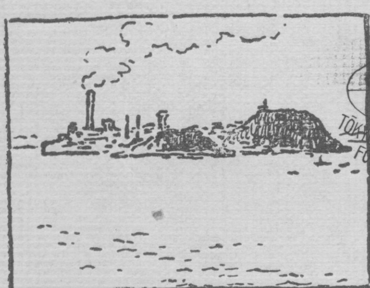
GUIDE-BOOK EXCURSION E–2

(Nov. 15th–19th, 1926)

THE BESSHI COPPER MINE AND YASHIMA



PAN-PACIFIC SCIENCE CONGRESS, 1926

JAPAN

BESSHI COPPER MINE AND YASHIMA DISTRICT, SHIKOKU

CONTENTS

I. GENERAL TOPOGRAPHIC AND GEOLOGIC SKETCHES OF SHIKOKU ISLAND

BY YOSHIAKI OZAWA

GENERAL TOPOGRAPHY

With respect to both topography and geology, the Island of Shikoku[1)] is divided into two dissimilar parts by the median dislocation line which extends in a nearly straight line from Tokushima to Matsuyama. The northern part together with the Setouchi (Inland Sea) and Chûgoku has been termed the Inner Zone, while the southern area belongs to the Outer Zone. In character of relief these two zones present an interesting contrast.

a) **Northern part of Shikoku** :—Along the southern margin of the Inner Zone there is the Sanuki mountain range, which being composed of folded Cretaceous rocks shows some linearity in the disposition of

1) Shikoku or the "Four Provinces," is so named because it comprises the four provinces of Sanuki, Awa, Tosa, and Iyo, corresponding to the four administrative prefectures of Kagawa, Tokushima, Kôchi, and Ehimé respectively.

its crests and valleys; while the northern area, consisting mainly of granite and several flows of andesitic rocks, is irregularly mountainous in its topography. In the northern area, the continuity of the mountains is broken by broad, open, and nearly flat-bottomed valleys and alluvial plains. In northern Sanuki, many beautiful cones and flat-topped mountains capped with sanukite[1] flow are widely distributed, and give the landscape its characteristic appearance.

b) **Southern part of Shikoku**:—This part of the island has the general profile of a much dissected orographic tilted block with a gentle slope to the south and a crest line on its northern border. Therefore, if the valleys were filled, the surface of the Shikoku ranges would be a plateau sloping gently to the south. On the contrary the northern margin of this plateau rises from the Inner Zone abruptly in slopes that reach heights ranging from 800 to 1,900 meters. Being composed mainly of zonally arranged sedimentary rocks, the Outer Zone is marked by notable linearity in its crests and valleys, and its geomorphy is in general less mature than that of the northern part. The most remarkable linear feature is the mountain range of the northern border of the Outer Zone, which runs close and almost parallel to the river Dôzan-gawa, a branch of the Yoshino-gawa, with the largest and most mature valley in Shikoku. The Yoshino-gawa (236 km.) cuts across the terrain of the Sambagawa and Ôboké Series forming a sharply incised gorge. It turns suddenly to the east at Kawai, where the median fault line passes, and flows longitudinally through the broad valley of Tokushima toward the Kii Channel.

c) **Setouchi or the Inland Sea**:—The most striking features of the topography of the Setouchi are its large number of islands and the exceedingly irregular form of its coast-line, which is of cala type. It is a low submerged part of a subsiding land area. If the region were uplifted about 50 meters so that the water were drained out of the Inland Sea, the depression would not differ in its essential features from the lands now bordering its coast.

Before the Setouchi was submerged there were at least five large inner basins which were represented by the present Suô-nada, Aki-

---

1) See the description of Sanukite, p. 13.

nada, Bingo-nada, Harima-nada and Izumi-nada which have features entirely anologous to the inner basins of the present day, such as Yamato and Biwa which were formerly connected with the Inland Sea by narrow channels or valleys.

The waters of the Inland Sea that lie away from the main channel are comparatively shallow and in depth never exceed 40 fathoms. The Naruto channel or Whirlpool of Japan has a maximum depth of 119 fathoms in the narrowest place, but the depth of the water in general in the Harima-nada ranges from 10 to 20 fathoms. The water of Bungo-Suô-nada in most places does not exceed 40 fathoms in depth, but in the Bungo Channel it deepens notably. The fact that the deepest channel lies in the most constricted parts indicates that these depths are maintained by tidal scour and that the present deep water channel can not neccessarily be assumed to represent throughout its length the course of an ancient river. For example, the Naruto Channel as stated above is very deep, while the nearby Konaruto Channel, though very shallow, shows in its general outline the characteristics of a drowned valley.

STRATIGRAPHY AND AREAL GEOLOGY

The Island of Shikoku is composed of many different kinds of rock, both igneous and sedimentary. The geologic history of the region is complicated, including records of deposition, diastrophism, and volcanic eruptions, and the geologic structure is correspondingly complex and interesting. The formations comprising the sedimentary rocks in both the Outer and Inner Zones are shown in the following table.

The stratified rocks in the Outer Zone generally show zonal arrangement, the older group lying on the north, and the younger on the south margin. The boundary plane of the different groups is generally a fault running from east to west, i.e., almost parallel to the median line. In the Inner Zone the rocks which enter into the main geologic structure are granite, gneiss, Palaeozoic and Mesozoic sedimentary rocks. The newer rocks, both sedimentary and igneous, though they occupy a broad area, are only superficial deposits.

1) It is not however strictly a whirlpool, for Naruto rather means Roaring Sea-Gate.

Sedimentary Rocks of the Island of Shikodu.

System	Series	Inner Zone	Outer Zone
Quaternary	Alluvium	Alluvial Plain and Fan Deposits	Alluvial Plain and Fan Deposits
		Terrace Deposits	
	Upper Pleistocene	Pluvial Age (Gravel Beds)	*Elephas* Bed of Sakawa
	Middle and Lower Pleistocene	Setouchi Group	
Tertiary	Lower Pliocene	—	Shell Beds *Operculina* Sandstone Ishizuchiyama Deposits (mainly conglomerate)
Cretaceous	Lower Senonian	Izumi Sandstone Group	Toyajo Series* or *Pravitoceras* Beds
	Cenomanian		Monobegawa group: Subara Series* or *Acanthoceras-Puzosia* Beds
	Lower Cretaceous	Inkstone Series (?)	Monobegawa group: Yoshihara Series* or *Trigonia* SS. group Ryoseki Plant Beds
Jurassic	Upper Jurassic		Shimanto-gawa group: Akigawa group Torinosu group
Triassic	Noric		*Pseudomonotis* SS.
	Ladinic		*Daonella* Beds
	Scythic?		*Meekoceras* Beds
Permian-Carboniferous		Chichibu System	Chichibu System
Pre-Cambrian (?)			Mikabu System
			Sambagawa System Ôboke Series Besshi Series

*) Name given by Dr. J. Takahashi to the Cretaceous formations developed in the area lying south of Wakayama, province of Kii.

II. FORMATIONS AND ROCKS DEVELOPED IN THE BESSHI AND YASHIMA DISTRICT

By Yoshiaki Ozawa

The rocks developed in the district of Besshi and along the railway between Niihama and Takamatsu are briefly described in the following.

Sambagawa System

The Sambagawa System was named from the Sambagawa Valley in the mountainland of Kwantô, where it is exposed extensively, and from which it was described by Dr. B. Kotô. Afterward Professor Ogawa of the Kyôto Imperial University surveyed the Shikoku mountainland where the older rocks are well-developed, and proposed a twofold division, viz., the Besshi and the Ôboké Series, the former considered to correspond to the middle and lower divisions of the Sambagawa System of Dr. Kotô. And so far my considerations are concerned, the Ôboké Series underlying the Besshi Series would be a representative of the upper division of the Sambagawa System. The explanation will be given in the later pages.

In the Island of Shikoku, the crystalline schists terrain on account of its extensive copper deposits in Japan has undergone detailed stratigraphical examination, but no general uniform sequence in the formations has been established, though locally the succession has been precisely determined.

Because of the absence of fossils, only a classification based on lithological characters is possible at present. The generalized succession of the Besshi and Ôboké series is as follows:—

Besshi Series	Upper division	Sericite-graphite-schist intercalating thin beds of chlorite-amphibole-schist.
	Lower division	Manifold alternations of graphite-sericite-schist and various green schists intercalating several piedmontite-schists and lenticular limestone.
Ôboké Series	Upper division	Epidote-chlorite-phyllite and graphite-phyllite.
	Middle division	Schistose sandstone or Ôboké gneiss of Prof. Ogawa.
	Lower division	Alternation of phyllitic slate and chlorite-phyllite intercalating hematite-quartzite.

The district of Besshi is one of exceptionally fine exposures, which afford an excellent opportunity for the study of the stratigraphical relations between the Besshi and Ôboké rocks. Most of the rocks are hard and the streams flowing from the central mountain ranges have cut deep gorges, on the sides of which the formations are beautifully exposed. The rocks in the Besshi district strike in general nearly E-W., and seem at first sight to have an enormous thickness, since they dip almost invariably toward the north. However, the recurrence of easily identifiable beds of very persistent piedmontite-schists associated with extensive sericite-graphite-schist has led to the recognition of several folds closely compressed and over-turned toward the south, so that the strata on opposite limbs of all the folds dip in the same northerly direction, producing isoclinal structure. In the following figure is given a cross section showing the general structural relations of the rocks.

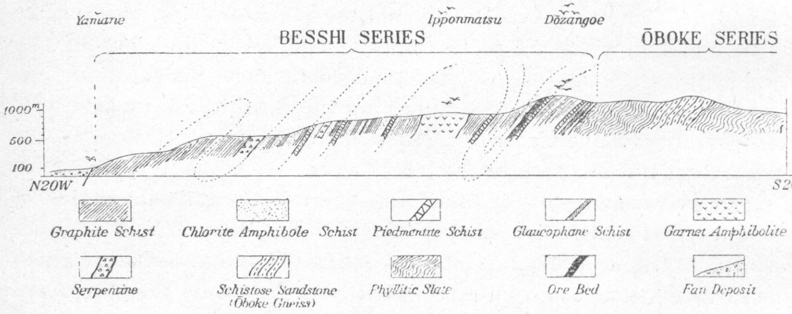


Fig. 1.

1) **Besshi Series** :—The lower division including the most important bedded deposits of copper pyrite in Japan, is a complex of several kinds of rocks, all of which show an intense degree of metamorphism. The predominant rocks are sericite-graphite-schists and chlorite-amphibole-schists, the manifold alternations of which produce a considerable thickness up to 1,000 meters. The most characteristic rocks are beautifully colored piedmontite-schist and glaucophene-schist, both of which are generally constant in their lithological character and are readily recognized wherever they occur. They are very persistent strata although they are very thin, commonly varying from 5 to 10 meters.

Glaucophene-schist, which occupies the lowest bed of the green schists, marks the beginning of the Besshi Series. Being of a beautiful color varying in tone from a greyish blue to a purplish blue, the rock can be easily recognized in hand-specimens. The glaucophene-bearing schist contains, besides other ingredients, a long rectangular, olive green epidote, yellowish green crystals of garnet, quartz, sericite, some feldspars, and rarely rutile. The glaucophene-schist is believed by some writers to have resulted from the alteration and recrystallization of basaltic volcanic ashes and lava flows containing nepheline or other sodiferous components.

Piedmontite-schist is characterized by pink or violet piedmontite together with fine quartz grains, and in virtue of its parallel disposition, gives to the rock itself a schistose structure, a vertical section of the rock presenting a regular banded appearance formed by the fine alternation of the piedmontite and quartz layers. Accessory components are sericite, greenish yellow garnet, rutile, non-striped feldspars, blood red iron-glance and also opaque crystals of the same mineral. The rock may represent radiolarian chert which has suffered complete recrystallization or dynamometamorphism.

The spotted graphite-sericite-schist is essentially made up of feldspars, sericite, graphite, hematite and quartz together with the characteristic accessories, tourmaline, garnet and rutile. The spots are generally an inflated disc-shaped feldspar, the inflated side of which lies parallel to the plane of schistosity of the rock.

The structural modification of the rock varies widely from a coarse-lamellar rock to a thin-tabular graphite-slate; in the latter the spots are scarcely visible, except on weathered surfaces. In the coarse extreme, the spots attain a size of ½ cm. or more, and at the same time the rock becomes less graphitic, while the sericite increases proportionally in quantity, the colour consequently changing from black to brown.

The spotted chlorite-amphibole-schist is a thick, imperfectly schistose rock of a grass-green or bluish green colour with an uneven plane of schistosity. It is full of white spots, 1 mm.-5 mm. in diamter, on a green ground, presenting an aspect quite similar to currants in a pudding. Slides show that each spot is nothing but an individual grain of feldspar, or an aggregate of irregular grains showing the characteristic cataclastic structure. The general mass of the rock consists of grass-green, lamellar fibrous chlorite and green amphibole.

The accessory minerals are iron pyrites, iron-glance, chalcopyrite, titanite, quartz, rutile, calcite and tourmaline. The rock may be a schist transformed from a tuff of a feldspar-pyroxene rock of eruptive origin.

Intrusive garnet-amphibolite is best exposed along a synclinal axis passing Tônaru from west to east, but its outcrop disappears in the pitching of the syncline towards east. This great intrusion of garnet-amphibolite as well as of some serpentine and actinolite rock possesses a more or less distinct internal foliation which is seen to conform in general to the strike of the invaded rocks. The intrusive amphibolite has suffered complete recrystallization, so that we can not recognize the original mineral constituents. Their external appearance varies, and the varieties form a continuous series in texture from a dioritic and gabbroic to a compact monomineralic rock. Important constituents are the deep green amphibole showing strong pleochroism, and the reddish brown garnets which are often very large, even attaining a diameter of 5 cm. In leucocratic facies plagioclase plays an important rôle as a constituent. The accessory minerals are an almost colorless epidote (zoicite), blue glaucophene, sericite, titanite, pyrite, and chalcopyrite. Calcite often occurs abundantly as an intersticial substance.

The upper division is mainly composed of a monotonous coarse lamellar graphite-sericite-schist with thin intercalations of chlorite-amphibole-schists. But the portion which has undergone contact action with the garnet-amphibolite is highly metamorphosed and abundant garnet and biotite are introduced.

2) **Ôboké Series**:—Beneath the Besshi Series, a thick complex of schistose rocks is exposed in a very large outcrop, forming a broad anticline in the valleys of the Ôboké and Dôzan-gawa. This schistose complex, known as the Ôboké Series, shows less metamorphism than the Besshi Series and is characterized by a schistose graywacke sandstone, known as the Ôboké gneiss. The Ôboké Series includes three principal types of rock; 1) green schists; 2) phyllitic slate including piedmontite-hematite-quartzite; and 3) schistose sandstone (the so-called Ôboké gneiss). The first group is of tuffaceous origin and mainly forms the uppermost horizon; but the others undoubtedly are sediments.

The relation of this series to the Besshi schists is not known with certainty; but it is probable that they are conformable, because the Ôboké rocks have been found in contact with the same membesr of the Besshi Series. It is generally believed that the Ôboké Series, as a whole, is younger than the Sambagawa schists, though the former underlies the latter, and the present succession can be explained by a great over-folding toward the south, because the Ôboké gneiss is apparently less metamorphosed than the Besshi Series. If this consideration be correct, the succession of the crystalline schists above described should be reversed.

Izumi Sandstone Group

The Izumi Sandstone group[1] constitutes an important feature of the geology of the Island of Shikoku and is chiefly confined to the outer border of the Inner Zone, forming a syncline running from east to west. Its south limb lies in contact with the Sambagawa schists, the juxtaposition being due to the median fault, while the north limb is intruded by the late Mesozoic batholithic granite.

It consists chiefly of a coarse grey sandstone and black shale associated with lenticular beds of conglomerate and calcareous sandstone. Several characteristic fossils indicating the Lower Senonian age have been found in these beds. The more important fossils found here as determined by Professors Yabé and Yehara are as follows:

Pravitoceras sigmoidale Yabé
Turrilites oshimai Yabé
Turrilites otsukai Yabé
Pachydiscus cf. *subtililobatus* Jimbo
Puzosia denisoniana Stol.
Anisoceras awajiense Yabé
Hamites sp.
Cucullaea cf. *sachalinensis*
Inoceramus cf. *regularis* d'Orb.
Cycadeoidea ezoana Krysht.

According to Professor Yabé the above is undoubtedly an open sea fauna. Cretaceous formations containing the same fossil fauna are known from several localities in the Outer Zone, hence it seems most probable, if not absolutely sure, that the Lower Senonian transgression took place in a broad area covering almost the whole of Shikoku of the present day.

---

1) Named from the Izumi Mountain Range where this group is extensively developed.

Gneiss and Late Mesozoic Igneous Rocks

1) **Gneiss** :—There are several kinds of gneissose rocks such as biotite-gneiss, injection-gneiss, granite-gneiss, and amphibole-gneiss, frequently intercalating saccharoidal limestone and granulite. Granite- and amphibole-gneisses show in several cases the characters of metamorphic intrusive rocks; while the biotite-gneiss and the crystalline limestone are Palaeozoic sedimentaries metamorphosed by the contact action of the metamorphic intrusives. The injection-gneiss is most prevalent and probably formed by lit-par-lit injection of granite into the Palaeozoic rocks.

The distribution of the gneiss is confined to the Inner Zone of Japan. Gneissose rocks developed in the island of Miyoshima off Niihama are composed of gneissose hornblende-granite, biotite-gneiss, and amphibole-gneiss intercalating crystalline limestone.

2) **Granite** :—This is the predominant rock of the Inner Zone and makes up the main bulk of the mountainland. There are two kinds of granite, viz., hornblende-biotite-granite and biotite-granite. Their age relation has not yet been determined, but there is no doubt that the great intrusions must have taken place in the late Mesozoic times (probably both pre- and post-Cretaceous). Besides the granites, there are several products of igneous activity of the Inner Zone of southwestern Japan. The more important are porphyrite and quartz-porphyry, which form extensive ourflows and intrusive dykes.

For further details concerning the igneous rocks and ore deposits of the Inner Zone of Japan reference should be made to Professor Katô's papers (especially "The Periods of Igneous Activity in Japan, with special Reference to Metallogeny. Jour. Geol. Soc. Tokyo. Vol. XXXI., No. 364, pp. 1-13).

The Setouchi Group

This group named from the Inland Sea or *Setouchi* is made up of fresh-water deposits, fluviatile and lacustral, and various lavas, tuffs, and agglomerates. The principal accumulation which has the widest distribution, consists of loose conglomerates mixed with sands, clay and pumiceous sands with intercalated beds of lignite. But locally these deposits are interrupted here and there by eruptive flows of various andesites and small but relatively thick layers of agglomerate andtuff.

The group containing the andesitic flows mainly occupies northern Shikoku and the adjoining islands, but the andesitic rocks of the Setouchi type can be traced from east to west in or on the south margin of the Median Groove of South Japan or the area of Setouchi subsidence. On this volcanic belt, Dr. B. Kotô wrote as follows:

"The whole trait of volcanoes in this belt of South Japan is quite uncommon and foreign to those which we are accustomed to see in other parts of Japan. Dr. Edmund Naumann had long ago apprehended the existence of a special volcanic region in Shikoku on the side of the Inland Sea, where a brownish and compact, quartz (?)-bearing and sonorous augite-andesite, known as 'Kankan-ishi', is found at several places. E. Weinschenk examined the rock and found it to be a colorless glass, full of needles of bronzite and grains of magnetite with sporadic phenocrysts of plagioclase and garnet; and as it is a unique kind of rock, he gave it the name of sanukite. Since then little has been done to determine its geographic distribution beyond what Naumann had already written about it."

"In examining hundreds of slides of rocks of this belt, the writer has always been able to detect a multitude of slender prisms of almost colorless bronzite in the glassy groundmass. In North Japan, the pyroxene in the groundmass is represented by deeply colored short prisms or grains of augite, and the phenocrysts of pyroxenes are also strongly colored augite and hypersthene. In the present area the pyroxene-phenocrysts are light-colored, sometimes pale rosy bronzite, and sometimes pale green diopside. Consequently we have in Japan a remarkable instance of a petrographic province of bronzite-andesite in a comparatively small and limited area. The content of SiO_2 varies from 55% to 61%, corresponding to a mica or hornblende-andesite, while the alkalies are low, and MgO and CaO are high, as compared with those of both the mica-hornblende-andesite and the pyroxene-andesite of other areas."

A most excellent succession of various lavas including sedimentary deposits can be observed at Futakami-yama in the province of Yamato. According to Dr. Ôyu, late professor of the Imperial University of Sendai, the Setouchi group lies upon foundation of granodioritic orthogneiss. The general sequence of the various members shown in the following table, in the second column of which are placed what appear to be the probable correlatives of the Yashima table-land.

	Yashima	Futakami Volcano
Setouchi group.		Lacustral deposits (Clay, sand, and gravel
	Granitic sand	V. Bronzite mica andesite
	White tuff Sanukite	IV. Sanukite Donzuribo γ—Clay and clay-slate containing plants
	A complex of tuff-breccia, sandstone, conglomerate	III. Bronzite-hypersthene-andesite Donzuribo β—Sandstone with garnet-conglomerate II. Mica-garnet-andesite Donzuribo α—Alternation of tuff-breccia and tuff
		I. Pitchstone
	Granite	Orthogneiss

A fresh-water and terrestrial equivalent of the above mentioned volcanic group extensively develops in the area of Setouchi subsidence and contains mammalian remains.

In the sandy clay revealed in an excavation at the Ubé coal mine, in the province of Nagato, have been found *Stegodon orientalis* Owen, together with *Buffelus* sp. and fresh-water shells (*Anodonta* sp., etc.) obtained from the lacustral deposits developed in the Ohmi Basin. *Stegodon orientalis* obtained from Ubé, according to Dr. Matsumoto, Professor of the Imperial University of Sendai, indicates the early Pleistocene age.

The vertebrate fossils dredged from the sea bottom off the Island of Shôdoshima are

Stegoden sinensis Owen
Stegodon orientalis shodoensis Matsumoto
Loxodonta (*Elephas*) *namadicus* Falc. et Cart. *naumanni* Makiyama
Cervus (*Sica*) sp.
Bison occidentalis.

According to Professor Matsumoto, these fossils establish the age of the formation as Middle Pleistocene or Milazzian-Tyrrhenian.

Based on the above evidence, the greater part of the Setouchi group can be referred to the Lower and Middle Pleistocene. The shell-containing sand deposits exposed at Suma in the province of Harima may be regarded as a marine equivalent of the present Setouchi group.

Description of Sanukite:—The following is Dr. Kotô's description of the peculiar rock, "sanukite," cited from his paper on the Volcanoes of Japan.

"There are two kinds of sanukite different in their petrographic development, appearance, color and mineralogical composition. The first variety A is the sanukite of Weinschenk, which has the same relation to (bronzite-) andesite as augitite has to basalt. There are two subtypes. The subtype α is a homogeneous crow-black, resinous and flinty, with conchoidal fracture, and clinks with a sharp tinkling sound when struck with a hammer. The subtype β is often a banded wet-gray, less resinous and flinty, and gives only a dull sound. These differences are solely due to the mineralogical nature of the microlites which are crowded in a horizontally felted network in the colorless glass intermixed with dust of magnetite. A section of rock at right-angles to the direction of flow shows, however, the parallel arrangement of the microlites in one plane, and the sonorous property has, as the writer presumes, its origin in this special orientation.

"The microlites of the subtype α are essentially composed of very minute colorless needles of bronzite without terminal faces, and those of the β subtype, of minute forked laths of simple feldspar. The two kinds of microlite are more or less intermingled in both modifications, and when they are represented in about equal quantities, the color and lustre and other properties stand midway between the two extremes. Accessories are garnet, biotite, hornblende, diopside, olivine and quartz. The writer distinguishes the two extremes by the adjectives bronzitic and feldspathic sanukites.

"The second variety B is differentiated from the first which may be called bronzite-andesite or ortho-andesite, and is characteristically porphyritic. It is mostly brownish gray, but varies according to the 'bronzitic' or 'feldspathic' nature of the groundmass, and also of the color and the state of preservation of the glassy base. It is usually compact, semi-resinous and slightly flinty. Phenocrysts are mafic and small, the maximum size being 4 mm. They occur one or two at a time, and are resorbed hornblende and biotite, almost colorless and cleavable anhedral diopside, and colorless or slightly rounded phenocrysts of tabular plagioclase. They then have an appearance of a black andesite. Xenomorphism is a characteristic feature of the phenocrysts of this variety. The glass is either colorless or brown, in the latter case showing flow-texture by the fluidal arrangement of the magnetite dust. The feldspathic groundmass often, but not always, displays the hyalopilitic texture".

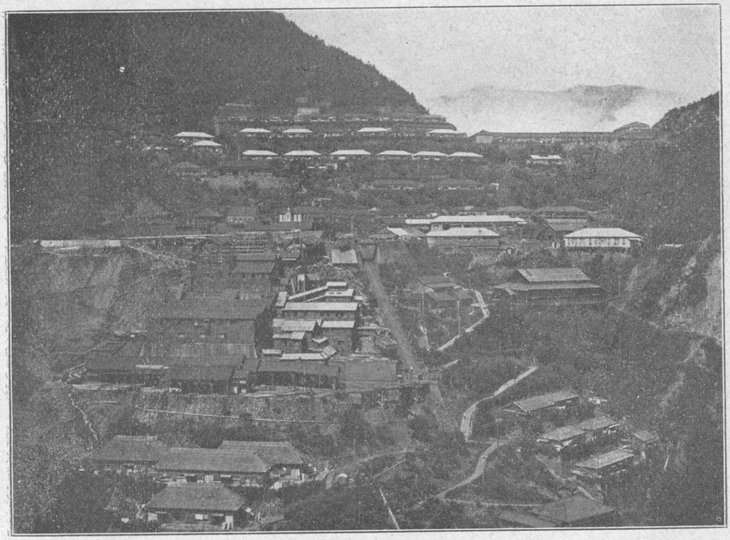
Gravel Beds (Torrential Stage of Professor Nakamura)

After the volcanic and lacustral deposits of the Setouchi group had accumulated, the Setouchi area was disturbed by a sharp orogenic block movement, associated with a relative upheaval of the land area, which formed the general outline of the median inner basins; but the marine invasion did not take place at that time, because upon the Setouchi group lie a great series of coarse gravel beds and no marine deposition is known in inner Japan. The gravel beds, which are developed extensively at the foot planes of the mountains in both Chûgoku and Shikoku, were built up by torrential floods from the high mountains; such floods are of course intimately connected with meteorological changes (increasing the rainfall), and more especially with the upheaval of the mountain ranges.

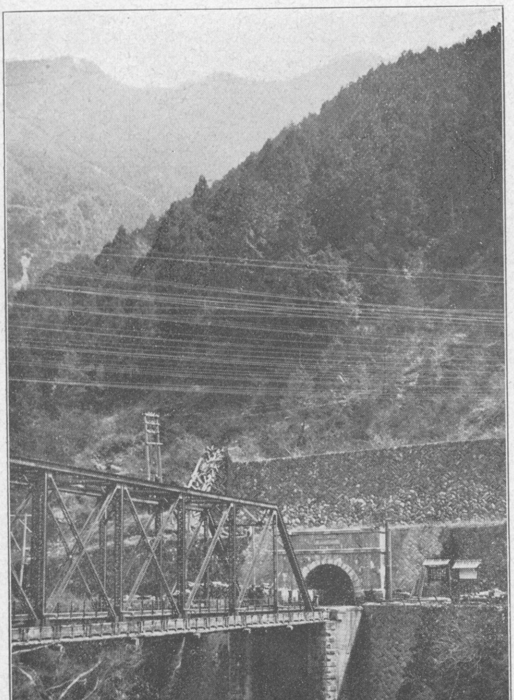
The gravel beds are a rudely stratified deposit of angular fragments of rock and water-worn pebbles of various beautifully colored quartzite and vein-quartz, phyllitic rocks, and, rarely Sambagawan schists, of all sizes up to blocks with a diameter of one meter or more. The matrix is more or less fragmental consisting largely of clayey matter, quartz, decomposed feldspar and small pieces of rock of the same kind as those composing the pebbles. The thickness differs from place to place, but its maximum does not much exceed 100 meters. The best development can be observed along the coast of northern Awaji, where the deposit has been thoroughly dissected and terraced. One of its highest points is in the vicinity of Torikai where its surface stands 90 meters above sea-level.

Terrace and Fan Deposits

After the Torrential stage the Setouchi region was lowered relatively to the sea-level and the sea gradually encroached upon the land until the present general outline of the Setouchi was complete. It might be that the encroachment of the marine water in a basin, as Professor Yabé suggested, was wholly or at least partly due to the positive movement of the sea-level. In the present instance, however,



View of Tonaru, the present mining center of the Besshi Mine.



Entrance to the Fourth (or Main) Adit of the Mine, at Hateba.

it must be added that the Inland Sea evidently consists of submerged land basins, and the geomorphic features of its periphery and its many islands were manifestly shaped by the ordinary agencies of erosion, but as the valley lies on the relatively depressed sides of the blocks of the Inner Zone, it was probably in large part outlined by the movement that tilted these blocks, and to that extent it is of diastrophic origin.

Since the invasion of the sea-water the Inland region has undergone several changes. That the earth movements in this region were not simple is shown by the facts that on the east side of the Kii Channel there are two terraces, the one more than twenty meters high and the other just twenty meters high, and that the elevated deposits of the latter exposed near Tanabé in the province of Kii contain marine shells of species showing a more or less tropical nature, and that on the south side of the province of Nagato, the western extremity of the mainland Honshû, there develops a twenty meter-terrace, whereas in the area west of Awaji, i. e., in the greater part of Setouchi there are no such terraces or elevated late Quaternary marine deposits. On the contrary, in spite of the steep slope of the median fault-scarp, the fans developed at the north foot of the Shikoku mountain ranges are generally small and low. This can be explained on the theory that the subsidence of the Setouchi zone along the median line occurred during the formation of the fan deposits.

III. OBSERVATIONS *EN ROUTE* FROM NIIHAMA TO TÔNARU

BY YOSHIAKI OZAWA

From several places on the Niihama alluvial plain, good views of the frontal range of the Shikoku mountains may be obtained, as well as of the more massive and rugged peaks of Akaishi (1,626 m.) and the lower mountains surrounding them. From Niihama the Sumitomo private railway passes through tunnels and cuttings in the Izumi Sandstone for about two miles. From the train good outcrops of grey sandstone dipping to the south can be seen. Just before entering Tsuchihashi the train passes under the tracks of the main line of the Sanuki Railway that runs from Takamatsu to Imabaru. From here we can get a view of the fault-scarp along the median dislocation line to the south. Passing an Alluvium extending to the mountain front, the train enters the narrow gorge of the Sambagawan terrain at Yamané station. Cuttings and tunnels between the stations of Yamané and Kuroishi were excavated through grayish black graphite-schist, the uppermost member of the Sambagawa Series which strikes N 80° W and dips generally N 10° E at rather low angles, although in places the dip is reversed by the irregular plication of the strata. Near Hateba, the terminus of the railway, a dike of serpentine is exposed at the bottom of the rapids. Spotted chlorite-amphibole-schisis intercalated in graphite-schist are well developed. At Hateba there is a branch office of the mine. From here the Main or Fourth Adit extends southeastward and at a distance of 15,000 feet it connects with Ôtateko (the Main Shaft). The tunnel is partly timbered.

The general succession of the rock formations (the rocks obtained at the time of driving of the Fourth Adit are preserved in the branch office at Hateba) is graphically represented in the following figure.

The road leading from Tônaru to Hateba, is made along a steep narrow down-cutting stream and accordingly the outcrop of the Sambagawan rocks is very good. The succession of the rocks is shown in the following route map.

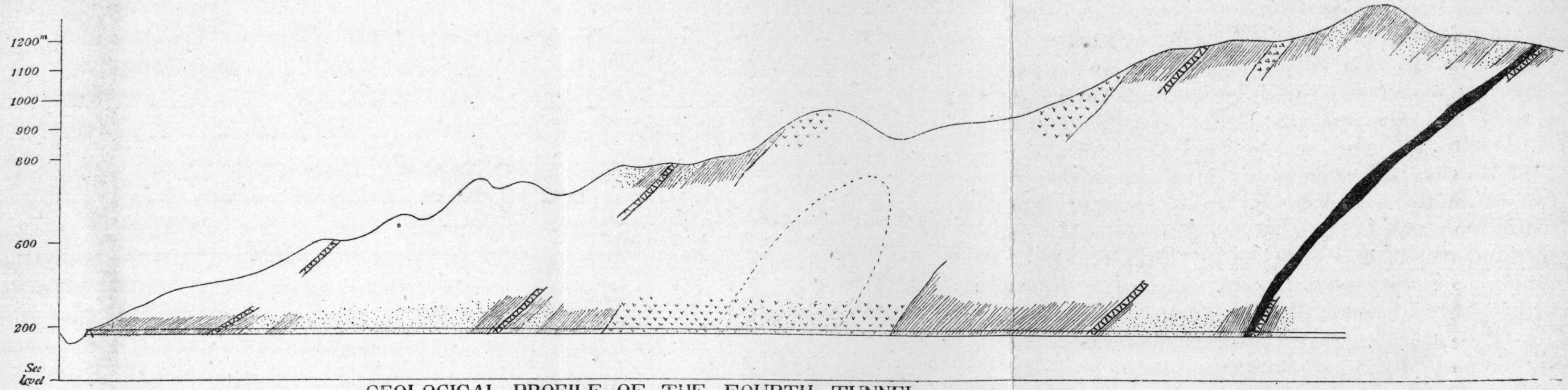
IV. BESSHI COPPER MINE

By Takeo Katô and Hidenosuke Sano

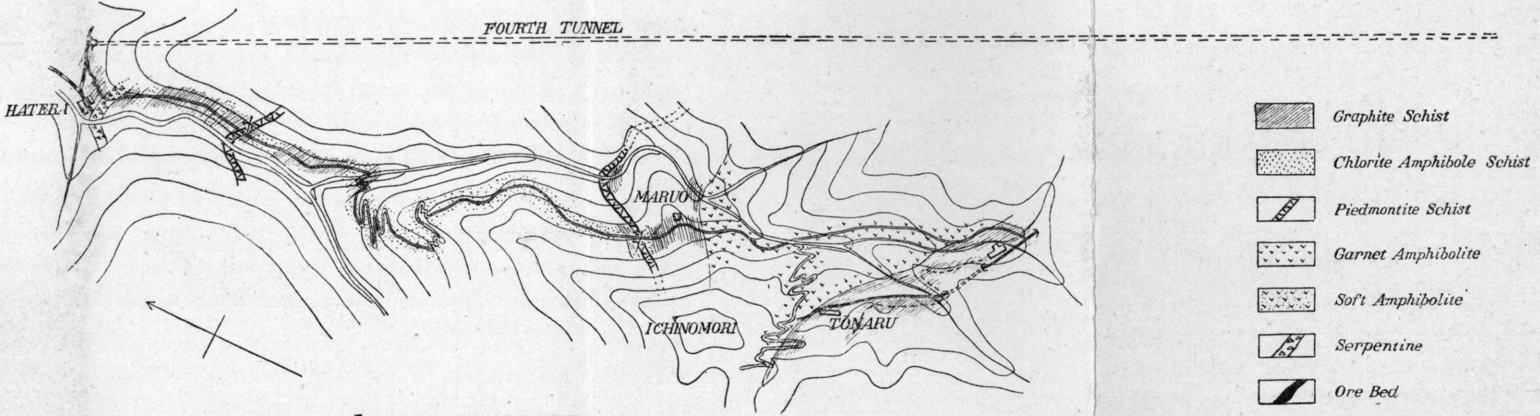
I. HISTORICAL SKETCH

The Besshi mine, one of the largest copper mines of Japan, is situated in the rugged mountain district, called Besshi-yama, which forms part of the back-bone of Shikoku, to the south of the coast of Niihama. The general office is at Niihama, while the mining centre is situated at Tônaru about 12 miles south of Niihama. The smeltery is located on the small island of Shisaka, about 9.5 sea-miles due north of Niihama.

The first discovery of the ore deposit was made in the 3rd year of the Genroku era (1690 A.D.). Mining and smelting operations were



GEOLOGICAL PROFILE OF THE FOURTH TUNNEL



ROUTE MAP FROM TŌNARU TO HATEBA

SCALE 1:24,000

begun in the next year by the Sumitomo family, and have continued to the present day, the total production for the past 235 years (up to 1924) being as follows:—

Refined copper	379, 339, 000	pounds.
Electrolytic copper	57, 472, 500	,,
Gold	4,450	,,
Silver	94,862	,,

In ancient times the ore was roasted and smelted in the Japanese way at Besshi on the southern side of Mt. Besshi, and the blister copper thus obtained was sent to Osaka where it was refined. In 1868, the smeltery was removed to Tatsukawa-yama at the northern foot of Besshi-yama. In 1883, water-jacket furnaces were erected at Sôbiraki near Niihama, and from 1885 to 1887 trial smelting was carried on. The results were encouraging and repeated extensions of the smelting-works were made there, while only a little smelting was done at Takatsuka-yama.

After great damage by the flood that occurred in the Besshi district in 1899, all smelting operations hitherto made at Takatsuka-yama, except roasting, were transferred to the Sôbiraki smeltery. Meanwhile a new smeltery was being built on the islet of Shisaka, about 9.5 sea-miles off Niihama, which was completed in December, 1904. In January, 1905, all the smelting operations were transferred from Sôbiraki and Takatsuka-yama to the plant at Shisaka.

Mining operations had been carried on at Besshi since the first development of the mine. The Third Adit was completed in 1902, and in 1904 the center of the mining operations was removed from Besshi to Tônaru (about 2,500 feet above sea-level) on the northern flank of Mt. Besshi.

Hateba is situated at the northern foot of Mt. Besshi, and is the terminus of the railway leading to Niihama, and the site of the entrance to the Fourth Adit. The Fourth or Main Adit, more than 15,000 feet long, and the Great Shaft, 1,922 feet deep and connecting the Third and Fourth Adits, were completed in September, 1915, after 6 years' work. This place is expected to become the center of future mining operations.

An electro-refining plant was completed at Niihama in June, 1919, and all the blister copper smelted at Shisaka is now electrolytically refined at this plant.

A dressing plant has been under construction, since May, 1923, which, on completion, will treat all low-grade ores sent from Tônaru by the flotation method. In future, when the mining center has been removed to Hateba and all the ore will be carried out of the Fourth Adit, a hand-dressing plant will be constructed at Hateba and a gravity-dressing plant at Niihama.

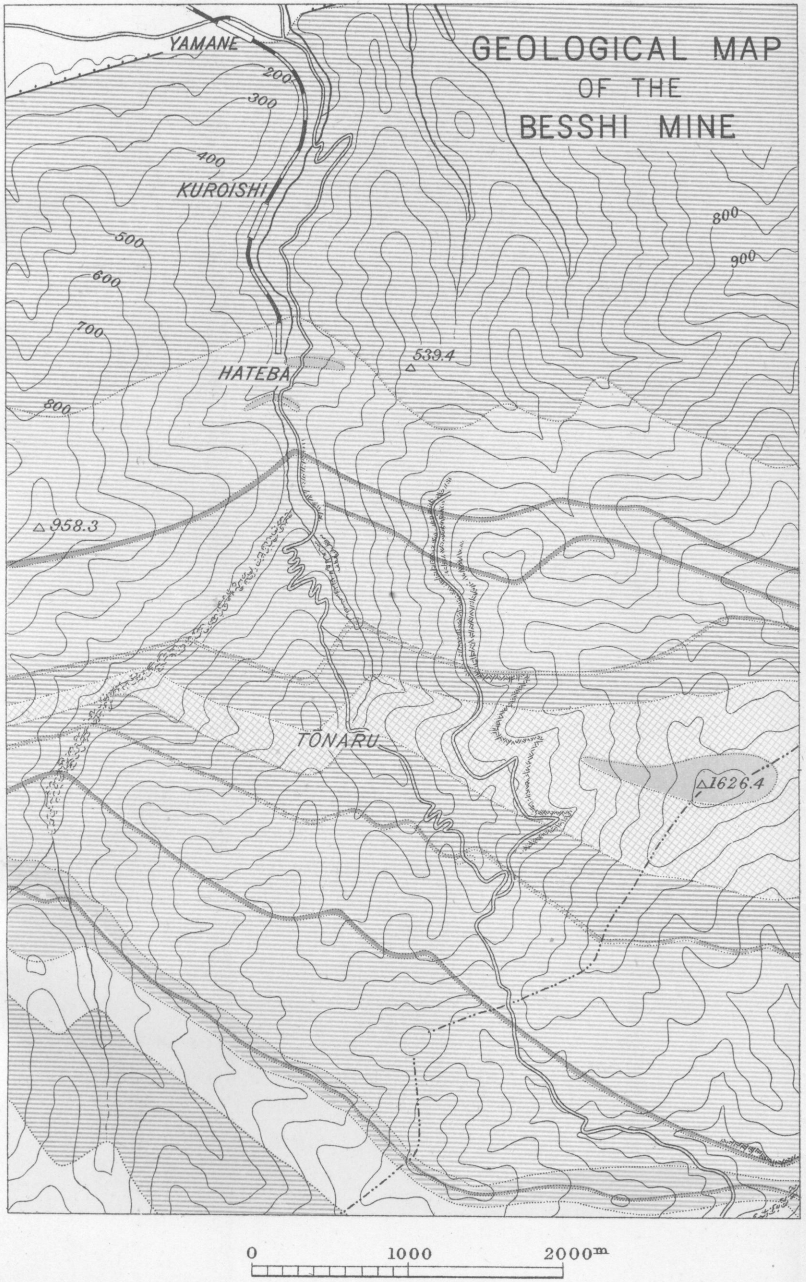
II. ORE DEPOSIT

The ore deposit of the Besshi mine is intercalated in the Sambagawa Series which consists chiefly of graphite-schist and chlorite-schist with thin layers of sericite- and piedmontite-schists and others. The deposit outcrops on the southern slope, near the summit, of a rugged mountain ridge at a distance of about 12 miles south of Niihama. The succession of the schists in reference to the ore deposit is shown in the profile along the Main or Fourth Adit (Fig. 2). The occurrence of a great mass of metamorphosed basic igneous rocks, comprising amphibolites, hornblendites and others, on the hanging-wall side is worthy of special notice.

The deposit is bedded in form, striking exactly in accordance with the wall rocks. It strikes N 60° W and dips about 45° northward in the upper part and 60° to 75° northward in the lower. It extends about 5,000 feet along the strike, up to 25 feet thick, and the deepest level now being worked is about 4,000 feet along the dip from the outcrop. The deposit is developed downward obliquely to the dip of the walls, on an angle of about 45°, from the east in the upper levels to the west in the lower.

a) Kinds of Ores and Their Arrangement

The ore deposit is enclosed in graphite-schists and is bordered by quartz and light-coloured schistose rocks such as quartz-schist, sericite-schist, etc., which are called *habu* by the miners. In the eastern part of the deposit sericite-quartz-schist with a small limestone lens associated with chlorite-schist is extensively developed



LEGEND

Besshi Series:

- Graphite Schist
- Zone of Green Schist (Mainly Spotted Chlorite Amphibole Schist with Graphite Schist)
- Piedmontite Schist

Ōboke Series:

- Chlorite Epidote Schist
- Phyllitic Shale
- Schistose Sandstone (or so-called Ōboke Gneiss)

- Serpentine
- Garnet Amphibolite

(Fig. 4). The following three kinds of ores form the essential part of the ore deposit :—

1. Massive cupriferous pyritic ore

This is the most common ore and consists of minute grains of pyrite firmly cemented by chalcopyrite. The presence of chalcopyrite as the cementing matter is well displayed on polished ore-specimens under the metallographical microscope. This ore forms tabular masses developed along both walls; they are called the hanging-wall pyrite and the foot-wall pyrite respectively. Toward the east end they are united and form a thick pyritic mass, in places attaining a thickness of 15 feet. This ore represents a green schist completely replaced by pyrite and chalcopyrite, and contains about 3 % of copper and about 2 % of silica.

2. Banded ore

This ore is intercalated between the above-mentioned compact pyritic masses developed along the hanging- and foot-walls, and varies in thickness from 2 to 20 feet. It consists of chlorite- and quartz-schists thinly interbanded with thin layers of pyrite-chalcopyrite aggregates, often represented by green schists impregnated with abundant pyrite in association with chalcopyrite. It contains, on an average, about 3% of copper and about 30% of silica, but it is transitional to a green schist and quartz-schist very poorly mineralized. This ore is thus a partially replaced green schist.

3. High-grade chalcopyrite ore

This ore occurs in the form of a vein cutting the ore deposit longitudinally. It occurs adjacent to the compact pyritic ore mass of the foot-wall in the eastern part of the deposit, whereas it exists along the pyrite mass of the hanging-wall in the western part, thus evidently obliquely crossing the banded ore. It varies in thickness from a fraction of one inch to more than two feet, and contains about 20% of copper and about 3% of silica. Massive aggregates of magnetite sometimes border this chalcopyrite ore. The high-grade ore in question represents a later deposition of chalcopyrite along a fissure formed in the highly mineralized green schist.

The distribution of the three kinds of ores is shown by the following diagrammatic cross section of the fourth level (Fig. 4).

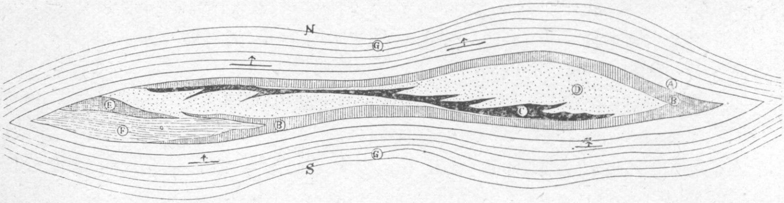


Fig. 4

Diagrammatic cross section of the Besshi ore body on the 4th level, showing the distribution of various ores and rocks. The width of the deposit is shown much enlarged.

A, quartz and quartz-schist, in places garnet-bearing; B, massive cupriferous pyritic ore; C, chalcopyrite ore, vein shaped, often intermingled with patches and streaks of chlorite; D, banded ore. i.e. chlorite-schist impregnated with pyrite and chalcopyrite, often banded with thin layers of cupriferous pyrite along schistose planes; E, sericite-schist and sericite-quartz-schist; G, graphite-schist, the wall rock.

b) A Suggestion as to the Origin of the Besshi Deposit

As is well known, cupriferous pyritic deposits occur extensively in metamorphic rocks throughout the world. Their origin has long been debated, and still remains an open question. The following paragraphs published by T. Kato in the journal of Economic Geology, Vol. XX, No. 1 (1925) may serve as a suggestion as to the origin of similar deposits in general:—

" Most of the cupriferous pyritic deposits of Japan are found in the terrain of a highly metamorphosed crystalline schist complex, called the Sambagawa Series by Professor Kotô, and probably corresponding to the Algonkian formation[1] in North America. The Sambagawa Series consists of sericite-gneiss, sericite-schist, piedmontite-schist, chlorite-schist, and graphite-sericite-schist, frequently accompanied by such metamorphosed basic igneous rocks as eclogite, amphibolite, antigoritic serpentine, and others. This series is most typically developed in the western limb of the Japanese Arc,

---

1) The exact age of the Sambagawa Series remains unknown. But in the Outer Zone of Japan, where all the geological formations ranging from the oldest to the youngest are well developed, the oldest fossiliferous formation is the Upper Chichibu system (Permo-Carboniferous). The thick complexes underlying this fossiliferous formation may, therefore, be of Devonian and later age. As the Sambagawa Series seems to occupy the lowermost position, though usually it is bounded by a fault with the less metamorphosed Palaeozoic formations, it is here assumed to be of pre-Cambrian age, until more definite correlation becomes possible.

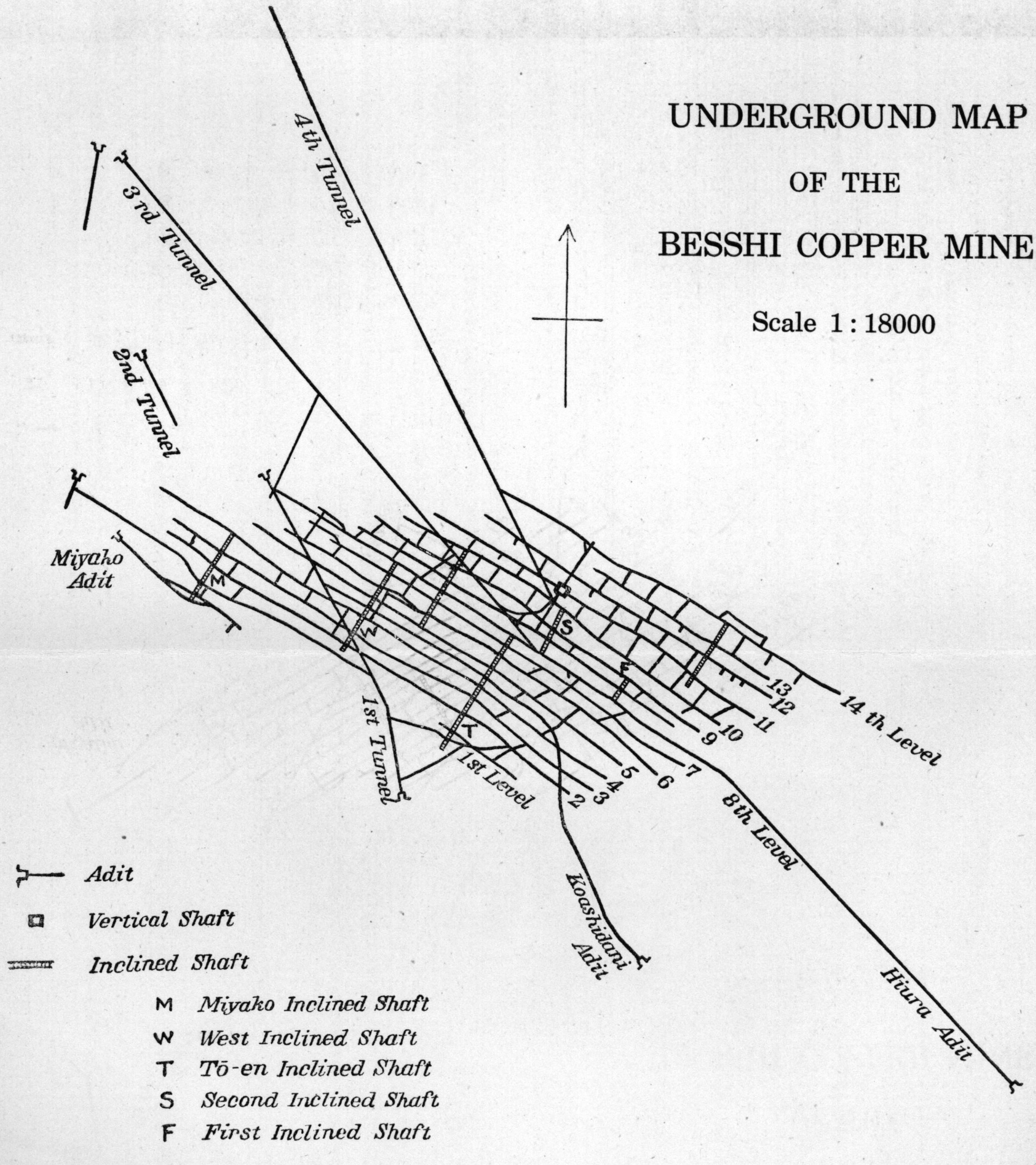
with a northeasterly trend, extending from the Tenryu-gawa district, over the peninsula of Kii and across the island of Shikoku, to Kyushu. The ore deposits are commonly found in lenticular or bedded forms along the planes of schistosity. The largest of this type is the deposit of the Besshi mine in Shikoku, which has a length of more than 1,600 meters along the strike, over 1,200 meters down the dip, and is usually 6 to 10 meters in thickness. It consists of massive cupriferous pyrite and fahlband-like banded ore cut by a pure chalcopyrite vein, and is enclosed in chilorite- and graphite-schists, in close relation to eclogite and amphibolite. Another interesting example of the deposits in the same zone is that of the Seki mine in Kyushu, which is very small but affords instructive data. It is developed along the contact between chlorite-schists and an intrusive mass of serpentine, and is intricately folded and wrinkled, the ore mass often replacing both walls in a complicated manner. On examining, under the microscope, the banded or low-grade ores from these two mines, it is revealed that the crystallization of the constituent minerals and the development of the schistose structure of the chlorite-schist preceded the deposition of ore minerals, so that pyrite and chalcopyrite have partially replaced the components of the rock and filled up the interstices between them, the massive cupriferous pyrite being nothing but a wholly replaced portion. But it is evident that the metallization occurred at a late stage of the dynamo-metamorphism, i.e., before the cessation of the schist-forming process, because the mineralized zone is intricately folded and contorted with the wall rocks. It is noteworthy that there is no stock nor apophysis of granitic rock to be found in the terrain of the Sambagawa Series, and it is inferable that the deposits of this category are genetically connected with the pre-Cambrian basic igneous rocks, which have been metamorphosed into eclogites, amphibolites, and other schistose green rocks during or subsequent to the metallization. . . . .

The cupriferous pyritic deposits of the Hitachi mine in Kwanto constitute another interesting type. They are similar in character to those found in the Sambagawa schists, already referred to, but they are more or less bedded masses, formed chiefly by a replacement of the metamorphic rocks (amphibolites) of the Lower Palaeozoic formation, evidently related to intrusive granitic and dioritic rocks, the mineralizations ranging from contact-metamorphic to hydrothermal stages. The igneous intrusions are related to the Late Palaeozoic or Late Mesozoic orogenic movements, and the metallization represents, clearly, post-igneous actions belonging to a late stage of the long-continued diastrophic period. The metallic minerals replace and surround the constituents of the metamorphic rocks, including various contact minerals, such as biotite, garnet, vesuvianite, cordierite and others ; but the ore deposits show intricate contortion, in accordance with the wall-rocks, due to the schist-forming process. . . . . . .

In summary, most of the cupriferous pyritic doposits of Japan are of hydrothermal metasomatic origin, accompanied by more or less fissure-filling and impregnation, although they are of various geological ages and are related genetically to diverse igneous rocks, either basic or acidic. That they have a similar character, so that they may be designated by the general name of cupriferous pyritic deposits, is due principally to the fact that the country rocks were subjected to similar dynamic processes, continuously, before and during, and even after, the formation of the deposits. In other words, the metallization represents, in most cases, the latest phase of igneous activity accompanying the great crustal movements, which continued even after the formation of the ore deposits was concluded, ascension of the mineralizing solutions and replacement of the wall-rocks having taken place, most pronouncedly, in the sheared or fissured zone along the schistosity formed by dynamic processes. No one of the deposits in Japan can be explained as an injected sulphidic partial magma differentiated from the gabbroic magma."

III. MINING

To work the ore-body an inclined shaft (the Tôen inclined shaft) was sunk 1,742 ft. from the outcrop at a point called Tôen, (3,780 ft. above sea-level), at an angle of 49° northward, in the footwall to level No. 8. Drifts reached by crosscuts from the shaft stations are driven, at intervals of about 260 ft, along the course of the ore-body in both directions. To develop the western part of the ore-body an inclined shaft (Western inclined shaft), 1,166 ft. on dip of 48° was sunk from


UNDERGROUND MAP
OF THE
BESSHI COPPER MINE
Scale 1 : 18000
4th Tunnel
3rd Tunnel
2nd Tunnel
Miyako Adit
1st Tunnel
1st Level
2
3
4
5
6
7
8th Level
9
10
11
12
13
14 th Level
Koashidani Adit
Hiura Adit
M
W
T
S
F
Adit
Vertical Shaft
Inclined Shaft
M Miyako Inclined Shaft
W West Inclined Shaft
T Tō-en Inclined Shaft
S Second Inclined Shaft
F First Inclined Shaft

level No. 3 to No. 8. To open the lower part of the deposit below level No. 8 an inclined shaft (The second inclined shaft), 703 ft. at an angle of 58° was sunk in the ore-body from level No. 8 to No. 10, level No. 9 being taken at about 350 ft. below level No. 8. From level No. 8 a vertical blind shaft was sunk to No. 14 and from the shaft drifts run along the course of the ore-body in both directions. Levels No. 11, No. 12, and No. 13 are taken at intervals of 300 ft. Level No. 14 taken at 420 ft. below level No. 13 is the level of the 4th adit. A winze (Winze No. 7, E., Level No. 14) extends to about 200 ft below level No. 14 or to an elevation of 243 ft. above sea-level.

Besshi pluggers, Besshi stopers, Hardy drills, and Turbro-drills are used for drifting and stoping. Stopes are supported by waste filling. Ore is mined by overhand stoping. On upper levels the stopes are narrow; but on lower levels stopings are systematic and carried out on a larger scale with machine drills according to the horizontal or vertical slicing system. On level No. 10 the shrinkage system is also being tried. Japanese dynamite is used exclusively in excavation.

The broken ore in the stopes can be run through the ore pass into cars on the drift below, which are conveyed to the shaft stations by hand-tramming or by a storage battery electric locomotive. Ore cars above level No. 8 are lowered upon cages in the Tôen, or Western inclined shaft, to level No. 8. Ore cars on level No. 9 are lifted by the hoist in the second inclined shaft to level No. 8. About half the number of ore cars on and below level No. 10 are also lifted through the vertical shaft to level No. 8. The cars thus gathered from several levels to level No. 8 are hauled along the 3rd adit to the Tônaru mill. The other half of the cars on and below level No. 10 are lowered upon cages in the vertical shaft to level No. 14 and hauled along the 4th adit to the Hateba mill.

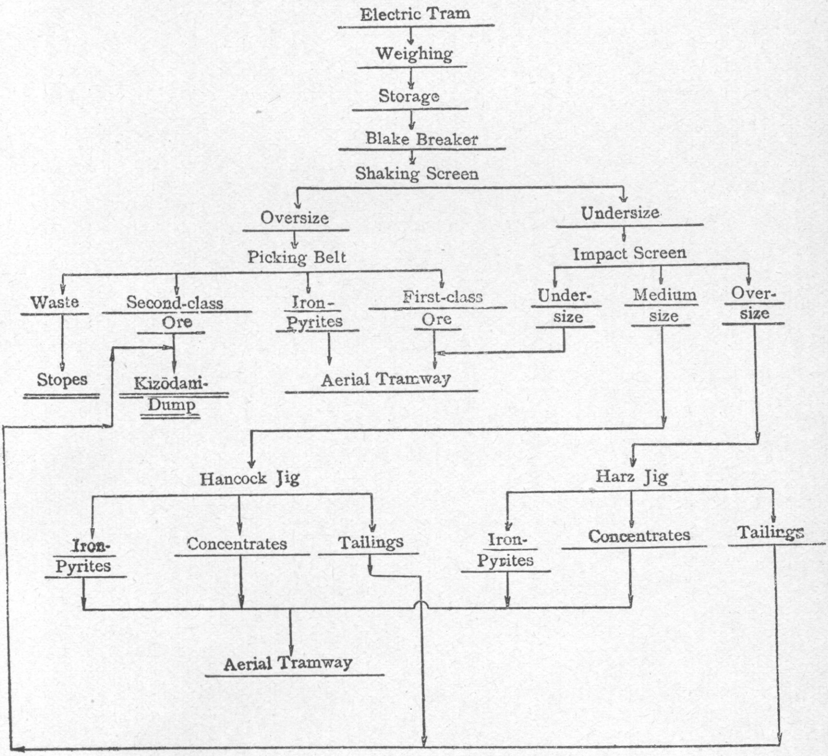
The mine water is conducted in ditches and flumes to Niihama to be discharged into the sea, passing on the way through two precipitation ponds (at Tônaru and Yamané) filled with scrap-iron where the copper contained in the water is recovered.

In the Ikadatsu mine an inclined shaft, 700 ft. on dip, was sunk from the outcrop. Drifts are driven from shaft stations, at intervals of about 220 ft, along the course of the ore-body in both directions.

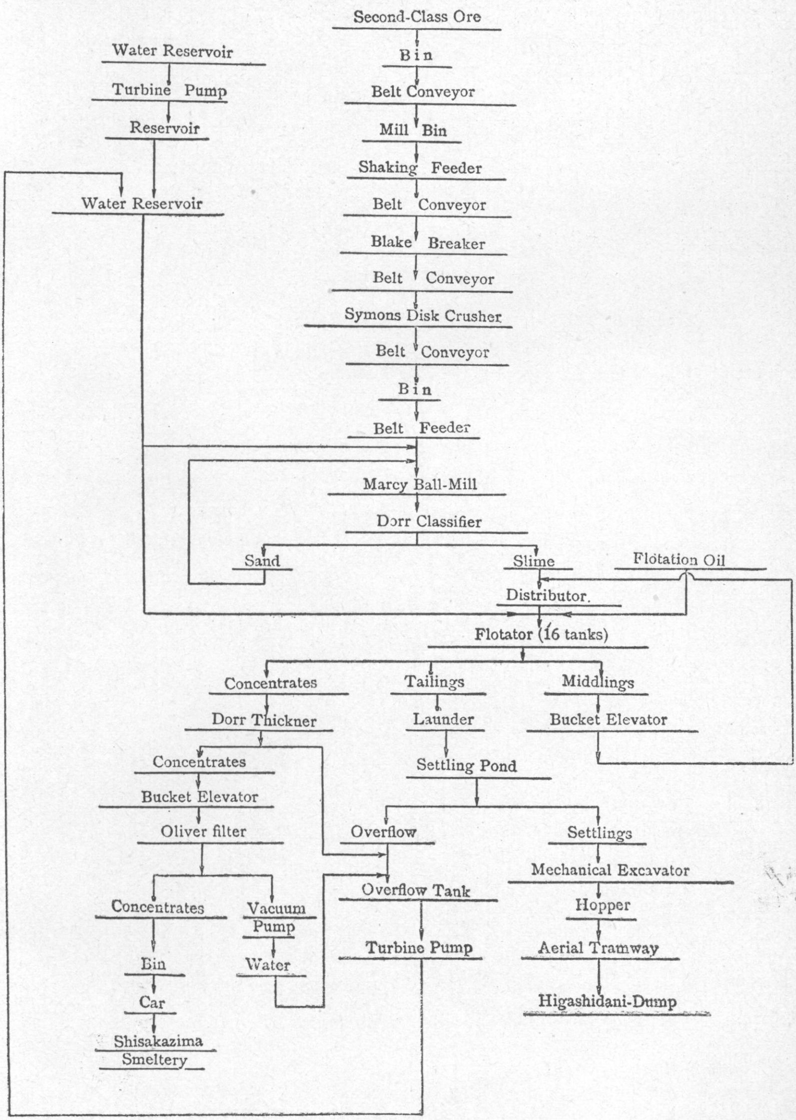
State of Development

Levels and Shafts	Level Interval or Depth		Length	Inclination
	On dip	Vertically		
	ft.	ft.	ft.	
Miyako Adit	—	—	1,772	
Drift (Level) No. 1 . . .	250	159	6,299	
Drift No. 2	278	191	4,713	
Drift No. 3	143	98	5,171	
Drift No. 4	259	181	5,450	
Drift No. 5	288	200	4,602	
Drift No. 6	255	199	4,763	
Drift No. 7	248	202	4,738	
Drift No. 8	110	85	5,383	
Drift No. 9	401	324	3,970	
Drift No. 10	327	273	3,842	
Drift No. 11	343	302	3,715	
Drift No. 12	338	300	3,257	
Drift No. 13	329	300	2,005	
Drift No. 14	449	420	3,947	
The 1st Adit	—	—	3,378	
Hiura Adit—the 3rd Adit	—	—	12,790	
The 4th Adit	—	—	15,167	
Tôen inclined Shaft . .	1,742	1,315	1,742	49° 00′
Miyako incl. Shaft . . .	524	380	524	46° 30′
Western incl. Shaft . . .	1,218	910	1,218	48° 21′
The 1st incl. Shaft . . .	207	161	207	51° 00′
The 2nd incl. Shaft . . .	704	597	704	58° 00′
Crosscuts	—	—	1,168	
The vertical Shaft . . .	—	1,922	1,922	90° 00′
Footwall Drift No. 8 . .	—	—	2,230	
Footwall Drift No. 14 . .	—	—	1,200	
Ikadatsu Drift No. 1 . .	142	106	1,380	
Ikadatsu Drift No. 2 . .	117	89	1,645	
Ikadatsu Drift No. 3 . .	217	157	1,480	
Ikadatsu Drift No. 4 . .	219	160	1,160	
Ikadatsu 1st incl. Shaft .	—	512	694	48°00′–46°00′

FLOW SHEET OF TONARU MILL.



FLOW SHEET OF NIIHAMA MILL.



IV. ORE DRESSING

Tônaru Mill.—The operation consists of hand-picking and mechanical concentration. Crude ores are crushed by a Blake breaker and the crushed droduct is separated by a shaking screen ints lumps and fines. The lump ore is hand-picked on a belt into waste, second-class ore, iron pyrites, and first-class ore. Iron pyrites and first-class ore are transferred to separate bins. Second-class ore is conveyed to the Kizodani-dump and thence by railway to the Niihama mill. The waste is sent back to the stopes to be used as filling material. The fines are separated by an impact screen into three classes ; on 18 mm., through 18 on 9 mm., and through 9 mm. The 1st class and the 2nd class are treated by a Harz jig and a Hancock jig respectively, producing concentrates, iron pyrites, and tailings. These products are transferred to bins. First-class ore and concentrates are thence transported to the Shisaka-jima smeltery.

Hateba Mill.—The crude ore is hand-picked.

Niihama Mill.—The second-class ore delivered from the Tônaru or Hateba mill is transferred to the lower bin and thence by the conveying belt to the upper mill bin. From the mill bin the ore goes through the bottom gate to the conveying belt, the rate of feeding being controlled by a shaking feeder, and is fed to a breaker, a crusher, a ball-mill, and a classifier, in series to be reduced to slimes. The slimes are led to the oil-flotator. The concentrates from the flotator, after being thickened by a Dorr thickner and an Oliver filter, are sent to the Shisaka-jima smeltery. The waste from the flotator goes to the settling pond. The settled mud is removed by a mechanical excavator and sent by aerial ropeway to the dump at Higashidani.

V. TRANSPORTATION AND COMMUNICATIONS

The transportation system comprises about 10 miles of electric railway, about 5.5 miles of aerial ropeway (Bleichert type, 3.5 miles ; Tamamura type, 1.75 miles), about 6.5 miles of steam railway, and a ferry boat service. The telephone service is well developed along the transportation system.

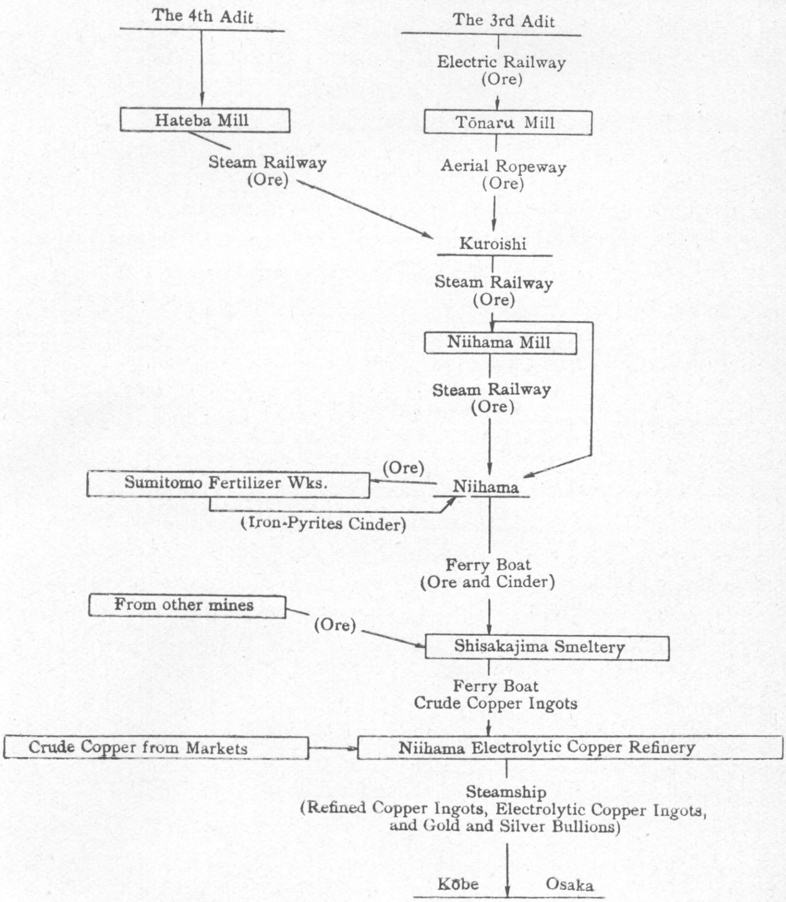
VI. SMELTING

Ores, fluxes, and fuel brought to the shore of Shisaka-jima (island) are landed by Temperley, Wharf or locomotive cranes and thence transferred by conveying belts or electric trams to the bins. Concentrates and fine ore go from the bins through a Challenge feeder and mixer to the sintering furnace, 10 ft. wide and 16 ft. long. The heat required for sintering is generated by the oxidation of the iron and sulphur contained in the charge. Coarse ore, cake from the sintering furnace, slag from the copper converter, other miscellaneous cupriferous substances, silicious gold-silver ore, and limestone are charged by electric train service to the blast furnace, 24 ft. long, 4 ft. wide, and 18 ft. high from tuyere to charging floor, equipped with water jacket. Iron pyrites from the mills is supplied to the Niihama factory for the manufacture of sulphuric acid and the cinder obtained from it is sent to the Shisaka-jima smeltery to be added to the charge for the blast furnace. Although a small amount of coke and coal (through tuyeres) is charged to the blast furnace, a greater part of the heat required is generated by the oxidation of the iron and sulphur contained in the ore. Matte delivered from the blast furnace is transferred by 30-ton crane service in to the basic converter (Great Falls type), 10 ft. dia., and as flux silicious ore is added to it. Crude copper from the converter is made into anode plates which are sent to the Niihama electrolytic copper refinery. Slag from the converter is sent back to the blast furnace. The Niihama electrolytic copper refinery is equipped with a reverberatory furnace room, electrolytic tank room (312 tanks), power room, etc. Anode slime containing gold, silver, etc., which falls to the bottom of the tanks in which copper sulphate solution (electrolyte) is held, is treated to recover the gold and silver. The annual productive capacity of clectrolytic copper (purity, higher than 99.98) is about 12,000 tons. One part of the electrolytic copper is charged into the reverberatory melting furnace and is re-moulded into ingots or bars, of which the annual output is about 7,800 tons.

Number of furnaces :—

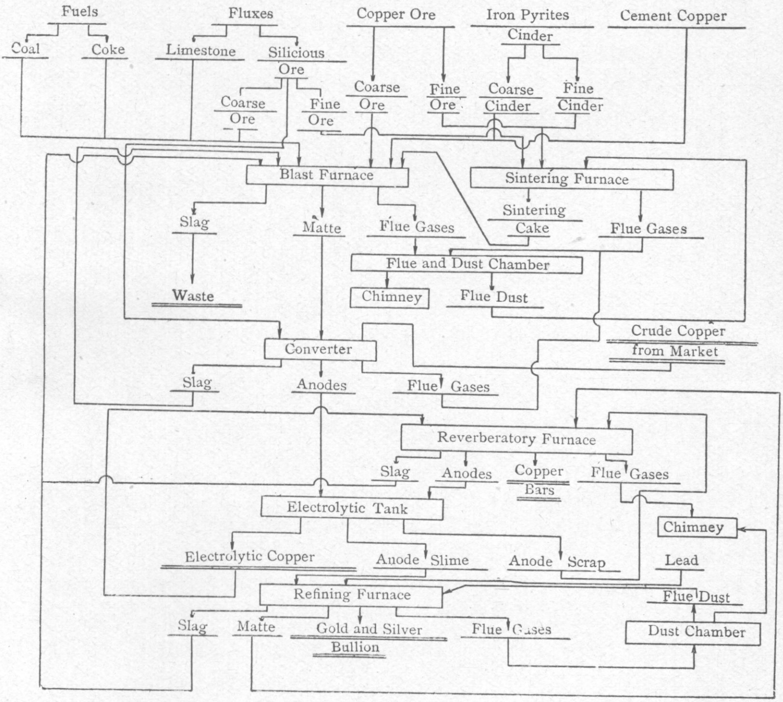
	Sintering Furnace	Blast Furnace	Converter	Reverberatory Furnace
Shisaka-jima Smeltery	3	4	3	—
Niihma Refinery	—	—	—	2

TRANSPORTATION SYSTEM.



SCHEME FOR SMELTING COPPER ORES.

(Shisakajima Smeltery and Niihama Electrolytic Copper Refinery.)



Annual Production.

Year	Gold	Silver	Refined Copper	Electrolytic Copper
1921	14,936 oz.	339,823 oz.	4,251 tons	7,643 tons
1922	25,599	529,584	3,528	10,263
1923	21,094	428,387	3,220	10,847
1924	14,599	376,999	2,753	11,037
1925	18,971	456,803	654	14,676

V. FROM NIIHAMA TO TAKAMATSU

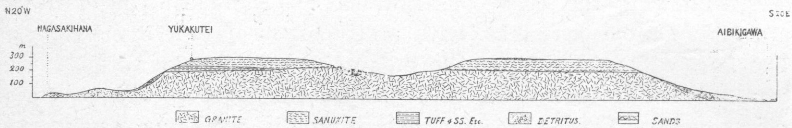
By Yoshiaki Ozawa

From Niihama the railway runs along the Izumi Sandstone mountains, through cuttings and a tunnel in the sandstone. To the south of Doi, the triangular facets along the median fault are distinctly visible. Many small hills of Cretaceous sandstone skirt the foot of the mountain.

Following the coast of Kawanoé to Kannonji, the railway traverses Cretaceous rocks, with pretty views of the Inland Sea on the left, while far off rise the mountains of Chûgoku through the haze. From Kannonji, the geological and topographical aspect becomes quite different: the foundation rock is granite upon which lie various andesitic flows. The granite is highly decomposed, weathering and erosion having reduced it to low hills and more or less rounded slopes; while the andesitic flows, which are hard and compact, make a steep cliff above the granite, though the top surface is almost flat and table-shaped.

Tadotsu is one of the best ports on the Inland Sea. From here a branch railway turns S E and skirts a range of bulky and densely wooded hills to Kotohira where the Kompira shrine is situated. The main temple stands on an elevated terrace cut on the beautifully wooded slope of Zôzusan (Elephant Head), and is flanked by some splendid old trees and several auxiliary shrines. It is the holiest shrine in Shikoku and next to the Isé shrines at Yamada, more pilgrims annually visit this shrine than any other in Japan. Most of pilgrims worship the tutelar Kompira, a redoubtable Buddhist divinity who is believed to protect seamen and travelers by sea.

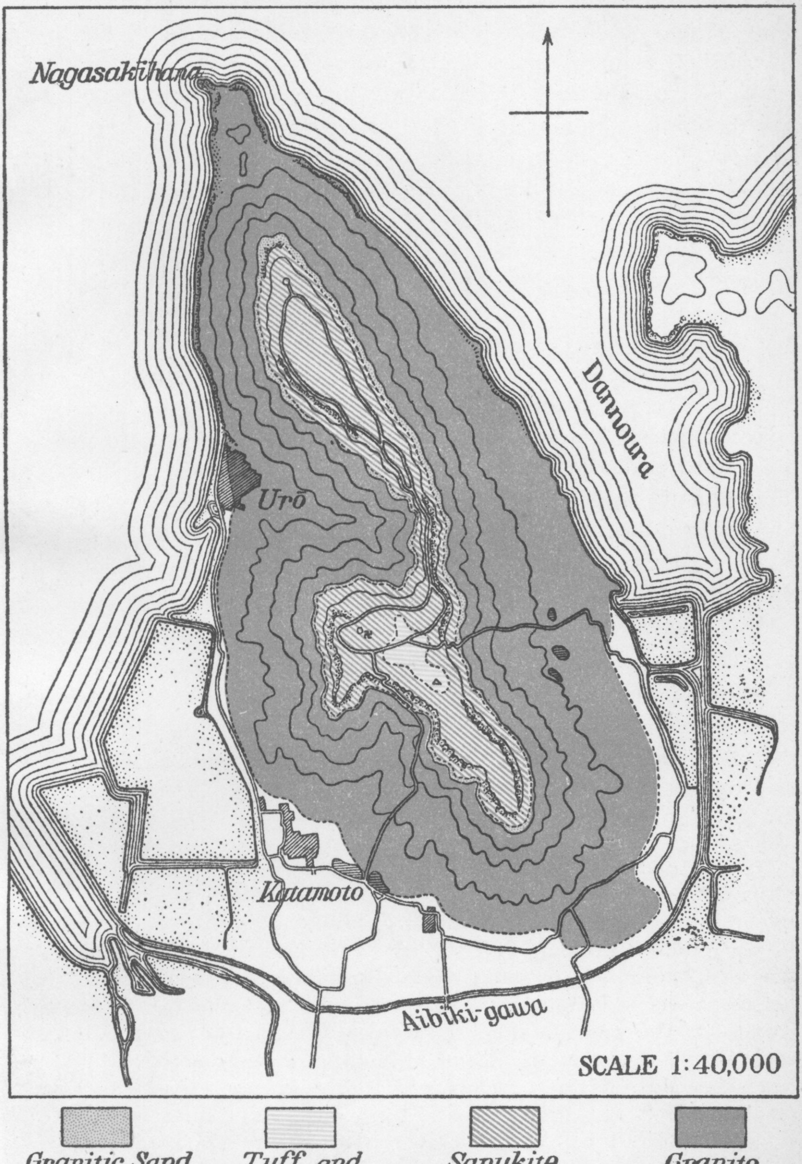
From Tadotsu the main railway follows the contour of the coast. Along the shore we pass a number of charmingly situated but monotonously similar little towns whose chief industry is the making of salt in a primitive way from the sea water. Miles of salt pits line the beach while conical hills and rice fields stretch away inland. Among these conical eminences Iinoyama (441 m.) is a most picturesque miniature of Mt. Fuji, and accordingly is often referred to as the Sanuki Fuji. It may be mistaken for a volcanic cone, but it is not a cone in the ordinary sense of the term: for about one third of its height is built of granite, the upper two-thirds being of compact bronzite-andesite with platy joints. We do not yet know whether it is an erosion relic of a mesa or the eroded head of a volcanic neck. Many of the pointed and conical hills in the district are also capped with this lava, which attains a thickness of 30 meters. The sanukite flows on the other hand form buttes or flat-topped hills of considerable extent. Good examples are Yashima (300 m.), Kokubudai (350 m.), and the adjoining islets in the province of Sanuki, which are the remnants of a once extensive volcanic mesa resting upon granite.



Geological section through the table-land Yashima.

Takamatsu is the terminus of the Sanuki line and the port of Shikoku nearest the main land: the jetty adjoins the station. The port moreover maintains steamship connections with several islands in the Inland Sea. It is the largest town in the Island of Shikoku and is the commercial center of the province of Sanuki, one of the largest areas of irrigated plain in Shikoku and one that is noted in Japan for the good quality of its rice. Takamatsu Castle, the most conspicuous object at the left of the station, was erected in 1335 by Yorishigé Matsudaira, a governor of the province: it is now in a ruinous state, but the ancient castle park is perhaps finer than it was originally, for it has been deftly converted into a charming garden, the Ritsurin-Koen, which is regarded by many as one of the best examples of landscape gardening in the Empire.

GEOLOGICAL MAP OF YASHIMA



VI. YASHIMA AND ITS ENVIRONS

By Yoshiaki Ozawa

Five kilometers to the east of Takamatsu rises pine-clad Yashima, a table-mountain projecting the sea. It is a well-known popular resort accessible either by railway or tram-car, and consists of a small flat-topped plateau with a height of 300 meters, and an area of about 5 square kilometers.

The mesa consists of compact black sanukite with platy joints lying at level of 200 meters and upwards, underlain by a large mass of granite which together with some Pleistocene or later Pliocene sediments forms the general underlying platform of the island. The sanukite flow forms mural precipices while the granite is to be seen sloping away from the sanukite base and the slope is covered with thick sanukite detritus.

Yashima together with many small islands nearby is a fragment of a sunken land area which was broken up in post-Setouchi times. The main axis has a N-S trend, probably determined by parallel fault lines, so that the island may be regarded as horst which has been further broken up by transverse fractures.

The panorama from the terrace is superb, embracing as it does a score of villages, hundreds of square miles of the lovely Inland Sea with entrancing views of its many islands, range after range of blue mountains and league upon league of cultivated valley and plain.

Among the islands, Shôdoshima is the most picturesque, its geologic structure and prevailing rocks being almost the same as those of Yashima. The following description of the geology of Shôdoshima is taken from Dr. Kotô's paper on "Volcanoes of Japan."

"An abraded granite foundation is here covered first with a loose conglomerate of granite and siliceous slate, succeeded by alternations of sandstone, shale and comminuted glass particles, containing a seam of inferior lignite. The whole is then covered with brown or dark brown lava-breccias of bronzite-andesite from 200 to 300 m. in thickness. The flat-topped mesa of 913 m. with the much cleft romantic escarpment of Kangaké is well known to scenery lovers of this region. The Tertiary is here preserved from erosion by the volcanic deck, but the very same facies of Tertiary is found extensively developed in Awaji Island, west of the Bay of Osaka, and on the northern shore of the Inland Sea, with marine shells in the middle, and lignite seams in the upper horizon. Orthobasalt or olivine-bearing bronzite-andesite occurs at three localities in Shôdo-shima in isolated tholoides, piercing through the bronzite-andesite and partially covering the Tertiary. It is the latest effusive of the present volcanic zone."

A short distance east of Yashima rises Goken-zan[1]. Here the basement granite is well exposed and quarried at several places on the west flank. Upon the granite lie clay, white tuff and agglomerate, which are curiously sculptured by weathering and give the mountain its peculiar appearance.

Between Yashima and Goken-zan extends an arm of the sea called Dannoüra[2] which is of historic interest to Japanese. The curious dried and polished crabs (Kani) called 'Heikegani' obtainable at the refreshment-stands at the summit or some of the local shops are said to be caught along the coast of Dannoüra and are of peculiar significance to one versed in Japanese history. Because at Dannoüra (at that time the sea covered the present alluvial plain surrounding Yashima) the great Heiké Clan was beaten (February 19, 1185) by the Genji Clan led by the intrepid Yoshitsuné. The spirits of the drowned and slaughtered Heiké clansmen according to the current legend assumed such shapes that 'the fury or the agony of their death-struggle can still be discerned in the faces and upon the backs of crabs.

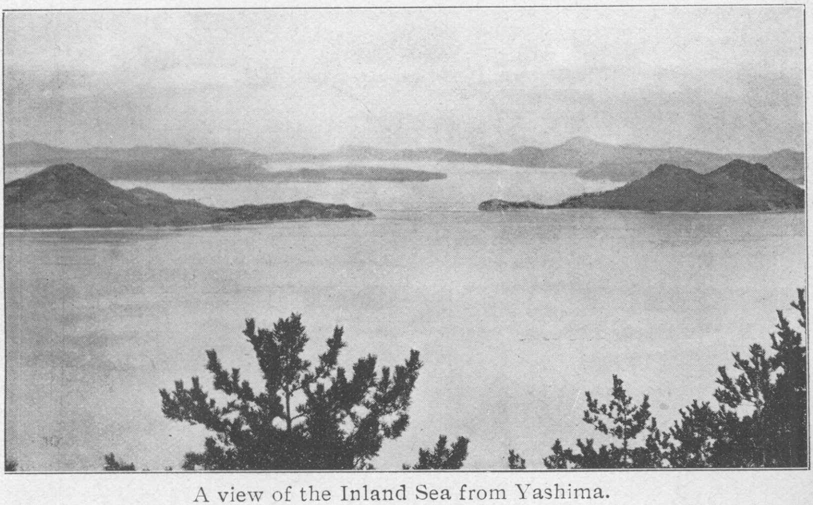
The Museum, or Homotsukwan (Treasure House), attached to the Yashima temple on the table-land, contains curious old weapons and costumes (armour and helmets) used by the Heiké and Genji warriors.

---

1) Meaning "Five Swords Mountain"—so-named because it is composed of five jagged spire-like peaks.

2) Named after Dannoüra the western extremity of the main land Honshû, where the Heiké Clan was exterminated by the Genji Glan.

Ritsurin Park, Takamatsu City.



A view of the Inland Sea from Yashima.

大正十五年十二月二十日印行
大正十五年十二月二十五日發行

第三回汎太平洋學術會議

印刷者　木　下　憲
東京市日本橋區兜町二番地

印刷所　東京印刷株式會社
東京市日本橋區兜町二番地

發賣所　東京地學協會
東京市京橋區木挽町九丁目二十九番地

Executive Office: Rooms of the National Research Council,
Department of Education, Tokyo

CABLE ADDRESS:—KENKYU, TOKYO.

Printed by the Tokyo Printing Co., Ltd.