Notes on the Ore Deposits of the Nakase Mine in Hyôgo Prefecture, Japan.

By

Kyûbê AKATSUKA

With 11 Tables, 3 Text-figures, and 3 Plates.

ABSTRACT: The Nakase Mine is situated at Yoshii, Sekinomiya-chô, Yabu-gun, Hyôgo Prefecture, Japan and its surroundings are geologically consisted of the Sangun metamorphics, serpentinite, granitic rocks, Manju volcanics, Kinosaki Subgroup belonging to Hokutan Group, Saruo-no-taki dikes including micro- quartz-diorite, Tentaki lavas belonging to Daisen volcanics, and basaltic dike in descending sequence.

It seems to be remarked that the ore bodies of this mine are found deposited as lodes mainly in the metamorphics as well as in the Manju volcanics, micro-quartz-diorite, and rather scarcely in serpentinite or others but are cut in particular by basaltic dikes. The ores concerned are naturally assumed to have been produced through certain processes in four main periods such as *Period I*, *Period II*, *Period III*, and *Period IV*. The fact of importance is that activities of porphyrite and breccia dikes are evidently recognizable intervening between *Period II* and *Period III*.

Certain minerals selected out from more than twenty-eight specimens are röntgenometrically scrutinized, whereas horizontal or vertical variations in their assemblages as well as in genetic relation are not conspicuously determinable within each lode.

It however results in at least that the main lodes originated in *Period III*, that is the veins containing gold, silver, and antimony ores, especially seem to be grouped into an ordinary category of epithermal deposit.

CONTENTS

I. INTRODUCTION.

The mine in question is located along the southern side of the Yagi river at Yoshii, Sekinomiya-chô, Yabu-gun, Hyôgo Prefecture, about 18 km west of Yôka station on the San-in railway line and is situated about 11 km NNW of the Akenobe mine.

The ore deposits appeared in the Nakase mine are now being worked mainly for excavation of gold, silver, and antimony ores though since the Tenshô age (about 400 years ago) they have long been mined merely for production of gold ores and even now beautiful grains of native gold are easily discernible with naked eye.

Several researches published already by cerain authors such as T. KOCHIBE (1892), T. KATÔ (1946), T. TATSUMI (1946, 1951, 1955, 1956), and T. KITA (1950) are related to general views concerning the deposits, and some others to respective minerals or to specific problems, while the work accomplished by K. WADATSUMI and T. MATSUMOTO (1958, 1959) as to geology composing the area is accountably of significance. On the other hand, the present writer (1960) has recently elucidated a possibility of formation of low-temperature veins containing gold, silver, and antimony ores to be confined within a comparatively limitted stage on the basis of some results obtained from investigation of this mine and will outline his veiw with respect to the deposit on the whole, exclusive of the details of ore genesis and of laboratory works, which will be referred to in the near future.

II. OUTLINE OF GEOLOGY.

The terrain is located in the northernmost part of the western "Maizuru Zone" varying into the "Tango-Tajima Zone" distributed within the Inner Zone of southwestern Japan.

In the central part of the area is observed serpentinite with a width of about 4 km and an extension of about 15 km from east to west, showing various facies caused by certain metamorphic processes. In its midst are exposed the Palaeozoic formation, a member of the "Sangun metamorphics", composing mainly of black-colored semischist ~phyllite, green-colored semischist~schalstein, and quartz-semischist as if they were captured as xenolithic masses. Quartz-diorite, granite-porphyry, quartz-porphyry, and acidic dikes are found sporadically injecting into the above-mentioned rocks, and are probably grouped into a sort of the granite representing the "San-in type". Neogene formation, which includes basal conglomerate lying unconformably over or abutting upon serpentinite and shows northward inclination with gentle dip, is developed both in the valleys and on the higher level of the mountain in the northern part of the district, and reasonably taken as a member of the "Kinosaki Subgroup", a part of the "Hokutan Group". There are some dikes of lithologically intermediate property, ranging from porphyritic to dioritic facies. They are observed in the northernmost parts of this area and penetrating into the Kinosaki Subgroup lenticularly or ordinarily with trend of N-S or NNW-SSE, belonging to "Saruo-no-taki dikes", parts of which are supposed to have an intimate relation to micro-quartz-

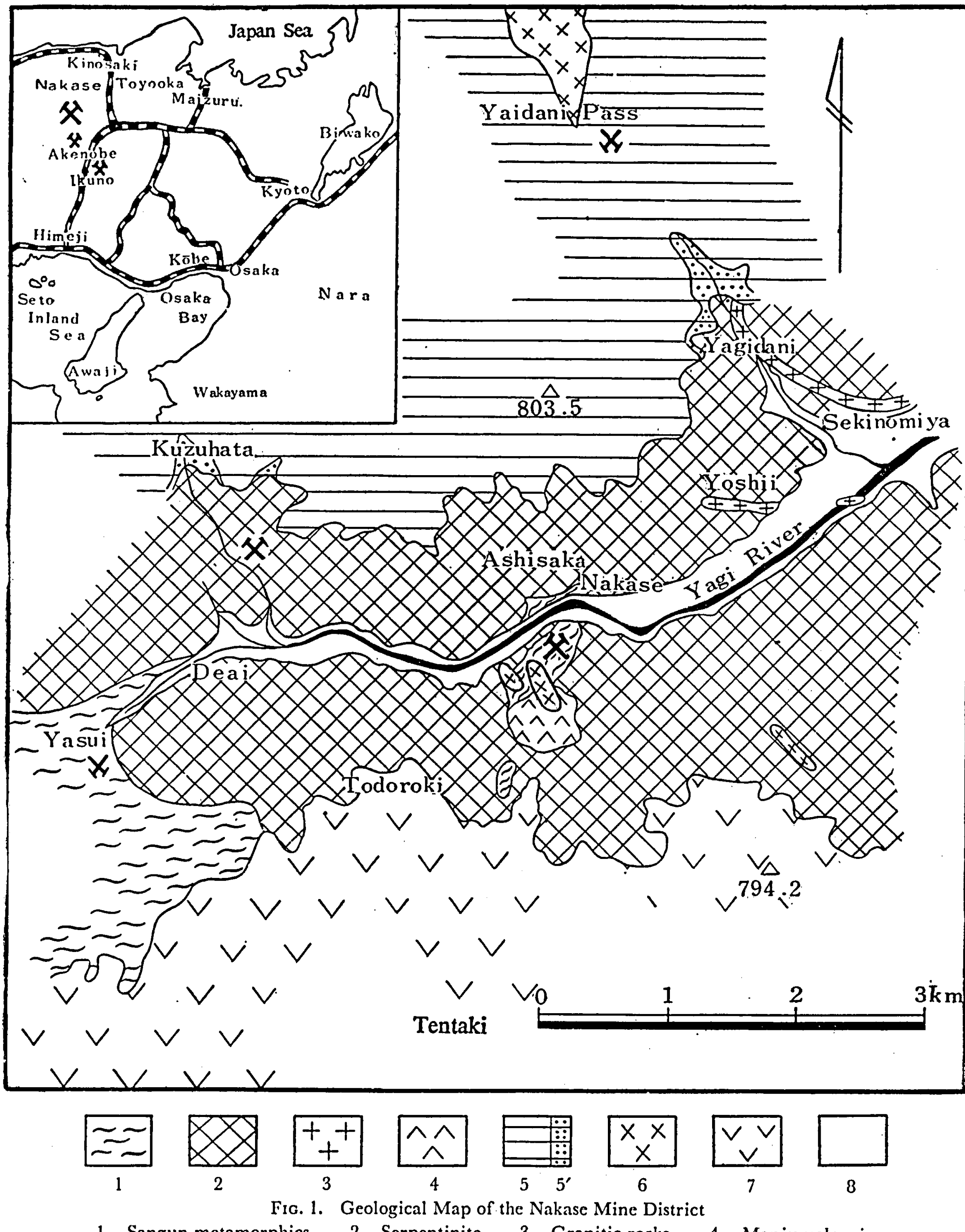


FIG. 1. Geological Map of the Nakase Mine District

1. Sangun metamorphics 2. Serpentinite 3. Granitic rocks 4. Manju volcanics 5. Kinosaki Subgroup 5′. *ibid.* Basal conglomerate 6. Saruo-no-taki dikes and Micro-quartz-diorite 7. Tentaki lavas 8. Alluvium

diorite appeared in the main ore deposits under consideration. Olivine-augite-basalt, a part of the "Tentaki lavas" extended from a southern part of the "Hachibuseyama andesite" belonging to the "Daisen volcanics" is observed coverring unconformably either serpentinite and paleozoic members appeared on the southern summit or the above-mentioned Tertiary member exposed in the western area.

In the enclosure of the mine it seems a tendency that the lodes are comprised mainly in the Sangun metamorphics distributed in the southern part of Ashisaka, whereas various kinds of rocks are ascertainable in the galleries. Occurrence of the very metamorphics in the underground clearly points to that, though parts of them seem to be enclosed in serpentinite on higher levels, they become more and more broader in dimension with increase of depth and are seemingly covered with the latter. Quartz-diorite, and quartz-porphyry are both considered to belong to a sort of the granite representing the San-in type intruding into the very metamorphics.

The "Manju volcanics" composing of tuffaceous agglomerates and tuffs intercalated with augite-hornblende-andesite is nearly of circular exposure with a diameter of ca. 500m at the outcrop on the landsurface. Its cylindrical or funnel-shaped body is not so much different in dimension on each level, e.g. both on the main level (−300 m) and on the Manju lower No. 6 level (−470 m), and abuts uncomformably on the above-mentioned metamorphics and quartz-diorite. This sort of andesite showing sheet-like or brecciated occurrence in the very volcanic member is black in color, compact in property, and characterized by scattered phencrysts of tabular hornblende amounting to about 1 cm in length.

Both the Manju volcanics and the Sangun metamorphics are injected and, in parts, captured by micro-quartz-diorite of a small-scaled stock or apophyse-like occurrence which shows either remarkable variation from hollocrystalline, fine-grained to porphyritic textures or conspicuous difference from the quartz-diorite alluded to already in petrographic feature but is quite similar in its characteristic and correlative to somewhat deeper facies of the Saruo-no-taki dikes.

Since acidic dikes are contained merely in the Paleozoic formations, their relation to the Manju volcanics and to other members is remained yet to be determined. Dikes of intermediate property inject into this volcanics but are not found in micro-quartz-diorite. A single dike of basaltic rock, the latest one of all, is well-continued in the micro-quartz-diorite as well as in all of the lodes and lithologically correlated not to the Tentaki lavas but rather to the "Gembudo basalt". A mere example that on the lower No. 10, and No. 11 levels of the Ishimabu gallery a porphyrite dike (see Fig. 7, Pl. 48) cuts across the higher-temperature sulfide lode produced in *Period II* and is cut by the lower-temperature gold-stibnite-quartz vein formed in *Period III* is of due significance in connection with the stage relating to ore genesis (see Fig. 3). Relations of the dike to other members are still now not determinable. The breccia dikes found elsewhere in the gallery may also give an important clue to confining the stage of ore formation.

Correlation of one to another is tabulated in Table 1, where the data referring to

Table 1. Correlation Table

Epoch	Stage	Northern Tajima District (T. Matsumoto & K. Wadatsumi, 1959; K. Wadatsumi & T. Matsumoto, 1958)			Nakase Mining District	Mineralization	San-in District (Mukae, 1958)
Holocene	K	Alluvium			Alluvium		Alluvium
	J	Gembudo Volcanics	Gembudô Basalt		Basaltic dike	*P IV*	Daisen Volcanics: Nogi Gr.
			Terrace Gravels				Daisen Volcanics: Gravel
	I_2	Daisen Volcanics	Hachibuseyama Andesite		Tentaki lavas		Daisen Volcanics: Mts. Ôe
Pliocene	I_1				Micro-quartz-diorite	*P III*	Tsunozu Formation
	H_2	Teragi Group	Haruki Formation	Saruo-no-taki Dikes			
	H_1		Takayama Formation	Rh Tr			Matsue Formation
Miocene	G						Fujina Formation
		Hokutan Group	Kinosaki Subgroup	Muraoka Formation An	Muraoka Formation		Ômori Formation (intrusives) Kuri Formation (intrusives)
	F_3			Toyooka Formation Rh An	Toyooka Formation (Breccia dike)?		Kawai Formation
	F_2		Yabu Subgroup	Yôka Formation An Bs	(Porphyrite dikes)?		(intrusives) Hata Subgroup (Kimitani Subgroup)
				Takayanagi Formation			
	F_1	Yadagawa Group		Rh	(Rhyolitic dikes)?	*P II*	
Pre-Miocene					Manju Valcanics		
	Pre-Tertiary	Basement	San-in Granites		Granitic Rocks	*P I*	Granitic Rocks & Schists
			Serpentinite		Serpentinite		
			Sangun Meramorphics		Sangun Metamorphics		

the Cenozoic stratigraphy appeared in the northern Tajima region, given by K. WADATSUMI and T. MATSUMOTO (1958, 1959), are taken into account since the terrain is situated in the southernmost part of the very area.

Parts of the lithology distributed within the district with special regard to the mutual correlation of small-scaled masses are hereunder referred to descriptively.

Sangun metamorphics

This member is exposed south of Ashisaka and east of Todoroki in the central area of serpentinite as xenolithic masses in small scale. Within the district concerned the part appeared in the former including the ore deposits shows the largest dimension with extension of about 800 m from south to north and with width of about 300 m from east to west. The member in the gallery becomes broader with depth and is apparently covered with serpentinite, while it is however surely divided by the presence of the Manju volcanics and of micro-quartz-diorite into the northern and southern masses. The latter enclosing the Manju lodes is covered with serpentinite and, accordingly, shows no exposure on the landsurface, where the upper part of the former containing the Ishimabu lodes merely crops out. The southern portion of the metamorphics is penetrated by quartz-diorite of small-scaled, stock-like occurrence and its contact seems to have been thermally metamorphosed into hornfels rich in tiny flakes of biotite, while on the other hand the northern portion is cut by quartz-porphyry with direction from northwest to southeast. In the western part of the gallery, however, both portions are combined completely with each other and reveal a sort of monoclinal structure with general strike of NS∼N60°E and dip of high angle toward east or west, though they are partially disturbed. With approaching to the eastern side the metamorphics indicate higher grade of metamorphism, foliation, and lineation and, vice versa, vary into non-metamorphic facies. On the level of crosscut from the Manju lode to the outcrop named the "Ôrotô", serpentinite, about 10 m in width, is appeared at the locality about 100m south of the very lode and shows upward and eastward broadening. On the southern side of this serpentinite the metamorphics are re-appeared, which are probably combined with the different one occurring on the landsurface in the eastern part of Todoroki. These relations as well as the resemblance in general trends of the members distributed either in the eastern part of Todoroki or in the southern part of Ashisaka indicate evidently their coincidence and further extension in the underground.

The Sangun metamorphics distributed in this district are composed mainly of facies varying from black-colored semischist to phyllite and from green-colored semischist to schalstein and of quartz-semischist intercalated with one another.

Black-colored semischists are regarded as the derivative from pelitic sediment, black or blackish brown in color, conspicuous in compositional banding, cleavable along laminae, subjected easily to ptygmatic folding, accompanying in parts quartz veins rheomorphically derived, indicating obvious lineations, and showing variation into massive facies. Their mineral constituents are quartz, muscovite (or sericite), chlorite, albite, and dusty graphitic matter often accompanied with apatite, garnet and others (see Fig. 1, Pl. 48).

Green-colored semischists are assumed to have been derived in the main from pyroclasts of basic rocks, dark or pale green in color, and showing variation from remarkably lamellated facies with compositional banding to nearly massive one. Their mineral constituents are actinolitic amphibole, epidote, chlorite, albite, quartz, and calcite often associated with small grains of titanite, but lacking in relics of original rocks.

Quartz-semischists are grey in color, and illustrate distinct compositional banding caused by the arrangement of quartz and muscovite (or sericite). Their mineral constituents sre quartz and muscovite (or sericite) sometimes accompanied with subordinate amounts of epidote, chlorite, albite, calcite, and graphitic matter.

From the fact of existence of black-colored semischist intercalcated in schalstein-like facies, it may easily be deduced that the Paleozoic formation, developed widely in the western part of Yasui and covered with the Tentaki lava, also belongs to a part of the Sangun metamorphics. The related formation composed mainly of schlastein-like or metadiabasic facies together with a little amount of cherty rocks has once been regarded by the present writer (1960) as a member of the Kawae volcanics situating in a lower horizon of the Kinosaki Subgroup and by T. Tatsumi (1955) as a part of the Mesozoic formation demarcated with serpentinite and basal conglomerate which is still now nowhere found. At Yasui are there arsenopyrite deposits formed metasomatically as impregnation in schalstein-like facies of the metamorphics concerned.

Serpentinite

Serpentinite is found distributed along the central zone with extension of about 15 km from east to west and with width of about 4 km within the district, and regarded as a part of that believed to have been intruded along the Maizuru Zone at certain stage in Mesozoic. Its variation in grade of alteration is considerably remarkable; some facies are earthy, waxy, lamellated or brecciated and others are blackish, greenish black, greenish, brownish, or yellowish brown in color. The black-colored serpentinite of compact property is appeared in considerable amount, and in this serpentinte relict crystals of olivine are microscopically recognized (see Fig. 2, Pl. 48). Ultrabasic facies, altered scarcely into serpentine and occurred in little amount, are composed of olivine, enstatite, diopside, and serpentine associated with a little amount of magnetite and chromite. These characteristics point to that the serpentinite in question might have been derived from alteration of peridotite.

Chromite ores are found scattered in little amount within the area of serpentinite. Along its northern margin located along the northern side of the Yagi River are there bulk of old galleries excavated for such ores as are hardly mineable. The ore body located on the northern side of Deai, however, is of somewhat larger scale and a mere one worked for ceramics.

Granitic rocks

As granitic rocks, which are regarded either as have been related to the igneous activity in the late Mesozoic or as are grouped into the San-in type, are mentioned granite-porphyry, quartz-porphyry, quartz-diorite and some of acidic dikes, all of which are found intruded sporadically into the Sangun metamorphics or into serpentinite.

Granite porphyry is exposed as dike with width of 10~20m and with trend of NW-SE from Yagidani to the northern side of Sekinomiya. It crops out also at Yoshii as dike with trend of EW and its extension is observed on the floor of the Yagi River. Another exposure of small scale is found near the top of the mountain pass to Nishitani south of Nakase. The porphyry of this group shows such heterogeneity as are micrograniticic, felsitic, granophyric and so on even within a single body, and is composed of quartz, perthite, and biotite with granular or porphyritic structure. Parts rich in feldspar are now being excavated for raw materials of ceramics. Some are ascertainable as xenoliths included in hornblende-andesite of the Manju volcanics.

Quartz-porphyry dike showing variation in width crops out at the conflux of the Yagi River with a stream of Asisaka and extends toward ESE, being cut across by the eastern part of the Ishimabu lode. The porphyry is white or greyish white in color and contains phenocrysts of corroded quartz and of stained plagioclase subjected to alteration, 1~5 mm in respective diameter, included in the compact or very fine-grained groundmass composed of quartz and alkali-feldspars with scarce amount of colored minerals altered into chlorite (see Fig. 3, Pl. 48).

Quartz-diorite is not exposed on the landsurface but revealed as tiny stock in a lower part of the Manju lode or including a part of the very lode. It is leucocratic in appearance and medium- or fine-grained, and metamorphoses thermally the Sangun metamorphics into biotite-hornfels, displaying such a marginal facies as becomes finer in grain-size or more melanocratic with approaching to its contact within a zone of about 50cm in width. Even at its contact with the Manju volcanics it seems that the former indicates no variation in its own property and no effects of contact metamorphism on the latter, while the former comes into contact with the latter not in relation of faulting but probably in that of abutting.

Microscopically this sort of diorite is hypidiomorphic and equigranular, and composed of quartz and alkali-feldspar showing micrographic texture, hypidiomorphic plagioclase disclosing zonal structure, green-colored hornblende and a little amount of biotite and epidote. Quantities of the mafic minerals are variable and in general diminish particularly in the parts predominant in micrographic intergrowth of quartz with alkali-feldspar. Noticeable characteristics of this intrusive are discernible in its micrographic texture and melanocratic facies around the margin (see Fig. 4, Pl. 48).

Manju volcanics

The volcanics are appeared near the Manju lode between the latter and the Ishimabu lode in the gallery and on the landsurface located directly upon the former, including tuffaceous agglomerates and tuffs intercalated with augite-hornblende-andesite. Their mode of occurrence is peculiarly cylindrical or funnel-shaped in form. Although their lower parts on the eastern side are not observable on account of no adits extended toward east, it seems sure that the volcanics come into contact almost vertically or in high angle with the surrounding Sangun metamorphics with undulatory surface, resulting in that their horizontal section on the lower No. 6 level, the deepest of all, of the Manju gallery is nearly similar to that revealed on the landsurface. Furthermore, it is used to be observed that the volcanics are revealed lying on the erroded surface of the Sangun metamorphics, which is apparently horizontal on the whole, whereas their distribution at the cross-cut toward the Manju No. 2 lode on the lower No. 6 level is rich in relief.

The Manju lode is comprised in the volcanics concerned on the southermost margin near, and parallel to, the inclination of their contact with earlier rocks such as the Sangun metamorphics and quartz-diorite or within the latter two but not at the contact. The contact of the volcanics with the earlier rocks is not in relation of faulting but displays evidently tiny relief. Inasmuch as some faults producing the small-scaled fissures and slips containing the Manju lode are found penetrating into the older rocks and the volcanics, they are by no means considered to have originated at the contact between the latter two. The eastern part of the North No. 2 lode extends from the Sangun metamorphics straightly to the volcanics both in the main gallery and on its middle level, where the contact of two members is nearly vertical and cut across by the very lode but any faults along the contact are not observed at all.

The volcanics are not obviously stratified but become rapidly less steep with remoting from the surrounding margin and nearly horizontal at the center, whereas on the contrary the southern and western parts of their contact with the Sangun metamorphics and quartz-diorite reveal almost vertical demarcation. It is distinctly confirmable at the entrance of the main gallery of the Sasakura lode that the volcanics might have been intruded by, and captured in, micro-quartz-diorite, resulting in their alteration into hornfels along a zone of contact.

Tuffaceous agglomerates and tuffs, the main components of the very volcanics, are pale grayish-green or faint grayish in color and solidified tightly but brittle in property. Most parts are composed of tuffaceous agglomerates including brecciated fragments, 1~10cm in diameter, of the Sangun metamorphics, andesite and so forth partly together with a considerable amount of fine-grained quartz. Tuffs are the components much less in quantity than the agglomerates, and only an alternation of argillaceous and arenaceous tuffs is found near the shaft of the lower No. 2 level of the Manju gallery. Information* as for the discovery of radioralian tests in argillaceous

* Oral communication by T. Kita and K. Nakaseko

tuffite is remained yet to be confirmed by the present writer.

Augite-hornblende-andesite, disclosing sheet-like occurrence or appearing as blocks in the very volcanic member, is black in color, compact in property and characterized by scattered phenocrysts of tabular hornblende amounting to about 1cm in length (see Fig. 5, Pl. 48). Sheet-like ones distributing mainly around the volcanics reveal variation in width (1～8m) and inclination in high angle toward the center, while block-like ones, 1～10m in size, are predominated in the central part and irregularly undulated on their upper surface but almost horizontal at their base, each of block being elongated laterally. That the ones appeared in smaller scale or the marginal facies are very fine in grain-size may suggest rapid cooling. These rocks seem, in parts, to have captured granitic rocks and volcanics of intermediate property, of which the latter, granular or porphyritic in texture, is of igneous origin and composed of plagioclase, monoclinic pyroxene and biotite, displaying the thermal effects earlier than those given by the present surrounding rock. Microscopieally, this sort of andesite is compsed of large-sized, brown-colored hornblende surrounded with blackish rim, green-colored hornblende in parts, augite and plagioclase as phenocrysts embraced in the groundmass containing plagioclase, monoclinic pyroxene, greenish hornblende, and glassy matters predominant specifically in the fine-grained facies around the margin. The andesite metamorphosed through thermal effects of the later micro-quartz-diorite remains a sort of porphyritic texture, composing of phenocrysts representing the relics of plagioclase, brown-colored hornblende with black-colored rim, green-colored hornblende, and monoclinic pyroxene (augite) with the rims in a little amount, including minute flakes of biotite observed similarly in the groundmass, while in the groundmass mosaic texture composed of relics of plagioclase with secondarily formed biotite and monoclinic pyroxene are observed. In the zone, about 0.5cm in width, of its contact with micro-quartz-diorite the latter commonly illustrates either decrease of mafic minerals or increase of quartz (see Fig. 6, Pl. 48). The Manju volcanics under consideration are for the present compositionally and lithologically correlative to the Yadagawa Group designated by K. WADATSUMI and T. MATSUMOTO (1958). In its correlation to the resembling members distributed in Hokuriku, Kinki, and Chūgoku districts, this group is, according to their study (1959), regarded as a part of the products derived from repeated activities of acidic volcanics during certain periods from the late Mesozoic to the milddle Neogene. Taking into account of this circumstance, its occurrence, stratification, relation to other formations and so on, it is deducible that this member might have been accumulated in a sort of crater at certain stage of the last Cretaceous or earlier Tertiary, even if regarded as the latest.

Kinosaki Subgroup

In the northern part of the district is widely appeared a member of the Neogene formation with extension nearly from east to west and dip of about 10°N. In the ravines such as Kuzuhata and the northern part of Yagidani it lies unconformably on serpentinite and is stratified successively with basal conglomerate, sandstone and shale. In the upper part of the mountain located north of the central area of the district, alternation of sandstone and shale without basal conglomerate comes into contact directly with the serpentinite, pointing to a sort of abutting of the former upon the latter. This member is surely considered to be corresponding to the southern part of Kinosaki Subgroup reported already in ditails by K. WADATSUMI and T. MATSUMOTO (1958) and contains numerous kinds of fossils, basing on which sedimentation of this member is reasonably determined to have taken place during the periods from F to G*. Excepting the mere fact that the member discloses an unconformable connection with the serpentinite and granite porphyry, its relations to other members are of obscurity because of no contacts with one another in this district.

The basal conglomerate is composed mainly of rounded pebbles, 5~10 cm in diameter, of the Sangun metamorphics, granitic rocks, quartz-porphyry, porphyrite, serpentinite together with some others, and is about 50m thick at Yagidani.

Stibnite vein reported by K. MASUTOMI (1954) from the locality about 1 km northwest of Yagidani is contained in the fault cutting across the Yubunegawa black shale, a part of this member.

Breccia dikes and their allied rocks.

In the gallery are found the breccia dikes having a comparatively close relation to the lodes. These dikes including abundance of pebbles of the Sangun metamorphics, hypidiomorphic plagioclase, subangular quartz and partly sulfide ores penetrate into the lodes of *Period II* and are cut across by those of *Period III*. Their petrographic characteristics indicate a good resemblance with those of breccia dikes relating to mineralization appeared throughout the "green tuff" district (see Fig 8, Pl. 48). According to the oral publication by H. TAKEDA** the latter might have been formed at Onnagawa stage (F_3) and contemporaneously related to the volcanic activity of acidic lava. If this be the case with the breccia dikes in Nakase district and the Kawae volcanics (rhyolitic facies) included in the Kinosaki Subgroup are considered to have been chronologically correspondent to these dikes, their formation might have been contemporarily completed at F_3.

Because of its lithologic property similar to the dikes concerned, the lenticular mass, with a larger width, appeared along the western part of Ishimabu lode is to be necessarily inspected in more details.

Saruo-no-taki dikes and Micro-quartz-diorite

At the pass of Yaidani situated in the northern part of the district is revealed the green-colored porphyrite intruding lenticularly into the Yubunegawa black shale nearly from south to north. It is surely connected with the southern end of Saruo-no-taki

* Denoted according to denomination ordinarily provided for the Tertiary formations.

** At the ordinary meeting of the Western Blanch of Geol. Soc. Japan, Dec. 11, 1960 dike designated by K. WADATSUMI and T. MATSUMOTO (1958) and bears various facies including porphyrite of nearly proper character, grayish white-colored micro-quartz-diorite showing dioritic texture and so on. Under microscope, porphyrite-like facies appeared at the pass of Yaidani is mainly composed of plagioclase displaying zonal structure, brown-colored hornblende surrounded with reaction rims, and monoclinic pyroxene (augite) as phenocrysts buried in coarser-grained groundmass of nearly similar constituents (see Figs. 1 and 2, Pl. 49). Saruo-no-taki situated 8 km north of the Nakase mine is its type locality where the rock concerned represents either dioritic texture regarded as somewhat deeper facies indicating slight difference between phenocrysts and matrices or micro-quartz-dioritic one, while it is composed of plagioclase indicating remarkable zonal structure and a little amount of quartz as well as mafic minerals, varying partly in sorts and quantities, such as augite, hypersthene, and brown-colored hornblende (see Figs. 3 and 4, Pl. 49).

In the southward cross-cut, the eastern part of Sasakura lode and the western part of Gingiri lode is found grayish white-colored micro-quartz-diorite intruding into, capturing, or metamorphosing thermally, the Sangun metamorphics and Manju volcanics. This diorite is observed partly on the landsurface as tiny stocks or apophyse, revealing noticeable variation ranging from triflingly porphyritic texture to equigranular fine-grained one, and represents a characteristic similar to a little deeper dioritic facies of Saruo-no-taki dike, lacking only in green-colored porphyritic texture.

Microscopically, its acidic facies is almost granular but partly fine-grained in texture, composing of plagioclase displaying variation in grain-size and zonal structure, brown-colored hornblende and a little amount of biotite, while more basic one, slightly porphyritic in texture, involves plagioclase bearing zonal structure to remarkable extent and monoclinic pyroxene (augite) as phenocrysts embraced in finer-grained parts composing of plagioclase with zonal structure, monoclinic pyroxene, biotite and a little quantity of quartz. Besides, green-colored hornblende, olivine with reaction rims and epidote happen to be included, indicating difference in mineral assemblage in every specimen (see Pl. 49).

Since the micro-quartz-diorite appeared in the gallery is located remotely from the Cenozoic formations the relation to each other and, accordingly, its stage are for the present not identifiable. Basing on its lithologic character and others, it resembles the quartz-diorite intruding into the Kimitani formation distributed in San-in district and differs considerably from the intrusives later than the very formation in stage. On the other hand, the diorite under consideration seems, as alluded to already, to be most probably correlated to the Saruo-no-taki dike assumed by K. WADATSUMI and T. MATSUMOTO (1958) as a sort of underground volcano related to the activity of Hachibuseyama volcanics.

Tentaki lava

It is the lava-flow covering the higher level of the mountain situated in the southern and western parts of the terrain, composing of melanocratic or grayish green-colored olivine-basalt of hard property. Microscopic inspection of the rock indicates the constituents such as plagioclase, olivine and augite as phenocrysts embedded in the groundmass including the similar minerals, in nearly parallel arrangement, together with opaques, more or less amount of glassy matters and rarely with a little quantity of biotite, revealing intergranular texture. Grain-size of phenocrysts and their proportion in amount to groundmass are various in each locality (see Fig. 5, Pl. 50).

This lava is connected with southward extension of the Hachibuseyama andesite relating to the earlier eruptive of Daisen volcanics at I but contains no traces of ore deposits.

Basaltic dike

It is the well-continued dike, 1m～20cm in width, with nearly constant strike of N40° E and dip of 75° N, as is observed in the gallery. Microscopically it includes plagioclase, augite and calcite derived probably from alteration of olivine as phenocrysts embedded in the groundmass composing of plagioclase in certain arrangement, augite and opaque minerals together with glassy matters, and seems on the whole to have been subjected to carbonatization, terminating in formation of calcite in remarkable amount (see Fig. 6, Pl. 50).

Considering either its occurrence cutting across all of the lodes or lithologic characteristics, this dike is reasonably believed to represent the latest activity within the district and to be correlative not to the Tentaki lava but rather to the Gembudo basalt (J～K).

III. Occurrence of ore deposits.

The ore deposits of Nakase mine are comprised mainly in the Sangun metamorphics, while some of them are recognizable similarly in the Manju volcanics, micro-quartz-diorite, granitic rocks and serpentinite. On the basis of their formation stage or of characteristic mineralization, the lodes appeared therein are roughly grouped into four main kinds: The first is represented by the green-colored silicified ores produced in the earliest period (*P I*); the second by the yellow-colored sulfide veins formed at higher temperature in the next period (*P II*); the third, the mere one worked in an industrial scale in this mine, by the lodes originated at lower temperature in the isolatedly subsequent period (*P III*); and the fourth by the latest veins (*P IV*) filling the faults, wherein the mineralization is weakest of all and considerable amounts of minerals are not contained.

The former two are, though for the time being hardly inspected in details becanse of being ignored in the mine, surely confirmed either in the galleries or as the outcrops on the landsurface.

The "Ôrotô" named by the miners is the largest exposure connected with *PI* locating in serpnetinite, pointing to a general trend of NS. It reveals a greenish or bluish exposure impregnated with networks of pyritiferrous quartz-veinlets along the fissures showing the directions of NE–SW or NS. They say that in the old gallery situated near the "Ôrotô" this colored part is found cut across by a white-colored felsitic dike. In the gallery these veins, more than 10 cm~some m in width, acconpanying silicified zone, are found cutting across the adit along the schistosity planes of the Sangun metamorphics and cut obliquely by the lodes formed later than *P II*. They bear peculiar appearance as if they were corresponding to special parts of wall rocks silicified selectively through subsequent lodes. These parts, however, are regarded not as alteration products but as independently mineralized zone, the ores included in which are, on account of their color, called the "blue ore" in this mine. Although this zone or lodes of their own are worthless for mining, such parts as include quartz vein (*P III*) bearing gold, silver, and antimony are, because of increasing Au content, being worked. The quartz-veinlets included similarly in bluish parts found both in the Hommabu-Kijimabu gallery and on the uppermost level of the Manju lode are called to have ever been excavated but more details are not ascertainable since it is now

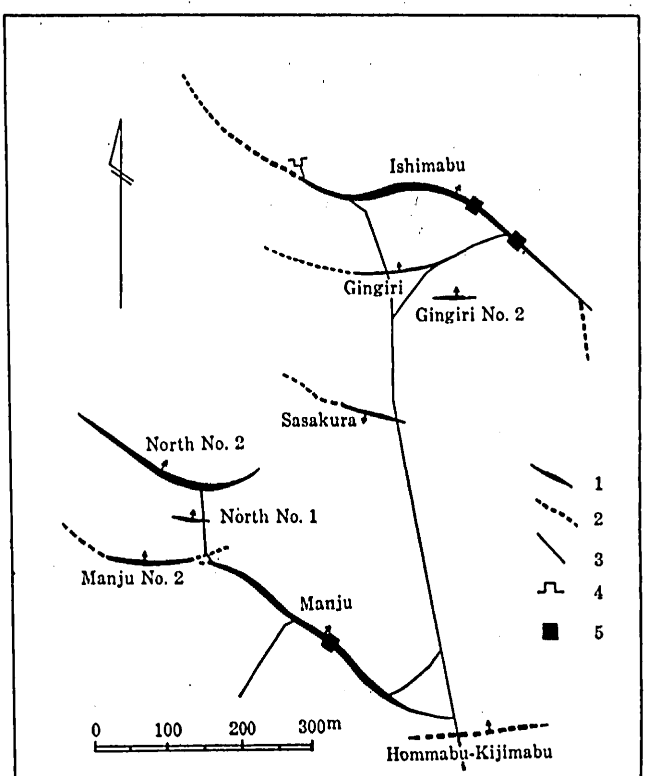


Fig. 2. Distribution of the main lodes.

1. Lodes on the level of the main gallery 2. Lodes on different levels 3. Cross-cut 4. Entrance 5. Shaft

impossible to enter into the related spots.

The lodes formed in *P II* are divided into two kinds. One is characterized by the continuously developed veins composing of white-colored quartz and the other by remarkable variation in width along strike- and dip-sides, forming in parts a sort of metasomatic bonanza. These lodes revealing the strike of EW in the Sangun metamorphics and serpentinite run along or are cut obliquely by the lodes produced in *P III*.

The lodes deposited as workable veins containing gold, silver, and antimony ores at lower temperature in *P III* represent bulk of parallel ones, with general trends of EW or NW-SE, appearing within a width of 1km from north to south. In southward order the lodes called lshimabu, Gingiri, Gingiri No. 2, Sasakura, North No. 2, North No. 1, Manju No. 2, Manju, and Hommabu-Kijimabu are mentioned as the main ones in this mine. Of all, those of Ishimabu and Manju No. 2 are now most important since the Hommabu gallery and the upper level of the Manju gallery are not actually pursued for inspection. In general, these are of fissure-filling type with a local variation in width and roughly divided into two groups of Ishimabu and Manju.

The Ishimabu lode representing the Ishimabu group shows an extension of 750 m within known range along the strike-side, disclosing a general trend of WNW-ESE and that of 400 m along the northward dip-side in high angle. As will be stated, these, however, are not the simple ones but display a linear arrangement of some shorter lodes. On the southern side locating 120 m and 150 m far away from the Ishimabu lode are respectively appeared those of Gingiri and Gingiri No. 2.

The main ore bodies belonging to the Manju group are composed of three lodes such as Manju No. 2 and Manju together with Hommabu-Kijimabu located from north to south. Strikes of the respective lodes are different from one another but, on the whole, in accordance with a trend parallel to that of the Ishimabu lodes. Those of North Nos. 1 and 2 are found respectively 50 m and 110 m north of the main bodies.

The Sasakura lodes intervening between those of Ishimabu and Manju only indicate the southward dips and are difficult to be worked for such reason as will be alluded to later. General strike, dip and extension confirmed at present in the galleries are shown in Table 2. Inspection of each lode in more details makes it possible to consider a sort of échelon structure in its own, a common characteristic.

As will be shown in the case of Ishimabu lodes, the main bodies of Manju group are to be isolatedly named, whereas each lode is given independent name such as Hommabu, Kijimabu, Nanju and Manju No. 2 etc., since each one reveals severer variation in strike and in dip than in the Ishimabu lode and seems to have been excavated down from the respective outcrops. The names of the former two are evidently afforded to the parts situating on different levels in the simple lode, because they have ever been worked from the old entrances differring from each other. Although the eastern part of the Manju lode seems to be cut by the Hommabu-Kijimabu

Table 2. The main lodes developed in the Nakase Mine.

Name of lode	General		Extension along	
	Strike	Dip	Strike-side	Dip-side
Ishimabu	N70°W	N70°	750m	400m
Gingiri	N80°W	N75°	300m	300m
Gingiri No. 2	E-W	N85°	80m	100m
Sasakura	N70°W	S 65°	170m	50m
North No. 2	N70°W	N70°	250m	200m
North No. 1	N80°W	N70°	90m	150m
Manju No. 2	N80°W	N70°	300m	300m
Manju	N45°W	N80°	400m	400m
Hommabu-Kijimabu	E-W	N80°	200m	300m

lode, the fact is that with approaching to the latter the former changes its strike into nearly parallel arrangement with the latter and pinches, and one never cuts across, or coincides with, the other. The eastern part of the Manju No. 2 lode together with the western extension of the Manju lode are appeared at the same time on the lower No. 1 level and at present being excavated along their strike in the upper and lower adits.

The Manju lode more and more pinches with approaching to its western side, where the eastern veinlet of the Manju No. 2 appears from the northern wall (the hanging wall of the Manju lode) and runs along the Manju lode pinching away in the southern wall of the gallery. Such a lode as is now being and has been regarded as a western branch of the Manju No. 2 is actually the different one, and contains native gold in large amounts on the lower No. 2 level connected with the lower No. 4 level. This therein displays an obvious discrepancy against the Manju No. 2 lode in strike pointing to N45°W, and is clearly distinguishable from the latter.

The North No. 2 lodes have an appearance as if they were a single one with a strike of WNW-ESE either in the main gallery or on the western side of the cross-cut on the lower No. 2 level of the North No. 2 gallery but are separated into two remoting from each other both with width of about 20 m in horizontal dislocation on the lower No. 4 level and with more width on the lower No. 6 level. This shows nothing but the fact that two lodes indicating difference in dips happen to appear in a linear arrangement on the upper levels and are not a single one separated with fault on the lower level. On the eastern side of the cross-cut of the lower No 2 level of North No. 2 gallery are observed three or more lodes in subparallel and side-by-side going arrangement, whereas all of them are not mineable.

The lode located in the easternmost part of the Ishimabu group, showing either a considerable content of gold or the trend of NNW-SSE with dip of 50~60°E in an average, seems to be branched from another one extended in direction of WNW-ESE but both are essentially to be distinguished from each other as different lodes. The main body of Ishimabu lodes bear an appearance on the main level of the Ishimabu gallery as if it were a single one developed with the trend of WNW-ESE. It however pinches in the serpentinite intervening between the Sangun metamoephics appeared about 30 m west of the shaft on the lower No. 7 level of Ishimabu gallery and seems to re-appear as workable one in the metamorphics in the furthermore western part about 80 m far from the very shaft. This seems to imply that the metamorphics are lithologically more convenient for formation of fissures or deposition of ores than the serpentinite since the lodes are apparently far more predominant in the former than in the latter. On the other hand, it is certainly confirmable on the lower No. 10 level that the eastern and western parts of the lode appeared on the lower No. 7 level are not simply connected with each other but the western part belongs to the different lode revealing a horizontal discrepancy of about 30 m from the eastern part. Toward south, in consequence, the respective parts located on both sides of the serpentinite on the upper levels are considered to be the upper parts of two different lodes having nearly similar trends, although the lithologic features of country rocks might have been related to these occurrences of the lodes to certain extent. In the furthermore western part of the lower No. 7 level of Ishimabu gallery the lode extended toward WNW along the adit pinches gradually and disappears away into the northern wall, while at the same time another one appears from the southern wall and swells in workable scale. These relations are surely observed not merely in three parts on this level but also in all of the gold-, silver-, antimony-bearing lodes (*P III*) appeared in the Ishimabu gallery.

P III lodes appeared in specific situations named Ishimabu and Manju might have deposited in such fissures as were in échelon-like arrangement and slightly different in respective dips, and are accordingly used to continue along the dip-side but not so along the strike-side.

Although the reason of why these side-by-side going fissures or zones with respective directions were formed and point to a nearly definite trend on the whole in particularly confined area is of uncertainty and remains to be reasonably answered, mere conclusion is that they might have been a sort of relics of, or ascribed to, old structures.

The lodes deposited in *P IV* are found in the fault-fissures cutting across and or intersecting perpendicularly or obliquely with *P III* lodes and nowhere display the considerable contents of ores.

IV. Minerals and mineralizateon

As was already stated, the ore bodies in this mine are roughly divided into four groups produced through certain processes in four main periods as follows:

Period I (*P I*). The ores produced in *Period I* prior to the main mineralization in this mine are composed mainly of pyrite, marcasite, and ullmannite (?), indicating characteristics in their greenish or bluish color derived certainly from traces of nickeliferrous components as well as in severe silicification.

Period II (P II). Those produced in *Period II* are composed mainly of sulfide ores representing the ones formed at a higher temperature compared with others in this mine, and further subdivided into two groups distinguished from each other merely in mineral assemblage.

Group 1 (G 1) contains mainly arsenopyrite, sphalerite, pyrrhotite, pyrite, marcasite, chalcopyrite, and galena associated with unascertainable nickeliferrous mineral. Its characteristic is revealed in that it is extremely abundant in sphalerite and swells intermittently and uncontinuously in parts to form bonaza of sulfide ores along which metasomtic alteration is used to be recognized to considerable extent on their country rocks. Furthermore, the lodes belonging to this group are often found near the Manju group.

Group 2 (G 2) including mainly pyrite, pyrrhotite, arsenopyrite, chalcopyrite with stars of sphalerite, bismuthinite, native bismuth and marcasite is charcterized with white-colored quartz and yellowish tint of sulfide ores. Such parts as are composed merely of quartz are predominated and indicate either little variation in width as continuously well-defined veins or little effects of alteration on country rocks, distributing in the vicinity of Ishimabu lodes.

Interrelation between these two groups and accordingly their sequence of formation is remained yet to be determined. The lodes produced in this period, however, reveal a general trend pointing nearly to EW.

Period III (P III). Those produced in *Period III* are represented by the gold-, silver-, and antimony-bearing lodes as one of the workable ones in this mine. According to the sequence of mineralization stage, this period is furthermore subdivided into two stages.

Stage 1 (S 1) is related to the mineralization of pyrite, galena, arsenopyrite, sphalerite, berthierite, stibnite, and jamesonite. Concerning the deposition of these minerals several processes are to be taken into account. Brecciation together with fissure-opening seems to have taken place just prior to formation of the lodes at this stage. Earlier minerals such as pyrite, arsenopyrite, and sphalerite etc. are assumed to have produced so-called brecciated ores because of fracturing in the beginning of their formation during this process and embraced with the fragments of country rocks in quartz veins or quartz-dolomite veins containing later minerals such as arsenopyrite, berthierite, and stibnite etc. as well as jamesonite, the last one, in their druses. This sort of lodes indicates macroscopic characteristic both in contents of greasy quartz as gangue and in scarcity of antimony minerals and gold. The lodes produced at this stage are almost always in association with, and cut by, those deposited at the following stage (*S 2*) but not so much powerful. Consequently, the Sasakura lodes are hardly workable because of superiority of *S 1* lode.

Stage 2 (*S 2*) is concerned with mineralization of pyrite, sphalerite, berthierite friebergite, stibnite, marcasite, and cinnabar, accompanying native gold. The lodes formed at this stage are most important in this mine and accordingly the adits are principally elongated along them. A unique mineralization taken place as an out-rider just prior to deposition of the main lodes seems to have produced pyrite-quartz veinlets and to have given remarkable sericitization and carbonatization on country rocks accompanied with silicification as well as with impregnated pyrite, resulting in coloring into brownish tint of the surrounding. Inasmuch as in these parts the main lodes related to this stage are included, the scale of their formation is not always in correspondence with the grade of alteration observed on the country rocks.

The lodes concerned are characterized with higher contents of native gold in the macroscopically identifiable grade as well as of colorless and transparent quartz which, however, becomes bluish and shows calcedonic appearance in the parts formed at the later stage, containing well-developed crystals of freibergire, berthierite and stibnite.

Period IV (*P IV*). The lodes produced in *Period IV* are the last one which include only pyrite in scarce amount and fill the fissures intersecting almost perpendicularly to the preceding main lodes.

Quartz and carbonate minerals accompanied in each period are naturally mentionable as gangues in all of the lodes.

Since such mineralogenetic sequence as has already been outlined is on the whole based roughly on the results derived almost from macroscopic inspection more accurate reference is believed to be necessary. As for this regard, a part of examples will hereunder be introduced. In the case of the lodes formed at *S 2* in *P III*, sphalerite might have been derived more than three times: The first is related to the *'earlier'* mineralization, the second to that activated a little later than in the beginning of the 'later' one associating freibergite, and the third to that taken place a little earlier than the middle of the 'later' one following stibnite.

There are also three kinds of freibergite: The first is found in quartz vein formed at the earliest stage of the 'later' mineralization, the second is related to the earlier of the 'later' mineralization in paragenesis with stibnite, and the third is deposited with predominant sphalerite a little later than the former also in the beginning of the 'later' mineralization. It seems common that stibnite is found produced later than berthierite but its occurrence is rich in variety. Beside that formed subsequent to berthierite in succession, it is included in quartz-freibergite veins, quartz-sphalerite veins, quartz veins, quartz-dolomite veins, quartz-calcite veins, and calcite veins deposited in the 'later' mineralization and also in bluish-colored chalcedonic veins formed nearly at the last stage. Native gold is contained mainly in various kinds of veins

* The earlier, the intervening and the later here adopted do not imply the sequence of substage but represent the term relating mainly to formation of minerals without antimony-bearing ores, berthierite, and stibnite respectively.

included in the intervening to later mineralization. In consequence, successions or repetitions of mineral deposition result in formations of composite lodes, e.g. production of sphalerite prior or subsequent to that of berthierite. More details as to mineralogenesis will be enlightened in the near future.

Some representative minerals relating to those originated principally in *Period III* are shown in the followings.

Stibnite: The specimens are now obtainable only from the lodes belonging to *P III.* Those collected from *S 1* occur as aggregates of fine-grained and acicular crystals used to coexist with white-colored greasy quartz in minor amount, while those considered to have been repeatedly precipitated in *S 2* are, as referred to in the precedings, the main ores, larger in shape, coexisting often with saccharoidal or prismatic quartz, quartz-dolomite, quartz-calcite, and calcite as gangues. Particularly, their

Table 3. Röntgenometrical Data for Stibnite

Specimen of *S1* from the lower No. 7 level of the Ishimabu gallery		Specimen of *S2* coexisting with freibergite from the lower No. 12 level of the Ishimabu gallery		Specimen of *S2* from the lower No. 5 level of the Manju gallery		Specimen from Nmokain, Aragai, Iyo, Japan. (Am. Mineral. 27)		A. S. T. M.	
d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
7.97	4							7.99	16
7.17	4								
5.67	24	5.65	5	5.66	42	5.60	2.0	5.654	36
5.05	25	5.04	6	5.04	40	5.00	2.0	5.052	57
3.99	10	3.980	3	3.98	16	3.95	1.0	3.987	28
		3.690	4					3.632	29
3.58	36	3.564	11	3.57	62			3.573	67
						3.55	6.0	3.556	72
		3.443	5					3.458	25
		3.164	3					3.178	18
3.13	15	3.126	5	3.12	23	3.11	2.0	3.128	37
3.05	10	3.045	10	3.04	35	3.05	3.0	3.053	95
2.763	16	3.763	8	2.75	31	2.77	3.0	2.764	100
2.713	14								
		2.676	5	2.67	14	2.67	0.5	2.680	52
2.611	3	2.603	3	2.61	6			2.609	25
2.529	17	2.521	6	2.52	31	2.52	3.0	2.525	46
2.426	7			2.42	5	2.42	1.0	2.426	22
2.274	5			2.27	9	2.28	1.0	2.277	24
								2.252	14
				2.23	11	2.23	2.0	2.233	25
2.195	7							2.202	7
								2.185	6
2.100	7	2.100	3	2.09	14	2.10	3.0	2.101	21
								2.088	12
						1.990	0.3	1.992	10
1.941	11	1.936	6	1.94	20	1.941	4.0	1.940	46
1.918	6	1.917	4	1.91	11			1.920	36
						1.885	0.3	1.885	9
								1.871	9
								1.858	5
								1.846	9
						1.785	0.3		
1.728	6	1.723	3					1.729	19
						1.725	2.0	1.725	20
1.692	9	1.689	4	1.69	14	1.690	4.0	1.6906	34
1.636	6							1.6358	8
						1.540	1.0	1.5431	10

crystals occurring in druses are of elongated prism in well development, some of them being 12～15 cm long and 0.7～0.8 cm wide. They are, in many cases, solitarily found accompanying no other ore minerals but also happen to be in paragenesis with berthierite, freibergite, sphalerite, pyrite, and native gold. Concerning the mineralizations of stibnite, those appeared at the later stage of *S 2* are of the largest scale in this mine.

Berthierite: Occurrence, chemical composition and others of the specimens obtained from this mine have already been studied by T. Tatsumi (1948, 1951), K. Sakurai and E. Tanda (1948), and H. Muraoka (1949). They are included mainly in the lodes produced at *S 1* and *S 2* in *P III* and generally found almost isolatedly as mas-

Table 4. Röntgenometrical Data for Berthierite

Specimen of *S1* from the main level of the North No. 2 gallery		Specimen of *S2* berthierite-quartz vein from the lower No. 11 level of the Ishimabu gallery		Specimen of *S2* coexisting with stibnite from the lower No. 7 level of the Ishimabu gallery		A. S. T. M. and Am. Mineral. 27	
b (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
7.08	4	7.06	5	7.09	10		
4.36	7	4.36	9	4.36	17	4.30	60
3.67	14	3.67	16	3.67	23		
3.64	10	3.64	11	3.64	18	3.62	90
3.54	5	3.54	5	3.54	11		
		3.46	6	3.46	5		
3.38	8						
3.35	10	3.35	89*	3.35	100*	3.35	60
3.19	12	3.19	13	3.19	16	3.15	90
3.07	5	3.07	5	3.07	5		
3.01	9	3.01	10	2.998	16	3.01	60
2.964	3						
2.872	11	2.869	11	2.870	13		
						2.83	90
2.799	3						
2.626	17	2.622	16	2.627	18		
				2.614	17	2.60	100
2.538	6	2.538	5	2.535	10		
2.512	4	2.510	4			2.51	60
2.270	4						
2.242	4	2.235	6			2.23	40
2.221	3						
2.170	5	2.171	6	2.171	9	2.155	60
2.067	5						
		2.047	5	2.047	6	2.035	60
2.007	5	2.006	5	2.005	6	1.99	70
1.917	5	1.917	4	1.917	6	1.90	60
1.880	7	1.881	7	1.881	7	1.870	70
1.816	3						
1.802	4	1.804	4	1.803	5		
1.780	5	1.781	5	1.781	5	1.785	60
1.770	5	1.765		1.769	5		
			4	1.760	4	1.760	60
1.697	3			1.696	4	1.690	40
1.672	4					1.660	40
1.593	3					1.630	?
1.559	2					1.585	60
1.542	2						
1.505	3					1.549	20

* probably overlapped with quartz

sive ores or in paragenesis with the stibnite deposited at the last stage of the intervening mineralization in close relation to quartz but not to dolomite or calcite. The minerals in question display the appearance resembling stibnite but are more slender and smaller in shape than the latter. The specimens are used to bear darker and

Table 5. Röntgenometrical Data for Freibergite, Tetrahedrite, and Andorite

Specimen included in berthierite vein from the lower No. 12 level of the Ishimabu gallery		Specimen included in quartz-dolomite vein from the lower No. 7 level of the Ishimabu gallery		Specimen included in sphalerite-quartz vein from the lower No. 11 level of the Ishimabu gallery		Tetrahedrite A. S. T. M.		Andorite from Oruro, Bolivia (Am. Mineral. 27)	
d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
7.45	6								
5.28	5								
4.29	5					4.2	30		
		3.87	3						
3.72	14	3.73	8	3.71	10	3.68	10	3.7	0.5
		3.42	12	3.41	8			3.41	0.5
		3.30	21	3.30	17	3.29	40	3.28	4.0
		3.25	6	3.25	5				
				3.20	6				
3.13	7	3.13	8	3.12	50*				
3.03	ca100	3.04	21	3.03	51				
		3.00	9	2.990	9	3.00	100		
				2.893	12			2.90	3.0
				2.862	6				
2.811	12			2.811	5				
		2.747	8	2.739	8	2.78	20	2.75	2.0
2.629	25	2.632	3	2.627	11	2.60	50		
2.478	13			2.476	7	2.45	40		
2.352	4					2.33	10	2.38	0.2
		2.270	4	2.264	3			2.27	0.5
2.242	5			2.239	3	2.22	10		
2.145	3							2.14	0.3
		2.13	4	2.127	4	2.12	10		
				2.119	3				
		2.096	5	2.093	4				
2.062	13	2.063	7	2.061	10	2.04	70	2.06	1.0
				2.012	3			2.01	0.5
				1.981	3			1.98	0.3
1.920	11	1.919	6	1.913	35*	1.90	40		
		1.884	5	1.880	4			1.88	2.0
1.859	44	1.861	8	1.858	18	1.84	100		
		1.820	3	1.817	3				
1.805	5			1.804	4	1.78	40		
		1.789	5	1.786	4			1.795	2.0
		1.783	5			1.73	40		
1.705	8			1.706	5				
						1.69	80		
						1.64	10	1.681	0.2
						1.61	10		
1.586	23	1.586	3	1.585	8				
						1.57	90		
						1.53	20		
						1.50	20		
1.488	4					1.47	30	1.481	0.3
						1.45	30		
						1.42	20		
						1.39	10	1.385	0.3
1.336	5					1.37	10		
						1.32	40		
						1.30	80		
						1.28	50		

* Probably overlapped with sphalerite

nearly dark-grayish tint compared with that of lead-grayish stibnite. On exposure in air they become more blackish and get to be iridescent and bronz-brown in color. terminating in severer rusting than in the case of stibnite.

Freibergite: Chemical study of the specimens has been given by H. MURAOKA (1949). Their contents in the Ishimabu lode are particularly conspicuous and seem to have been derived from the last of the intervening mineralization to the beginning of the later ones. The crystals found in druses of the veinlets are completely tetrahedral in form and in parts about 1 cm in maximum size. Since the specimens are considered to be corresponding to tetrahedrite determined by K. SAKURAI and E. TANDA (1948) and T. TATSUMI (1951), and the occurrence of andorite mingled irregularly with these specimens has also been reported by K. SAKURAI and E. TANDA

Table 6. Röntgenometrical Data for Jamesonite

Specimen from the lower No. 3 level of the Gingiri gallary		Specimen from Cornwall, England (Am. Mineral. 27)		A. S. T. M.	
d (Å)	I	d (Å)	I	d (Å)	I
8. 21	8				
6. 07	20			6. 03	5
5. 05	8			5. 10	5
4. 31	27				
4. 28	9				
4. 09	21			4. 10	30
4. 04	9				
3. 93	14				
3. 85	36			3. 87	40
				3. 72	20
3. 53	13			3. 59	30
3. 43	60	3. 40	3. 0	3. 44	100
				3. 34	10
				3. 18	50
3. 09	23	3. 10	1. 0	3. 09	50
3. 03	6				
2. 953	9			2. 95	20
		2. 81	2. 0	2. 84	90
2. 722	21	2. 72	2. 0	2. 75	80
				2. 63	10
2. 525	4				
				2. 36	10
2. 296	24	2. 28	1. 0	2. 30	30
2. 241	7	2. 23	1. 0	2. 24	40
				2. 16	10
				2. 11	5
		2. 04	1. 0	2. 06	50
2. 023	21	2. 01	1. 0	2. 02	40
				1. 965	10
1. 911	5	1. 90	0. 5	1. 907	10
1. 869	4			1. 866	10
1. 834	15			1. 831	30
		1. 825	1. 0		
				1. 797	10
				1. 768	10
		1. 75	0. 2	1. 752	10
1. 736	3				
1. 717	4	1. 71	0. 2	1. 725	10
				1. 661	10

(1948) and K. KINOSHITA (1957), inspection with much more accuracy is by all means indispensable.

Jamesonite: The mineral, the last product of *S 1*, commonly discloses characteristic wooly appearance in druses of quartz contained in the brecciated veins of the Gingiri and Sasakura lodes, and is distinguishable in its less flexibility as well as in stage of deposition from wooly crystals of stibnite formed at *S 2*.

Cinnabar: This mineral together with metacinnabarite in this mine has once been described by K. SAKURAI and E. TANDA (1953) but not referred to their location of occurrence. Some specimens are found in a little amount either in the Shiraiwa adit or in the western part of the lower No. 7 level of Ishimabu gallery. They are the last product of *S 2* occurring as networks of tiny veinlets impregnated in earlier veins of *S 2* or in fine fractures within country rocks.

Table 7. Röntgenometrical Data for Cinnabar

Specimen from the lower No. 7 level of the Ishimabu gallery		Specimen from Almaden, Spain (Am. Mineral. 27)	
d (Å)	I	d (Å)	I
3.36	78	3.34	9.0
3.16	22	3.16	1.0
2.86	83	2.85	9.0
2.37	6	2.36	0.5
2.07	20	2.07	3.0
2.03	10	2.02	1.0
1.98	20	1.980	3.0
		1.900	0.3
1.77	13	1.765	2.0
1.73	17	1.735	3.0
1.68	15	1.680	4.0
		1.581	1.0
		1.560	1.0
1.43	5	1.435	2.0

Table 8. Röntgenometrical Data for Arsenopyrite.

Specimen of *S1* from the lower No.2 level of the Sasakura gallery		Specimen from Auburn, Maine (Am. Mineral 27)		A. S. T. M.	
d (Å)	I	d (Å)	I	d (Å)	I
3.62	30			3.62	40
				2.90	40
2.84	25	2.82	1.0	2.81	50
2.67	85	2.66	1.0	2.65	100
				2.53	20
2.44	100	2.48	3.0	2.42	100
2.20	25			2.19	40
				2.09	40
		2.02	0.5	2.00	50
1.95	30	1.95	0.3	1.95	20
				1.94	40
1.82	55	1.82	2.0		
1.81	55			1.81	80
1.76	30			1.76	20
				1.75	40
				1.73	20
				1.68	40
1.63	50	1.63	0.5	1.63	60
1.59	30			1.60	60
				1.58	50
1.55	25	1.54	0.2	1.54	60
1.54	25			1.50	60

Arsenopyrite: Their massive ones formed at higher temperature are contained in both groups of *P II*, while acicular crystals produced at low temperature are related to deposition in the beginning of *S 1*. As to whichever the minerals may belong, they are surely assumed as the earlier products in each mineralization. Röntgenometrically they indicate considerable variation in their spacings.

Sphalerite: The specimens concerned are used to be contained either in *P II* or in *P III* and most abundantly in *G 1* wherein the lode indicates, in parts, an appearance as if it were composed merely of sphalerite. Most of the specimens obtained from *P II* are dark-brown in color and of relatively compact mass displaying cleavable lamellae, while on the other hand they are considered to have been originated at consi-

Table 9. Röntgenometrical Data for Sphalerite

Specimen of *G1* from the lower No. 5 level of the Manju No.2 gallery		Specimen of *S1* from the lower No. 7 level of the Ishimabu gallery		Specimen of *S2* included in freibergite-quartz vein from the lower No. 11 level of the Ishimabu gallery		Specimen from Butte Montana (Am. Mineral 27)	
d (Å)	I	d (Å)	I	d (Å)	I	d (Å)	I
						3.95	0.5
3.14	48	3.13	80	3.13	83	3.12	6.0
2.713	7	2.709	8	2.705	7	2.70	2.0
1.918	18	1.918	42	1.914	64	1.91	5.0
1.634	12	1.635	23	1.632	16	1.63	4.0

derably higher temperature because exsolution blebs of chalcopyrite, a part of which involve vallerieite, and those of pyrrhotite are microscopically recognizable in them. Those included in *PIII*, scarce in amount, are commonly pale-colored and often found comprised solitarily in quartz grains. The main parts of them are to be connected with earlier mineralization at *S1* and *S2* respectively. As for the specimens deposited especially at *S 2*, some seem to have been produced with freibergite in quartz veins formed in the beginning of the later mineralization, and others are found involved with stibnite in quartz veins somewhat later than the former. The furthermore later specimens are ruby-red in color, nearly transparent, indistinct in cleavage, and, owing to no exsolution blebs, regarded as the product at low temperature.

Galena: Most of the specimens are comprised in the lodes produced at *G1* and *S1*. They are assumed to have deposited at last at *G 1* and partly in a little amount in the beginning of *S 1*.

Table 10. Röntgenometrical Data for Galena

Specimen of *G1* from the lower No. 5 of the Manju No. 2 gallery		Specimen of *S1* from the lower No. 7 level of the Ishimabu gallery		Specimen from Jopiin, Missououri. (Am. Mineral. 27)	
d (Å)	I	d (A)	I	d (Å)	I
3.43	61	3.43	69	3.42	3.0
2.967	83	2.969	90	2.96	6.3
2.097	44	2.101	47	2.08	5.0
1.787	27	1.790	31	1.785	5.0
1.722	13	1.715	15	1.710	3.0

Table 11. Röntgenometrical Data for Marcasite

Specimen of *S2* from the main level of the North No. 2 gallery		Specimen from Creighton, Ontario. (Am. Mineral. 27)	
d (Å)	I	d (Å)	I
3.45	18	3.47	3.0
2.698	29	2.715	6.0
2.415	14	2.42	2.0
2.318	14	2.32	2.0
1.913	10	1.925	1.0
1.759	21	1.762	4.0
1.719	5		
1.694	8	1.692	1.0
1.676	6		
1.596	7	1.600	2.0

Marcasite: They are always found in relation to *P1*, *G1*, and *S2*. Specimens collected from *P 1* are believed to have been formed almost contemporaneously with pyrite, while those obtained from *S 2* seem to have precipitated on the surface of druses in dolomite deposited at the later stage of *S 2*, being covered, in parts, with colorless and transparent crystals of calcite, as are observed in the main gallery of North No. 2 lode and on the druses appeared on bluish-tinged quartz of chalcedonic appearance, as are found on the lower levels from No. 7 to No. 10 in the western part of the Ishimabu lode.

Nickeliferrous mineral and some others: Occurrence of ullmannite obtained from the severely silicified and greenish-tinted phyllite along the lode bearing gold and antimony in the eastern part of the Hommabu lode has been reported by T. Matsukuma (1953). Althogh these green-colored parts seem to be corresponding to *P I* designated by the present writer and the related mineral is remained yet to be more accurately determined, contents of nickel only are chemically confirmable in the part including abundance of pyrite and marcasite as well as in the lode of *G 1*. T. Kita (1960) reported on pyrargyrite from the lode corresponding to *S 2* and on native bismuth, bismuthinite, wittichenite and magnetite from the lode produced in *P II*, but it is still pending to identify röntgenometrically them all.

Negative molds after barite: They are surely observed in druses of the vein appeared between the western part of lower No. 7 and No. 10 levels of the Ishimabu lode. K. Masutomi and K. Takaoka (1953) and K. Takaoka (1954) reported as to this material but it is very difficult to confirm it only from the remainder of cavity. Their crustal part show bluish-tinged chalcedonic appearance but vary completely into quartz correlative to that belongs to the later product of *S 2*. To be noted is that this kind of quartz contains a small amount of stibnite and is found at the bases of all lodes. On the surface of this quartz appeared on druses are found fine-grained crystals of marcasite.

V. Consideration on ore genesis

As was alluded to frequently, it seems reasonable to divide the principal mineralizations into those taken place in four main periods such as *P I*, *P II*, *P III*, and *P IV*.

The fact of importance is that the ores produced in *P I* are found merely in the Sangun metamorphics and serpentinite. As for their trend, the lodes included in the metamorphics point to identity with schistosity of the latter and are remarkably different from any other later ones. Since the lodes completed in *P I* are cut across by leucocratic dike showing extension from south to north and the latter is furthermore penetrated by the lodes later than those produced in *P II*, a sort of igneous activity is to be considered at certain stage intervening between *P I* and *P II*. According to the view given by T. Matsukuma (1953) "silicification on the wall rock seems to have played an important role prior to the formation of gold-, and antimony-bearing lodes and to have accompanied the deposition of iron components derived from country rocks or from mineralizer as pyrite and marcasite associated at last with ullmannit" and "nickeliferrous ores formed prior to the deposition of gold-antimony lodes are found in phyllite situating on both sides of the former lode, yielding greenish tint on the severely silicified wall rock with width of about 1 m along the very lode in the Hommabu gallery". This seems to affirm the silicification simply through alteration of wall rocks. Nevertheless, these silicified zones are solitarily located in no relation to gold-antimony lodes, so far as they are now observed in the galleries, and indicate no variation in components or in appearance even far from the lodes concerned, whereas effects of these lodes on the Sangun metamorphics are generally appeared as variation of the latter in color into grayish-brown or grayish-white tints, and silicification also is not believed to have taken place selectively on each wall rock. From these facts it may be reasonably deduced that these silicified parts are a part of the so-called "blue ores" regarded as have been derived through a unique mineralization other than that relating to gold-antimony ores and surely belong to *P I*.

For the time being there are no materials to prove chronologically the stage of intrusion of leucocratic dike into the silicified parts and it is accordingly impossible to determine even the upper limit of the latter. However, their formation is rationally assumed to have been prior to the mineralization in *P II* representing a stage of Miocene.

The mineralization in *P II* and that in *P III* are not continuously connected with each other. Basing on the fact that activities of porphyrite (see Fig. 7, Pl. 48) and then of breccia dike (see Fig. 8, Pl. 48) are found sandwiched between these mineralizations a chronological interval is to be considered between them.

Porphyrite dike runs along the lodes of *G 2* and *P III* appeared on the lower No. 11 level in the eastern part of Ishimabu gallery, wherein the dike is not cut by *G 2* and, in parts, contains the extension of *P III*. *G 2*, however, is separated away from porphyrite and *P III* at the western end of their parallel arrangement, 100 m east of the shaft, where *G 2* is cut across by the dike. Similarly the same lode is, as it were

The ores (*G 2*) cut by the porphyrite dike appeared in the eastern part on the lower No. 11 level of Ishimabu gallery (100m east of the shaft).

The ores (*G 2*) partially cut by the porphyrite dike appeared in the eastern part on the lower No. 10 level of Ishimabu gallery (130 m east of the shaft).

Xenolithic occurrence of ores (*G 2*) included in the porphyrite dike appeared in the eastern part on the lower No.10 level of Ishimabu gallery (170m east of the shaft).

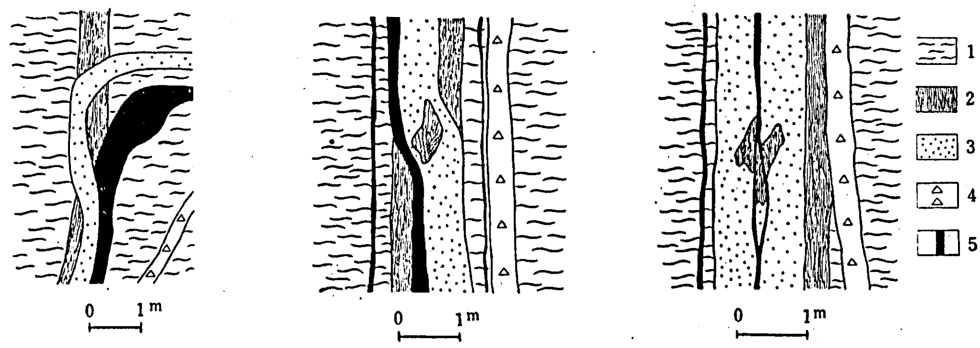


FIG. 3. The relation of porphyrite dike to lodes appeared on the hanging wall.

1. Wall rock (semischist) 2. Sulfide-ore vein (*G 2*) 3. Porphyrite dike
4. Breccia dike 5. Gold-stibnite-quartz vein (*S 2*)

teared off, cut by the very dike on the lower No. 10 level in the eastern part of the Ishimabu gallery, 130 m east of the shaft, and then captured by the dike furthermore 40 m east of the above spot.

Breccia dike penetrates either into *G 2* or into porphyrite, and captures their brecciated fragments together with breccias of the Sangun metamorphics in the part where the former approaches to the porphyrite and *G 2*. This breccia dike is surely in identity with those accompanying certain mineralizations observed in the green-tuff region, which have been correlated to the volcanic activity at the Onnagawa stage (F_3) of Miocene by H. Takeda. In the light of his view and activity of the Kawae volcanics at F_3 in the northern Tajima region, the breccia dike under consideration is naturally to be connected with certain activity in the middle of Miocene.

It thus is concluded that two kinds of dikes mentioned above might have been produced respectively at the earlier, and the middle stage of Miocene, though each is remained yet to be accurately confined.

As for the geologic structures observed within this district, T. Matsumoto and K. Wadatsumi (1959) are of opinion that one of two remarkable trends appeared in the northern Tajima region points to the extension of NE-SW represented by the Yumura, and Okusazu faults in accordance with the structure controlling sedimentation of the Hokutan Group, and formation of these faults is correlative in stage to the later Muraoka Formation (G). At any rate, this movement seems to have accompanied sedimentation of the Hokutan Group. On the other hand the fault systems comprising the lodes showing the trend of EW (including *P II* and a part of *P III*) in the Nakase Mine are located in the zone between the Hokutan Group and its southern basement, and regarded as a group of faults related to movement forming the basin concerned. In consequence they are to be in connection with the faults mentioned above and accordingly considered to have been moved with sedimentation of the Hokutan Group. In the galleries, fissures and faults including gold-antimony lodes (*P III*) with trend of NW-SE are recognized and reveal such a relation that on the distribution map of the adits they are cut by the EW faults and their northern parts dislocate westwards on the lower level in the eastern part of Ishimabu gallery, although the reality may be that development of these subsequent faults has been barricaded by the preexisting ones. And the later faults are interpreted to belong to such system pointing to the trends of NS or NNW-SSE as is represented by the Hiroi fault and some others which are congruent with the structure of Plio-Pleistocene, the other representative in the northern Tajima region, and cut across the Teragi Group (H). Consequently these NS faults are supposed to have been activated prior to activity of the Hachibuseyama andesite and subsequent to sedimentation of the Teragi Group, namely between H_2 and I_1, displaying similarity in trend to the Saruo-no-taki dikes. It appears of due significance that the lodes belonging to *P II* are included simply in EW faults.

On the basis of the phenomena referred to already formation of *P II* lodes is, though in obscurity concerning its relation to that of the Manju volcanics, decidable to have been taken place at the initial stage of Miocene. That the constitituents composing these lodes suggest their deposition at considerably higher temperature may justify the view connecting with a part of mineralizations appeared in the ore deposits of Akenobe Mine locating in the southern vicinity of the Nakase Mine, as has been stated by T. KITA (1960).

As for the mineralozation in *P III*, the contacts of the concerned lodes with the known Cenozoic formations are recognizable nowhere in the galleries. At Yagidani situating about 4 km northeast of the mine a sort of quartz-calcite vein including gold, silver, antimony, and pyrite is found filling the fracture of fault cutting across the Yubunegawa black shale, a part of the Muraoka Formation, showing the trend of NS with dip of 80°E. Granting that *P III* lodes are, on account of their occurrence and characteristics, possibly correlated to this quartz-calcite vein, their mineralization is reasonably proved to have been at least later than sedimentation of the Muraoka Formation, and accordingly at G. On the other hand, since the main lodes of *P III* appeared in the galleries cut across the micro-quartz-diorite correlated to the Saruo-no-taki dike, their deposition is considered later than H_2. Their trends pointing to EW or EW-SE may, as was referred to in the preceding, suggest that their formation is in structural relation to that of $H_2 \sim I_1$.

K. WADATSUMI and T. MATSUMOTO (1958) described the old gallery worked for gold ores contained in the Terada volcanics (H_2) occurring in the northern Tajima region. S. IMAMURA and H. YOSHIDA disclosed orally a view in that the Ômori deposit of silver ores ever worked in large scale also is confirmed extending partly into Ôe-Takayama volcanics (I_2), and S. TANEDA and T. MATSUKUMA (1953) seem to emphasize that epithermal gold deposits appeared in Kyushu might have been produced specifically at I.

In view of these opinions as well as the results obtained by the present writer it follows that formation of *P III*, one of the important mineralizations in this mine, may come down till I but be prior to volcanic activity of the Gembudo basalt because of being intruded by the latter. Now that there are no traces of mineralization in the Tentaki lava and this basaltic dike is even correlative to the Hachibuseyama andesite, it results in that *P III* mineralization might have been earlier in stage than I and accordingly confined within Plio-Pleistocene.

As regards the respective lodes, those belonging to *P III* display no remarkable variation in their mineral assemblages along the strike- and dip-sides. Mere exception may be that mineralization at the later stage of the last group might have diminished on the lower levels, terminating in formation of extremely low-temperature minerals such as chalcedony or others, as to which, however, researches in more details are to be added to. Besides this, of importance is that repetition and overlapping of mineralization are used to be distinctly ascertained in all directions of respective lodes either laterally or vertically. In consequence *P III* lodes are assumed to have been derived ordinarily from epithermal solution, the source relating to which will furthermore be pursued.

It however is very dangerous to establish a category of so-called xenothermal deposit concerning formation of the ores in the Nakase Mine merely for such reason that various kinds of minerals produced at higher to lower temperatures are coexistent with one another, because sequences of minerals derived from different solutions are to be strictly distinguished.

ACKNOWLEDGEMENT: For the most invaluable suggestion as well as continuous encouragment afforded by Professor Yoshiharu UMEGAKI of Mineralogical Institute of Hiroshima Uuiversity throughout this research wishes the writer to express his hearty thanks. He is similarly much indebted to Asistant Suguru NAGATOMI, Mr. Hiroshi MIYAKE, Research fellow, of the same Institute, Professor Yoshio KINOSAKI, Professor Sotoji IMAMURA, Professor George KOJIMA, Lecturer Kei HIDE, Asistant Akira SOEDA, Asistant Hironao YOSHIDA, and all members of the same University for their useful advices. Thanks are also due to Mr. Tosirô KOGA, Head of the Nakase Mine of Nippon Seiko K.K. for affording facilities and to Mr. Iwao KAMADA of the same mine for lending an useful assistance on surveying of the related terrain.

REFERENCES

AKATSUKA, K. (1960): On the stage concerning ore formation in the Nakase Mine, Hyôgo Pref. (in Japanese), Preliminary report, *Jour. Earthscientist and Amateurs, Japan, Vol. XI, No. 6.*

KATÔ, T. and TATSUMI, T. (1946): Report on Nakase Mine (in Japanese), *Report of the 58th subcommittee, The Japan Society for the Promotion of Scientific Reseaarch, No. 84.*

KINOSHITA, K. (1957): Colored illustrations of economic minerals (in Japanese), *Hoikusha, Osaka, Japan.*

KITA, T. (1950): Nakase Mine (in Japanese), *Chishitsu, Chikashigen Kyôkai, Osaka, Japan.*

KITA, T. (1960): Mineralization in Nakase Mine, Hyôgo Pref. (in Japanese), *Abstract, Jour. Geol. Soc. Japan, Vol. LXVI No. 778.*

KOCHIBE, T. (1892): Nakase Mine (in Japanese), *Jour. Geography, Japan. Vol. IV.*

MASUTOMI, K. (1954): Stibnite from Yagidani, Sekinomiya, Yabu-gun, Hyôgo Pref. (in Japanese), *Jour. Earthscientist and Amateurs, Japan, Vol. VI, No. 6.*

MASUTOMI, K. and TAKAOKA, K. (1953): Pseudomorph after barite from Nakase Mine, Hyôgo Pref. (in Japanese), *Jour. Earthscientist and Amateurs, Japan, Vol. VI, No. 4.*

MATSUKUMA, T. (1953): Nickel ores associating gold deposits (in Japanese), *Jour. Mining Institute, Kyûshû, Vol. XXI, No. 2.*

MATSUMOTO, T. and WADATSUMI, K. (1959): Cenozoic Structural Development in Northern Tajima (in Japanese) *Jour. Geol. Soc. Japan, Vol. LXV, No. 762.*

MUKAE, M. (1958): Volcanostratigraphical study on the Miocene volcanism in the Shimane Pref. Japan *Jour. sci Hiroshima Univ. Vol. II, No. 2.*

MURAOKA, H. (1949): On some minerals such as berthierite, frisebergite from Nakase Mine (in Japanese), *Abstract, Jour. Geol. Soc. Japan Vol. LV. Nos. 648～649*

SAKURAI, K. and TANDA, E. (1948): Berthierite from Nakase Mine, Hyôgo Pref. (in Japanese), *Mineralogy and Geology Vol. II, No. 8.*

SAKURAI, K. and TANDA, E. (1953): Cinnabar and metacinnabarite from Nakase Mine, Hyôgo Pref. (in Japanese), *Jour. Earthscientist and Amateurs, Japan, Vol. VI, No. 2.*

TAKAOKA, K. (1954): Supplementary coment on pseudomorph after barite from Nakase Mine, Hyôgo Pref. (in Japanese), *Jour. Earthscientist and Amateurs, Japan, Vol. VII, No. 2.*

TANEDA, S. and MATSUKUMA, T. (1953): On the mineralogenic stage of epithermal gold deposits in Kyûshû (in Japanese), *Abstract, Jour. Geol. Soc. Japan, Vol. LIX, No. 694.*

TATSUMI, T. (1948): Some animony-bearing minerals from Nakase Mine (in Japanese), *Abstract, Jour. Geol. Soc. Japan, Vol. LIV. No. 639*

TATSUMI, T. (1951): Note on berthierite from the Nakase Gold-antimony Mine, Japan *Miscellaneous Reports of the Research Institute for Natural Resources of Japan. Nos. 19～21.*

TATSUMI, T. (1955): Nakase Mine (in Japanese), *Mineral resources of Japan. Part BI-a.*

TATSUMI, T. (1956): Nakase Mine (in Japanese), *Progress in Economic Geology.*

WADATSUMI, K. and MATSUMOTO, T. (1958): The stratigraphic note of the Neogene Formations in the Northern Tajima (in Japanese), *Jour. Geol. Soc. Japan, Vol. LXIV, No. 759.*

YAMADA, M. (1959): Report on chromite deposits in Sekinomiya District, Hyôgo Pref. (in Japanese), *Bull. Geol. Surv. Japan, Vol. X, No. 11.*

EXPLANATION OF PLATE XLVIII

All figures ×15

FIG. 1. Black-colored semischist. Crossed nicols.

FIG. 2. Serpentinite. Crossed nicols.

FIG. 3. Quartz-porphyry. Crossed nicols.

FIG. 4. Quartz-diorite. Crossed nicols.

FIG. 5. Augite-hornblende-andesite belonging to Manju volcanics. Crossed nicols.

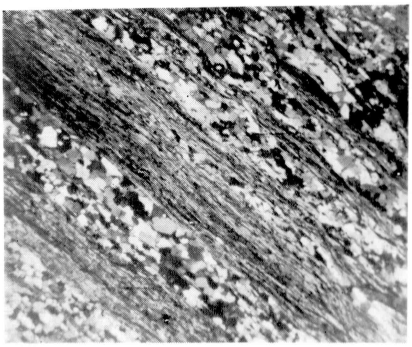
FIG. 6. Augite-hornblende-andesite (upper parts) and marginal facies of micro-quartz-diorite (under parts). Augite-hornblende-andesite is metamorphosed thermally by micro-quartz-diorite. Crossed nicols.

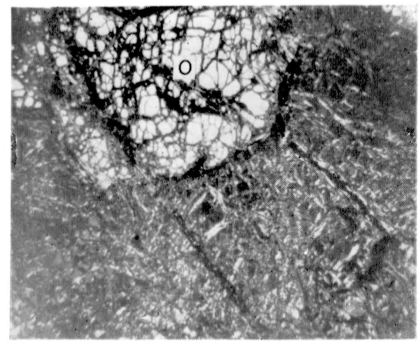
FIG. 7. Porphyrite dike cutting across *PII*. Crossed nicols.

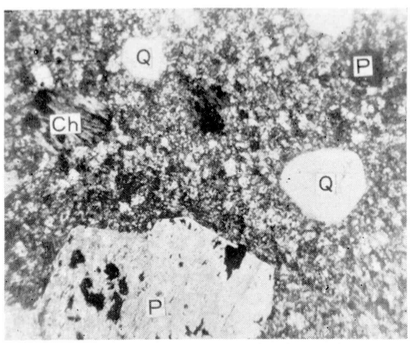
FIG. 8. Breccia dike. Crossed nicols.

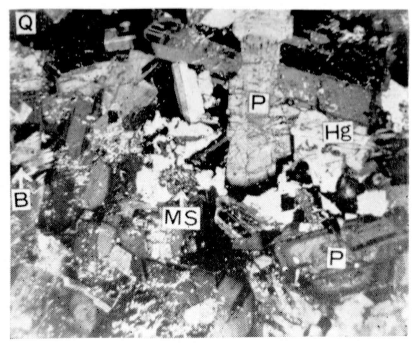
Abbreviation

B .... Biotite.
C .... Calcite.
Ch .... Chlorite.
Hb .... Brown hornblende.
Hg .... Green hornblende.
MS .... Micrographic structure of quartz and K-feldspar.
O .... Olivine (forsterite).
P .... Plagioclase.
Q .... Quartz.
Sch .... Schist.

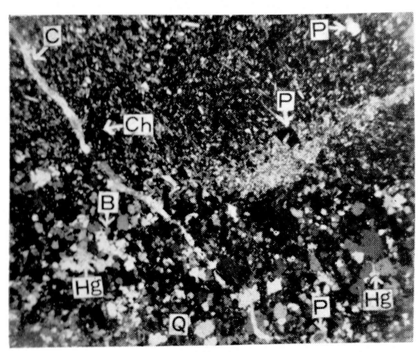
1


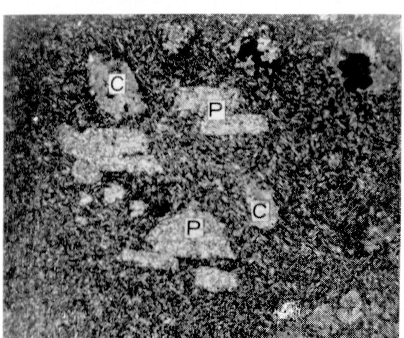
2


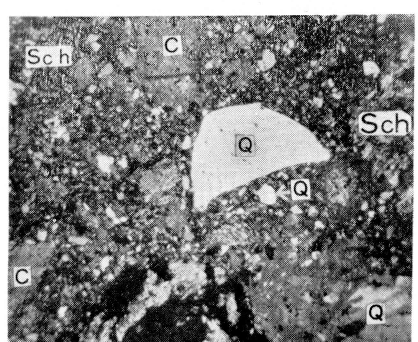
3


4


5


6


7


8


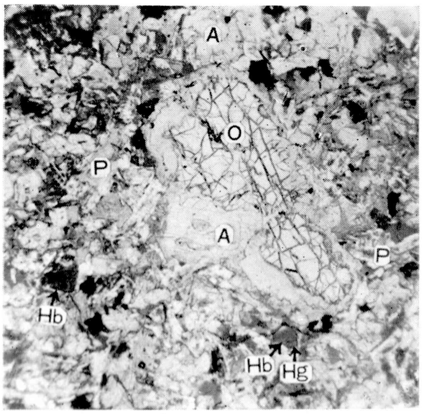
Explanation of Plate XLIX

All figures ×17

Fig. 1. Micro-quartz-diorite. Basic facies. Lower nicol only.
Fig. 2. *ibid.* Crossed nicols.
Fig. 3. Micro-quartz-diorite. Lower nicol only.
Fig. 4. *ibid.* Crossed nicols.
Fig. 5. Micro-quartz-diorite. Acidic facies. Lower nicol only.
Fig. 6. *ibid.* Crossed nicols.

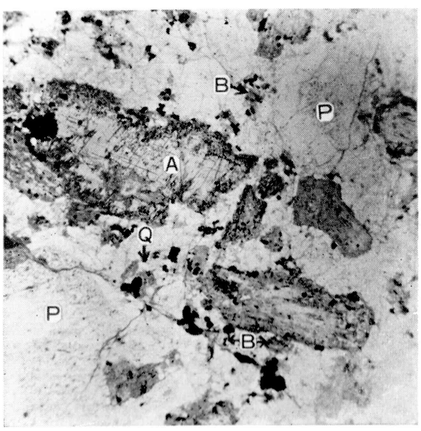
Abbreviation

A .... Monoclinic pyroxene (augite).
B .... Biotite.
Hb .... Brown hornblende.
Hg .... Green hornblende.
O .... Olivine.
P .... Plagioclase.
Q .... Quartz.



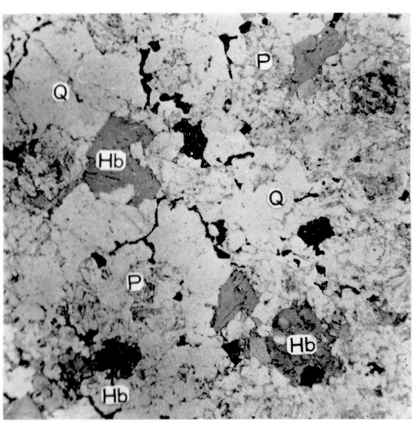
1

2

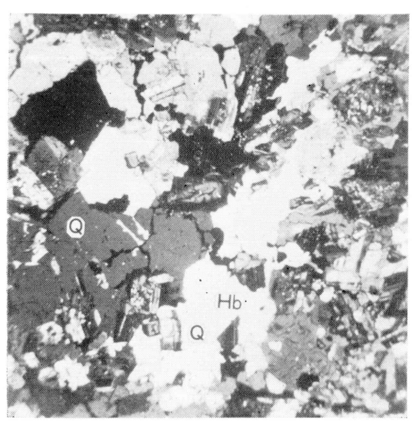


3

4



5



6

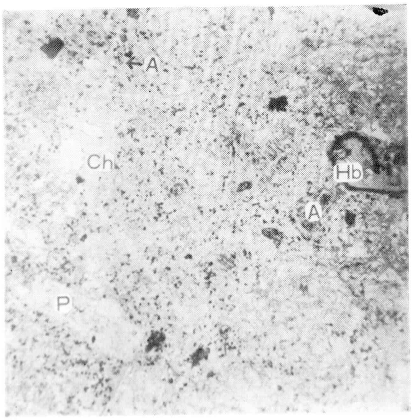
Explanation of Plate L

All figures $\times 17$

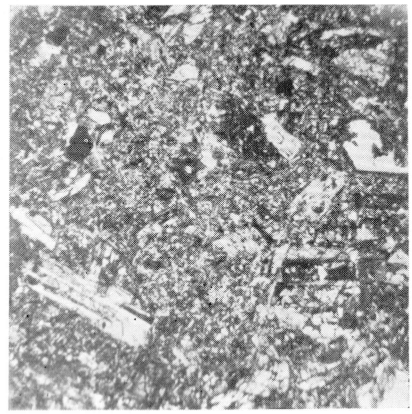
FIG. 1. Saruo-no-taki dikes. Porphyritic facies from Yaidani pass. Lower nicol only.
FIG. 2. *ibid.* Crossed nicols.
FIG. 3. Saruo-no-taki dikes. Dioritic facies from Saruo-no-taki. Lower nicol only.
FIG. 4. *ibid.* Crossed nicols.
FIG. 5. Tentaki lava. Crossed nicols.
FIG. 6. Basaltic dike. Lower nicol only.

Abbreviation

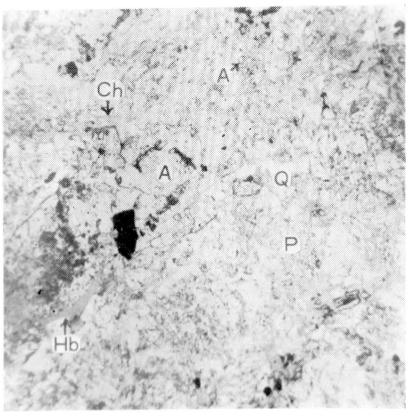
A .... Monoclinic pyroxene (augite)
B .... Biotite.
C .... Calcite.
Ch .... Chlorite.
Hb .... Brown hornblende.
O .... Olivine.
P .... Plagioclase.
Q .... Quartz.



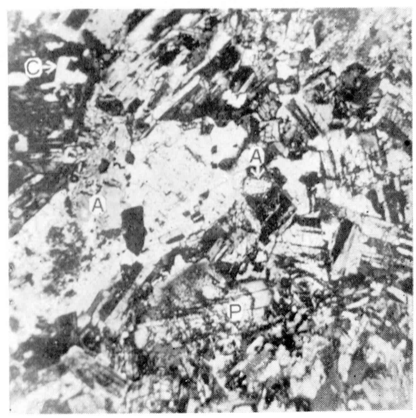
1



2

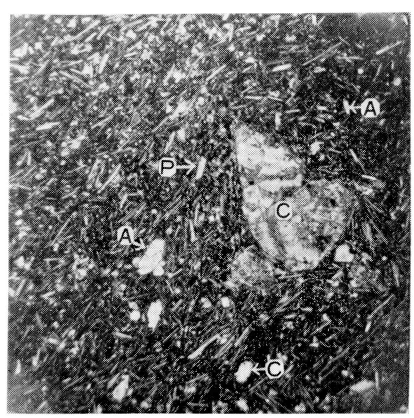


3



4

5



6