Notes on the Geology of the Dependent Isles of Taiwan.

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With Plates I-V.

THE HÔKO GROUP (PESCADORES).

I. Introductory.

Between the, geologically neglected, south-east coast of China and Taiwan, the expanse of sea is studded with a great number of islands, collectively called the Hôko or Pescadores Group. It consists of islands, islets and rocks, great or small, altogether numbering 57, besides countless hidden rocks under the water. The waterway on the continental side of the Pescadores is the shallow Fokien Strait, only a hundred miles wide, and on the Taiwan side, is the still narrower Hôko Channel,—the only passages which allow free communication to the waters of the depressions of the North and South China Seas. The region is alternately subjected to strong ebbs and floods through the influence of the branch currents of the swift *Kuro-shiwo* from the north and south, creating foamy and turbulent waves, in conjunctin with the steadily blowing heavy north-easters,—the dread of coasting navigators for ship-wrecks and other deplorable accidents.

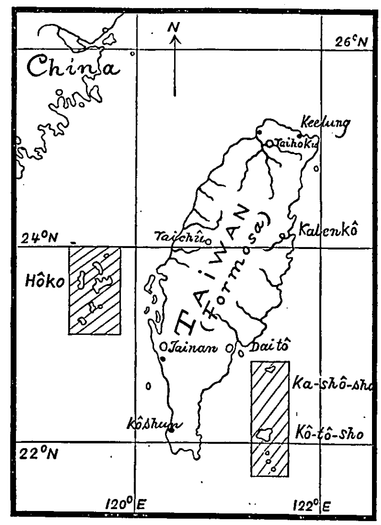

FIG. 1.—Index map of Taiwan to show the position of the islands described.

I have not yet had opportunity to learn by my own inspection the geology of the Pescadores Group; but through the kindness of Messrs. Y. Saitô and T. Tada, I have obtained about forty specimens of rocks, which no doubt fairly represent the types that build up the crust of the islands. In anticipation of a fuller report by Prof. Yokoyama, who has made the islands the subject of his special study, I may give here brief notes on the descriptions of rocks and the inference drawn as to the probable geologic structure of this interesting volcanic group.

The islands are, broadly speaking, distributed within an elliptical space. On the north of the Tropic of Cancer lie mainly the larger islands which are arranged after the manner of Santorin. They resemble the latter not merely in general outlines, but they owe their very existence to the same cause; both are of volcanic origin. These Santorin-like islands are Gio-ô, Hôko, Hakusha, and Chû-don, the latter three fuse together, especially during low tide, into one mass with the intervening coral-reefs which stretch from one island to the other, making the shape very much like Thera. The single island of Gio-ô, then, corresponds in shape and position to that of Therasia. Here, however, we look in vain for the active centre of Kaimenis of Santorin. Taking into account the general distribution of the above-mentioned islands, and also the bathometrical condition, which the chart, *Plate IV* plainly shows, it is likely that they form an independent centre of effusion, in contrast to the Southern group (the Rover group), from which this Northern is separated by the Rover Channel, though both sit upon the eastern end of the so-called Formosa Bank, which stretches out hither from the coast of Fokien. The same type of topography seems to prevail throughout the whole group. It is simple, monotonous, flat-topped and low; the highest prominence scarcely exceeds 56 m. (located at the south-west point of Gio-ô), and the land can only be recognised from the sea within few miles. The islands consequently are wanting in wind-protected harbours, being constantly exposed to the north-east stiff gales during full three-quarters of a year. The land surface is bare, desolate and barren, being entirely destitute of green covering, due, it is said, mainly to the savage violence of the wind, against which even hardy shrubs can not maintain their footing.

The rain-fall, which the south winds occasionally brings thither during the summer season, is soaked up as soon as it falls on the craggy ground; and there are scarcely any rivulets that properly deserve the name. The erosive actions of running water thus become totally suspended, and valleys and dales are scarcely to be seen in the interior, but only the butte-like table-land capped with the Basalt-sheet. The deflation alone is instrumental in modelling the topography, and here we have a *quasi*-desert, and not an oasis, amidst the green island-world of South-eastern Asia.

Forty of Mr. Tada's specimens of rocks, on which I base my petrographical descriptions in the present paper, were collected from the following islands:—

1) Hôko island, the largest of the whole group.

2) Haku-sha-tô,[1] lying north to the foregoing.

3) Impai-sho.

4) Chô-sho, the eastern neighbour of Hakusha-tô.

5) Kippai (Bird Island of English Admirality chart), the northernmost of the whole group.

6) Gi-ô-tô (Fisher Island), west of Hôko-tô.

7) Hattô-sho, lying farther to the south of the main group.

In addition to these, I have received lately a few specimens collected by Mr. Y. Saitô.

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1) The words '*tô*' and '*sho*' recurs frequently in the geographical name of Taiwan, the former signifying an island, the latter an islet or rock.

II. Stratigraphical Characteristics.

HÔKO ISLAND.

Hôko or Tai-san-sho[1] is the largest among the forty-seven islands of the Hôko group, having an area of 62.7 square kilométres. Its general outline is k-shaped, curving in at three points in the coves, Fûkibi,[2] Giû-bo-ken,[3] and Kôtei.[4] The relief is simple, low and flat-topped, the maximal elevation being Mount Tai-bu,[5] located nearly at the centre, with a height of only 48 m. The coast is cliffy, interrupted often by sandy flats fringed with coral reefs.

Mr. Y. Saitô has geologically reconnoitered the principal islands of the group during last winter, and has kindly placed at my disposal the written account of his observations, which I am here following in its main points.

The island is essentially composed of the *Tertiary Basalts*, of which *three different flows*, poured out after long intervals, are well marked by the intervening tufaceous sedimentaries of a considerable thickness. The *topmost flow* caps the surface of butte-like elevations, or makes the flows of extensive 'mesas,' the surface being covered with its eluvial products—a fine, ferruginous loam which gradually passes downwards into a blocky loam and then the massive lava. The flow is rather thin, and characteristically *columnar*. It is frequently wanting in some parts of the island.

In the irregularly formed strip of land—the Fûkibi-Jiri[6]

1) Tai-san-sho (大山嶼), signifying 'great mountain islet,' is by no means literally true, though undoubtedly it is the largest of the whole Pescadores.

2) 楓櫃美 3) 牛毋件 4) 港底 5) 大武山 6) 堺裡.

tongue, which projects out from Sei-shi-an[1] towards the citadel of Bakô, thus enclosing within it a safe harbour,—we see the *second sheet of flow*, beautifully exposed along the steep declivity all round the shore under the uppermost lava-flow, from which it is separated by a thin bed of tuffite. This is a most extensive and strong sheet, aggregating about 10 m. In its upper portion, the lava is *porous*, whitish, and much decomposed, while the lower portion is fresh and compact. It is the one which we usually see along the sea-shore on whose trappean floor the rollers break and recoil in tumultuous waves.

The *third* is the lowest, consequently the oldest flow visible in the Pescadores, and frequently forms the floor of the coast, when the second sheet, already referred to, makes its appearance higher up the precipice. It is likewise doleritic and *porous* as in the above flow, and this Basalt is well seen at the environs of Jiri, already referred to, where it is underlaid by a meagre lignite-bearing bed. It rarely happens to come to the surface not because of its absence but that it is hidden under the level of sea.

Tertiary strata, often accompanied by lignite seams, occur inserted between the first and second flows, and also below the third sheet. An undeterminable cast of gasteropod together with an *Arca* were secured by Saitô from the corresponding bed at Run (Lun) point in the Island of Gio-ô. The sure proofs of their being of the Tertiary age are not at hand ; but from the analogy of the occurrences of Basalts in the neighbouring regions, I conjecture the sedimentaries, here referred to, to be of later Tertiary. According to Cholnecky[2], two volcanic lines are said to be

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1) 井仔垵.

2) 'Vorläufiger Berichte über meine Forschungsreise in China.' *Petermanns Mitth.* 45, 1899, S. 8.

distinguished in Eastern Asia; the one has served for the welling out of an enormous quantity of Basalt in later Tertiary age, the other has given rise to the chains of modern (Andesitic) volcanoes. In the north of the Chang-pei-shan, in Korea, he announced recently the discovery of an extensive Basaltic mesa more than 60,000 square km., which extends from Mukden through Kirin to Ninguta, forming the water-shed of the Sungari River and the Tumen-kiang. I have been informed, verbally by Mr. Nishiwada, of the occurrence, outside of Manchuria, of a trappean plateau, of small extent, along the eastern water-shed of the Korean Peninsula, and the island of Quelpart; and Vénukoff[1] cites a number of localities where Basalts make their appearance on the plateau of Mongolia. Furthermore, the Basalts occur sporadically in Liau-tung, and Shang-tung as far down as Nanking, approximately in a straight line, and v. Richthofen[2] brings the line in connection with the tectonic movement which has created the 'great plain' of China, and he assigns the age of this crustal movement to the *Tertiary* period. The Basalts of the Pescadores seem to me to be included in this petrographical province of Eastern Asia.

Since the beginning of the *Diluvial epoch*, a subaerial condition has prevailed over Hôko, as well as in all the islands of the whole group, and erosion and disintegration have been at work, thereby carrying off the greater part of the uppermost flow, and gradually diminishing the area of the islands, and finally reducing them to ruins, as we see at present. Consequently, no record is left of the deposit representing this period, unless we take for it the

1) 'Les Roches basaltiques de la Mongolie,' *Bulletin de la Société belge de Géologie, etc.*, tome II, p. 441.

2) 'Shantung und seine Eingangspfort Kiautschou,' 1898, S. 66.

thin superficial covering of ferruginous loam which is in part at least the product of decay of Recent epoch, though a certain portion may have been defladed away and lost during dust-storms.

Along the shore free from escarpment, white sandy beaches stretch from one point to another. They are the *Alluvial deposits*, into whose composition enters a special element which we are not accustomed to see in our own coast. Nearly all round the island, coral reefs grow upon the Basaltic shelf, and the detritus derived from them is driven up to form low sand dunes, leaving behind them, if the coast-line is deeply indented, as it is in many places, muddy shallows filled with the residual clay of decomposed Basalt.

Such is the general outline of the geology of the Island, and of the rest of the group as well.

Looking more into the details, we find that at Bakô[1] Point, on which is situated the town of the same name, the second flow extends in a great sheet, covering all but a few points of elevation which are capped with there lics of the young columnar lava, being separated from it by a blue rock. The last is a *fuller's earth*, which is a bluish-grey, dull, compact mass of greasy lustre, splitting, when dry, into angular clods with sub-conchoidal fracture. It adheres to the tongue, and falls readily to a muddy state on placing in water, and is not plastic. Under the microscope, the whole mass consists of brownish, double-refracting particles, and seems to have been derived from the decomposition of a Basaltic glass. It crops out for a short distance, and on shore a poor bed of Tertiary lignite occurs associated with it.

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1) 媽公.

The same state of things prevails throughout the tract southward as far as Sei-shi-an[1], the surface being covered with thick ferruginous loam mixed up with Basaltic fragments, and the upper and middle flows coming in direct contact, distinguish-

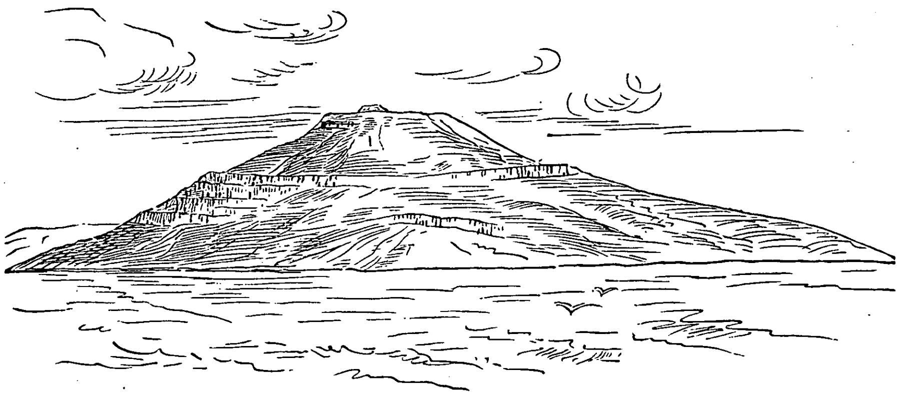

FIG. 2.—Isolated erosion hill Sha-bô-san, near Jiri, showing two upper flows with interbedded sedimentaries.*

able only in the difference of structures. At the last-mentioned locality, a 'haul-over' of base-levelled middle flow, masked with coral sand, separates the tongue of land Jiri[2], on which stands a Basaltic, hat-shaped Sha-bô-san[3], 47 m. high (Fig. 2).

A good section may be seen along the shore, west of Jiri, as is shown in Fig. 3. The *columnar*, upper (No. 1), and doleritic, *porous* middle flows (No. 2), aggregating about 6 m., cap the cliff, 20 feet high. That the two flows are separated by long time intervals can be clearly shown elsewhere (Fig. 2) by a bed inserted between them. I may cite the case of a lignite bed at Bakô, occurring in company with fuller's earth. Another instance may be given of it just east of Jiri, where an ash bed makes its appearance. This ash bed is a fine, greyish-white, pulverent

1) 井仔坡 2) 塒裡 3) 紗帽山.

*All the figures in the following wood-cuts, not otherwise mentioned, are originally sketched by Y. Saitō.

earth, wholly consisting of the microscopic particles of plagioclase, a few fragments of pleochroic *hypersthene*, and little magnetite, but no glass splinters are seen. It reminds me of the felspar sand that cover the flat and form the ground of Pampanga, north of Manila[1]. After this short digression, I return to the former subject. Now, a yellowish-brown, loose sandy bed, 3 m. thick, comes below the middle flow, locally with limonitic nodules (Fig. 3). This is succeeded by another complex bed, 3 to 4 m. thick, made up of multifarious alternations of clays and sands, all retaining the original horizontal position. Then comes the third sheet of *porous* lava

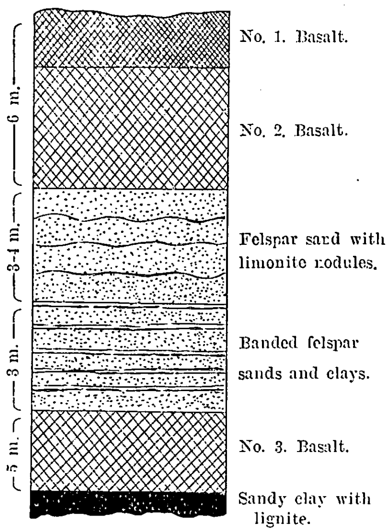

FIG. 3.—Section exposed at the west coast of Jiri, Hôko.

of variable thickness, underlaid by a lignite bed, the last one can be only seen at low tide. The whole seems to me to be one complex bed belonging to *later Teritary*; and this profile serves as a type of the stratigraphical order of the island. After passing over the second 'haul-over' to the Fûkibi point (*Plate V*), opposite to Bakô, nothing but the two upper flows is exposed.

A table island, named Ko-sei-sho[2], off the coast of Jiri, already referred to, is an erosion relic of the Basaltic mesa, surely connected in former times with the main island of Hôko. The adjoining wood-cut shows clearly the geological structure

1) B. Kotô, 'Geologic Structure of the Malayan Archipelago.' This *Journal*, Vol. XI., p. 113.

2) 虎井嶼.

and the general view, as seen from Jiri, exhibiting the two upper flows, mainly hidden by debris cones. This island served for the Chinese in former times for the strategic base against

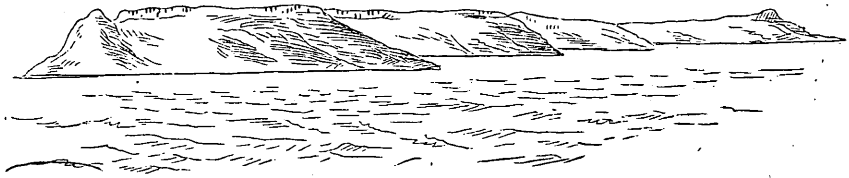

FIG. 4.—A view of the Isle of Ko-sei-sho, an erosion relic of Basaltic mesa, as seen from the coast of Jiri.

the Hollanders and Koku-sen-ya (Koxinga), in maintaining the sovereignty over her supposed vassal domain of Taiwan.

Starting again from Sei-shi-an, already referred to, and going round the south coast along the points of Kan-on-san[1)] and Kô-kaku[2)], Basaltic cliffs with underlying sandy bed, and sandy coves repeatedly occur as far as A-kan[3)]. At Sa-kan[4)], a little south of the last-mentioned locality, fuller's earth similar to that of Bakô, is said to occur according to Tada and Ishii. Upon the walls of the cliff at the recesses of the coves are found, attached, according to Saitô, apparently recent shells, telling the fact that at no geologically remote period, probably Diluvial, a negative shifting of sea-level has taken place in this tract. We are, however, not informed of the height of the former level, as compared with the present; but at any rate it is of paramount importance for us to have been acquainted with this movement in view of the fact that on the opposite coast, *i.e.* on Front Taiwan, there are not wanting evidences tending to prove the negative change on the shore.

1) 觀音山 2) 候角 3) 烏崁 4) 鎖管.

Between A-kan and Ri-sei-kaku[1], the easternmost point of the island, a white sandy beach bounds the south shore.

All along the coast from Ri-sei-kaku to Hoku-ryo[2], coral reefs limit the eastern shore, and the detritals derived from them form the beach-flat. It is a noteworthy fact that on the north side the coast is very deeply indented in the north-south direction, and the lowland, partly marshy, is covered likewise with coral sand. I may here mention an *occurrence of coal* which was once considered to be a very important natural resource of the island, though afterwards it turned out to be almost worthless and unworthy of public attention. At one of the points, called Kotô or dragon head, that stretches out northwards, a butte of Basalt, 22 m. high, elevates itself from the shore, and at its northern foot a seam of lignite, 5 feet thick, crops out with a sandy rock between the first and second flows, corresponding to the *Arca* zone in Gio-ô Island, already referred to. The exposure is meagre and soon disappears under the rubbish to be seen no more. This mineral combustible is but imperfectly incarbonized, and the woody structure is said to be yet well preserved.

From Sei-kei[3] through Kô-tei[4], and Sha-kô[5] as far west as to the oft-mentioned Bakô, along the north coast, the two upper flows are the sole rocks that can be seen, being covered with an incoherent brownish, coarse and craggy earth.

HAKU-SHA ISLAND.

Haku-sha-tô,[6] or the white sand island is bodily connected with Hôko through the intervening islet of Chû-don[7], at the

1) 裏正角 2) 北寮 3) 西溪 4) 港底 5) 沙港 6) 白沙 7) 中墩.

two narrow necks of the abraded second flow of Basalt, and forms a part of the geological unit, differing from them only in that here the interstratified sedimentaries seem to be wanting. The other features that strike the eyes of observers are firstly, the lowness of its relief, the highest point being Kô-don-san[1], 36 m. high, and secondly, a considerable development of Alluvial accumulation of the shells and skeletons of low organisms, hence the name of the island. Cliffs, however, can be seen in its northern shore, exposing the youngest flow with its usual *columnar* structure at the water's edge. White sandy flats prevail throughout the rest of the lonely island, especially towards the Bay of Hôko, and the residual product of considerable thickness, derived from the Basaltic decomposition, covers the interior.

One thing worthy of mentioning is a sporadic occurrence of lapilli that had run aground on the east shore, probably from one of the Indonesian volcanoes. The pumiceous fragments, worn and rounded, belong to a Hypersthene-andesite with a highly pleochroic, rhombic augite, and this rock either massive or pumiceous can be seen in no other parts of the group.

The islets, Impai[2] and Chô-sho[3] or Bird Island, off the east coast, seem to be geologically identical, representing the erosion-relics of the Diluvial epoch. A luxuriant growth of coral reefs fringes the latter, as well as the neighbouring islets, just as in Haku-sha.

KIPPAI ISLAND.

Farther away in a northerly direction lies the islet of Kippai[4], which is a low Basaltic flat, covered with half-

1) 後墩山 2) 員貝 3) 鳥嶼 4) 吉貝.

hardened foraminifer sand (*Pl. II, Fig.* 6.) of Recent age; fragments of corals, bivalves and serpula mixed with other components. The foraminiferal rock consists of millions of discoidal and spiral, water-worn shells. Rarely they have spines well-preserved. Viewing a section of the shell under the microscope, it is seen that the test consists of the tubulated proper walls of chambers, besides the canaliculated intermediate skeleton which forms spur-like marginal appendages, characteristic of *Calcarina,* and its external form and microscopic details agree well with *C. Spengleri,* Linné[1], dredged for the first time near the coast of Amboina at the depth of 1,425 fathoms. This species seems to be quite as abundant in the East Indian Archipelago, as we find here in the Pescadores. By wear and tear of rolling waves, the surface of the test becomes smooth, and the presence of spines can be usually only recognized in examining the structure of the supplementary skeleton which points to the former existence of some sort of prominence.

GIO-Ô ISLAND.

Gio-ô, or Fisher Island, lies to the west of Hôko, and encloses with the latter the head-less Bay of Hôko, or rather an arm of sea. What has been said of other islands as regards the geology and the topography, holds true also of Gio-ô, with the differences, that the island is really table-shaped, bounded on all sides by cliffs, leaving no space for Alluvial deposits, excepting the shore and fringing reefs; and that the igneous sheet as well as the interbedded sedimentaries are developed to their full advantage, thus affording the best opportunities for geolo-

1) *Challenger Report,* 'Foraminifera.'

gists to get insight into the geological structure, and to study the stratigraphic details, of the whole Pescadores.

The oft-mentioned three flows and interstratified tuffites as well as the underlying bed are likewise present, and well seen especially in that portion that lies southwards of Shô-chi-kaku.[1] Between the last-mentioned locality that is situated in the middle of the island and Shû-ba-wan,[2] good sections may be traced, as in fig. 5, in descending order. Under the superficial covering of the ferruginous soil of decomposition from Basalt comes the No. 1. Basalt-flow, with its usual columnar structure, of about one foot, and sometimes disappears altogether. The third in the series consists of pelitic sand and loose sandstone, the latter being made up of *muscovite*, plagioclase, and Basalt-glass. Concentric nodules of hematite are frequently found in them. Saitô is fortunate enough to find in this complex bed casts of an *Arca* and gasteropod (*Turbo*) in the matrix of ferruginous felspar sand with a little magnetite. Judging from the cast, the shell of the

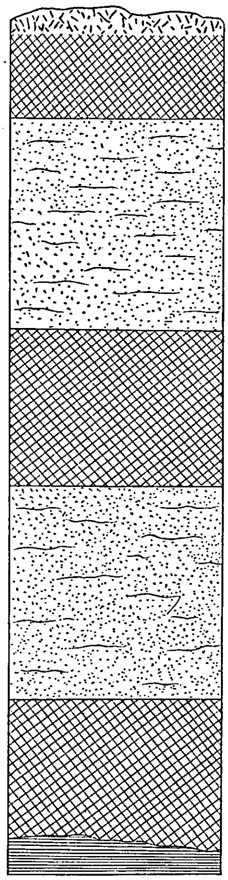

FIG. 5.—General profile as seen in the southern part of Gio-ô.

1) 小池角 2) 茸馬灣

Arca is thick, egg-shaped, the ends of the margin obtuse-angled; the margin anteriorly rounded, posteriorly sloping; the beak prominent, anteriorly inclined, widely separated and inflated; coarse radial ribs more than 20 in number. Our specimen apparently resembles *A. subcrenata*, Lischke, though in details they may differ, if perfect samples are taken in comparison.

The next in the series is the porous, No. 2. sheet, underlaid by a fine felspar sand bed. Then the lowest, No. 3. sheet of 6-7 feet, often Agglomeratic; and lastly, the bluish-grey sandy clay, consisting of clay, *muscovite*, plagioclase and brownish opaque grains probably of Basaltic glass together with carbonaceous matter. It is remarkable that muscovite is more or less intermixed with in all the sedimentaries.

Before quitting Gio-ô, it should be remarked that the area north of Shô-chi-kaku, as well as the whole east coast is composed of the two upper flows only with or without interstratified beds; while the rest of the island, as may be seen in fig. 5, are built up of the second and third flows, accompanied with sedimentaries, unsurpassed in complexity and in thickness.

According to Tada, the islands of the *Southern Group* (*Pl. IV.*) of the Pescadores, are geologically of the same type. Counting southwards, they are:—Hattô,[1] with the dependent isle of Shô-gun-ô[2]; the Smaller and the Larger Biô-sho[3], so named cat islands from their appearance as seen from a distance; Tai-sho[4] and Shô-hei[5] with columnar Basalt; Tô-kitsu[6] and Sei-kitsu[7], likewise Basaltic; all being encircled by coral reefs.

1) 八罩 2) 將軍嶼 3) 猫嶼 4) 大嶼 5) 小平 6) 東吉 7) 西吉.

III. Petrography of the Effusives.

The groundwork of the Pescadores is essentially built up of Basalts, making extensive flows to the water's edge, and the whole is encircled by the fringing reefs of corals, which, in parts raised above the water, connect many of the detached rocks with the shore, thus contributing greatly to the enlargement of the areas of the island. Each and every island visited by Tada and Saitô, presents the same physiognomy, and consists of the same black rock. The specimens, brought back from most of the islands, and of which descriptions will be given in the sequel, have a certain common feature which stamps them as genetically identical, and their field relations in different areas seem to point to a common centre of volcanic activity. They exhibit, however, a considerable variation of character. Thus from the same island, I have specimens at one place perfectly massive and compact, at another vesicular and porous, and sometimes Doleritic. Colours vary from black to bluish-grey in fresh ones, and through weathering the Doleritic and vesicular varieties become whitish or grey, while the compact rocks acquire a reddish brown tinge.

We are indebted to Mr. Y. Saitô, for characterising the different flows, and for tracing their vertical as well as horizontal distributions in the Northern group. According to him, there are three distinct Basaltic flows of nearly the same distribution, separated by long time-intervals which are represented in inter-bedded sedimentary rocks. Judging from the nearly perfect horizontality which the beds and flows keep in all the islands, it seems probable that there existed a lava field or volcanic *mesa* of considerable extent. But, on account of its remote age, probably *later Tertiary*, and of its insular position, waves gnawed the ground in time, finally reducing the once wide volcanic field into the ruins of islands, as we see at present. It is not easy to know the former extent, and the ancient surface feature, of this lava-flat; but, generally speaking, the relief becomes higher as we go southwards from one to the other in the islands of the Northern group. Saitô recognises, as I have already said, three lava-flows in the Northern group, *viz., the uppermost or youngest being of columnar, the middle porous and vesicular, and the lowest also partly vesicular, and Agglomeratic.* After the comparative study of the Basaltic rocks, to which the effusives exclusively belong, several important facts are brought to light, and now I am able to say, that the youngest flow (a, b and ? d types) contains the iddingsitized olivine, at least in one type, and violet brown titan-augite; the second (c and ? d types) the brown augite, olivine sometimes lacking, being often replaced by hypersthene; and the third (e type) the analcime-bearing. I will record first my observations on the *component-minerals,* and then give the *special description of rocks.*

A. Component-minerals of Basalts.

OLIVINE.

Olivine is rarely automorphic, but mostly xenomorphic, being the remains of resorption by magma. The olivine in the Basalts of the Hôko Islands seems to be of several varieties. Automorphic ones show vivid polarisation-colours, and alter usually into some red minerals. The xenomorphic type shows comparatively a low degree of polarisation, and suffers deep corrosion, often being reduced to a mere grain, and is also traversed with fractural lines, from which the mineral begins to form a serpentinous substance. The olivines are undoubtedly the intratelluric products, being sometimes enclosed by an automorphic augite, and large individuals are habitually surrounded by heaps of the crystals of augite (in Andesites, instead of it often hypersthene). Inclusions of gas and liquid are not rare, and the octohedra of magnetite are also found in the olivines.

Zonal structure of olivine is, as is well known, of rare occurrence, and if it really exist, this could only be discerned either by measuring the optical angles at different portions, or by finding the altered zones in a crystal in consequence of the formation of the *mineral rouge*. The zone of the red mineral is not constant in position, for, it makes its appearance sometimes on the periphery, at other times in the interior; but, so far as my experience goes, the recurrent zones are never found. The condition under which the isomorphic shells of different chemical compounds are formed in the olivine, seems to depend, as Lagorio[1)] and Morozewics[2)] say, mainly on the *Massenwirkung*, that is, the degree of saturation of magma in certain temperature and pressure. In my slide, in which olivine has a red central zone (the Kippai Island specimen), magnetite is scarce, and large in its size and rod-shaped; while the magnetite-rich rock (the Hôko specimen) has an olivine with an external red zone. Here the magnetite occurs in small isometric crystals and grains.

The red mineral, that forms the periphery (*Pl. I. Figs.* 1, 4 *and* 5) and the kernel (*Pl. I. Fig.* 6), differs in habit. The

1) 'Ueber die Natur der Glasbasis, sowie der Krystallisationsvorgänge im eruptiven Magma.' T. M. M. Bd. VIII, 1887.

2) *Ibid.* Bd. XVIII, 1898.

first has a facile cleavage but brittle, and consequently becomes lamellar like a brittle micaceous mineral. It is probably identical with the so-called biotite, which we occasionally find mentioned in petrological literature, as being formed from an alteration of olivine, just like as schillerspar has been considered to be a mica, as an alteration-product of enstatite. Recently, Iddings[1] and Lawson[2] described a similar mineral and the latter author named it *iddingsite.* In the *second,* we fail to find such a distinct cleavage, and it seems to me to be the same body which Michel-Lévy called the *mineral rouge*[3]. Now, a question suggests itself to me, whether the red micaceous mineral is identical with the *mineral rouge* or not? It is true that the *former* confines itself to the margin, and in the case where the entire substance of olivine has been transformed to this mineral, the process of alteration has started from the periphery, and it not infrequently happened to me to find every stage of progress from the very beginning to the complete alteration. The *latter,* on the contrary, starts from the centre in irregular patches, and gradually attacks the whole body but the clear and granulated, thin margin. The formation of the red lamellæ begins with the development of a fine parting which appears like stripes, and which runs parallel to the vertical axis (*Pl. I. Fig.* 1) ; while cracks on the margin favour the olivine being changed into the red mineral in the centre.

In my opinion, there may be a slight difference in the

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1) U. S. Geol. Surv., 'Monograph' XX., p. 388. Iddings identifies this mineral to thermophyllite, a foliated mineral having the composition of serpentine.

2) 'The Geology of Carmelo Bay.' Bulletin of the Department of Geology in the University of California, Vol. I., p. 31. See also Pirsson's paper, Amer. Journ. Sci., XLV, 1893, p. 381.

3) 'La Chaine des Puys et le Mont Dore,' *Bull. Géol. Soc. France,* 3me Serie, XVIII, 1890.

chemical composition of the two alteration-products, yet on the whole they must be practically identical. The lamellæ are oriented parallel to one of the pinacoids, as may be deduced from the position of the optic plane (in the *fresh substance of olivine*), which stands at right-angles to the easy cleavage (*Pl. I. Figs.* 1 *and* 5). Pleochroism is distinct; it is brownish-green in the direction of facile cleavage, but greenish-brown when at right-angles to it. Hence, $c>a$ or b. Mügge[1], however, says that the absorption is stronger in the direction perpendicular to the '*Längsrichtung*' than in that parallel to it. Zirkel[2] and Rosenbuch[3] interpret the above statement in the terms, that the rays vibrating parallel to c absorb far *less* than those parallel to a and b. The observers, however, seem to have examined the *mineral rouge*. My observation, therefore, accords well with that made by Lawson for iddingsite; but it is not known to which pinacoid, 010 or 100, the lamellæ are parallel, though it is probable that the *brachypinacoid* is the *lamellar plane*, as may be inferred from the fact that the elasticity perpendicular to the lamellæ is greater ($\mathfrak{A}=b$) than that parallel to the c-axis, the latter corresponding to the mean axis of elasticity.

With HCl, the iddingsitic mineral becomes bleached, and then acquires a *greenish-yellow* colour, with corresponding decrease of pleochroism. Bearing in mind the fact of the brachypinacoidal lamellar cleavage, of the colour, and of the chemical composition which is a hydrous non-aluminous silicate of iron, lime, magnesia, and soda, *I am rather inclined to consider the iddingsite to be a mineral approaching to basite.* Prof. Rosenbusch[4],

1) *Neues Jahrbuch,* 1883, II, S. 205.
2) 'Petrographie,' Bd. I, 1893, S. 353.
3) 'Physiographie,' Bd. I., 1892, S. 469.
4) 'Physiographie,' 1892, Bd. I., S. 461.

in speaking of bastite, says 'die Umbildung scheint in hohem Grade durch die gleichzeitige Anwesenheit des Olivin und dessen Umwandlung zu Serpentine befördert zu werden.' Chemically speaking, there exists a close resemblance between iddingsite and the 'crystallised diallage' of Baste[1], considering out of question a trace of alumina. Optical schemes differ, of course, in the two minerals, but I could not make out *surely* the optical orientation of iddingsite in my slides, on account of its extremely fine lamellar structure.

PLAGIOCLASE.

Plagioclase has, generally speaking, crystallised out in a single generation of the flow period. Differing from the Andesitic plagioclases which present various dimensions, the felspar of Basalt is uniform in size. It is, however, not wanting in large, phenocrystic crystals in some slides, which also belong to the products of the effusive period, slightly earlier in crystallisation than the ones in the general mass; for, the small laths of plagioclase are partly embraced by the phenocrysts,—a fact which also leads me suppose that the plagioclases have grown in a comparatively motionless magma. They show no signs of corrosion, so common in the olivine of the intratelluric origin, though the effects of tossing and fracturing of crystals are by no means seldom observed.

The *phenocrystic plagioclase* (*Pl. II, Fig.* 2) has a tabular form on M, somewhat elongated towards the vertical axis. Zonal structure is rare in contrast to the Andesitic felspar; the same

1) Hintze, 'Handbuch der Mineralogie,' Bd. II., S. 972.

is the case of glass-enclosures, save that ground-mass which fills up the rectangular space between the lamellæ, showing as if the larger crystals have grown out by the apposition of numerous flowing lamellæ. Penck[1] holds the same view, as given here. In consequence of this lamellar composition, which is one of the causes of the paucity of inclusions, both terminations of the ledges became indented and forked, after the manner of a parapet (*Pl. I, Figs.* 4 *and* 6., *Pl. II, Fig.* 5), a characteristic common to all the plagioclases of Basalts. *It seems more reasonable to consider these monstrosities as incipient forms of growth, having simultaneously many centres of crystallisation in space, which in later stages have grown together to make up one individual with but internal complex compositions.* Morphological and optical homogeneities are, however, frequently disturbed through the flowing motion and sudden cooling of the consolidating magma. Several stages of similar kind in crystallisation may be frequently observed under the microscope in the formation of artificial crystals.

Symmetrical but contrary extinction takes place at the maximum angle of 33°−35°, with reference to the suture of the albite-twinning, and the extinction with regard to the pericline-lamellæ amounts to −16°, showing that the plagioclase is of a *basic* labradorite. It is easily acted on by HCl. The Baveno twins were once observed.

The *plagioclase in the ground-mass* is lath-shaped, extremely slender, and polysynthetic; termination being also a parapet-like. The habit of crystals is prismatic, and such a form is said to be elongated parallel to the a-axis. This is indeed true; for,

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1) 'Studien ueber lockere vulcanische Auswürflinge.' *Zeitschr. d. d. geol. Gesell.* Bd. XXX., S. 101. Taf. V., Figs. 3, 5, and 7.

along the longest extension lies the axis of greatest elasticity, and there are tens of thousands of laths visible in microscope slides, with but a few tabular sections. Symmetrically opposite extinctions make the maximum angles of 23° to 25° with the suture of lamellæ. Microlithic sections twinned on the albite type extinguish at the angles from 0° to 26°, with reference to the longer dimension. According to Michel-Lévy, labradorite and albite have similar optical deportment, but as they do not usually come together, and as we are dealing now with a basic rock, the nature of the microlite should be considered to approach that of an *acidic* labradorite. In a few slides, the poles of the laths resolve themselves into a number of prisms, and such fine slender needles are scattered through the whole groundmass.

AUGITE.

Augite, so says Morozewicz[1] belongs to one of the '*verhangnissvollen* minerals. It does not obey Fouqué and M.-Lévy's rule of crystallisation of silicates in the reversed order of fusibility, nor Rosenbusch's scheme of crystallisation according to acidity. It is rather subjected to the influence of masses, *i.e.* a degree of saturation under certain temperature and pressure. Under such circumstances, augite may form crystals before plagioclases, and at other times, just the reverse may occur, while in the third case they may individualise at the same time. According to the priority of secretion of either of the two minerals, in other words, the relative idiomorphism of one to

1) 'Experimentelle Untersuchungen ueber die Bildung der Minerale im Magma.' *Tschermak's Mitth.*, Bd. XVIII., S. 84.

another, various structures may be brought about under varying conditions, and these we find in fact in my slides.

As regards the forms of augite, it is sometimes idiomorphic, bounded by faces $\infty P\bar{\infty}$, $\infty P\breve{\infty}$, ∞P, and $P\breve{\infty}$, the first being well developed, consequently the crystals become tabular; at other times granular, needle-shaped, in ophitic plate, and in partial crystals. Prevailing colour is either violet or yellowish-brown. It is to be expressedly remarked that the typical Basaltic augite with a tinge of *violet* occurs only in the Pescadores, and in the dykes of Basalt near Taihoku and Taikokan, in *Formosa*. My long experience forced me to conclude that, in Japan proper, the Basalt with the violet augite is confined to the northern Kiûshiû, and Chiu-goku, in Hondô, as far east as the provincial boundary of Tajima and Tamba. The same type of Basalt is also known to be wide-spread in Korea, Liau-tung, and Mongolia. *Thus the distribution of the Basalt with the violet titaniferous augite marks a definite area, being, so far as my knowledge goes, confined to the inner side of the festoon islands and the adjoining continent in Eastern Asia, constituting the well-defined Japan-China petrographical province.* Larger crystals show a zonal structure, coloured intensely on the periphery, and the hour-glass structure occurs frequently with deeply-coloured, additive cones in the prismatic zones, which have at the same time a greater angle of extinction. Pleochroism is stronger in the direction parallel to the c-axis. Polarization-colours are generally weak in comparison to those of the Andesitic augite. Twins on $\infty P\bar{\infty}$ have a suture, running just along the middle of the body of the crystals. Crystals often form stellar aggregates; they are generally free from foreign interpositions, excepting the larger ones which have sometimes enclosures of glass and magnetite,

HYPERSTHENE.

Hypersthene takes the place of olivine in some Basalts of the Pescadores; consequently the presence of one totally excludes that of the other,—a state of thing quite exceptional to the *modern Japanese Andesite* of a glassy, black, porphyritic type, in which *both minerals appear always concomitantly*. We have then the Hypersthene-Basalt, in lieu of the Basalt proper. It is a noteworthy fact that this stray variety of rock seems to be widespread, at least in my specimens, in the out of the way islets, such as Impai, Kin-sho, and Hattô, the only exception being the one from Sei-kei (West Valley) in Hôko, though I could not find a sufficient reason accounting for the special distribution of this hypersthene-bearing rock.

It is usually a comparatively easy task to discriminate hypersthene from olivine, but in the present case some difficulty is experienced in making out for certain the presence of the former.

In regard to the form, the (1) hypersthene is extremely *slender*, being about six times longer than broad, and, as being of the intratelluric origin, it has a marginal zone deeply corroded and partly granulated, and has indefinite faces at the poles of the crystals (*Pl. II, Fig.* 3). I observed once a morphotropic growth of a highly-polarising, monoclinic pyroxene around a hypersthene, just as is the case in Andesites. Cleavage is developed along the longest extension of the crystals. In a patch of a coarse aggregate which appears as an endogeneous or homogeneous enclosure in the finer general mass, the (2) hypersthene comes together with plagioclase and augite, and in this case the hypersthene occurs in *broad* plates (*Pl. II, Fig.* 4), with only a few traces of cleavage, but with numerous fissures; and has an appearance exactly like olivine.

The hypersthene possesses a brown colour, and its pleochroism is scarcely discernible. In favourable cases, the ray vibrating parallel to the c-axis is slightly green. Sections present a rough surface, owing to its having a high index, approaching to that of olivine; its polarisation-colour is grey.

From the brief diagnosis, given above, of the hypersthene, its cleavage, colour, non-pleochroism or very weak if present, high index, but low magnitude of refraction, extinction-direction, and similar chemical composition,—these several physical properties afford no means of discriminating it from a fresh olivine. Olivine has, however, a lighter colour, and has usually but one trace of cleavage in a section. The hypersthene on the other hand possesses the characteristic traces of prismatic cleavage, which in a random section gives scarcely a clue to distinguish it conoscopically from monoclinic pyroxene. A basal section, once observed, presented a square outline, truncated little at the four corners.

From the combined evidence of more slender section, of the want of decomposition-products, of indifferent behaviour towards common acids, of the presence of comparatively numerous traces of cleavage, I infer, in the Basalts, the presence of a hypersthene. It is to be remembered that the *prismatic* sections of olivine show also a low colour of polarisation, exactly like that of a hypersthene. It seems to me that the hypersthene in the Hôko Basalts stands in its chemical composition near to that of *bronzite*. The want of a distinct pleochroism may be attributed to the same cause. Axial angles, therefore, become large, and the axial poles were not observed in any of the pinacoids by ordinary methods.

APATITE.

Apatite occurs in the Doleritic or Anamesitic rocks in the form of extremely fine needles, devoid of terminal faces, being colourless, and always traversed by transversal fissures. Its crystals sink almost to a minimum size, and are not, comparatively speaking, so large as those found in the typical European Dolerites; and for this reason they might be easily mistaken for the microlites of felspar which often resolves from the poles of a larger crystals in Basalts. The apatite is typically found in the three slides only, which are in my possesion (Kippai and Hôko), and both are magnetite (not ilmenite)-bearing rocks. The crystals are dark-margined, owing to the total reflection of light on the prismatic faces; and sometimes a single brown-coloured axis entirely or partially runs through the crystal. A grey or light-brown variety, so often found in Andesites, is entirely absent, though a dark-brown crystal of an apatite-like mineral was once observed with strong absorption parallel to the prismatic axis. The sure criterion of the presence of apatite can only be found in its hexagonal cross-section.

ANALCIME AND NATROLITE.

A cave-rock in the southern Gio-ô, presents an anomalous habit; a slide made of it contains a colourless mineral in angular or polygonal interspaces between the crystals of plagioclase (*Pl. II, Fig.* 5). It shows no signs of any crystallographic face, nor cleavage, but only has a frittered appearance, being traversed with irregular cracks, and also being pierced through in all directions with the needles of apatite which is excessively rich in this rock. The polysomatic mineral has a smaller index of refraction, when compared with that of the accompanying plagioclase, as may be easily experimented upon by Becke's method. These colourless patches, as a rule, behave optically isotropic; at times, however, faintly double-refractive, and separate into several optical fields. They readily dissolve in HCl, with the formation of the cubes of rock-salt. The same patches frequently resolve themselves into a radial-fibrous, somewhat brownish and highly double-refractive body (well seen at the margin in the lower, left quadrant in *Pl. II, Fig.* 5) with the positive sign along the axis of the needles.

The polygonal base-like mineral, moulded upon plagioclase and augite, seems to be identical with what Büking[1] calls the '*Basis zweiter Art*,' and is allied to the *pitchstone-glass* of Hunter and Rosenbusch.[2] Recently, this base was studied with great zeal by the American petrologists, Lindgren,[3] T. F. Williams,[4] Kemp,[5] Fairbanks,[6] Cross,[7] Coleman[8] and Pirsson[9]; the last author especially paid close attention to this subject, in making careful analyses and also recalculating the analytical result, obtained by Hunter. From his study, Pirrson is forced to the conclusion that the so-called colourless base has exactly the

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1) 'Basaltische Gesteine, etc.,' *Jahrb. K. K. preuss. geol. Landesanstalt.* 1880, S. 153, und 1881, S. 606.

2) 'Ueber Monchiquite, ein camptonitisches Ganggestein aus der Gefolgenschaft der Eleolithsyenite,' *Tschermark's Min. Mitth.* XI, 1890, S. 445.

3) Proc. Cal. Acad. Sci., Vol. III, 1390.

4) Cited in Pirsson's paper.

5) 'Trap Dikes,' Bull. 107, U. S. G. S. 1893.

6) 'On Analcite Diabase from San Luis Obispo County, California,' Bull. Geol. Depart. Univ. Cal., Vol. I. p. 273.

7) 'An Analcite-Basalt from Colorado,' Journ. Geol. Vol. V. p. 684.

8) 'A new Analcite Rock from Lake Superior' Journ. Geol. Vol. VII, 1899, p. 432.

9) 'The Mochiquites or Analcite Group of Igneous Rocks,' Journ. Geol., Vol. IV. 1896, p. 679.

same chemical composition as that of *analcime,* and the physical properties observed give no hinderance to the assumption that this component actually is that mineral. He thinks the analcime is primary, having been formed from the magma, containing water and much soda, under pressure with considerable rapidity.

From what has been stated before, I have also, to all appearances, the primary analcime in the interspaces of the components in the Basalt from Gio-ô, and the radiating bundles of a strongly birefringent *natrolite* are formed secondarily from the analcime through a molecular rearrangement. Both components make their appearance with the dodecahedric networks (*Pl. II, Fig.* 5) of the skeleton magnetite which occupies the other portion of the slides.

THE IRON ORES.

Both ilmenite and magnetite are present, and they usually belong to a single generation, and indeed the product of the effusive period, as the iron ores were not found enclosed in the olivine of the intratelluric crystallisation. Both ores, especially the ilmentite, have crystallised *later* than plagioclase, but slightly prior to, or contemporaneous with, the monoclinic pyroxene. The ilmenite and magnetite are, under the microscope, not easy to be distinguished, as every petrographer will agree, if crystal forms are not serviceable for their diagnosis.

The *ilmenite* is, however, tabular and needle-shaped in section in the Basalt with a strong lustre and a violet tinge, when seen by reflected light, on the flanks corresponding to the thickness of slide. The laths are slender, appearing merely as lines, and cross several crystals of felspar and augite, meanwhile the substance of the ilmenite entirely disappears when traversing other crystals, and comes again into view in the same direction as a continuation of the interrupted crystals. Unfortunately basal sections were not frequently observed, and this was the greal obstacle in ascertaining the presence of ilmenite n microscopic analysis. The ore with above-mentioned lamellar habit occurs exclusively in a *coarse-crystalline* type of intersertal, or ophitic structure, irrespective of hypersthene or olivine-bearing Basalt; and this fact lends evidently a strong support to the view advanced by K. Hofmann,[1] that the ilmenite accumulates in the lower portion of lava-flows, and in that which has crystallised under high pressure, while the magnetite is rich in the upper part that has consolidated under a low pressure. Fr. Sandberger[2] says also that Basalts may be classified into Dolerite and Basalt proper, by the presence of ilmenite in the former and magnetite in the latter. These fruitful ideas inaugurated by both authors, now unfortunately passing into oblivion, deserve the careful attention of petrologists.

A slide of the Basalt from the islet of Hattô was treated for a considerable length of time with a strong hydrochloric acid without any appreciable result. A large quantity of the pulverised sample of the same specimen was then digested in boiling HCl with the addition of tin-foil, and the solution was coloured slightly violet, showing the presence of titanium in the dissolved portion of the ore. Ilmenite also occurs, according to Vénukoff[3], very abundantly in the Basalts of Mongolia, and even transparent lamellæ were found by him, just as in the Pescadores rocks. The ilmenite is fresh and leucoxene not noticed.

1) 'Basalt von Bakony,' *Zeitschr. d. d. geol. Ges.*, XXIX., 1877, S. 191.

2) Rosenbusch, 'Mikroskopische Physiographie,,' II., 3te Auflage, S. 1015.

3) 'Les Roches Basaltiques de la Mongolie,' *Bull. Soc. belge de Géologie, etc.* T. II., p. 413.

In my few slides of Basalts, bearing the *iddingsitised* olivine, *ilmenite seems to be wanting,* though the rocks approach to a Doleritic type, being replaced by magnetite. I cannot say positively that this rule holds true for all the iddingsite-bearing Basalts.

The *magnetite* is, on the other hand, the prevailing ore in the compact Basalt, and in the Limburgitic type, in the form of isometric crystals and dust, occurring either in the general mass, or else enclosed in augite and olivine. The face of the crystals shows a metallic lustre with a tinge of blue by reflected light. The dust is sometimes peripherally altered into a blood-red iron-glance. A slide made of a chip from Hôko, was digested in HCl with the addition of KI; and then the black ore, therein contained, was entirely removed, and the solution not coloured when tested with tin-foil, proving thus the presence of a pure magnetite. As it is already stated above, the magnetite-rich, compact type seems to make up the upper portion of the thick flows of the Hôko Basalts.

In the Anamesitic type from the islet of Gio-ô, we find beautiful networks of the skeleton-crystals of magnetite in a devitrified mesostasis within the polygonal spaces between crystals. They are the *dodecahedric dendrites,* consequently the skeletons intersect each other at the angles of 60° and 120°, and are said to consist of garnetohedrons. They all go into solution by treating with HCl. Morozewics[1] tells us that the spire and filigree-work of the skeleton magnetite, crystallising out of the magma rich in iron oxides, consist of minute *octahedra,* arranged rectilinearly in the direction of the crystallographic axes with secondary and

1) 'Experimentelle Untersuchungen über die Bildung der Minerale im Magma,' *Tschermak's Mittheilungen,* **18**, 1898, S. 90.

tertiary offshoots. This mode of growth, the *octahedric dendrite*, so called by Morozewics, is well known in petrographical literature, since the publication of Prof. Zirkel's[1] work. On the other hand, it is said that the dodecahedric dendrite, as is in the present case, is formed out of the magma *poor* in iron-oxides.

B. Special Description of Individual Occurrences of Basalts.

A. THE GRANULAR TYPE.

(*Pl. I, Figs.* 1 *and* 2.)

As seen by the naked eye, it is greyish-black and compact, with the dots of olivine which is the only visible component of the whole mass. This type is represented by two specimens from Hôko, and one from Hakusha.[2] Microscopically it is holocrystalline with the smaller phenocryst of olivine, imbedded in the still finer aggregate of the ground-mass.

The fineness of the ground-mass, however, varies in different specimens, and even in the same slide. Some portion of the same slide is, therefore, extremely rich in idiomorphic augite to the total exclusion of felspar and olivine, but with small patches of brown glass. Were this portion independently developed, it would be fitly called the *Augitite* (*Fig.* 2). It is the local assemblage of augite within the rock, and that mineral es-

1) 'Die mikroskopische Beschaffenheit der Mineralien und Gesteine.' Leipzig, 1873, S. 244.

2) Collected at Ryô-bô-san (雰望山); and, according to Mr. Saitô, it appears in I. horizon, *i. e.*, the uppermost sheet, consequently the youngest of all the lavas of the Hôko Group (*Pl. I, fig.* 1).

pecially accumulates near the margin of the secretionary mass, the augite being sometimes arranged along the linear common base, with the free ends of the crystals toward the interior. These phenomena indicate that the lava had consolidated in a quiet state.

The relative proportion of augite and plagioclase is also various, and in the cases where the former outweighs the latter, the olivine increases in its quantity and comes also in the ground-mass, as a product of the crystallization of the effusive period; and at the same time the texture of the rock becomes finer. If, on the other hand, the plagioclase becomes predominant over the augite, then, the texture gets coarser and more crystalline, and the distinction between phenocrysts and ground-mass is not then commonly well marked. Apatite and ilmenite seem to occur in the latter variety only, the ilmenite is sometimes transparent with a deep brown colour.

The only mineral that serves as the *phenocryst* is *olivine*. Its forms are various, owing to the various degrees of resorption. Most have partial crystallographic faces with deep indentations of corrosion, and a drop-like black *iron-ore* and *felspars* were formed in those spaces. Sometimes the act of corrosion has advanced so far that there remain but patches as the relics of a large crystal, and the eating away of the body by the magmatic menstruum proceeds always from the lateral pinacoids. As usual, the crystals of the olivine are not fresh; but the routine of change is the same in all. They become fibrous and lamellar, parallel to one of the lateral pinacoids, the altered portion being yellow or brown, according to the degrees of transformation. The mode of change is similar to *iddingsitization* (*Figs.* 1 *and* 2).

The *ground-mass* consists, first of all, of the crystals and grains of augite, all of a *violet*-brown colour, besides the grains of olivine, and the laths of the multiple-twinned plagioclase, the octahedra and dust of magnetite, and ilmenite. The texture of the rock is crystalline and typically *granulitic*. In a coarse variety, the idiomorphic augite with hour-glass structure forms stellar aggregates, and these aggregates closely resemble the glomeroporphyritic phenocryst.

B. THE TYPE OF THE IDDINGSITE-BEARING BASALT.

(*Pl. I, Figs.* 4, 5 *and* 6; *Pl. II, Fig.* 1.)

Megascopically this type is greyish-black Anamesitic-looking, and finely uniform-granular, owing to the nearly equal size and form of the laths of plagioclase which predominates quantitatively over the other components.

The characteristic features of this group are firstly, the presence of large phenocrysts of olivine which is more or less iddingsitized; secondly, the majority of the augite is xenomorphic or granular, and of small size, and these grains are grouped together intersertally with the devitrified glass between the laths of plagioclase. The structure is typically *intersertal*. The prominent characters distinguish this group from the rest of the Basalts. This type is represented in my slides from the Pescadores by three specimens, one from Kippai, and two from Hôko, one of which was struck off at the locality Tai-san;[1] according to Y. Saitô, it forms the *uppermost flow* there. The same may be said of the specimen from Kippai, since the youngest

1) 字大山, 嵵裡鄉, 澎湖. The rock effervesces with acid. The microscope discloses the fact that the radially arranged fibres of calcite fill up the polygonal spaces between other components, showing bars which correspond to the position of crossed nicols.

lava-flow is the only effusive that can be met with on that island.

The *olivine* is the *sole phenocryst*; it is variable in size (the largest one measures even 5 mm.), irregular in distribution, and multifarious in form, some having partial crystallographic faces, while others have none of them. The iddingsitization is peculiarly inherent in the olivine of this rock-group, and I refer the readers for further details to the topic: "component-minerals" p. 18 *et seq.* By the way, I have only to mention that the name iddingsite may conveniently be applied to a special transitional form of the alteration of an olivine which, after passing this stage, changes into dirty-green spherulitic fibres of an optically positive character.

In the felspar-rich rocks (*Pl. I, Fig.* 6), which are prevalent in the group under question, the *plagioclases* are all approximately of the same size, and surpass the augite both in dimension and quantity; while in the augite-rich rocks (*Pl. I, fig.* 4), the plagioclases are of two generations, and the larger ones behave porphyritically towards the minor ones. They are lath-shaped, and multiple-twinned, the terminations being imperfect and sheafy, and these laths are thrown together in an orderless plexus, which eminently characterises the structure of normal Basalt in contradistinction to that of Andesite.

The *augite* is all of a single generation, consequently uniform, but inferior in size to the plagioclase and olivine. Some are rudely idiomorphic, but by far the most of it is granular, occurring in groups, and filling the angular spaces left by the laths of plagioclase. The augite is, as usual, of a violet-brown colour, but in the specimen from Tai-san, it is almost colourless in sections. It is free from foreign inclusions, and the hour-glass structure is faintly indicated in some individuals. In the coarse, felspar-rich specimen, the *iron-ore* is present only in small quantity (*Pl. I, Fig.* 6), but comparatively large, lamellar and flat with glittering bluish lustre on the perfect cleavage-surface. It looks rather more like ilmenite than magnetite. Stiff, slender *apatite*-needles, sometimes with a brown canal traversing the whole length, are particularly abundant, being scattered through the whole mass.

In the dark fine specimens (*Pl. I, Figs.* 4 and 5), small regular crystals of *magnetite* are plentiful, and in these slides, I found abundantly the small laths of *twinned plagioclase*, which resolve at the ends into slightly *diverging columns* (*Pl. I, Fig.* 5), and these may be easily mistaken for those of apatite, if needles are found detached from the waist. Optical properties are not independtly shown in them, on account of their extreme thinness. Similar bodies are noticed by H. S. Washington in the sanidine of some Ischian - Trachytès and named by him *keraunoid.*[1] He and also Lehmann[2] attribute the splittings and ramifications from the main crystal to the existence of internal tensions in felspar, but the cause of the existence of such tensions remains to be solved.

The *glass* together with the augite fill up the polysynthetic space left by the laths of plagioclase. The glass-base is coloured bottle-green, sometimes dirty brown, and devitrified in various ways. It consists of polarizing scaly aggregates of vermiform, spherulitic, or, irregular shapes. Sometimes *fascicular and radiating needles,* which are *colourless and birefringent,* are imbedded, in the green base as a product of devitrification. The

1) 'On some Ischian Trachyte.' Journ. Amer. Sci., May, 1896, p. 380.

2) 'Molecularphysik,' I, 1888, S. 378.

needles may possibly of a felspathic nature and such a structure is termed *variolitic* by Harker,[1] though in the present case those circular, whitish spots, called varioles, are wanting. Green, fresh base is here and there also found between the angular spaces.

Thin lamellæ of rugged outlines, with violet-brown colour, may be frequently noticed in all of my slides, and they closely resemble those found as interpositions in a hypersthene. I conjecture the mineralogic nature of these plates to be ilmenite.

C. THE OPHITIC TYPE.

(Pl. II, Fig. 2)

This type is represented by a single specimen from Hôko, and Gio-ô[2] respectively, and two from Haku-sha, though the 'lie' is not known to me exactly; but it is highly probable that samples are taken from the *second* sheet which is separated usually from the uppermost columnar flow by an ash bed of a certain thickness. It is a greyish-black, Anamesitic rock, with the *brownish*, lath-shaped phenocrysts of plagioclase (4 mm. length). This is the coarsest type of the Hôko Basalts, and is the one rich in plagioclase in comparison with ferro-magnesian silicates; it seems to have solidified in the lower portion of the lava flow.

Under the microscope, it shows a porphyritic, hypocrystalline, diabasic structure (*Fig.* 2) with the ophitic plates of augite of considerable dimensions, enclosing the laths of plagioclase which lie in all possible directions. The *augite* is of a

1) "The aggregates of felspar-microlites or fibres with fan-like or sheaf-like groupings. They may be closely packed to make up the entire mass of a portion of the rock (Basalt)." Petrology for Students.' 2nd. Edit., p. 191 and 201, Fig. 41 A.

2) The exact locality being Sho-chi-kaku, (小池角) at the middle of the island.

kind of *light-brownish* colour, and its plates are often multiple-twinned, and enclose, besides plagioclase, a number of round and corroded crystals of olivine which is for the most part changed into green, pleochroic fibres ; the iddingsitization of the olivine was so far not observed. The *plagioclases* are of *two* generations (*Fig.* 2), the larger, probably intratelluric, species has fissures (see *Fig.* 2) filled with films of brown hydrous sesquixide of iron, which cause the phenocrystic feldspar to appear *macroscopically* like an *olivine.* The plagioclase is partially embraced by the ophitic plate, while the smaller laths became entirely enclosed in it. The polygonal interspaces, when not occupied by augite, are otherwise filled up with the fibrous devitrified glass, the latter containing globulites, sometimes dendritic, and apatite ; and the thick lamellæ of *ilmenite* traverse the base, but not the plate of augite, consequently the crystallisation of the ore must have taken place posterior to that of the pyroxene. Sometimes the greenish-yellow augite is coarse-granular, and in this case the structure approaches to that of *intersertal. Magnetite* seems to be wanting. Owing to the coarseness of the structure, the rocks are often *porous,* and the polygonal, angular spaces are often filled up with banded, purplish chalcedony.

D. THE TYPE OF THE OLIVINE-LESS BASALTS.

(*Pl. I, Fig.* 3 ; *Pl. II, Figs.* 2 *and* 3.)

The olivine-less, hypersthene-bearing Basalts are represented in my collection by two specimens from Wampai[1], and one from each of the following islands, Hôko[2], Kin-sho[3], and Hattô-sho[4]. They are megascopically wet-grey, and fine-granular,

1) 灣貝 2) Sei-kei 西溪 in Hôko 3) 金嶼 4) 八罩島.

the general microscopic aspect being a crystalline Andesite-like. They are all extremely rich in augite, and the structure is *granulitic.* The felspars are of two generations (*Pl. II, Fig.* 2 and 3), and the rock is consequently porphyritic, owing to the presence of a few large crystals of plagioclase, though this structure could not be easily recognised as such in the present group.

The *phenocrystic plagioclase* is narrow-tabular with a few twinning lamellæ (see *Fig.* 3), and is remarkable in its being traversed through by sets of cracks which run approximately parallel with each other. In one instance, only *one lamella*, out of many twinned parts after the pericline law, is provided with *closely set fissures.* This anomalous feature can be seen in all the specimens of the present type, but not common in others, and the *same peculiarity recurs also in augite* whose granular aspect is due in great measure to the same cause. I cannot offer at present a satisfactory explanation to account for this phenomenon ; but, as Judd says, it might in part have been caused by a slow but constant movement of a crystallizing magma, and also *chilled* suddenly, perhaps by the access of water at the final stage of consolidation. I may here adduce in support of my ground a fact of the special distribution of the Hypersthene-basalt which, so far as I am aquainted with, occurs only in the outlying islets, excepting the locality Sei-kei, on the north coast of Hôko, which also lies not very far from the present sea-shore.

Hyperthene occurs exclusively, though insignificant in quantity, in the form of phenocryst (*Pl. II, Figs.* 2 *and* 3) and takes the place of olivine in the present rock-group. It is sedge-like in general shape, and granular in its margin (especially in Fig. 2), being fringed with grains of common augite, whose presence becomes strikingly apparent between crossed nicols, on account of their vivid colours of polarisation in contrast with the grey tint of the hypersthene in the interior. Pleochroism is scarcely perceptible. Traces of a few rough cleavages run through the hypersthene lengthwise, and as in the case of the plagioclase, it is trasversed with many fissures. The hypersthene is of intratelluric origin, and has the general aspect of its having been worn out caustically and frittered, and the peripheral accumulation of augite, already referred to, seems to have some genetic relation with the act of degeneration.

Large, monoclinic *augite* sometimes makes its appearance in company with the hypersthene and plagioclase, forming local patches of secretional origin, with the *hyperitic* structure.

The *ground-mass*, which constitutes the main bulk of the rock, consists of laths of plagioclase and grains of the frittered and corroded augite, together with rugged clumps of magnetite. The relation of the first two components cannot be told in a few words. In one instance, the mutual relation is such that we could almost say it is ophitic; in another, it is intersertal in company with a little remnant of brown glass, while in the third, no such arrangement could be discovered, but a simple aggregate of felspar and grains of augite, thereby calling forth the structure which is termed *granulitic.* The augites of both generations are of *yellowish brown* and not violet-brown.

Shingly *tridymite* fills up polygonal spaces, and the loose brushes or tufts of either plagioclase or apatite are thrown through the whole mass. A doubtful *iddingsite* (*Pl. I, Fig.* 3) was once observed, and some rocks are calcareous too. The stratigraphic position of this type is not known to me. It may be the lava of either the first or the second flow.

E. THE TYPE OF THE ANALCIME-BASALTS.

(*Pl. II, Fig.* 5.)

This to the naked eye is macroscopically *deep-grey*, and fine-granular. Under the microscope it is hypocrystalline and more or less porphyritic, either the xenomorphic olivine or the aggregate of the automorphic augite being the phenocryst, or sometimes both. The texture varies within a wide range, but generally speaking is coarse (*Fig.* 5). The porphyritic elements, however, *differ generally not much in size* from the crystals of the ground-mass, and the mode of arrangement of the several components is *granulitic*. Plagioclase predominates over augite in quantity; and magnetite is not plentiful, and completely soluble in HCl. The paucity of iron-ore causes the rock to appear of a grey shade.

Olivine occurs as a *phenocryst* in the xenomorphic grains, a few of which have been reduced even to mere flecks through gradual resorption. Cleavages are not noticeable in contrast to other olivines, but in stead of them there are curvilinear cracks, conforming approximately in their direction to the boundary of resorption. The substance of the olivine is colourless, and usually more or less altered into a greenish or yellowish, fibrous substance (not iddingsitic). Brown decomposition is quite foreign to the olivine of this type. The present olivine seems to belong to *a variety rich in magnesia*. *Phenocrystic pyroxene* is scantily present in some, but none in others. The augite is of the typical Basaltic variety, with a *violet-brown* type, possessing the hour-glass structure, and idiomorphic, *flattened* on the *orthopinacid*. It occurs singly or in stellar aggregate. *There is no felspar-phenocryst.*

The *ground-mass* consists of laths of plagioclase, crystals and crystalloids of violet-brown augite, magnetite, and xenomorphic olivine, with the interstitial mass of analcime and base. The laths are multiple-twinned with the parapet-like terminations (*Pl. II, Fig.* 5) produced by the shifting of lamellæ to the one end or the other with reference to the adjacent plate. The slide treated with HCl shows a considerable corrosion of the interior lamellæ of the laths, while the exterior remains intact and fresh, as if a frame is enclosing the hollow space. The crystals of a violet-brown augite of the short prismatic habit, rather flattened towards the ortho-axis, are freely developed, or occur in clusters. The augite and plagioclase must have, therefore, crystallized simultaneously, and at their contact the one is partially penetrating the other and *vice versa*. Magnetite is idiomorphic, but frequently possesses irregular outlines, owing to the penetration of the crystals of plagioclase, augite, and apatite, and the larger crystals are anhedrons, as they are moulded upon the neighbouring laths of the plagioclase. The magnetite is comparatively large and few, excepting its dendritic skeleton crystals which are found abundantly in the specimen from Gio-ô, in company with devitrified glass. In the specimen, which is wanting in dendritic magnetite, there are brown, biotite-like lamellæ usually in association with the hexahedral iron-ore. The lamellæ are anisotropic, and distinctly pleochroic, and the mineral is conjectured to be *ilmenite*.

It is of no small interest to note the presence of *analcime*. It occurs sporadically rather in large patches in the cuneiform spaces left by other crystals. It is generally fresh and colourless, and isotropic, but often shows the optical anomalies so common to this mineral. At times, the analcime resolves into a dirty, fibrous *natrolite* (as in the left, lower margin in *Fig.* 5). The analcime seems, so far as my experience goes, to be exclusively confined to this type, though it is possible that the colourless base in minute interspaces of other Basalts of the Hôko Group, might turn out to be that mineral, if the means are at hand in ascertaining its presence.

Another accessory to be mentioned is apatite in colourless prisms, which is especially plentiful in this type.

The *colourless base* and *analcime* are rather *unexpected guests in the basic, black rock,* such as we have here, and the mode of occurrence is that they fill up the polygonal interspaces left by the crystals of other components of the rock. If we accept the primary origin of the analcime, as Pirsson[1] would do, it is all the more very striking to see that the residuum of a Basaltic magma should have an exact composition of $Na_2O \cdot Al_2O_3 \cdot 4\ SiO_2 \cdot 2H_2O$. Yet the analcime seems to all appearances to be of primary origin, if we take into account the perfectly fresh state of the rock in which it is found, and not only in the Basalts of the Hôko Group, but in the Teschenite of the Nemuro promontory in Hokkaidô, I had several occasions to observe the same mode of occurrence of the analcime, so that it could not be attributable to a mere accidental circumstance to find it in such state, as several foreign writers also noticed the same. It excludes the idea of its having replaced the base which formerly occupied the place of the now-existing analcime.

The present mode of occurrence of the analcime may perhaps be explained by supposing that, when the Basalt was consolidating on the surface in a quiet state, carrying in it the intratelluric olivine, the newly created crystals, such as those of plagioclase, augite,

1) 'The Monchiquite or Analcite Group of Igneous Rocks.' Journ. Geol., Vol. IV., 1896, p. 679.

magnetite, apatite, together with the olivine had then sunk down, and formed the heap of crystals at the bottom; meanwhile the unconsolidated residuum of the magma was actually slowly flowing through the sieves of crystal-heap, or changed its chemical composition through diffusion, after the manner of liquation as in a metallurgical process. And, then, the solution having the composition of the hydrous alumino-sodium-silicate has finally crystallised out in the interspaces of the meshes of crystals. Similar process can be frequently observed during the formation of crystals on the stage of the microscope. If this be the actual condition under which the Analcime-Basalts have consolidated, considerable leaching and percolation must have taken place during the formation of rocks, and the structure of such a rock should better be called the '*leached.*' This structure is therefore properly seen only either in the *granitic* or in the *granulitic* rock, consequently it is wanting in the family which has a fluxional arrangement of the components.

The Analcime-Basalts are represented in my collection by three specimens from Gio-ô, and one from Hôko. The hand-specimen from Nai-an[1] in Gio-ô, is, according to Y. Saitô, said to occur at the water's edge, the main portion of the flow usually lies under the level of sea, and constitutes *the third sheet of lavas, and is the lowest, consequently the oldest of the accessible lava-flows of Gio-ô.*

Other Analcime-Basalts of the Hôko Group no doubt belong to the same horizon.

1) Nai-an 內安, 漁翁島.

THE ISLAND OF KÔTÔ[1] (BOTEL-TOBAGO).

Starting from Makian[2], one of the Spice Islands, a long chain of the Moluccan volcanic system runs upwards, and joins at the solfataric volcano of Api, in Mindanao, with that of the Sangirs, that comes from the north end of Celebes. The united system of volcanoes in the Philippines, then, receives the name of the Mayon system. It goes right through the whole breadth of Mindanao, and enters Caminguin, Leyte, Biliran, and, afterwards, the peninsula of Camarines of south Luzon. It is in the last-named region that the volcanic activity of the Philippines is fully displayed. Albay or Mayon stands foremost in rank among the mighty cones. For a while, we lose sight of the chain northwards under the Pacific bottom, and it reappears in full force at the crater of Cagua near Cape Engano, in north Luzon.

The northern prolongation of the Mayon system may still be traced through the little-known Babuyans,[3] the Batans, and the Bashi islands. All are said to be of volcanic origin. Among the Bashi or Vasshi[4], the five larger islands, going from the south to the north, are Liayan, Mabudis, Tanem, Maysanga, and Tami, the last being the largest of the forlorn isles. An active volcano is said to exist in the southern region (?), spreading fire and destruction.

The Balintang Canal at 20° N. lat. separates the Japanese

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1) 紅頭.

2) B. Kotô, 'On the Geologic Structure of the Malayan Archipelago.' This *Journal*, vol. XI, pages 111 and 118. Wichmann calls the chain the 'North Moluccan bow.' 'Der Wawani auf Amboina und seine angeblichen Ausbrüche, III.' *Tijdschr. v. h. Kon. Nederl. Gen., Jaargang* 1899, S. 32. This bow is now said to start from Batjan, lying to the south of Makjan. *loc. cit.* S. 14.

3) Kotô, *loc, cit.* p. 118.

4) The *Japan Mail*, August 10th 1897, 'Forlorn isles.'

domain from that of the United States. Within the Japanese waters lie the Batans, the Bash islands, the rocks of Gadd and Forest Belle, the islands of Shô-Kôtô (Little Botel-Tobago) and Kôtô (Botel-Tobago), and, lastly, Kashô (Samasana), as the continuation of, I conjecture, the Mayon system of volcanoes (*Fig.* 1).

The smaller isle of Kôtô is, geologically speaking, entirely unknown, but the Larger Kôtô has been several times visited by the Japanese, since the first landing of a staff of the governorship of Taiwan, in April, 1897. Among our University men, Mr. Tada stayed there a week collecting zoological specimens, and, lately, Mr. Torii remained longer in this lonely island among the aborigines for his anthropological study. I myself have not had the opportunity of visiting it, though the island has been within my sight for a week long, while travelling the pathless beaches of south-eastern Taiwan.

The island of the Larger Kôtô (*Fig.* 1) lies in a south-eastern direction about 50 miles off the coast of Pinan, and 35 miles north of north-east from the Cape of Galambi in Taiwan. Its north-south extent is 3 *ri* and the breadth 1½ *ri*, with the circumference of 9 *ri*. It is the abode of 1,500 nude aborigines. Seen from a distance, this scapula-shaped island appears plateau-like in general profile, crowned by a prominence of 120 m., somewhat excentrically situated in the north; and is bounded by steep declivity all round the coast, so that it leaves only a narrow patch of lowland on the south-western shore, which serves at the same time for the chief anchor-ground of this islet.

Being situated amidst the stormy and swift *Kuro-shiwo* current, the narrow beach is highly cobbly, as may be seen from Mr. Torii's photographs; and the steep cliff undoubtedly owes its present form to the abrading action of dashing waves.

Fringing reefs are said to skirt the shore, some portion attaining double the man's height above the water's edge, indicative of a recent negative shift of the relative levels. It seems to me probable, that they are not the reefs of Neocene time, which usually attain a considerable height of more than 200 m., as in the Apes Hill of Takao, but those of a comparatively recent date, possibly representing a *Diluvial formation.* The plateau-like elevation, which faces the sea in cliffs, seems in parts at least in the north-east point to consist of volcanic agglomerate. A greater part of the interior seems to be built of volcanic rocks with a gabbro-like plutonic mass as the foundation of the island exposed at the west coast, but their mutual relations and area of distribution are quite unknown to me.

In the following, I will give a succinct account of rocks, kindly placed at my disposal by Messrs. Ishii and Torii.

A. FELSPAR-BASALTS.

(*Pl. III, Figs.* 3 *and* 4.)

My slides of Basalts and Andesites are prepared from chips of water worn gravels, used as weights attached to a fishing net of the aborigines.

The Basalt is rather porous, greyish-brown mass with a few *phenocrysts* of a brown olivine (1-2 mm.) and black common augite. Under the microscope, the *olivine* occurs in two generations (*Fig.* 4). Its forms are acute six-sided, sometimes nearly square, truncated at corners, but mostly corroded and disfigured, with a few traces of basal cleavage. The crystals are slightly decomposed in their margin, being either yellow or brown; but as a whole the interior is fresh. It is the iron-rich variety—*hyalosiderite,* as is proved by the micro-chemical reactions, which show only a trace of magnesia. The olivine encloses a large quantity of regular octahedra or elongated crystals of the brown, transparent *picotite,* mixed with the crystals and dust of magnetite.

Plagioclase, as a phenocryst, is observed only once in my three slides; it is long-rectangular in form, with negative crystals, filled with a gas. The crystal is multiple-twinned, extinguishing light symmetrically with the maximum angle of 32°; consequently it is the calcium-labradorite. The *augite* is rather automorphic, showing, however, a slight corrosion marginally. This character is common to all of the specimens. The crystal occurs in polysynthetic twins; the colour *yellowish-green* and non-pleochroic. As usual, it has glass-enclosures with air-pores. Sometimes, the augite is *internally* and *nucleally* resorbed, leaving an accumlation of grains of the same in its place. The augite is of nearly the same size as the olivine.

The *ground-mass* is seen, under the microscope, to make the main bulk of the rock. The micro-phenocrysts of olivine and augite are the same in habit as the macro-phenocrysts. The augite is in a few cases fringed with *skeleton-crystals.* They are inbedded in the plexus of the felspar-laths and clumps of magnetite, rudely showing a flow structure. The laths are twinned simply or polysynthetically, and in many case *hollow,* with the very thin external rim, partially or entirely filled up with glass. So far as I am aware[1], such skeleton-crystals of felspar seem to

1) The same skeleton laths are observed by E. Elich in the Amphibole-pyroxene Andesite from the Rio Blanco, West Cordillera, Ecuador. Reiss u. Stübel, 'Reisen in Süd-Amerika, Das Hochgebirge der Repubik Ecuador, I.; Petrographische Untersuchungen, I. West Cordillere,' S. 163.

be of *extreme rarity*. The laths extinguish light symmetrically, but in the contrary direction at an angle of 26°-27°, proving the felspar to be more acidic than its phenocryst. Interstitial space is occupied by a brown glass which contains globulitic and rod-shaped bodies. *From the foregoing descriptions, it is evident that the Basalt of the Island of Kôtô does not properly belong to the category of normal Basalt with violet augite, presenting the intersertal structure, which is so common in the rocks of the Hôko group, already described.* Here exclusively monoclinic augite presents the character of *diopside*. Both the olivine and augite, all being equally corroded, present so great a variation in size from the macroscopic to the microscopic dimensions that I could not discriminate the products of the intratelluric from the effusive period of consolidation. The ground-mass, as I have said, is highly felspathic, and the structure is Andesitic and hypocrystalline-porphyritic, somewhat resembling a pilotaxitic type. Richness in olivine and paucity in iron ores, as well as globulitically granulated mesostasis make the rock approach to a *navitic structure* (*Fig.* 4), the only difference being the presence of feldpar-laths in the ground-mass. The rock seems to me to be a lava-flow, consolidated rapidly, accompanied by a brisk liberation of gas from the cooling magma.

B. HORNBLENDE-ANDESITES.

(*Pl. III, Fig.* 5.)

I have three specimens of rocks in Torii's collection, belonging to the same category. They differ in colour consequent on the various stages of decomposition. A fresh one is greyish and porous, speckled with phenocrysts of hornblende (2 mm. in length).

Plagioclase is long-rectangular along the zonal axis at right-angles to 010, and tabular when parallel to that face (*Fig.* 5). It varies in size so that between the phenocrystic felspar and that of the ground-mass we could find a series of dimensions. Zonary structure is typically developed in almost every individual, especially on the tabular section of 010. It contains, as usual, glass arranged in zones; sometimes encloses crystals of augite and hornblende, parallel to base and the positive dome; it extinguishes light in symmetrically opposite directions with the maximum angle of 30°-34°. The extinction observed on 010 amounts to 15° with reference to P/M, the trace of the pericline twins making 1.5° with P/M on the same face. These rough observations all point to the labradorite-nature of the felspar. *Hornblende* occurs only as the phenocryst and small in quantity. It is a brownish-green variety of optically normal character. The crystals are all corroded and enclosed by the opacitic margin (*Fig.* 5) which is composed of confused aggregate of crystalloids and grains of monoclinic pyroxene, and clumps of magnetite. The pyroxene appears in tolerably large size that it could be optically ascertained. Sometimes the substance of the margin has been replaced by *brownish, double-refractive fibres.* In one slide the body of the hornblende is impregnated with countless swarms of black dots which lend to the crystal a darker shade. With high powers, they resolve into *glass-enclosures* with *bubbles.*

Augite occurs *sporadically* as a phenocryst. Its coarse distinct cleavage, pale colour, and small angle of extinction (less than 32°) prominently characterise this pyroxene, and contrast pronouncedly with the brown, Andesite augite. That it is *diopside* is highly probable, but not proven. In one slide, I observed porphyritic aggregate of needles, producing the glomeroporphyritic structure, and they look more like a druse than like a mass of crystals, having a mutual relation, characteristic of plutonic rocks. *Thus our augite is remarkable in many respects.*

The *ground-mass* consists mainly of the idiomorphic plagioclase, long-rectangular or square in shape, and of various sizes, with some degree of parallel disposition. The square sections of the microliths show occasionally truncation of corners by domal face and at other times slightly diverge from rectangularity on the edge 001:010. The traces of cleavage run parallel to the same edge, and the sutures of twins run vertically. Symmetrical extinction takes place at 30°-32° with reference to the same trace, showing that the plagioclase stands just at the middle of the series between the sodium and the calcium labradorite[1]. According to Becker, these square sections, which are prismatic sections in vertical positions, are very convenient for the determination of the microlithic plagioclase. Intermixed with the felspar, we find the less idiomorphic crystals of pale augite, together with rounded magnetite and the crystals of apatite. The cuneiform space left by minerals being filled with the brown glass, densely charged with transparent augite. *The structure of the rock is therefore that kind which we call the 'orthophyric.'* In the β variety, minute felspar-needles make the greater part of the ground-mass, exhibiting the typical pilotaxitic structure.

C. APOANDESITES.

(*Pl. III, Figs.* 1 *and* 2.)

One variety is whitish, bleached and compact, the other is green through the presence of a chloritic mineral, having a por-

1) Becker, *Amer. jour. Sci.*, May, 1898.

phyritic structure with the phenocrysts of plagioclase and hornblende. They are much speckled with glittering iron-pyrites (a large black spot in *Fig.* 1), which likely attracted the attention of Mr. Narita, who had brought back the specimens to Tai-hoku.

The phenocrystic *plagioclase* has a tabular form being nearly equidimensional. It has a distinct zonary banding, like the preceding rock. Contrary symmetrical extinction of about 33° on both sides of the trace of the albite twins shows the plagioclase to be a labradorite of a similar composition as in the rocks, just described. *Hornblende* is entirely decomposed (in the right halves of *Figs.* 1 and 2) into an aggregate of pistacite, chlorite, and calcite-films, which together form the pseudomorph after the hornblende of a prismatic habit with the combination of 010, as may be conjectured from the original outlines of the now altered mass. The chlorite possesses the normal character, and pleochroic, showing a green shade parallel to the axis of fibres, which corresponds to 𝔄. The *epidote* occurs in tufts and in rugged plates.

The *ground-mass* consists of very fine laths, simply twinned, and they are arranged in more or less parallel disposition around the phenocrystic felspar. These minute crystals of felspar swim within the chlorite-lamellæ, mixed with the felspar-microlite, magnetite and the pyrites, the last does *not* contain any trace of *copper*. This Apoandesite is no doubt derived from the β variety of the Hornblende-Andesite, already described, by the pneumatolytic process which caused the impregnation of the pyrites in the rock-mass.

D. AMPHIBOLIZED GABBRO.

A dark-greyish, coarse rock of gabbroitic aspect, in which a cleavable hornblende lies after the manner of plutonics, and a plagioclase is moulded upon the amphibole. Patches of epidote and iron-pyrites complete the list of megascopic elements. Under the microscope, the greenish-brown hornblende is for the greater part altered into a nearly isotropic lamellæ of chlorite, calcite-films, and common epidote. The *hornblende* has been so highly altered that the original substance remains but in few stripes. The *plagioclase*-anhedra possess only a few twinned lamellæ, besides the Carlsbad type of twins. Suitable section could not be found for ascertaining the nature of the plagioclase. The general deep-greyish appearance of the felspar is due to the presence of a pennine-like chlorite in the fissure of it. Common *epidote* occupies the place of the felspar and hornblende in rugged plate. Crystalloid of *apatite*, full of air-pores, was only once observed.

I conjecture this rock to be a *metagabbro*, though a diallage-like augite was never seen in my slides. This gabbroitic mass probably makes the foundation of the island, and crops out on the *west* coast, together with the Apoandesite and Serpentine.

E. SERPENTINE.

Associated with the above rock, there occurs a Serpentine which is yellowish-blue in its general appearance. Under the microscope, the whole mass presents between crossed nicols a beautiful lattice-work, which is a characteristic feature of its having being derived from an amphibole. There are found intermixed with the Serpentine a little quantity of iron-ore.

THE ISLE OF KASHÔ (SAMASANA).

(*Pl. III, Fig.* 6.)

Kashô is a forest-covered, conical volcanic island (*Fig.* 1), only 8 km. in circumference, skirted by fringing reefs. The inhabitants are of the mixed blood of the Chinese and the Malays. According to Mr. Ishii, who gave me a rock-specimen, the island is Andesitic, consisting of Pumice and lava-flows, and carries two craters. My slide shows the rock to be the *Hypersthene-hornblende-Andesite.*

To the naked eye the rock resembles very closely those of Héradaké, in Shinano, and Hakusan in the Kaga province. It is greyish-looking, with the only phenocryst of hornblende, measuring 5 mm. by 2. The *hornblende* is the largest of phenocrysts (on the right half of *Fig.* 5), broad-columnar in form in combination of 110 and 010, and has always thick margin of opacite. The hornblende has dark-brown colour, and optically normal. It encloses the grains of felspar after the fashion of poikilitic plate, especially on periphery. This fact conclusively shows the simultaneous crystallisation of the hornblende in its later period with the forerunner of plagioclase. The formation of these crystals might have taken place at the close of intratelluric period of the magma. The opacitic margin consists, as usual, of the grains of monoclinic pyroxene and magnetite. They seem to have been formed by resorption and re-combination through the gradual caustic action of the surrounding magma upon the already existing hornblende, at a slightly lower pressure and in the upper column of effusive lava than the situation in which the original amphibole has crystallized out. The majority of crystals seems to have been eaten up by the magma, so that there remains nothing but the accumulation of magnetite-dust in the place of the hornblende.

A brown pleochroic *hypersthene* occurs in few quantity, and small in size and less idiomorphic when compared with the amphibole. Its base shows no axial poles, but symmetrical hyperbolas; it forms penetrating twins upon a domal face, and often moulded upon plagioclase. The *plagioclase* is of tabular or long-rectangular shape; extinguishes symmetrically in the direction at about 30° against the trace of the albite-twins, and the trace of pericline lamellæ makes -5° to -10° on 010 with P/M, indicating the presence of labradorite. The albite-lamallæ are clear and definite, but the width varies much from one lamella to another, and even in the same the width varies from one point to another,—these are also said to characterise labradorite. Zonary banding is pronounced, the interior abounds in glass-enclosures, with the clear shell of different optical orientations. We meet often with the broken crystals, from which it may be inferred that the rock is a lava-flow. The *ground-mass* consists of a plexus of augite-needles in a colourless base, intermixed with a somewhat larger plagioclase of a tabular, or long-rectangular form, after the manner of a micro-phenocryst. Twinned slender sections show symmetrically the opposite extinction at an angle of 20°, indicating that the felspar in the ground-mass is andesine in lieu of the larger, phenocrystic labradorite. *Magnetite* abounds in the glassy base. *Tridymite* fills free spaces in imbricated scales.

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(PHOTOGRAMS.)

PLATE I.

Fig. 1.—A fine compact basalt, with comparatively large phenocryst of olivine which is more or less iddingsitized. The ground-mass consists of small crystals and grains of augites, granular olivine and the laths of plagioclase, with the structure typically *granulitic*. Bô-ryo-san, Haku-sha Island. P. 33.

Fig. 2.—The same rock-type as the preceding, but rather coarse. On the right side in the figure is a augititic patch, composed of exclusively the crystals of augite in the base. Hôko Island. P. 33.

Fig. 3.—Olivine-less basalt from Hattô, Southern Group, and it probably belongs to the same type as Figs. 3 and 4 in Plate II. A doubtful olivine is present in the form of chloritic patches, but no visible hypersthene. General mass consists of a plexus of fine grains of augite and fine laths of plagioclase in the base. This is quite an anomalous rock. P. 39.

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Fig. 5.—Rock belonging to the same type as the preceding. It is also from Hôko Island. Olivine on the left side of the figure shows various stages of iddingsitization.

Fig. 6.—Also iddingsite-bearing basalt, with olivines changing from the interior, as may be seen on the lower side of the figure. Magnified 38 diameters and not 65, as is stated in the Plate. Nicols crossed. Kippai Island.

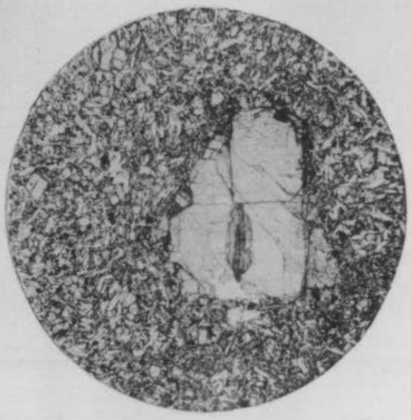

Fig. 1. ×24

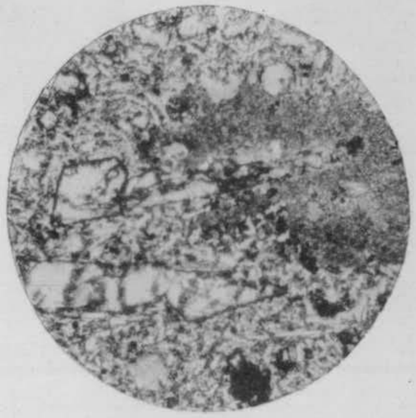

Fig. 2. ×24

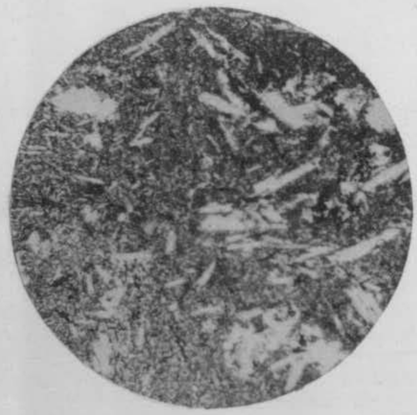

Fig. 3. ×65

Fig. 4. ×65

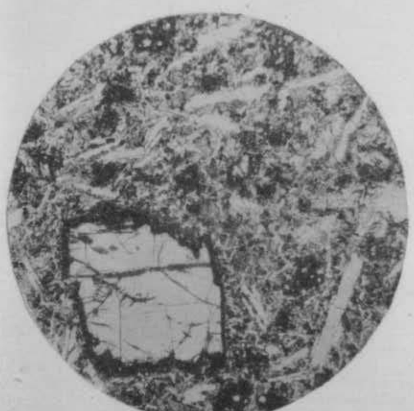

Fig. 5. ×38

Fig. 6. ×65 +*nicols*

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PLATE II.

(PHOTOGRAMS.)

PLATE II.

Fig. 1.—Iddingsite-bearing andesite, magnified 65 diameters, showing the typical intersertal structure. Olivine is here changed internally into a red mineral, which the writer believes to be iddingsite, as is well seen on the lower right octant in the figure (pp. 19 and 35). Kippai Island.

Fig. 2.—The slide of ophitic basalt (p. 38). Shô-chi-kaku, the Island of Hôko.

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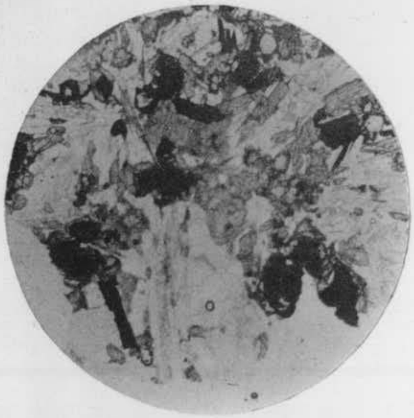

Fig. 1. ×65

Fig. 2. ×24

Fig. 3. ×24

Fig. 4. ×38 +*nicols*

Fig. 5. ×65

Fig. 6. *Nat. size*

Kotô phot.

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PLATE III.

(PHOTOGRAMS.)

PLATE III.

The Plate III illustrates the type-rocks from the Isles of Kôtô (Botel-Tobago), and Kashô (Samasana).

Fig. 1.—Apo or altered andesite, magnified 65 diameters, showing a phenocrystic hornblende, with opacite margin (on the right side of the figure). The hornblende is entirely decomposed into an aggregate of pistacite, chlorite, and calcite-films. Plagioclase is much decomposed. A dark spot (in the lower left octant) is the iron-pyrite (p. 52).

Fig. 2.—The same slide under crossed nicols.

Fig. 3.—A porous, greyish-brown basalt, with a rather large corroded olivine (on the left of the figure). The ground-mass, which encloses a corroded diopside-like augite, is highly felspathic. The structure is hypocrystalline-porphyritic, approaching to the pilotaxitic type (p. 48).

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Fig. 5.—Hornblende-andesite, with dark hornblende-crystals, surrounded by opacitic margin (on the upper and the lower end of the figure). The structure is orthophyric (p. 50).

Figs. 1–5 are all from the rocks of Kôtô.

Fig. 6.—Hypersthene-hornblende-andesite from the Isle of Kashô, with a large phenocryst of hornblende (on the right half of the figure). It is enclosed by a thick margin of opacite, but enclosing the grains of plagioclase after the fashion of poikilitic plate (p. 55).

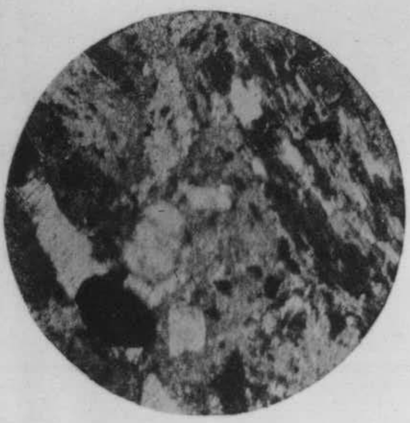

Fig. 1. ×65

Fig. 2. ×38 +*nicols*

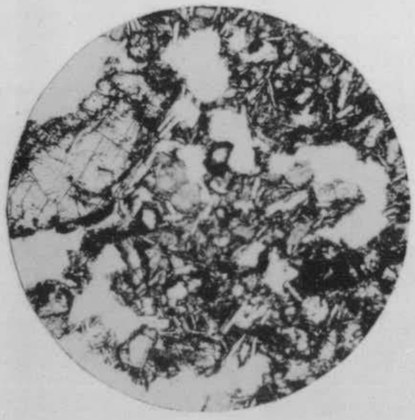

Fig. 3. ×38

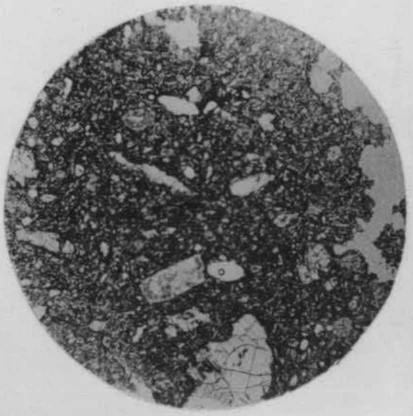

Fig. 4. ×38

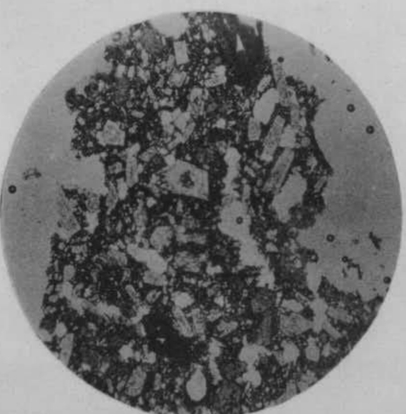

Fig. 5 ×38

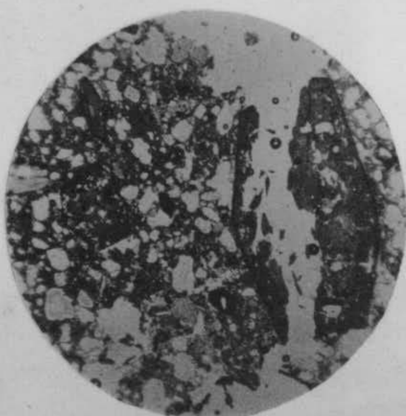

Fig. 6. ×38

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PLATE IV.

(MAP.)

PLATE IV.

The Plate IV shows the bathometric condition of the neighbouring seas of the Pescadores or Hôko Group. It seems to me that the North Group forms itself an independent centre of extravasation of magma, in contrast to the South or Rover Group, from which the Northern is separated by the incurve of the forty fathom-line,—the position indicated by the Rover Channel. Both groups are, however, located at the north-eastern end of the Formosa Bank, which is disconnected on the east from Taiwan by a channel of the same name (p. 3).

THE HÔKO GROUP.

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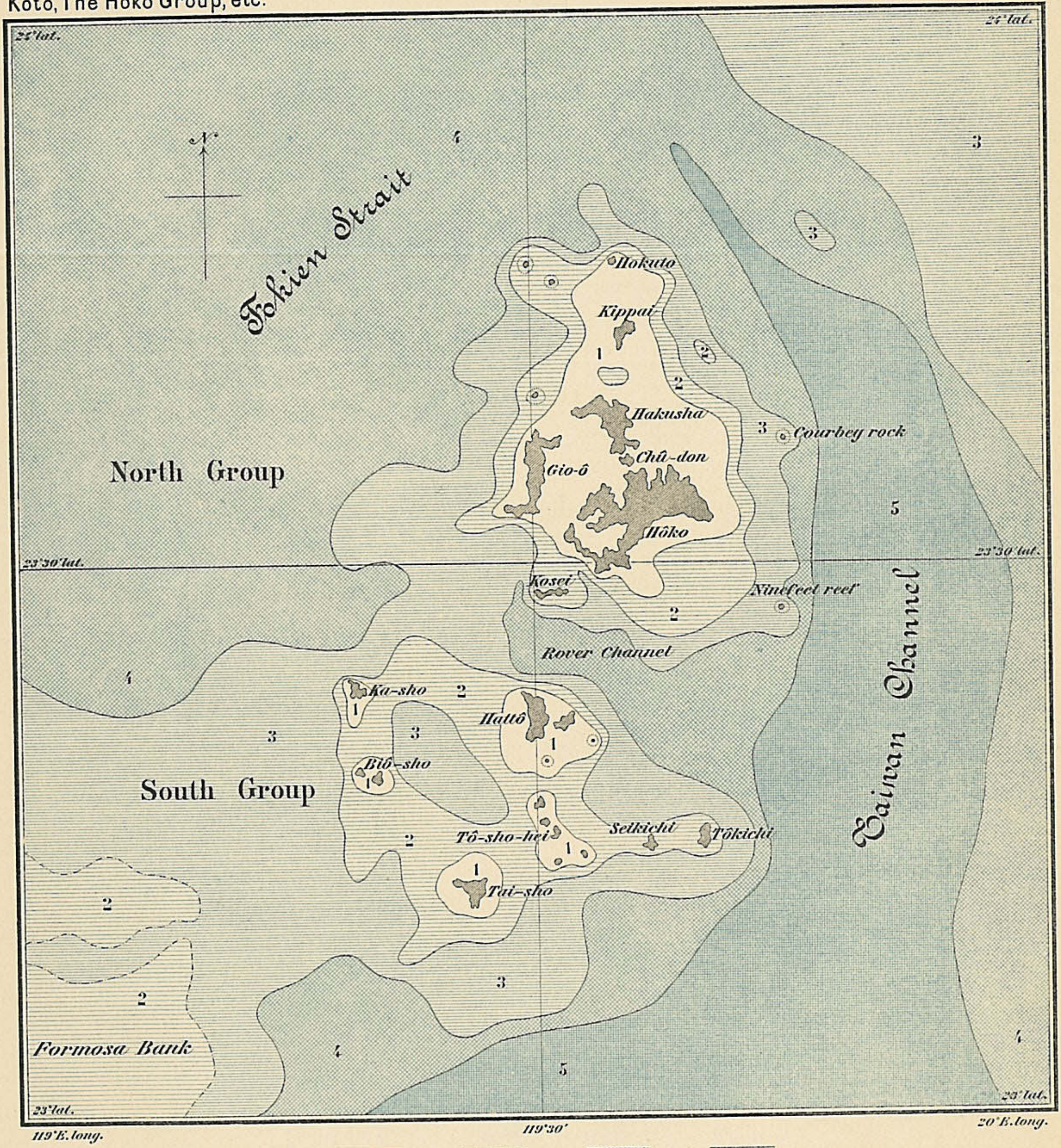


1 -10	2 10-20	3 20-30	4 30-40	5 +40 Fathoms

Scale 1: 680,000.

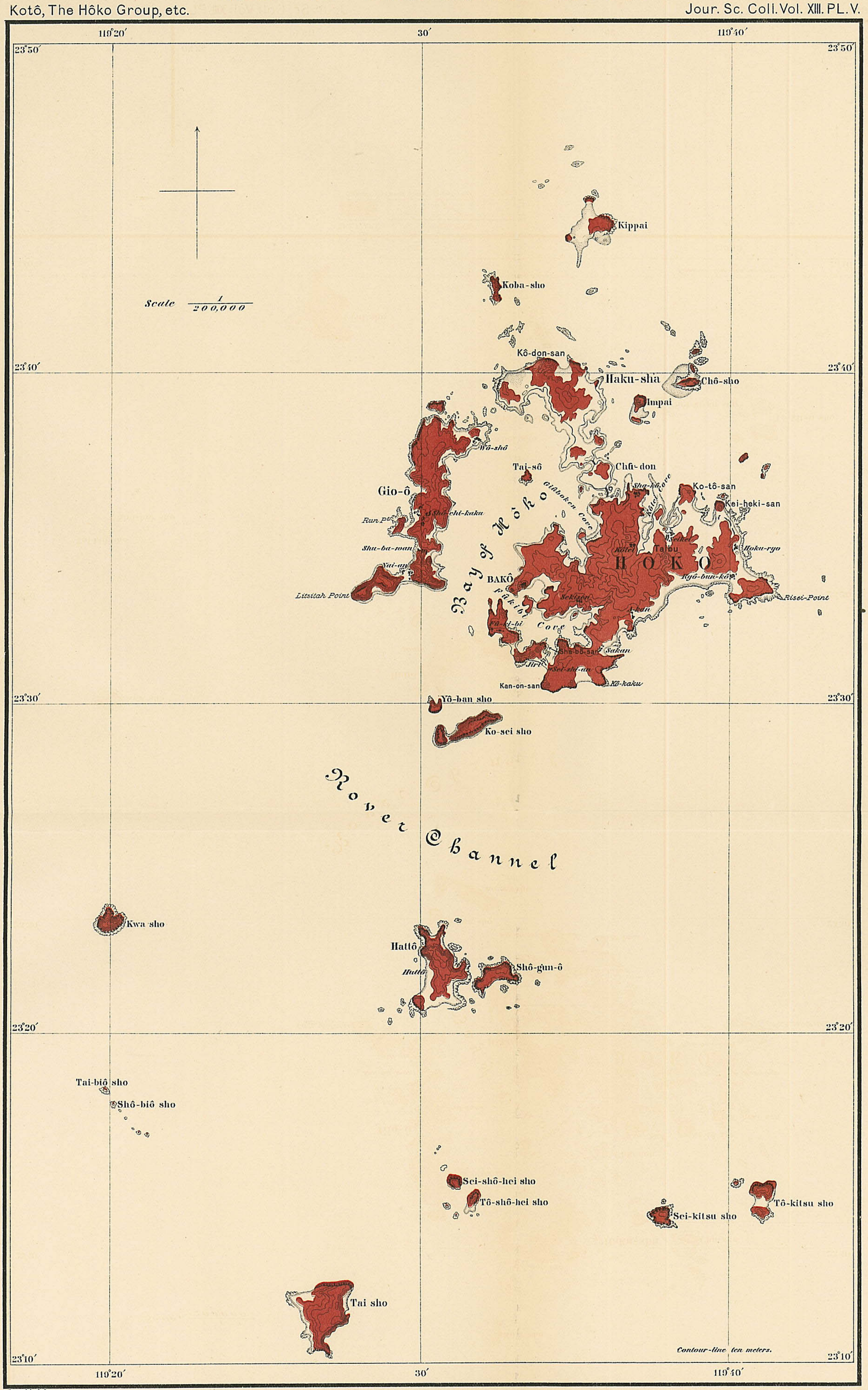
PLATE V.

(GEOLOGICAL MAP.)

PLATE V.

The Plate V is intended to show the geographical distribution of the Tertiary basalts with intercalated sedimentaries and several Recent formations, one among the latter being, the coral-reefs which fringe the coast all round. The topographic basis for the geological map is compiled by myself from various sources, the data being supplied chiefly by Mr. Y. Saitô, who also offered me assistance in colouring the geologic elements represented on the map.

MAP OF THE HÔKO GROUP.



Sasaki del.

TERTIARY — Basalt; RECENT — Coral sand, Coral reef, Clay