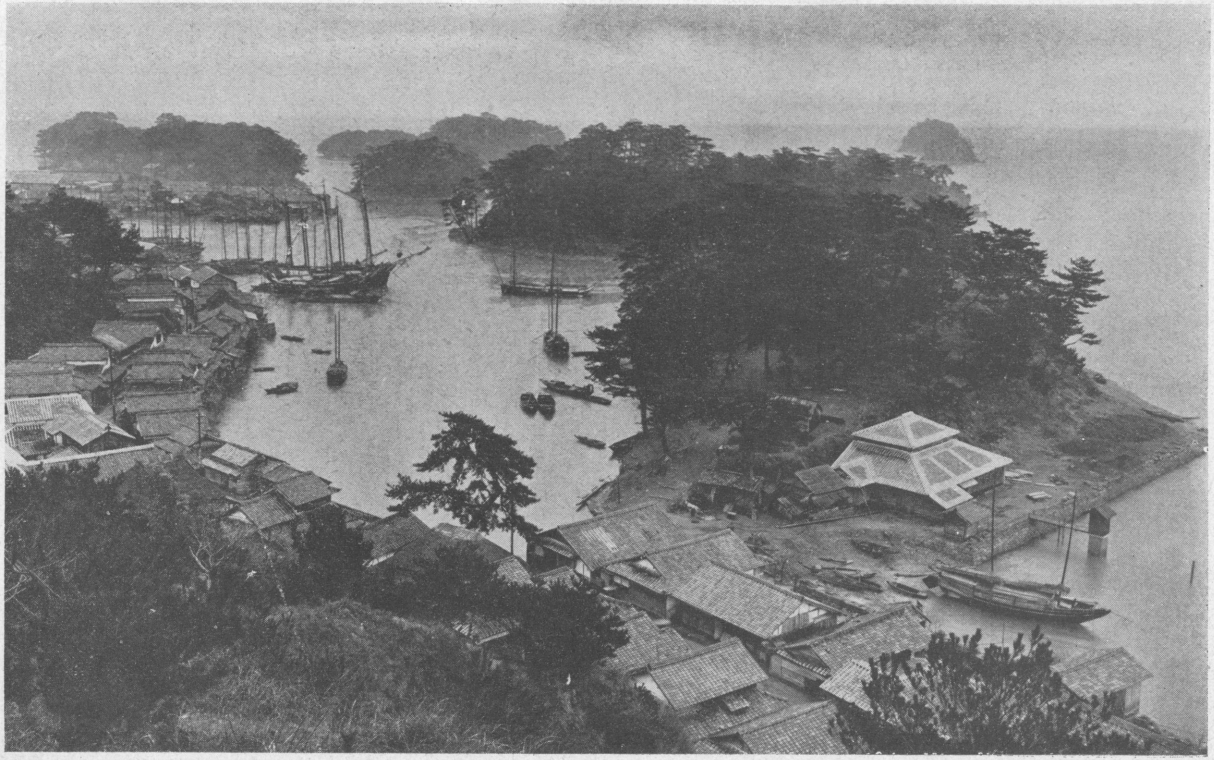


Fig. 12. Kujūku-shima in the Harbour of Shimabara.

judging from the fact that it took 60 days to reach Sembuki (2,320 m. distant from the crater).

The sites of the historical eruptions are indicated in the accompanying map.

The highest point of Mt. Fugen is called Sokuryo-Dai (1,359.7 m.).

A pond called Fugen-Ike, a small crater lake, is situated to the north of Sokuryo-Dai. Its outline has been artificially modified. The Hatono-Ana, or "Pigeon holes," were formed by the partial collapse of the lava tunnel of Furu-yake.

(9) Tawaraishi on the Extensive Block of Mud Flow underlying No-dake

After traversing the narrow pass between No-dake and Ya-dake, we go down the gentle slope of mud flow, on which No-dake is situated. This platform, consisting of mud flow, becomes wider as we approach the foot. Near Tawaraishi, at the lower flank of this gentle slope, we may, for the first time, enjoy a fine view of Ariake Sea and the eastern foot of the Unzen Volcanoes, where extends a wide plain with a dense population. At the eastern foot of Mt. No-dake, we find two distinct horseshoe-shaped depressions, formed by explosions. Farther northward, a well-formed parasitic cone is also seen, on the southeastern foot of Fugen-dake and the north side of Akamatsu-dani; and then to the east of Fugen-dake, Mae-yama, which played the principal rôle in the appalling catastrophe of Shimabara in the 4th Year of Kwansei (1792), comes into view.

(10) Shin-minato

We find here Mae-yama towards the east. The highly serrated ridge and sheer wall speak vividly of the tremendous event which took place in the 4th year of Kwansei. The volume of materials removed by the great landslip has been estimated as about 0.5 cubic km. by Mr. I. Komada, and the height of the mountain is recorded to have decreased by 150 m. When the materials were carried to the sea, tremendous waves resulted near the shore of Ariake Sea, and fifteen thousand inhabitants were killed. The Kujū-kushima, or "Ninety-nine Islets," in the harbour of Shimabara are relics of this disaster.

(11) Sembuki.

The *Shin-yake*, or "New lava," crept down to Sembuki two months after its effusion, filling a deep valley called Anasako-dani. The outlet of the eruption can hardly be seen from Sembuki, where the terminus of the lava flow forms about a wall. We can here see at the south of the lava flow, a beautiful hemispheroidal dome, formed as a basal parasitic cone of Fugen-dake. To the southeast of this dome, and to the west of Mae-yama, there is a loose pile of blocks and mud with a flat summit, called Itazoko, which was produced by an explosion earlier than the formation of Fugen-dake, but later than that of Mae-yama.

BOTANICAL NOTES ON UNZEN PARK AND SHIMABARA PENINSULA

By Kwan Koriba and Zentaro Tashiro

Unzen Park, situated in the middle of Shimabara Peninsula, is a well-known hot spring resort, especially famous in spring for its wild azalea flowers. It lies at an elevation of over 700 m., on a volcanic plateau amid a number of peake bearing the common name, Unzen-dake, and varying from 770 to 1,360 m. in height.

Unzen is also a popular summer resort, as it is fairly cool in the hot season, in contrast to Nagasaki or Kumamoto. The mean range of temperature in August is 18.5°-27.7° C ; but in winter, in spite of its high altitude, it is never very cold. The mean range in January is −1.9°-5.7° C.

The annual rainfall is about 2,300 mm., one-third or more of which is precipitated in early summer—the rainy season in Southern Japan. The air is tolerably humid in that season (92%). In October and November, however, fine weather lasts for many days, and the foliage of various deciduous trees exhibits beautiful autumn tints. The relative humidity is lowest from February to April (78%).

Phytogeographically speaking, the peninsula is situated in the zone of the warm-temperate evergreen forests. It has still, however, a vertical extension of temperate deciduous forests. The flora naturally varies in these different climatic regions ; its is affected also by the occurrence of fumaroles, lava beds, bogs, sea-coast, etc. The

present state of the vegetation has, however, been caused to a greater degree by biotic factors.

In this region are found about 1,200 species of flowering plants and ferns, including 250 woody plants, of which about 100 are evergreens. Though there is no species endemic to the peninsula, yet the flora has some peculiarities in regard to distribution. For instance, *Rubus Lambertianus* subsp. *xanthonerius*, indigenous to Formosa, is found on the eastern slope of Mt. Mae-yama. The occurrence of this species in such an isolated spot so far north is undoubtedly due to the activity of birds. *Evonymus Chibai* and *Ipomaea congesta* have also their northern limit here, while *Iris albopurpurea* has here its southern limit. A red fresh-water alga, *Thorea ramossisima*, also occurs in two rivers in the northern part of the peninsula. The locality is now set apart as a natural preserve. Let us now observe the vegetation a little more in detail.

COASTS

Along the seashore, besides such common strand plants as *Carex pumila*, *Vitex trifoliata* var. *ovata*, and *Wedelia prostrata*, southern elements are plentiful, such as *Ipomaea congesta*, *Eurya emarginata*, *Angelica kiusiana*, *Euphorbia Jorkini* and *Cladium mariscus*. On the southern part of the coast occur also *Turpinia ternata*, *Ardisia Sieboldi*, *Rapanea neriifolia* and other subtropical elements. At Hayazaki, in the southern end of the peninsula, a wood of *Ficus Wightiana* can even be seen. The genial influence of the sea-climate in winter is clearly recognisable.

PLAIN

The plain is for the most part a gentle slope of the mountain and represents the most highly cultivated area of the peninsula. The broad-leaved evergreen forest, which must have existed here originally, are now extremely rare, except on steep slopes or in shrine grounds, where they remain in a seminatural condition mixed with some deciduous trees.

Well-developed woods are to be seen at Obama on the western coast, and at Isahaya, 10 km. west of the neck of the peninsula. *Cinnamomum Camphor*, *Pasania cuspidata* and *Quercus gilba* are found there in luxuriant growth. *Machilus*, *Actinodaphne*, *Tetradenia* and some other trees of Lauraceae, Fagaceae, Aquifoliaceae, Theaceae,

Rosaceae, etc. are also abundant. Among the deciduous kinds occur frequently *Aphanantha aspera*, *Celtia sinensis* var. *japonica*, *Premna microphylla*, *Evodia glauca*, *Ficus erecta*, *Schoefia jasmonodora*, and *Rhus succedanea*. There are also a number of lianas, such as *Ficus pumila*, *Piper Futokadsura*, *Trachelospermum divaricatum*, *Lonicera affinis*, *Herrya augus- tiniana* f. *liukiuensis* and others. *Loranthus Yadoriki* is also found parasitic on *Pasania*, *Quercus* and others. Among the shrubs composing the undergrowth are *Viburnum japonicum*, *Fatsia japonica*, *Gardenia florida* var. *grandiflora*, *Rubus Sieboldi*, *Maesa Doraena*, *Damnacanthus indicus* var. *genuinus*, and *Ardisia villosa*; and among herbs and ferns., occur *Polygonum chinense* var. *Thunbergianum*, *Desmodium Tashiroi*, *Arisaema ringens*, *Liriope gracilis*, *Polypodium ellipticum* var. *pothifolium*, *Matteuccia strigosa*, *M. marginata*, *Polystichum aristatum*, *Pteridium semipinnata* var. *dispar* and others. Here and there are also woods compsed of black pines (*Pinus Thunbergii*) and some deciduous trees such as *Alnus*, *Malotus*, etc. They represent an area once cleared and should be replaced later by such climax dominants as *Pasania*, *Quercus*, etc.

As the plain is almost all under the plough, it may be worth while to note in passing some of the plants cultivated. Such cereals as rice, wheat, barley and Italian millet, and such vegetables as the soja-bean and other beans, sweet potatoes, radishes, watermelons, squashes, cucumbers, rakkyo-onions and eggplants are widely cultivated. Of the fruit trees, mention may be made of the Satsuma-orange, the *natsu-daidai* and other varieties of *Citrus*, *biwa* (*Eriobotrya*), *kaki* or Japanese persimmon, pear, peach, prune, *mume* or Japanese plum and grapes. Tea, mulberry, bamboo-bushes and tallow-rhus trees (*Rhussuccedanea*) also occur frequently. As for timber, *sugi* (*Cryptomeria*), *hinoki* (*Chamaecyparis obtusa*) and pines are exclusively planted.

UNZEN PARK

The park is situated on a plateau formed by an eruption in prehistoric times. There are, besides the hot-spring resorts, numerous fumaroles and solfataras, wet marshes, ponds, pastures and woods. The vegetation in general represents an intermediate stage between the evergreen lowlands and the deciduous high ranges. Woods of red pines (*Pinus densiflora*) and alder (*Alnus firma*), thickets of *inutsuge* (*Ilex crenata* var. *typica* f. *genuina*) and *sasa* (*Arundinaria*

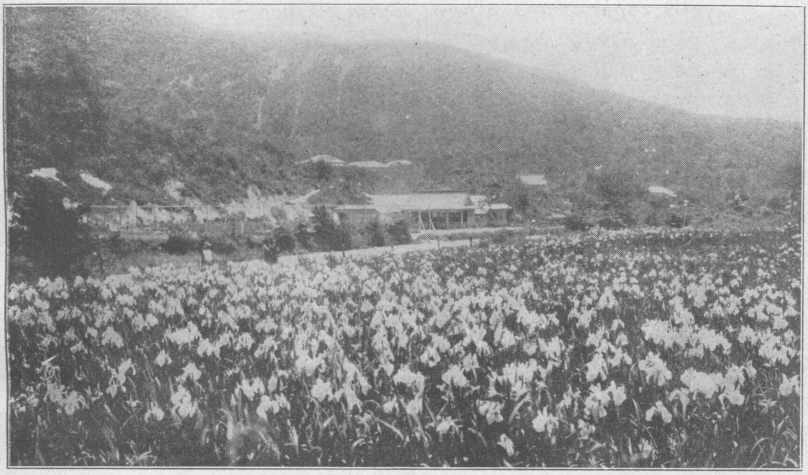


Fig. 13. Iris in Gensei-numa.

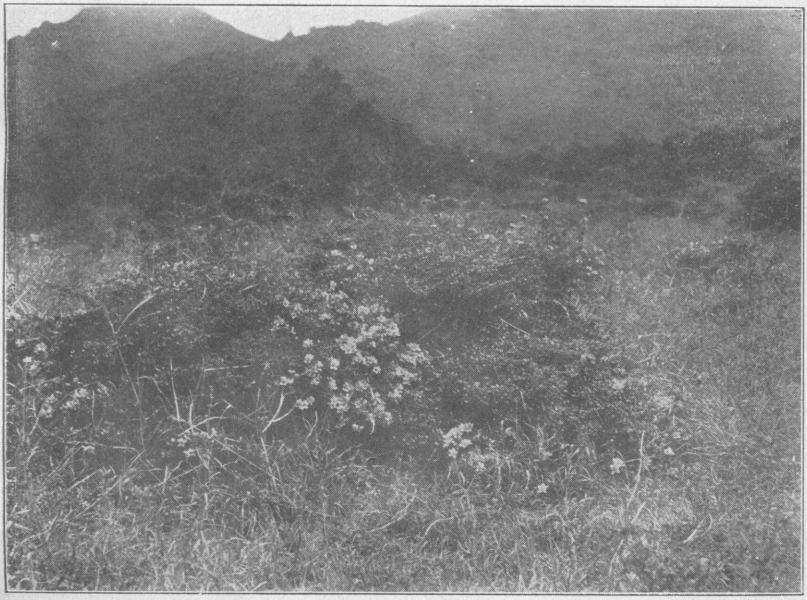


Fig. 14. Azaleas on Nita Slope.

Simoni var. *Chino*) are widespread. Among trees and shrubs to be noted here, are *Ilex pedunculosa* and *I. integra*, *Symplocos lucida*, *Eurya japonica*, *Illicium anisatum*, *Quercus acuta*, *Ternstroemia japonica*, *Cinnamomum pedunculatum*, *Viburnum japonicum*, *Elaeagnus pungens*, *Pieris elliptica*, *Enkyanthus Meisteria*, etc. Along the slope of the valley leading upwards from Bessho, there is a wood in nearly its natural state. As the conditions are very favourable there, evergreens predominate over the deciduous trees, though fewer species occur. Of the former, may be mentioned *Quercus acuta*, *Q. stenophylla*, *Skimmia japonica*, *Cinnamomum pedunculatum*, *Camellia japonica* var. *spontanea*, *C. sasanqua*, *Eurya japonica*, and *Symplocos myrtacea*; and of the deciduous trees, *Carpinus carpinoides*, *C. yedoensis*, *Sapium japonicum*, *Ilex dubia* var. *macropoda*, three species of *Acer*, *Kalopanax innovans*, *Cornus brachypoda*, *C. consa*, *Clethra barbinervis*, *Pieris elliptica*, *Styrax japonicum*, *Premna microphylla* and others.

Most worthy of notice here is first, the vegetation around the fumaroles, and secondly, that of a certain bog. *Fimbristyris ferruginea*, which we have seen already at Beppu, is found growing luxuriantly even at this high altitude nearest the fumaroles, especially in wet areas. *Cladonia* sp., *Pinus densiflora* and *Rhododendron kiusianum* also represent pioneers, which are replaced gradually by *Vaccinium bracteatum*, *V. ciliatum*, *Enkyanthus Meisteria* var. *rubens* and var. *typica*, *Pieris elliptica*, *Illicium anisatum* and *Abelia serrata*.

The occurrence of a sphagnum bog in this district is rather surprising, and is made the more interesting by the fact that in it are growing such charming plants as *Iris albopurpurea*, *Rhododendron glabris* and its variety *aureum*, associated with *Phragmites longivalvis*, *Scirpus cyperinus* var. *Eriophorum*, *Carex pruinosa*, *Drosera rotundifolia*, *Osmunda cinnamomea*, *Brechnum nipponicum*, *Polytrichum commune*, etc. The margin of the bog is being invaded by some shrubs such as *Pieris*, *Vaccinium*, *Ilex*, *Hydrangea* and others. This area, the so-called Gensei-numa, is set apart by the Government as a preserve.

FROM THE GOLF LINKS TO NITA

A climb of about 1 km. from the resort on the eastward slope leads to the golf links. The slope from here to Nita (1,100 m.) becomes gradually steeper and is for the most part grassland with low scattered bushes of azalea, *inutsuge* and other plants. There are on

Unzen-dake many tracts of grassland or other open areas, which undoubtedly owe their origin to eruptions, felling and grazing. This accounts for the dominant distribution of azaleas, which on slopes here and there display a riot of colour in the late spring. The azalea in question is almost exclusively *Rhododendron kiusianum*, a species endemic to Kyūshū, distributed only on relatively higher parts of the region. It varies greatly in the size and form of its leaves and flowers. The colour of the flowers also varies from purple to red, light or deep. There may also be some hybrid forms between this and *Rh. Kaempferi*, which grows widely in the lower region.

MT. FUGEN

Beyond Nita Pass and across the valley through tall bushes of *Ilex*, *Evonymus* and *Enkyanthus*, a path leads to Mt. Fugen (1,360 m.), the highest peak of the range. The vegetation here becomes gradually dense and distinctly deciduous, though some evergreens and a few conifers such as *Abies*, *Torreya* and *Cephalotaxus* are associated. The luxuriant growth of epiphytic mosses and ferns on the trunks, twigs and rocks indicates the extreme dampness of the air in this cloudy region.

The most peculiar feature to be noticed is that various shrubs ordinarily of low growth here attain the height of trees, while the trees themselves are not so highly developed as in Central Japan. Both kinds of woody plants grow together nearly to the same height. Of the shrubs predominating here, may be named *Evonymus striatus* var. *rotundatus*, *E. Sieboldianus*, *Sambucus Sieboldiana*, *Hydrangea paniculata*, *Diervilla decora*, *Viburnum erosum*, *Rhus trichocarpa* and *Lindera praecox*; and of trees, though not very frequent, may be found *Fagus Sieboldi*, *Micromeles alnifolia*, *Prunus Maximowiczi*, *Sorbus aucuparia*, some species of *Acer*, and others. On the other side of the peak occur also species of *Schima*, *Viburnum*, *Magnolia*, and pure consociations of *Diervilla* and *Alnus*. Near the summit of the peak we find also *Acer*, *Sorbus*, *Prunus*, *Alnus* and *Trochodendron* with undergrowths of *Tripetaleia paniculata*, *Viburnum phlebotricum*, *V. urceolatum* and *Rhododendron Keiskei*.

The number of species of woody plants is altogether about 100, of which about 90 are deciduous—far less than in the same region of other mountains in Kyūshū and Honshū. The same relation holds in regard to the herbaceous elements. It is quite conceivable, therefore,

that the migration of plants over the peninsula is still limited, though the volcanic activity of Mt. Unzen had already subsided in prehistoric times. The luxuriant growth of the shrubs mentioned above is due partly to favourable climatic conditions, but partly also to the circumstance that there are as yet no predominating trees to suppress the shrubs.

As the climate is at most seasons extremely wet but in autumn fair and cool, the leaves of many deciduous trees then change to every possible shade of red, while others tend to brown or yellow. The colourful display in the fall, therefore, makes one of the most lovely scenes in Unzen. Indeed, it is wonderful to look round on the autumnal tints of the adjoining peaks and valleys from the summit of Fugen, and away beyond to the picturesque peninsula and the lands across the bay.

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