GEOLOGY AND ORE DEPOSITS OF THE ONIKOBE-HOSOKURA DISTRICT, NORTHEASTERN HONSHU, JAPAN.

By

Eikichi NARITA

Contribution from the Department of Geology and Mineralogy,
Faculty of Science, Hokkaido University, No. 894

CONTENTS

I. Introduction

Along the whole inner side of the Japanese island arc bulk pyroclastic pilings of Miocene~Pliocene age are continuously developed forming a peculiar geotectonic unit, the "green tuff region". Particularly, in the northeastern part of Honshu, these pyroclastic pilings are typically exhibited. They continue in north-south directed belt of about 40 km width. The chief geotectonic trends, the arrangements of effusive rocks and trends of fault systems etc. are all included in this elongation (MINATO, M., et al., 1956, KITAMURA, N., 1959). Even in the recent topography the geotectonic unit is also clearly marked in the backbone mountain range, the western parallel running Dewa hilly land and other parallel tectonic valleys. However, it is also a prominent feature that there are evidences of NW-SE trending tectonic disturbances which cross the main N-S trend at regular intervals. It is considered that this later NW-SE tectonic trend is rather important in connection with the arrangement of Tertiary economic mineral deposits of the green tuff region.

The "Onikobe-Hosokura" zone is one of the members of those NW-

SE trending tectonic zones; it is situated to the northward of Sendai. It coincides with the "Ishinomaki-chokaisan" line proposed by OMORI, M., (1953). This zone is distinguished by huge effusions of Tertiary pyroclastics and several types of propylites. Further, many Tertiary mineral deposits are disposed in close association with those pyroclastics. Hosokura mine, working one of the largest lead-zinc deposits of Japan, is situated in the eastern corner of the zone. Tertiary igneous geology and geotectonic development of the zone is of interest, as a standard section, for the Plio~Miocence history of the inner zone of the island arc and also for the formation of associated mineral deposits.

In the present paper, the writer undertakes to describe the igneous geology and associated ore deposits on a regional scale, and to offer considerations on the formation of mineral deposits of the zone.

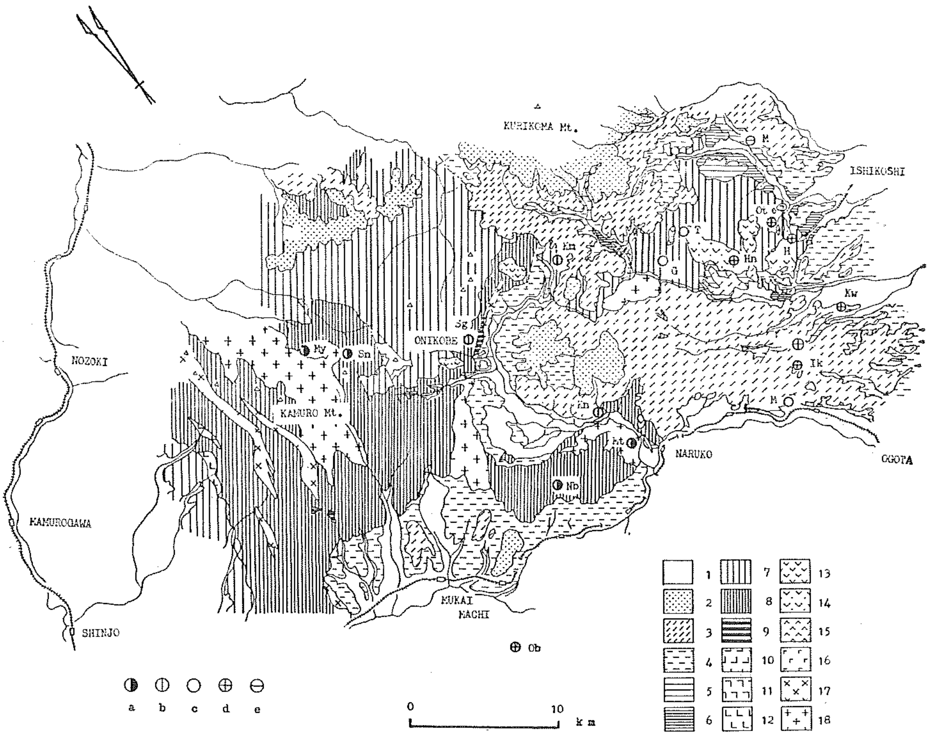
II. General Geology

Geographically, the Onikobe-Hosokura district, now under consideration, is wholly included in the backbone range area, the eastern main zone of the Tertiary "green tuff region" of northeastern Honshu. The district, as a whole, represents a unit of Tertiary igneous effusion of the green tuff region which is characterized by the scattered appearance of small units of activated igneous centres. The district is also characterized by minor so-called Palaeozoic masses as the basement complex covered by wide spread early Miocene effusive propylitic masses that form the backbone mountain ridge, and their covering formations of successive tuff breccias and tuffaceous shales that fill the eastern flanks of the backbone range. Other instrusive propylite and dacite masses are arranged in a zone of NW-SE direction, which seems to have close connection with the distribution of mineral deposits of the district.

The basement complex of the district (KATO, I., 1953, KATAYAMA, N., & UMEZAWA, N., 1958) is a granite massif or meta-sandstone, schist and mylonite, trending to NE direction. Elements of the basement complex are always separated by prominent sheared zones with Neogene Tertiary formations as if they had been pinched up tectonically into younger formation.

Those older basement rocks crop out as small masses scattered among wide spread early Miocene effusives, the Nozoki formation. In the Onikobe-Hosokura district, this formation constitutes a south-western high land stretched in NW-SE direction. It is composed chiefly of propylite and its clastic derivatives. It is covered by the Hosokura formation which

Fig. 1. Geological map of the Onikobe-Hosokura district, Miyagi Prefecture.



1. Recent 2. Quaternary volcanic rocks 3. Kawaguchi and Onikobe formation 4. Himematsu formation 5. Tozawa formation 6. Nakayama formation 7. Hosokura formation 8. Nozoki formation 9. Basement rocks 10. liparite 11. dacite 12. felsic andesite 13. quartz bearing hornblende two pyroxene andesite 14. propylite 15. dolerite 16. quartz prophyry 17. Tertiary diorite 18. basement granite
My: Myofuku mine, Sn: Sanko mine, Nb: Nabekura mine, Mt: Motoyama mine, Kn: Kanizawa mine, Sg: Suginomori mine, Km: Kamanai mine, M: Matsuhodo mine, G: Ginkaseki mine, T: Tozawa mine, Hn: Hanayama mine, Ot: Odomori mine, Kw: Kawaguchi mine, Mm: Memori mine, Ik: Ikezuki mine, M: Monji mine, (Ob: Obori mine) a: chlorite-copper vein, b: gold bearing chlorite-copper vein, c: gold-silver bearing quartz vein, d: lead-zinc vein, e: arsenic deposit.

is composed chiefly of green tuff breccia and often intercalates minor seams of mudstone and impure limestone. The succeeding upper formations are of upper Miocene agglomerate and lake deposits, the Nakayama and Tozawa formations. Several propylite and dacite intrusive masses are associated with each formation, especially with the Nosoki, Hosokura, Nakayama and Tozawa. The Himematsu formation is widely developed covering discordantly the above named formations. It is composed of dacitic tuff. The characters of each of these formations are roughly touched upon as follows.

Nozoki Formation: This is defined by KATO, I., as the basal member of the Miocene pyroclastic formations of the green tuff region of northeastern Honshu. It is disposed chiefly in the ridge zone of the backbone range forming the bulk central massif of early Miocene effusion. It is chiefly composed of propylitic materials, though stratified parts are also intercalated. With them, a facies changes from massive propylite to agglomerates or breccias, and even to tuffaceous stratified parts which are very often met with in a short distance. Several dikes and sheets of propylites, dacite, dolerite and diorite masses cut this basal formation.

Hosokura Formation: Succeeded from the Nozoki formation, the Hosokura formation which is constituted chiefly of pyroclastics is developed around the mass of the Nozoki formation; also it exists separately among younger formations in the eastern corner of the Onikobe-Hosokura district as the Hosokura-Hanayama mass. These pyroclastic sediments are divided into two members. The one is a green tuff facies which is disposed chiefly around the propylite mass, diminishing to the outer zone. The immediate neighbour of the propylite mass, the green tuff facies is found in all horizons of the formation. But, it is represented only in the upper horizon in far distant areas.

The other members are represented in a gray tuff facies, which is chiefly found in the area, apart from propylite mass. It intercalates green tuff breccia, and also tuffaceous mudstone and calcareous seams.

The area of the green tuff facies corresponds to a site of intrusion or effusion of propylite as well as of basalt, dolerite, diorite and quartz porphyry. Such a circumstance is also clear exhibited in the Ou province (OIDE, K., & ONUMA, K., 1960) that lies in the southernmost part of the NW-SE trending tectonic unit.

Nakayama Formation: This formation lies to the northeastern side of the Hosokura massif. The chief component of it is a prominent agglomerate. The lower half of it shows a greenish tint, and it gradually transits into the green tuff breccia of the Hosokura formation. At the basal part, some lava flows of peculiar felsic andesite are to be found.

Tozawa Formation: This formation lies unconformably on the Hosokura formation; it is composed of siltstone, sandstone and dacitic volcanic conglomerate. In its basal part, some plant fragments are found, which are indicative of lake deposits (KATO, I., 1953, KITAMURA, N., 1959). It is considered as a leading facies of the succeeding Himematsu formation. Also it is associated with a dacitic effusion that predominates in the Himematsu and Kawaguchi formations.

Himematsu Formation: This formation is composed of dacitic tuff, conglomerate, and soft silt; it is disposed in three separated destricts. It lies unconformably on the Hosokura formation, and often includes intercalations of lignitic seams at the basal part. In the lower part of the dacitic tuff formation pisolite is known, and in some parts the tuff is welded.

Kawaguchi Formation: This formation is characterized by dacitic welded tuff which is developed on a regional scale and fills the low land of the district.

Igneous Rocks

Igneous rocks of the district, are listed as follows:

plutonic rocks	hornblende granite and biotite granite
subvolcanic rocks	dolerite, quartz dolerite, diorite, quartz diorite, aplite and quartz porphyry
volcanic rocks	basalt, basic propylite, dacitic propylite, felsic propylite and quartz-bearing hornblend two pyroxene andesite

Those plutonic rocks of granite clan form the basement complex of the district. Cataclastic texture predominates through the whole mass, and further, the rocks have been affected by hydrothermal alteration of younger age. The greater part of the granite takes the form of biotite granite, but in the Mizunashi district, hornblende-bearing variety is also know.

Subvolcanic rocks such as dolerites, diorites and quartz porphyry are arranged immediately neighbouring the older basement granite; their intrusions are characteristically controlled by the NE trended Miocene tectonics that are represented as sheared zones or linear arrangements of igneous masses. These subvolcanic rocks are all of Miocene age (KATO, I., 1951a, NARITA, E., 1960).

The dolerite suit takes the form of dikes and sheets penetrating through the Miocene propylite; they are of augite dolerite, but in some cases, hypersthene dolerite is also found. They all suffer throughout the least effect of alterations. Granodiorite is restricted to the western margin of the domain of Tertiary holocrystalline intrusives that occur in the Nuruyu-Onikobe area. Various facies changes are noted in those masses, which are transformed granodiorite to hornblende diorite or dolerite facies. Frequently, they associate with irregular masses of aplite which is characterized by graphic intergrowth of quartz and orthoclase. Dikes of quartz porphyry are always found in and around the basement granite.

Some of them have intruded into Miocene propylite. It is altered hydrothermally; all of the plagioclase is albitized and epidote veinlets are conspicuous in some parts.

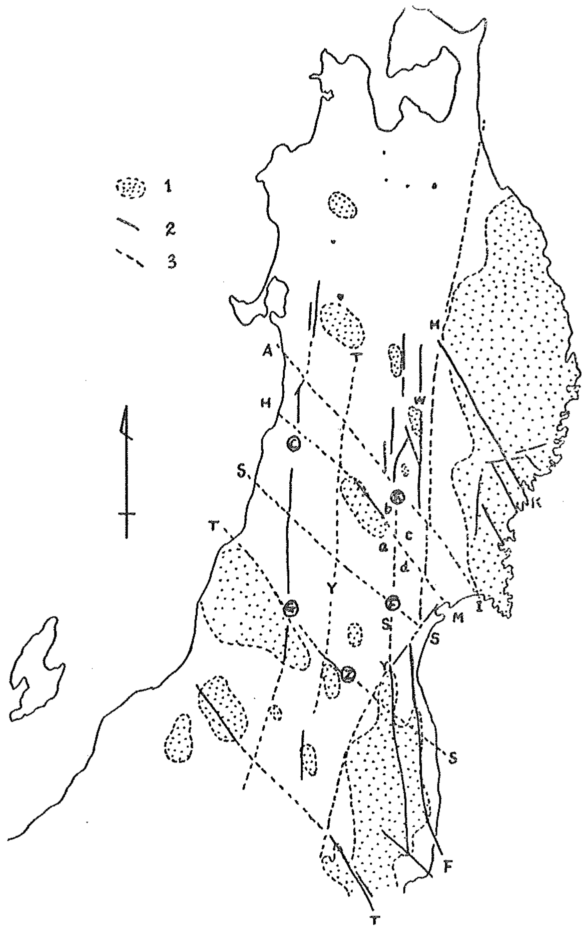
In this region, several types of volcanic rocks are arranged along the Honjyo-Matsushima tectonic zone (OIDE, K., & ONUMA, K., 1960). There are to be found basalt, basic and dacitic propylites, felsic andesite and quartz bearing hornblende two pyroxene andesite. Basalt is known from the Hanayama-Nuruyu area as dikes intruded into propylite. In some aspects, basalt is referred to the above-mentioned dolerite. Propylite is dotted in small masses, along the NW directed line that is characterized by the mineral deposits of the Onikobe-Hosokura district. Some of them have intrusive character. Their upper part was formed as lava which overflowed from the lower intrusive funnel-shaped big neck. Such an intrusive form is revealed in the Hosokura propylite mass, by the observations at every underground mining level and at the Kiridome-Nuruyu mass. In general, the original character of those propylites is two pyroxene andesite, but dacitic character is also known. Alteration in the propylite is distinguished by the formation of chlorite, sericite, kaolinite, albite and quartz. Several assemblages of those altered minerals are to be found, which are understood as representing grades of propylitization. Of the dacitic propylite, silicification is prominently developed as well as the above-mentioned alterations.

Felsic andesite overlies the Hosokura green tuff formation as a lava flow spread around the Nakayama and Aitatsu districts. It is the least phenocryst bearing glassy andesite with altered minerals, of sericite, chlorite and carbonate. Those are illustrated in Fig. 1.

Tectonic features of the Onikobe-Hosokura district

Recent geotectonic researches by OMORI, M., (1953) and OIDE, K., & ONUMA, K., (1960) on the green tuff region of northeastern Honshu have yielded remarkable items of information. According to them, every igneous mass is disposed in linear arrangement which is considered to be controlled by some tectonic features of the basement complex (OMORI, M., 1953, HIROKAWA, H., 1954, WATANABE, E., et al., 1955, YAMASHITA, N., 1957, SAKAKIBARA, T., 1958). It is considered that the Tertiary rejuvenated movement of those masses may have been accompanied by igneous effusions. Such linear arrangements are distinguished into two groups of NS trend and NW trend. Of the NS group, Chokaisan-Gassan (C-G), Tazawako-Yamagata (T-Y), Shirasawa-Yanakawa (S-Y) and Washiaimori-Futaba (W-F) are mentioned by the above students. Of the

Fig. 2. Tectonic line in basement rocks of the northeastern Japan.



1) basement rocks, 2) tectonic line, a. Motoyama-Kamuro area, b. Onikobe area, c. Nuruyu-Hosokura area, d. Ikezuki area.

NW group, Akita-Ishinomaki (A-I), Honjo-Matsushima (H-M), Sakata-Sendai (S-S) and Tsuruoka-Soma (T-S) are noted as represented in Fig. 2.

As already mentioned, the Onikobe-Hosokura district is disposed on the eastern half of the Ishinomaki-Chyokaisan tectonic zone that runs in NW trend. As to the detailed tectonic pattern, the district is surrounded by NS trendnig lines of (T-Y), (W-F) and NW trending lines of (A-I), and (S-S) while further inside the district is subdivided by (S-Y) and (H-M). Accordingly, the district is divided into the following four blocks

a) Motoyama-Kamuro, b) Onikobe, c) Nuruyu-Hosokura and d) Ikezuki.

Of the igneous rocks of the district as a whole, the following aspects are noteworthly. The holocrystalline rocks are preferably disposed on the western side of the district. Each propylite mass is elongated to NS trend, and is disposed on the line of NW trend (H-H line). In the western half of this linear arrangement felsic~dacitic propylites are found; the basic one is found in the eastern half. A dacitic tuffaceous formation of upper Miocene~Pliocene is restricted to the lines of S-Y and W-F. Furthermore an agglomerate of middle Miocene, the Nakayama aglomeratic formation, is also restricted to the same tectonic line.

As to the basement complex, it appears in the above mentioned a) Motoyama-Kamuro and b) Onikobe areas, but is not known in the c) Nuruyu-Hosokura and d) Ikezuki areas. It is already associated with the lower Miocene member, especially with Nozoki formation as NS stretched wedge shaped blocks that are arranged in echelon trending to NW. All these basement members have been crushed by serious shearing which trends to NS and NE.

The boundary zone between the areas of a) Motoyama-Kamuro~b) Onikobe and c) Nuruyu-Hosokura~d) Ikezuki, the eastern limit of the distribution of the basement complex, is considered as a probable northern extension of (S-Y) tectonic line that predominates in the Abukuma plateau as its eastern sheared zone. In the northern area of the Abukuma plateau, the Raisan area, some dacite masses occur along this (S-Y) sheared zone. In the Shiraishi district (OIDE, K., & ONUMA, K., 1960), a zone corresponding to this northern extension also shows evidence of dacite effusion. The above-mentioned boundary zone of this district, coincides with the zone of dotted dacite masses. In the Washiaimori district, a further northern extension of the zone, is also the site of prominent dacite effusion. Dotted effusions of volcanic rocks in a Tertiary igneous field, seem to have been controlled by the older tectonic zone of the basement complex. Such circumstances in the Tertiary igneous field may have significance in connection with tectonic events.

The above distinguished tectonic zones of the district are postulated in view of the data described.

III. Ore Deposits

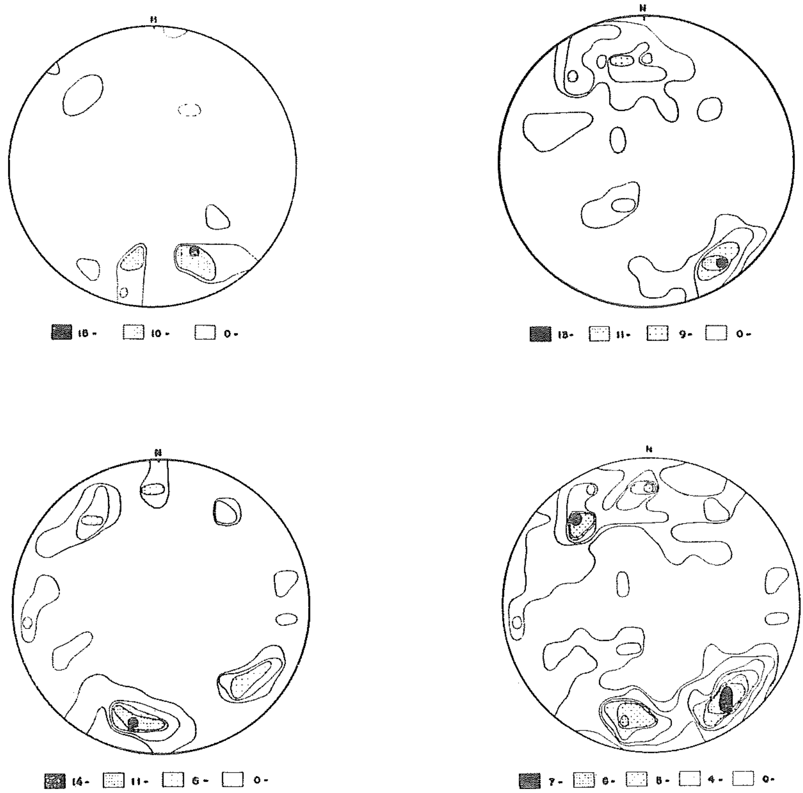
1) General features of the mineralized zone of Onikobe-Hosokura district

Ore deposits of the Onikobe-Hosokura district are those of copper, lead, zinc, gold and silver belonging to Miocene mineralization. They are differentiated into the types: copper, copper-gold, gold-silver, lead-zinc and arsenic. They are disposed in a broad zone of 20 km width that exhibits general NW-SE trend. Different types of deposits occur within this zone. It is convenient to classify them on the basis of the tectonic circumstances of the zone rather than to regard linear arrangement. The NS trending arrangements, provide one kind of zonal arrangement. That is, those deposits of the zone are grouped into one type, when they are included in a NS directed tectonical subdivision of regional meaning of the district. Such zonal subdivision is listed from west to east as follows.

Zones & Types	Vein Swarms	Worked Mines
i Motoyama copper zone: chlorite copper vein type	Sanko, Kanizawa, Motoyama	Sanko, Kanizawa, Motoyama
ii Suginomori-Kamanai copper-gold zone: gold bearing chlorite copper vein type	Suginomori, Kamanai, Matsuhodo	Suginomori, Kamanai, Matsuhodo
iii Nuruyu-Tozawa gold-silver zone: gold-silver bearing quartz vein type	Nuruyu, Ginkaseki, Tozawa	Ginkaseki, Tozawa
iv Hosokura-Ikezuki lead-zinc zone: lead-zinc vein type	Hanayama, Hosokura-Odomori Kawaguchi, Ikezuki	Hanayama, Odomori, Hosokura, Kawaguchi, Ikezuki
v Monji arsenic zone: arsenic deposit		Monji

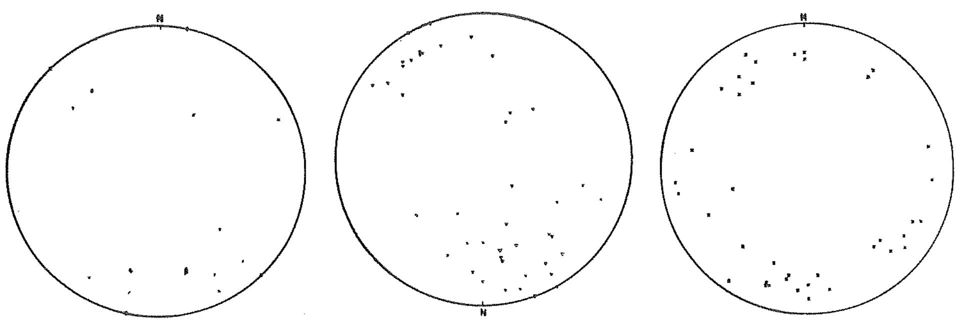
Each vein swarm occurs in an alteration aureole spread in NE direction about 3 km long and 2 km wide. The general trend of the main fracture, the principal vein of each swarm, is directed NE-SW. As a representative pattern of those swarms, the vein system of the Hosokura mine is presented in Fig. 5. The main part of this vein system, runs to NE-SW, acompanied by subordinate veins of NW-SE trend, but in the northeastern corner it turns to E-W. Although other important ore deposits are not known, the arrangements and spatial dimensions of other alteration aureoles are regularly maintained like those of the Hosokura mine (Fig. 14).

Fig. 3. Schmidt's diagram of veins and fractures.



a: zone 1 and 2, b: zone 3, c: zone 4, d: all the veins and fractures.

Fig. 4. Stereographic projection of veins and fractures.



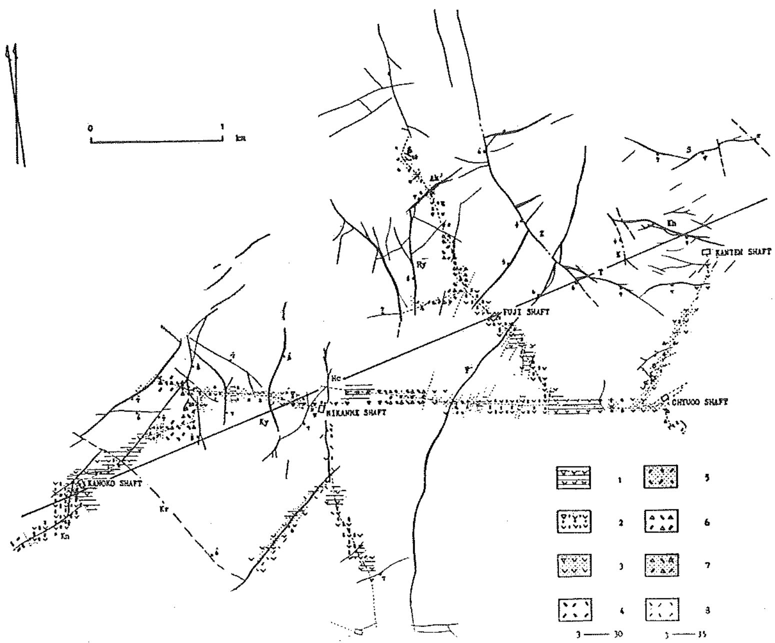
a: zone 1 and 2, △: vein, ×: fracture and veinlet, ○: dike,
b: zone 3. △: vein, ×: fracture, ○: dike,
c: zone 4. ×: vein.

In Fig. 3, all the trends of observed veins of the district as a whole are plotted in Schmidt's diagram. It is obvious that NE-SW system is highly predominant (Fig. 3-d). However, the proper character of each swarm can be discriminated as above cited.

In the Motoyama alteration aureole belonging to the westernmost mineralized zone of the district, veins of E-W trend prevail, with subordinate accompanying NE veins. Of the Suginomori swarm referred to zone 2, the main fracture takes NE direction. In the veins of the Nuruyu district belonging to zone 3, the main fracture takes also NE direction while associated minor fractures run to the same direction. The Tozawa aureole, belongs to zone 3. The trend of the veins and fractures is also the same as that of Nuruyu.

Veins and fractures of zones 1 and 2 are represented in Fig. 3-a as a whole. Veins and fractures of zone 3 are plotted together in Fig. 3-b. The observed veins number 44, and N 65 E direction shows maximum concentration in similar direction to veins of the former zones.

Fig. 5. Schematic diagram of Hosokura vein swarm.



1. propylity 2, 2. propylite 3, 3. silicified propylite, 4. tuff, 5. silicified tuff, 6. tuff breccia, 7. silicified tuff breccia, 8. argillic rock
Kn: Kanoko subswarm, N: Nikanme subswarm, F: Fuji subswarm, K: Kanten subswarm.

All the veins and fractures of the Onikobe-Hosokura district, are projected in Fig. 3-d. Two prominent areas of concentration, are revealed in the figure, of which the one of N 50 E and that of NE show over 7% concentration.

It is considered that such prevailing NE direction was caused by the N-S tectonic movement of the complex resulting in the production of the echelon fracture of tension nature along the N-S dislocation zone. However, that the general arrangement of ore deposits of the district points to NW-SE, is indicative of the existence of some controlling effect caused by NW-SE tectonic movement.

2) The nature of the ore deposits of the district

To classify the ore deposits of the district according to customary classification criteria, the following five types of deposits are to be noted:

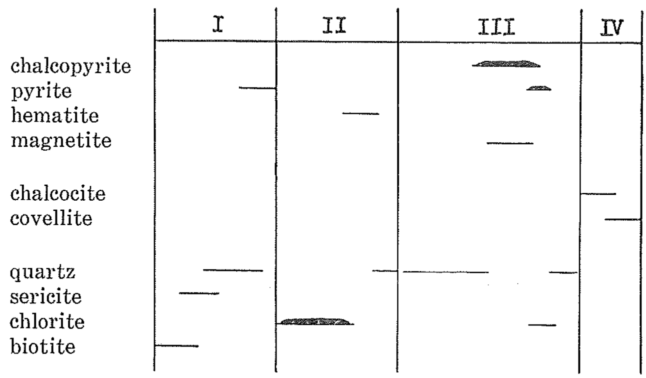
i type of chlorite-copper vein
ii type of gold bearing chlorite-copper vein
iii type of gold-silver bearing quartz vein
iv type of lead-zinc vein
v type of arsenic deposit

Throughout every type of the above named deposits, the following common mineralization process is revealed to have occurred. The process commenced by 1) incipient alteration forming wide spread aureoles surrounding the ore deposits, which exhibit silicified or argillic alteration. In the middle of this alteration aureole 2) some primodial zone of vein formation, "Hinouchi" as usually called by Japanese miner, is formed, which is marked by strong silicification or chloritization with rich pyrite impregnation. In general, a "Hinouchi" takes an obscure form of vein pattern, and is succeeded by 3) the deposition of ore minerals in the innermost part of it. Such a vein is clearly limited to the inner side of a "Hinouchi" alteration.

3) General sketch of vein types

i) chlorite-copper vein. Ore deposits of this type are disposed in the westernmost zone of the Onikobe-Hosokura mineralized zone. Vein swarms of Sanko (Sn), Kanizawa (Kn), and Motoyama (Mt) areas are assigned to this type of deposits. They are disposed in the boundary zone between the basement granite and Neogene Nozoki formation; they are associated with subvolcanic rocks such as dolerite, diorite and quartz porphyry. The deposits are characterized by chlorite, and the ore mineral is exclusively chalcopyrite and subordinate pyrite. However, in some cases, they are followed by hematite, magnetite and quartz. Around the deposits of the Motoyama mine, the country rocks are silicified with pyrite impregnation, and vary to quartz-sericite-biotite rock. The "Hinouchi" zone is filled with abundant chlorite and some hematite and quartz. Among "Hinouchi", vein formed parts are mineralized by chalcopyrite and pyrite; in this stage pre-existing hematite is transformed to magnetite.

Fig. 6. Successive process during ore mineralization of zone 1.



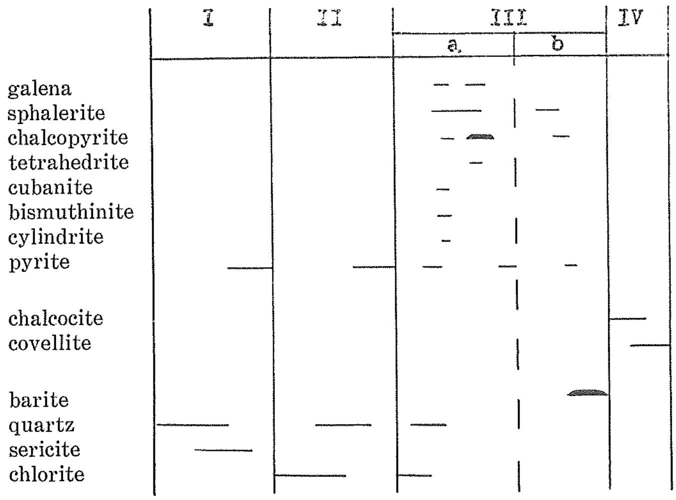
I stage of incipient alteration, II stage of "Hinouchi" formation, III stage of the deposition of ore minerals, IV stage of secondary alteration.

ii) gold bearing chlorite-copper vein. This type of deposit is disposed in zone 2; deposits are arranged in the massive propylite or Miocene quartz-diorite.

Vein swarms of the Suginomori (Sg), Kamanai (Km), Matsuhodo (M) areas are classed under this type. In contrast to the former type, abundant quartz was introduced with the chlorite mineralization. The deposits are characterized by a quartz-chlorite assemblage with chalcopyrite and pyrite, but various subordinate members such as sericite, sphalerite, galena, tetrahedrite, cylindrite, bismuthinite and native gold are also noted. In some cases, the deposits are composed of barite-quartz excluding chlorite.

Around the deposits, a wide spread pyrite-sericite-quartz assemblage is found. In such an alteration aureole, the next stage of mineralization is represented by a quartz-chlorite assemblage restricted to the "Hinouchi" alteration. The following mineralization is distinguished by the presence of sulphides. In the deposits of the Suginomori mine, two phases of mineralization are discriminated. The earlier stage is revealed in a common quartz-chlorite assemblage and associated chalcopyrite and other usual

Fig. 7. Successive process during ore mineralization of zone 2.



I stage of incipient alteration, II stage of "Hinouchi" formation, III stage of the deposition of ore minerals, a. chlorite-copper facies, b. quartz-barite facies, IV stage of secondary alteration.

sulphides, but the later stage is represented by a quartz-barite assemblage. And further, earlier mineralization is characterized by the existence of bismuthinite and cylindrite, the exceptional occurrence in the epithermal type of deposits of the green tuff region.

The deposits of the Kamanai mine, are represented by stock-works of veinlets in felsic propylite. In each veinlet a chlorite-quartz-copper assemblage is clearly identifiable. Chalcopyrite, pyrite, sphalerite and galena are the common ore minerals of these deposits, and they are also accompanied by native gold and cubanite.

iii) gold silver bearing quartz vein. This type of deposit is restricted to zone 3. Nuruyu (N), Ginkaseki (G) and Tozawa (T) vein swarms are representative of this type. Such veins are formed in the mass of dacitic or basic propylite, dorelite, diorite and quartz porphyry.

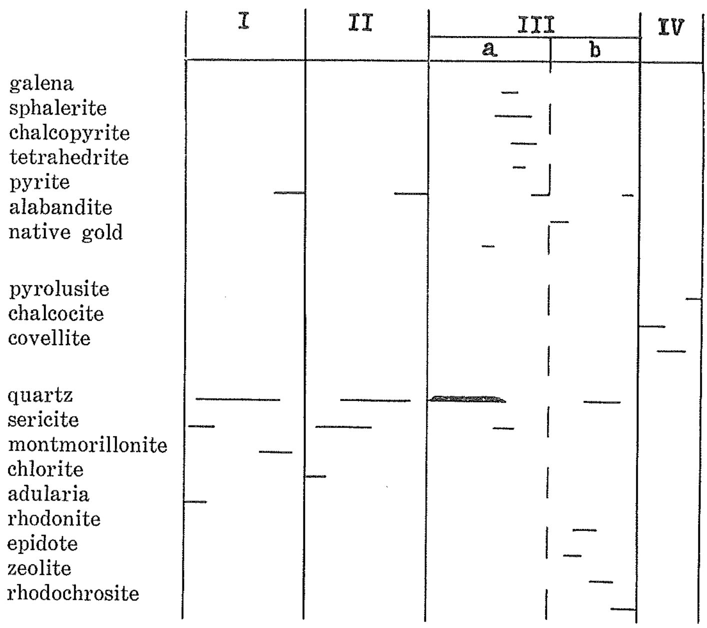
The main part of such a vein is formed of ore associated with quartz and typical base metal assemblage, comprising such materials as a minor amount of epidote, rhodonite, chlorite, sericite, zeolite or rhodochrosite.

Around the deposits, a wide spread alteration aureole formed of quartz-kaolinite-montmorillonite assemblage is noted. In the "Hinouchi" part, sericite-quartz assemblage predominates, which transformed to quartz vein. The mineralization of ore minerals was accompanied by the deposition of minor amounts of chalcopyrite, tetrahedrite, sphalerite, galena, pyrite and argentite accompanied by native gold.

In the deposits of the Nuruyu-Hanayama area, the earlier mineralization of such veins proceeded according to a normal course of mineralization, but curiously enough, a subsequent phase is represented by the deposition of manganese minerals such as rhodonite, alabandite, mangano-epidote, zeolite etc.

In the neighboring area, some curious type of deposit is also mentioned. In the silicified alteration aureole, deposit of magnetite-hematite-chlorite-quartz assemblage is formed.

Fig. 8. Successive process during ore mineralization of zone 3.



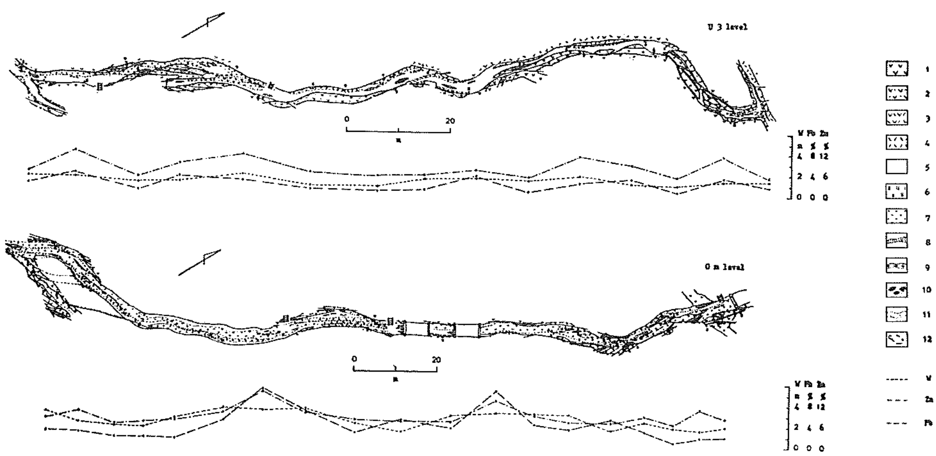
I stage of incipient alteration, II stage of "Hinouchi" formation, III stage of the deposition of ore minerals, a. banded quartz facies, b. rhodonite-quartz facies, IV stage of secondary alteration.

Associated with those diversed types of deposits, a quartz vein having banded streak of so-called "ginguro", an aggregation of minute grains of tetrahedrite, argentite, sphalerite, galena etc., is noted in the deposits of the Ginkaseki and Tozawa mines.

iv) lead-zinc vein. This type of deposit is found in zone 4, the eastern marginal zone of the district. Its host is a mass of propylite. Deposits of Hosokura (H), Hanayama (Hn), Odomori (Ot) and Ikezuki (Ik) mines are the typical representatives of this type.

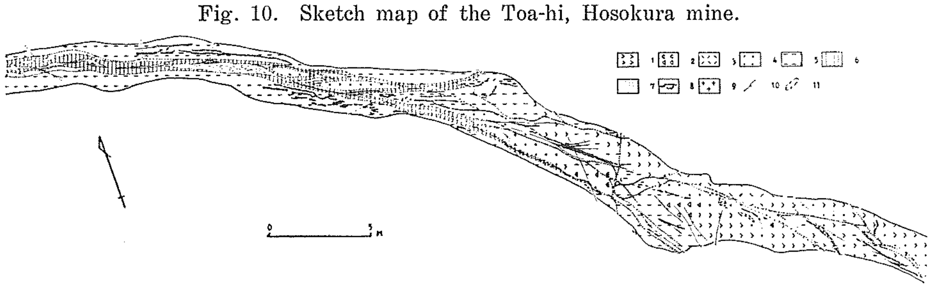
In the district, only basic propylite predominates, and subvolcanic intrusives are entirely lacking. Such vein type is characterized by a quartz-sphalerite-galena assemblage; the deposits are being worked in one of the largest lead-zinc mines in Japan. The vein swarm of Hosokura mine is subdivided into five groups: Kanoko, Nikanme, Fuji, Odomori and Kanten (Fig. 5). The first, a wall rock alteration appears as a silicification swelling over the deposits. The next mineralization resulted in the formation of abundant chlorite and quartz along the "Hinouchi" zone with pyrite impregnation and some sphalerite and galena. And then, abundant sulphide ore minerals were deposited along the "Hinouchi" core.

Fig. 9. Sketch map of the Kanoko-hon-hi, Hosokura mine.



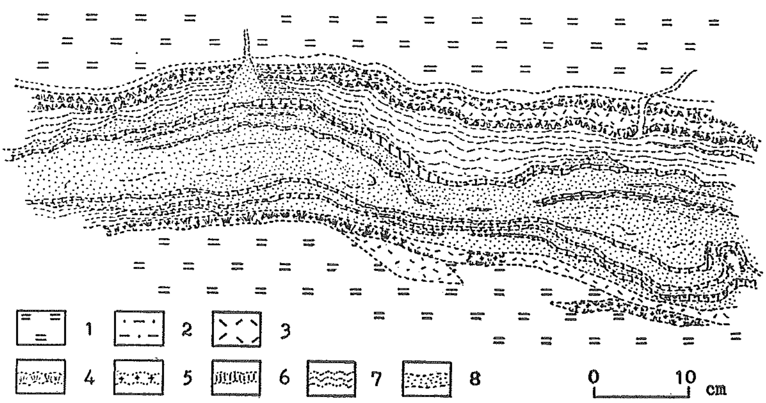
1. propylite, 2. silicified propylite, 3. argillic propylite, 4. argillic rock, 5. quartz facies, 6. chlorite-zinc facies, 7. quartz-zinc facies, 8. sphalerite, 9. galena, 10. chalcopyrite, 11. iron sulphid facies, 12. druse.

Fig. 10. Sketch map of the Toa-hi, Hosokura mine.



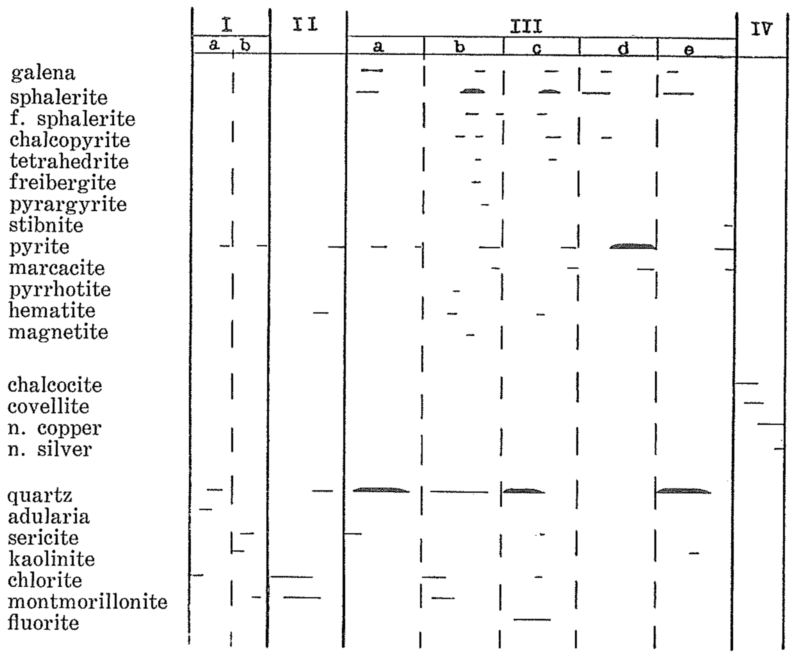
1. propylite, 2. brecciated propylite, 3. argillic rock, 4. silicified rock, 5. chlorite-zinc facies, 7. iron sulphide facies, 8. sphalerite, 9. galena, 10. fracture, 11. druse.

Fig. 11. Sketch map of the Toa-hi, Hosokura mine



1. chlorite-zinc facies, 2. granular fine quartz and sphalerite, 3. clay, 4. so-called wurtzite, 5. galena, 6. sphalerite, 7. quartz-zinc facies (banded quartz and fluorite), 8. iron sulphide facies.

Fig. 12. Successive process during ore mineralization of zone 4.



I. stage of incipient alteration, II. stage of "Hinouchi" formation, III. stage of the deposition of ore minerals, a. banded quartz facies, b. chlorite-zinc facies, c. quartz-zinc facies, d. iron sulphide facies, e. massive quartz facies, IV. stage of secondary alteration.

On the whole, only a sort of zonal arrangement of ore minerals is to be found in the Hosokura swarm, specifically, in the western part of the swarm. There exist some characteristic wall rock alterations of quartz-adularia or quartz-zeolite assemblages and such ore minerals as chalcopyrite, freibergite, pyrargyrite, pyrrhotite and magnetite. In the eastern part, stibnite, fluorit and pyrite are prevalent in some localized parts. In the detailed succession of the process of vein formation the following phases (NARITA, E., 1961b) are discriminated:—

a) banded quartz phase
b) chlorite-zinc phase
c) quartz-zinc phase
d) iron sulphide phase
e) massive quartz phase

Their mutual relations are shown in Figs. 9, 10, 11, 12.

v) **arsenic deposit.** This type of deposit is revealed in the form of network and impregnation. In a silicified part of sandy tuff of the Monji formation, ore minerals of realgar and orpiment are disposed.

4) Ore minerals

Sphalerite: Except for the chlorite-copper vein type, sphalerite is common in all vein types, but the grade of concentration is more rich in the eastern division as shown by the deposits of the Hosokura mine and its lead-zinc zone. Also, even in the vein swarm of lead-zinc vein type, concentration of sphalerite is locally different and it is rich in the eastern vein. In the Hosokura mine, the sphalerite of the chlorite-zinc phase is over 10% as Zn; that phase produces ore of the highest grade.

The form is granular or fibrous; the former is massive or occurs as a banded aggregation in veins; rarely it is subhedral in druse of vein. Its colour is pale yellow, pale brown, brown, reddish brown, dark brown and so on. In the gold bearing chlorite-copper vein dark brown sphalerite is common. In the ore of the chlorite-zinc phase of the Hosokura mine, it is pale yellow to dark brown, and in that of the quartz-zinc phase, pale brown to brown. The coloure of sphalerite does not depend on difference of Fe content but on that of S, as mentioned by TOGARI, K., (1954, 1959).

Fibrous sphalerite (so-called wurtzite) forms a banded structure in the ore of chlorite-zinc and quartz-zinc phases of the Hosokura mine. The colour is generally dark brown. Although the external form of this sphalerite is fibrous, like that of wurtzite, its internal diffraction pattern denotes true sphalerite style (IMAI, H., 1948). For the genesis of fibrous sphalerite, IMAI considered that wurtzite crystallized primarily at high temperature, and then it changed to low temperature sphalerite structure keeping pseudomorphs of wurtzite. But, fibrous sphalerite may have occurred primarily under low temperature condition as fibrous sphalerite, because it often have primary botryoidal and colloform texture and with radial galena, representing a low temperature origin.

Galena: Galena occurs in ore deposits of all vein types, excepting the chlorite-copper vein type. It is concentrated in the ore of the lead-zinc vein type. It is concentrated in the western part of the Hosokura mine. It is anhedral as a whole, and rarely it is subhedral in druse. In the case of association with fibrous sphalerite it sometimes takes fibrous or radial forms.

Chalcopyrite: Chalcopyrite is common in all vein types. Especially, it is concentrated in both chlorite-copper and gold bearing chlorite-copper vein types. It is generally anhedral, and occurs in close relation with chlorite of all veins. In the chalcopyrite two stages are found; the first, early stage, is associated sometimes with cubanite, pyrrhotite, bismuthinite, cylindrite and magnetite. In the later stage, veinlets of chalcopyrite cut sphalerite, without association with the above peculiar minerals.

Cubanite: Cubanite is found only in the Kamanai mine; it is associated with chalcopyrite exhibiting a distinct lamelar texture. It is brownish yellow and shows anisotropism.

Pyrrhotite: Pyrrhotite is found only in ore of the chlorite-zinc phase of the Hosokura mine. It occurs as entmisching's drops within chalcopyrite of early stage in association with magnetite after hematite. The drops are commonly small, but in some case, they grew to large size of 1 mm diameter at the boundary spaces between chalcopyrite and pyrite.

Pyrite: Pyrite is very common in all vein types and in altered rocks. Especially it is abundantly concentrated in "Ryusei-hi" of the Motoyama mine that belongs to chlorite-copper type, and in iron-sulphide phase of the lead-zinc vein type of the Hosokura mine. Pyrite occurs in late stages of each vein type, and according to conditions of its formation, it takes various form: cubic, dodecahedron, botryoidal, fibrous or acicular after hematite.

Marcacite: Marcacite is associated with pyrite, especially in the veins of the Hosokura mine. In a druse of massive quartz phase it is represented in pseudohexagonal plate, while in iron-sulphide phase of lead-zinc vein type, it is fibrous in form.

Melnicovitic pyrite: Melnicovitic pyrite is found in iron-sulphide phase of lead-zinc vein type; it shows colloformed and radial texture.

Alabandite: Alabandite is found in an out-crop of rhodonite-quartz vein of gold-silver bearing quartz vein type in the Nuruyu-Hanayama area. It is associated with abundant rhodonite and pink epidote. The form is granular, the colour is dark green and it is semitransparent. Spinel twin is sometimes found. Alabandite is replaced by rhodonite.

Bismuthinite: The occurrence of bismuthinite is very rare; it is found only in ore of the Suginomori mine. It has acicular form, and is galena white and shows strong anisotropism. It is associated with chalcopyrite of early stage.

Cylindrite: Cylindrite is found only in ore of the Suginomori mine; it is associated with chalcopyrite of early stage. It is enclosed in chalcopyrite, and it takes the form of drops or subhedral prisms. The colour is light gray and it shows moderate anistropism.

Stibnite: Stibnite is rare. It occurs in druse of the massive quartz phase in the Hosokura mine. Its association with orpiment in the Monji mine is mentioned by KATAYAMA, N., & UMEZAWA, K., (1958). The form is acicular, commonly of about 1~2 cm length though a large needle may reach to 5 cm.

Tetrahedrite: Tetrahedrite is scanty, but it is common in all vein types, excepting the chlorite-copper vein type. The form is irregular and it associates usually with sphalerite and chalcopyrite. It forms drops in sphalerite and chlcopyrite, or is found surrounding sphalerite and galena; sometimes it replaces sphalerite.

Freibergite: Freibergite is found in ore of chlorite-zinc phase at 0 m level of Kanoko-hon-hi of the Hosokura mine. It shows eutectic texture; it is associated with sphalerite, tetrahedrite and chalcopyrite, or it forms single crystals. It is light gray, more soft than chalcopyrite, and does not shows anisotropism.

Pyrargyrite: Pyrargyrite is found in ore of Akedoshi-hi in the Hosokura mine. It associates closely with sphalerte and galena. Sometimes it forms a quartz-pyrargyrite veinlet. It is irregular in form; occurrence within sphalerite is in the form of fine grains; other occurrences in veinlets are comparatively large, of about 0.2 mm thickness. It is bluish gray, and generally shows internal reflection and strong anisotropism.

Hematite: Hematite is found in ore of the Motoyama mine and at the Hosokura mine. Its form is micaceous or acicular. It associates closely with chalcopyrite and pyrite, and in some cases, varies to magnetite replacing it. Hematite of chlorite-copper vein type, or chlorite-zinc phase of lead-zinc vein type shows black metallic lustre, and in quartz-zinc phase has a red powdery appearance.

Magnetite: Magnetite occurs in two forms. One is granular; it is found in ore of chlorite-quartz-magnetite-hematite-pyrite. It occurs as massive ore in the silicified propylite of the Nuruyu-Hanayama area. The other form is associated with hematite as above mentioned, and it must have occurred genetically as a result of reduction of sulphur (NARITA, E., & HIRAMA, M., 1961a, MIYAZAWA, T., 1954).

Secondary minerals

Covellite: Covellite is a secondary mineral replacing sphalerite and chalcopyrite in all vein types. It forms along the rim or fractures of those host minerals. It is indigo blue and shows strong anisotropism.
Chalcocite: Chalcocite is associated with covellite in the same occurrence. It is pale bluish gray and shows weak anisotropism.
Native copper: Native copper is a secondary mineral of the same ore of the chlorite-zinc phase as that containing freibergite in the Hosokura mine. It exhibits copper metallic lustre, and wirelike or scale forms.
Native silver: Native silver associates with the same ore. It is pale yellowish white, and irregular wirelike in form. From its colour, it perhaps contains some copper component.

IV. Wall Rock Alteration

Altered rocks in this district are of two types. The first is regional propylite as named by AKIBA, C., (1955, 1957); it is propylite influenced by the autohydrated effects of volcanic activities. The other type is altered by local hydrothermal alteration; it is found in many hydrothermal altered rocks effected by the preceding actions of ore mineralization.

The present writer (1961 b) subdivided the propylite of the Hosokura and Tozawa bodies into three types on the basis of grade of alteration and from its mineral association. Because the locally propylitized facies (AKIBA, C., 1955) or epipropylite (COATS, R., 1954) relating to the action of ore fluid is weakly silicified, it has been treated as silicified rock.

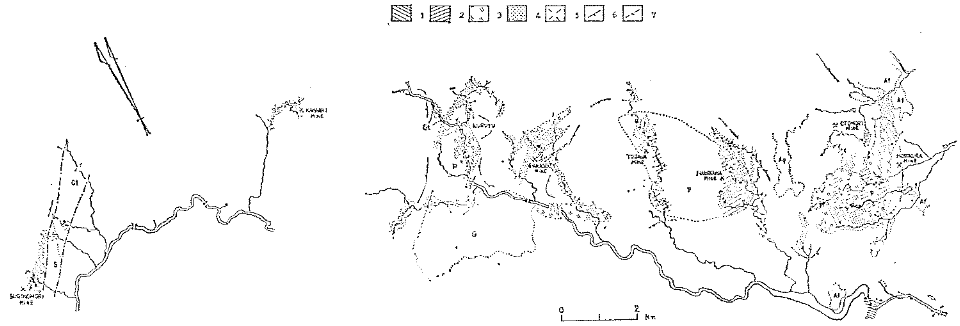
The two types of altered rock are as follows:

A) Regional propylite
 a) propylite 1, b) propylite 2, c) propylite 3

B) Local hydrothermally altered rocks
 a) silicied rock, b) argillic rock, c) chloritized rock

A) **Regional propylite.** Propylite of this type is found in the Hosokura, Ushibuchi, Hanayama-Tozawa, Iwanome, Mizunashi, Nuruyu, Aitatsu, Kamanai and Suginomori areas arranged in the NW zone (Fig. 13). Propylites occur generally as funnel stock, and partly, as dike and lava

Fig. 13. Alteration map of the Onikobe-Hosokura aistrict, Miyagi Prefecture.



1. propylite 1, 2. propylite 2, 3. propylite 3, 4. silicified rock, 5. argillic rock, 6. vein and veinlet, 7. fault, Aq: quartz bearing hornblende two pyroxene andesite, Af: felsic andesite and propylite, Pd: dacitic propylite, P: propylite, Gt: Tertiary holocrystalline rocks, S: basememt metamorphic rocks, G: basememt granite.

flows. Among them, basic, felsic and dacitic propylites are also noticed. Although those propylites differ originally in chemical composition, they are divided into three grades, as described in the following, by megascopic and microscopic appearances and by altered chief mineral associations.

a) propylite 1 This is a type of least alteration, which leaves original texture of two pyroxene andesite that carries a medium amount of phenocryst of plagioclase, hypersthene and augite. The ground mass is composed of a small lath of plagioclase and granular pyroxene together with interfilling glass and chloritic material. The altered feature of the rock is characterized by chloritization of pyroxene and plagioclase. The other signs of alteration are due to slight sericitization. On that account, the alteration is characterized by an assemblage of chlorite-sericite-calcite. The alteration of propylite 1 occurs not only in the Kanoko propylite body but also is shown in the weakest altered part of all propylite masses.

b) propylite 2 This type of propylite is found in transitional parts between propylites 1 and 3. The original texture is so far well preserved, but each rock-forming mineral is wholly converted into an aggregation of altered minerals. As for propylite 1, a characteristic feature is albitization of plagioclases, and further, an aggregate of chlorite and albite is produced from interstitial glass of the ground mass. Among the newly-formed minerals, sericite is much more prominent than those of propylite 1, so a separated assemblage of chlorite-albite-sericite-carbonate is characteristic of this type of propylite.

c) propylite 3 This type is observed in the outer zone of a propylite mass or, in some cases, thinly developed along a fracture or joint. It is distinctly different from above described types in its strongly bleached appearance. The original rock texture is obliterated by such growth of newly-formed minerals. Many pools of albite and quartz appear in the ground mass. Sericite and calcite are almost absent from the assemblage.

The above described three propylites shade gradually into each other, so no sharp separated boundary can be found. Often intermediate types are widely developed between those of propylite facies.

B) **Local hydrothermally altered rocks** Wall rock alteration developed immediately adjacent to the vein has a rather different nature than the alterations of above described propylites. As already mentioned, every vein is mantled by silicified rocks, while in part, strongly argillic rocks and "Hinouchi" is turned into chloritized rock. In those altered rocks, the original rock texture has almost vanished to be replaced by a closely mosaic aggregate of alteration minerals.

a) **silicified rock** This rock type is widely distributed as the upper mantle of a vein swarm. In the lower part of each ground, it developes in a limited extent from vein. Distinct features of those silicified rocks are grayish-green to grayish-white colour and hard granulitic appearance with net of quartz stringers and impregnation of pyrite. The mineral assemblage of such rock is different in the ore deposits of each division. Chlorite is found in weakly silicified rock; it is a light coloured variety and different from the chlorite of propylite, being almost colourless or light green and giving abnormal blue interference colour.

Such rocks are composed of assemblages of quartz-biotite-sericite, quartz-sericite, quartz-montmorillonite-kaolinite, quartz-adularia and quartz-zeolite in each area. Those rocks area arranged zonally from the western to the eastern part in the above altered mineral associations.

b) **argillic rock** As a whole, this rock type is developed narrowly along a vein side, sheared zone or a stratification of silicified tuff. It is composed of an assemblage of sericite-kaolinite-montmorillonite, when it is derived from propylite, but it is a kaolinitic yellowish white argillic rock that contains remnants of quartz and adularia, in those instances derived from corresponding tuff formation.

c) **chloritized rock** This type of altered rock is developed in the deep level of a vein, and it forms a part of a "Hinouchi", as a comparatively broad primordial zone of vein formation. It is stained with hematite, and is more or less impregnated with pyrite. In some parts, grains of sphalerite and galena are scattered amongst the chlorite bases.

chemical composition of altered rocks

Of the altered rocks in this district two types are found as above described; one type is the propylitic rocks of regional scale, the other is silicified, argillic and chloritized rocks as local altered rocks. Their respective chemical compositions shown in tables 1, 2 and 3.

Characteristic features of those alterations vary in respect to silica contents for the ratio Mg^{2+}/total Fe of local altered rocks. But with the addition of silica in altered rocks, Al^{3+} and total amount of iron are gradually decreased.

Variation of chemical components in propylite as well as in its mineral assemblage exhibits a gradual transition. Although propylite is originally basic or dacitic, its altered mineral assemblage is constantly revealed in the same manner. Least altered propylite is found in an assemblage of

Table 1. Chemical composition of propylite.

	K-43	K-96	K-92	5-47	Km-1	5-57
SiO_2	54.72	53.27	55.42	52.64	59.49	57.52
TiO_2	.84	.71	.64	.71	1.13	.89
Al_2O_3	16.08	15.18	14.50	16.61	15.17	13.64
Fe_2O_3	5.55	4.88	2.75	1.34	2.78	2.15
FeO	3.07	4.20	5.82	6.59	4.66	6.68
MnO	.21	.41	.23	.28	.19	.09
MgO	4.21	1.96	5.60	5.22	3.44	2.30
CaO	4.58	6.17	3.61	10.33	2.77	6.41
Na_2O	2.51*	1.58*	3.96*	1.43	1.93	4.24
K_2O	3.64*	6.50*	1.42*	.21	3.50	2.08
P_2O_5	tr	tr	tr	.03	.10	.38
H_2O (+)	2.91	3.61	4.84	3.39	3.51	3.19
H_2O (−)	.94	.62	.77	1.01	1.08	.47
CO_2	.28	.36	.03	nd	nd	nd
FeS_2	.94	.65	1.06	nd	nd	nd
	100.24	100.11	100.65	99.82	99.75	100.04

K-43: propylite 1 of Kanoko cross cut at 0 m level, Hosakura mine (NARITA, E., 1961b).
K-96: propylite 2 of foot wall side of Kanoko-mae-hi at U-1 level, Hosokura mine (NARITA, E., 1961b).
K-92: propylite 3 of foot wall side of Kanoko-mae-hi at U-1 level, Hosokura mine (NARITA, E., 1961b).
5-47 : propylite 1 of Tozawa district.
Km-1: felsic propylite 2 of Kamanai district.
5-57 : felsic propylite 3 of Aitatsu district.
* BY NASU, Y.

chlorite-sericite-calcite. Its chemical components are represented on Table

Table 2. Chemical composition of silicified, argillic and chloritized rocks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	K-157	K-66
SiO_2	61.96	75.69	58.84	63.29	81.04	55.77	61.32	58.33	49.57
TiO_2	.77	.17	.76	1.00	.18	.65	.79	.90	.50
Al_2O_3	18.26	10.48	14.54	10.49	8.37	13.74	14.41	18.44	12.94
Fe_2O_3	2.81	3.47	6.40	5.38	1.66	5.60	4.48	.70	1.74
FeO	2.63	.56	2.62	2.54	.49	4.25	1.30	tr	tr
MnO	.02	.01	.04	.17	tr	.24	.30	tr	.82
MgO	2.54	1.55	2.93	6.48	.72	2.66	1.52	1.41	11.40
CaO	1.45	.37	7.17	3.85	1.27	.29	.20	.23	1.70
Na_2O	1.14	1.93	1.85	.81	.05	.22*	.24*	1.82*	.25*
K_2O	3.68	2.43	.71	1.86	3.86	8.96*	8.01*	8.05*	.07*
P_2O_5	.02	.04	.01	.03	.11	.24	tr	tr	tr
H_2O (+)	3.52	1.64	3.19	3.45	1.47	5.03	3.04	6.88	4.50
H_2O (−)	.70	.38	.32	.70	.60	1.07	.81	1.65	2.27
CO_2	nd	nd	nd	nd	nd	.08	.03	.03	.05
FeS_2	nd	nd	nd	nd	nd	1.61	3.23	1.55	1.35
	99.50	98.72	99.38	100.02	99.82	100.41	100.04	99.99	99.55

(1) silicified diorite of Motoyama district, (2) silicified diorite of Suginomori district, (3) silicified propylite of Nuruyu district, (4) silicified felsic-propylite of Kiridome district, (5) silicified silt-stone of Tozawa district, (6) silicified propylite of foot wall side of Kanoko-mae-hi, Hosokura mine (NARITA, E., 1961b), (7) silicified propylite of hanging wall side of Kanoko-mae-hi, Hosokura mine (NARITA, E., 1961b), K-157 argillic rock of foot wall side of Kanoko-oku-hi, Hosokura mine (NARITA, E., 1961b), K-66 chloritized rock in Kanoko-hon-hi, Hosokura mine (NARITA, E., 1961b).

* BY NASU, Y.

Table 3. Calculated number of cations in the altered rocks. (O=160)

	K-43	K-96	K-92	5-47	Km-1	5-57	(1)	(2)	(3)	(4)	(5)	(6)	(7)	K-157	K-66
Si	53.3	52.6	54.0	51.5	55.7	55.7	57.6	66.9	55.9	59.3	69.6	58.2	65.4	61.1	50.6
Ti	.6	.5	.5	.5	.8	.6	.5	.2	.5	.7	.1	.6	.6	.7	.4
Al	18.6	17.6	16.6	19.2	16.7	15.6	20.1	10.9	16.3	11.6	8.5	16.9	18.1	22.7	15.6
Fe	7.1	7.4	7.2	6.4	5.6	6.4	4.0	2.7	6.7	5.8	1.6	8.9	6.5	1.4	12.5
Mn	.2	.4	.2	.2	.2	.1	.0	.0	.0	.1	.0	.2	.3	.0	.7
Mg	6.2	2.9	8.2	7.6	4.8	3.3	3.5	2.1	4.2	9.1	.9	4.2	2.4	2.2	17.5
Ca	4.8	6.5	3.8	10.9	2.8	6.8	1.4	.4	7.3	3.8	1.2	.3	.2	.3	1.9
Na	4.8	3.0	7.4	2.7	3.5	7.0	2.1	3.3	3.4	1.5	.1	.4	.0	3.7	.5
K	4.6	8.2	1.8	.3	4.2	2.6	4.4	2.6	.8	2.2	4.2	11.6	10.9	10.8	.1
P	.0	.0	.0	.0	.0	.2	.0	.0	.0	.0	.0	.2	.0	.8	.0

1. It keeps many original rock forming minerals, but propylite 1 of the Hosokura mine is rich in K_2O with a good example of constituent of secondary sercite.

Moderately altered propylite 2 varies in all rock forming minerals without exception; loss of Al_2O_3 take place gradually until strongly altered propylite 3 results. A slight decrease of MgO and addition of CaO is common in propylite 2. Generally, variation of FeO, Fe_2O_3, MgO and alkali is not constant, but K_2O increased in moderate propylite 2 and Na_2O in strongly altered propylite 3. The variation of potassium and sodium of propylite 2 and 3 clearly indicate sericitization and albitization.

Mineral association of silicified rock shows many local variations, as revealed in the variation diagram. The chemical components of such altered rocks are ordinarily different as in quartz diorite, basic propylite and shale, but except for the Nuruyu-Hanayama district, total iron, MgO, CaO, K_2O and $MgO/FeO+Fe_2O_3$ show comparatively regular variation.

High contents of K_2O in these altered rocks of the western division are found in the biotite and sericite association, while in the altered rocks of the eastern division adularia is found. Lower content of K_2O in center area of this district shows predominant association of kaolinite and montmorillonite.

Variation of the ratio of total iron to silica contents shows regular reduction. But variations of CaO, MgO and alkali to silica are not always reduced regularly.

Chemical composition of argillic rock presents important features. Though such rock contains high potassium like the silicified rock associated with quartz-chlorite-adularia, Al_2O_3 shows highest value in this rock while base components are less than that of original rocks. The argillic rock demonstrates well an association of quartz-kaolinite-montmorillonite.

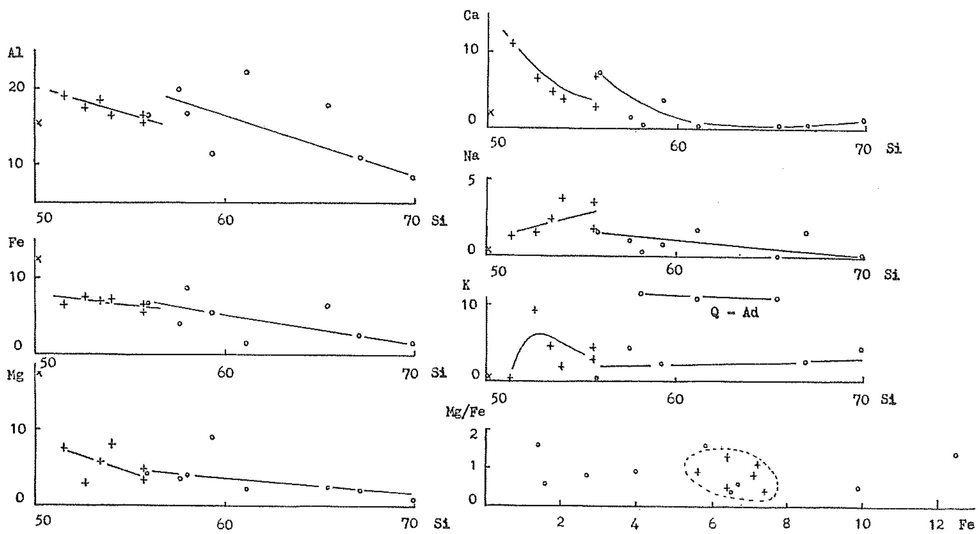
As mentioned above, variation of chemical components in altered rocks corresponds with the mineral association of them. Elements fixed in them have resulted from a process of alteration. Post volcanic solution affecting propylite seems to have been weakly acidic. This solution dissolved Fe_2O_3, MgO, CaO, Al_2O_3 and other base metals. As the culmination of its activity, bleached propylite 3 was formed. It reacted upon wall rocks, and it became weakly alkalic. It caused Al_2O_3 to dissolve.

Any solution effecting ore mineralization must be more acidic than solutions causing propylitization. Such a solution contained many workable base metals, and it permeated through the fractures and reacts upon wall rocks. It so acts that reacted solution was transformed to a comparatively alkalic solution, base metal were filtered out and deposits with

SiO_2 remained in fractures. Base metal in wall rocks acted upon more by sulphuric solution were leached off and high content of SiO_2 was deposited in them to form silicified rock surrounding the vein or on the upper cap of it. Solution reacting on them dissolved SiO_2, Al_2O_3 and alkali, and precipitated elements of Fe and Mg; it must be thus that chloritized rock was formed in a "Hinouchi".

The properties of ore solution are discussed in detail by GRATON, L. C., (1940), LOVERING, T. S., et al., (1949), SALES, R. H., & MEYER, C., (1949), KERR, P. F., et al., (1950, 1951a), KERR, P. F., (1951b), and STEINER, A., (1953). LOVERING, T. S., et al., suggest that the action of the solution was nearly like that of neutral chloride solution in the barren

Fig. 14. Relation of cation number to silica contents in altered rocks.



+: propylites, ○: silicified rocks, ×: chloritized rock.

stage, that is acid chloride and sulfate solution in the middle barren stage, neutral and possibly alkaline bicarbonate-sulfate-chloride solution during the late barren and productive stage.

In this Onikobe-Hosokura district, this ore solution is different from that causing propylitization and it may be more sulfuric and acidic than the later; further it must have varied to an alkaline solution during the stage of the formation of "Hinouchi" and ore deposition.

V. Summary

Concerning the igneous geology and ore deposits of the Onikobe-

Hosokura district, the following comments may be made in summary:

1) Ore deposits of copper, gold, silver, lead, zinc and arsenic are developed in close connection with Miocene volcanism that is revealed by the bulk effusion and intrusion of propylites and dacite. Tectonic features of those volcanic activities are of importance for accounting for the controlling of the situation of effusion and ore deposition.

The most prominent tectonic feature of the Miocene-Pliocene geology of the district is believed to reflect the pre-existing older tectonic zone of the basement complex. Above all, the NW-SE directed Chokaisan-Ishinomaki tectonic zone reveals the fundamental character of the spatial arrangements of igneous masses and ore deposits. This fact is suggested by the arrangement of effusion centres and spreading of igneous masses, and further, by the arrangement of sheared basement complexes which are tectonically pinched into overlying Miocene volcanic masses.

The initial effusion of the Miocene epoch of the district, the Nozoki formation, is represented by bulk massive aggregates of propylitic materials that constitute the backbone of the green tuff region, and also the igneous centre of the district. Further later effusive activities are represented by successive piling of tuff breccias, tuffaceous formation, and dacitic tuff in upper horizons. Simultaneous upheavals of older members at the time of deposition of younger members, and their accompanying tectonics bringing the intrusion of several small propylite masses are the chief determinants of the geotectonic circumstances of the district.

2) As to the ore depositions of the district, they are confined to a broad zone running in NW-SE direction. The same depositions also control the minor intrusions of propylite, dacite and Tertiary granite etc., which are disposed in separate areas arranged in echelon. Each ore deposit forms a broad alteration aureole that stretches to the NE, about 3 km length. Within each aureole a swarm of veins is found.

There are five types of ore deposits, which are arranged into zonally disposed tectonic units of the district. The western-most type is chlorite-copper vein type, and the eastern-most one is the deposits of arsenic, whilst between them gold, silver, lead and zinc assemblages are disposed as follows:

1. zone of chlorite-copper vein type
2. zone of gold bearing chlorite-copper vein type
3. zone of gold-silver bearing quartz vein type
4. zone of lead-zinc vein type
5. zone of arsenic deposit type

Of those deposits, mineral paragenesis of ore and wall rock alteration indicates, in general, that they are of epithermal origin. However, in some cases, so-called high temperature minerals are associated with them, which support the hypothesis of a mesothermal condition.

Recent studies have revealed the existence of so-called high-temperature or minerals such as cubanite, bismuthinite, pyrrhotite and magnetite among those Miocene epithermal deposits of the green tuff region. As the present time, it is rather common to find such curious association in some types of those epithermal deposits.

3) Of the wall rock alteration of those deposits, some unique types are discriminated.

a. hydrothermal alteration directly related to vein formation
b. regional silification and propylitic alteration
c. contact metasomatic alteration

a. Some of such alterations are of so-called high temperature type and the others are those of low temperature type. Their mode occurrences are of very diverse types. Concerning the wall rock alteration of Miocene epithermal ore deposit of green tuff region, four types of alteration were proposd by AKIBA, C., (1955). They are: i. regional propylization, ii. local propylization, iii. alteration of border zone of vein and iv. "Hinouchi" alteration. The new formation of primodial zone of veins, Akiba's proposal, is considered adequate concerning the Miocene epithermal ore deposits of Japan. In the Onikobe-Hosokura district, every deposit is surrounded by several types of alteration mineral assemblages constituted of biotite, chlorite, montmorillonite, sericite, kaolinite, adularia, quartz, carbonate, etc.

b. However, regionally spread silicification or propylitic alterations which have no direct connection with the ore formation are often found. Those alterations of the broad silicious part along the diorite contact zone, or various grades of propylitization observed beyond the mentioned alteration aureoles, are examples of this characteristic of the region.

c. Contact metasomatic alteration is represented by the high temperature assemblages which are obtained from diorite contact or xenolithic block (NARITA, 1960).

Acknowledgement

It is pleasure to acknowledge with gratitude the assistance afforded by the staff of both Motoyama and Hosokura mines. Thanks are also due to Prof. HARADA, Z., Prof. HUNAHASHI, M., Asst. Prof. KOBAYASHI, H., Asst. Prof. TOGARI, K. and Asst. Prof. KATSUI, Y. of Hokkaido University who gave valuable comments and suggestions during the preparation of the manuscript.

VI. References

AKIBA, C., (1955): The "Hinouchi" structure observed in some epithermal veins—with special reference to the distribution of the phases in wall rock alteration. Earth Sci., 24, 27–32.

______ (1957): Geology and ore deposits of the Ogane Mine, Shiribeshi Province, Hokkaido. —Especially on the Nishitani-vein group. Mining Geol., 7, 30–48.

COATS, R., (1940): Propylitization and related types of alteration on the Comstock Lode. Econ. Geol., 35, 1–16.

GRATON, L. C., (1940): Nature of the ore-forming fluid. Econ. Geol., 35, 197–358.

HIROKAWA, H., (1954): "Hitokobe" 1/50.000. Explanatory text of the geological map of Japan. Geol. Surv. Japan.

IMAI, H., (1948): On the wurtzite from the Hosokura mine, Miyagi Prefecture. Jour. Geol. Soc. Japan, 48, 505–515.

______ (1955): On the fissure system of the Hosokura mine, northeastern Japan. Jour. Min. Inst. Japan, 71, 1–5.

______ (1956): The vein system of the Hosokura and Odomori mines, northeastern Japan. Japan. Jour. Geol. Geog., 27, 21–26.

KATAYAMA, N., and UMEZAWA, K., (1958): "Onikobe" 1/50.000. Explanatory text of the geological map of Japan. Geol. Surv. Japan.

KATO, I., (1951a): Petrogenetic considerations on the lower formations in the oil-field of northeastern Japan (II).—On the Tertiary holocrystalline intrusives in the eastern part of the Shinjo basin. Jour. Japan Ass. Miner Petr. Econ. Geol., 35, 91–106.

______ (1951b): Petrogenetic considerations on the lower formations in the oil-field of northeastern Japan (III).—On the characteristics of the volcanic activity represented by the "green-tuff formation". Jour. Japan Ass. Miner. Petr. Econ. Geol., 35, 151–174.

______ (1952): Petrogenetic considerations on the lower formations in the oil-field of northeastern Japan (III).—On the characteristics of the volcanic activities represented by the "green tuff formation". Jour. Japan Ass. Miner. Petr. Econ. Geol., 36, 18–31.

______ (1953): On the green tuff geology of the southwestern foot of Kurikoma volcano and the origin of Sanzugawa, Onikobe uppermost Miocene basins. Jour. Japan Ass. Miner. Petr. Econ. Geol., 37, 178–190.

______ (1955): Petrogenetic considerations of the green tuffs found in the lower part of the Neogene developed in the Yokote Basin in Akita Prefecture and the Shinjo Basin in Yamagata Prefecture. Miner. Petr. Econ. Geol., Sci. Rept., Ser. 3, 5, 1–94.

KERR, P. F., et al., (1950): Hydrothermal alteration at Santa Rita, New Mexico. Geol. Soc. Amer. Bull., 61, 275–347.

______, et al., (1951a): Preliminary reports, reference clay minerals. Amer. Petr. Inst., New York. Res. Project 49. 704.

______ (1951b): Alteration feature at silver Bell, Arizona. Geol. Soc. Amer. Bull., 62, 451–480.

KITAMURA, N., (1959): Tertiary orogenesis in northeast Honshu, Japan. Inst. Geol. Paleo. Tohoku Univ., 49, 1–98.

LOVERING, T. S., et al., (1949): Rock alteration as guide to ore,—East Tintic District, Utah·

Econ. Geol., Monograph 1.
MINATO, M., et al (1956): Geotectonic synthesis of the green tuff region in Japan. Bull. Earthq. Resear. Inst., 34, 237-264.
MIYAZAWA, T., (1954): On hematite and magnetite from the Chichibu mine, Saitama Prefecture.—Studies on the genesis of the so-called contact metasomatic deposits in Japan. Mining Geol., 4, 139-146.
NARITA, E., (1960): On the Tertiary holocrystalline rocks of the Nuruyu district, Miyagi Prefecture. Jour. Japan Ass. Miner. Petr. Econ. Geol., 44, 152-161.
———, and HIRAMA, M., (1961a): On the magnetite and other iron-oxid minerals of the Katsuraoka mineralized zone, Hokkaido. Jour. Japan Ass. Miner. Petr. Econ. Geol., 45, 25-30.
———, (1961b): Wall rock alteration in the Kanoko vein swarm, Hosokura Mine, Miyagi Prefecttre, north-east Japan. Jour. Fac. Sci., Hokkaido Univ., Ser. IV, 2, 59-75.
OIDE, K., and ONUMA, K., (1960): On the laws concerning to the paleogeography and geotectonics of the green tuff geosyncline in the northeastern Japan. Earth Sci., 50-51, 22-55.
OMORI, M., (1953): Tectonic properties in Tertiary of north-eastern Japan. — (especially, on the "Ishinomaki-Chokaisan tectonic line") Earth Sci., 18, 16-23.
SAKAKIBARA, T., (1958): Mineralization in the northern part of Akita Prefecture, Japan. Jubil. Publ. Commen. 60th Barthday of Prof. SUZUKI, J., 473-481.
SALES, R. H., and MEYER, C., (1949): Results from preliminary studies of vein formation at Butt, Montana. Econ. Geol., 44, 465-484.
STEINER, A., (1953): Hydrothermal rock alteration at Wairake, New Zealand. 48, 1-13.
SUGAKI, K., and YAMANE, N., (1952): Thermal Study on the intergrowth of chalcopyrite and sphalerite. Sci. Rept. Tohoku Univ., Ser. 3, 4, 103.
TAKEUCHI, T., (1958): Some problems concerning the mineral diposits in Tohoku District, Japan. Jubil. Publ. Commen. 60th Barthday of Prof. SUZUKI, J., 407-441.
TOGARI, K., (1954): Colour of zincblend from the Hosokura mine, Miyagi Prefecture. Jour. Miner. Soc. Japan, 1, 391-402.
———, (1959): Colour of sphalerite from the Hosokura mine, Miyagi Prefecture. Jour. Miner. Soc. Japan, 4, 24-33.
WATANABE, I., et al., (1955): Igneous activities of the Abukuma plateau. Earth Sci., 24, 1-11.
YAMASHITA, N., (1957): Kurosegawa-type and Kesen-Numa-type tectonic line. (problems of the historical development of Japanese Islands—I) Earth Sci., 31, 1-15.