ESTADOS UNIDOS MEXICANOS

REPORT ON GEOLOGICAL SURVEY
OF
THE COAHUILA AREA, NORTHERN MEXICO

PHASE Ⅳ

GEOLOGICAL SURVEY
GEOPHYSICAL SURVEY
DIAMOND DRILLING

FEBRUARY 1979

METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

PREFACE

The Government of Japan, in response to the request of the Government of Estados Unidos Mexicanos, decided to conduct the Cooperative Mineral Exploration Project in the Coahuila area, northern Mexico and has entrusted its execution to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The Project started in 1975 under close collaboration with el Consejo de Recursos Minerales (CRM). Aeromagnetic survey, geological survey, geochemical prospecting, LANDSAT data analysis, photogeology, geophysical survey and diamond drilling were to be done in four years.

Between June 25 and December 10, 1978 the Metal Mining Agency of Japan dispatched a survey team headed by Mr. Motomu Kiyokawa and conducted geological survey, geophysical survey and diamond drilling for the Phase IV of the project.

This report hereby summarizes the outcomes of the Phase IV. Subsequently, the consolidated report will be prepared.

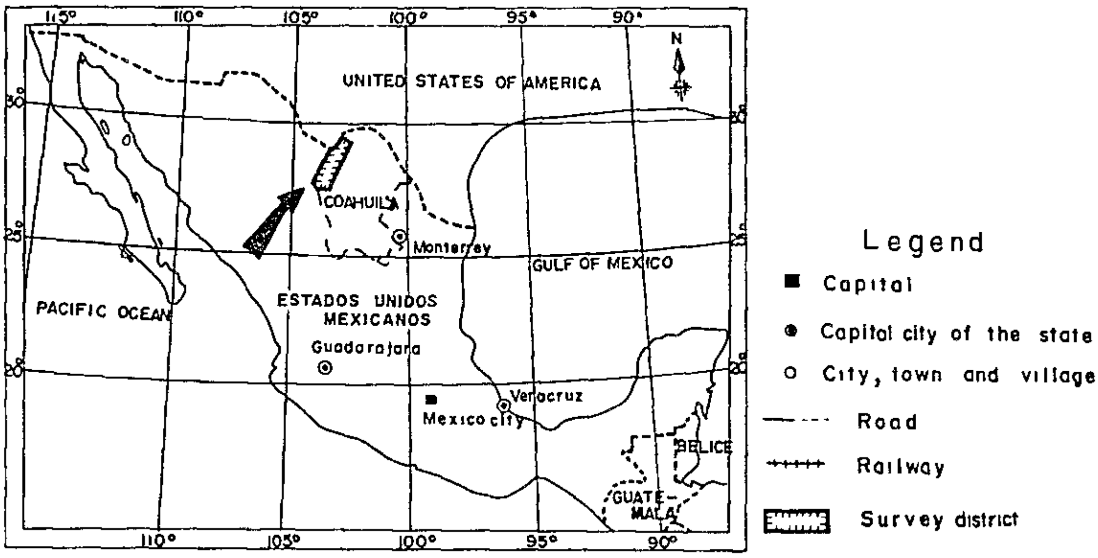
We wish to express our heartfelt gratitude to the Government of Estados Unidos Mexicanos, el Consejo de Recursos Minerales and other authorities conversed for their kind cooperation and support extended to the survey team.

February, 1979

Shinsaku Hogen
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

Fig.1 LOCATION MAP OF THE PROJECT DISTRICT



ACCESSIBILITY MAP

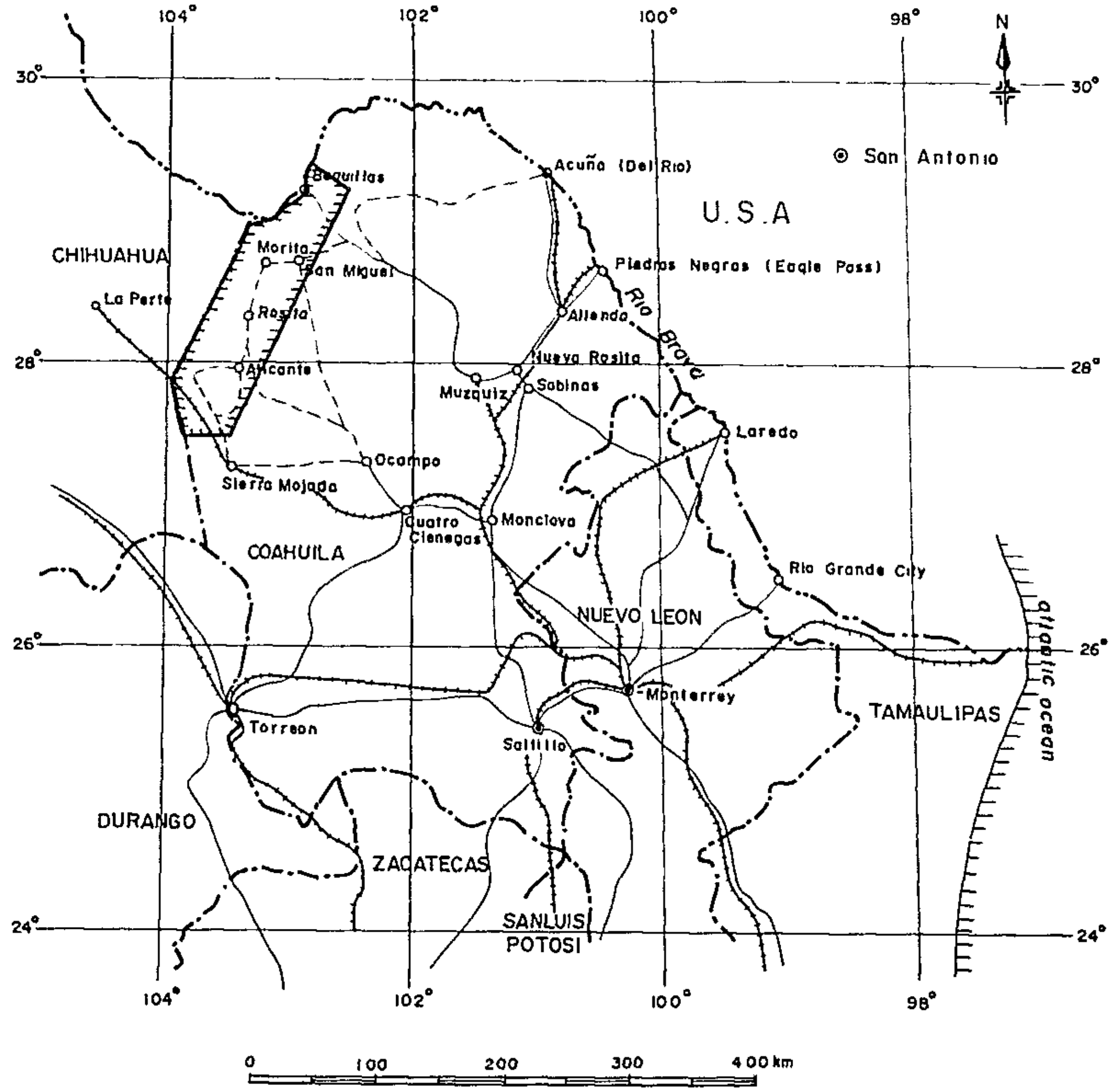
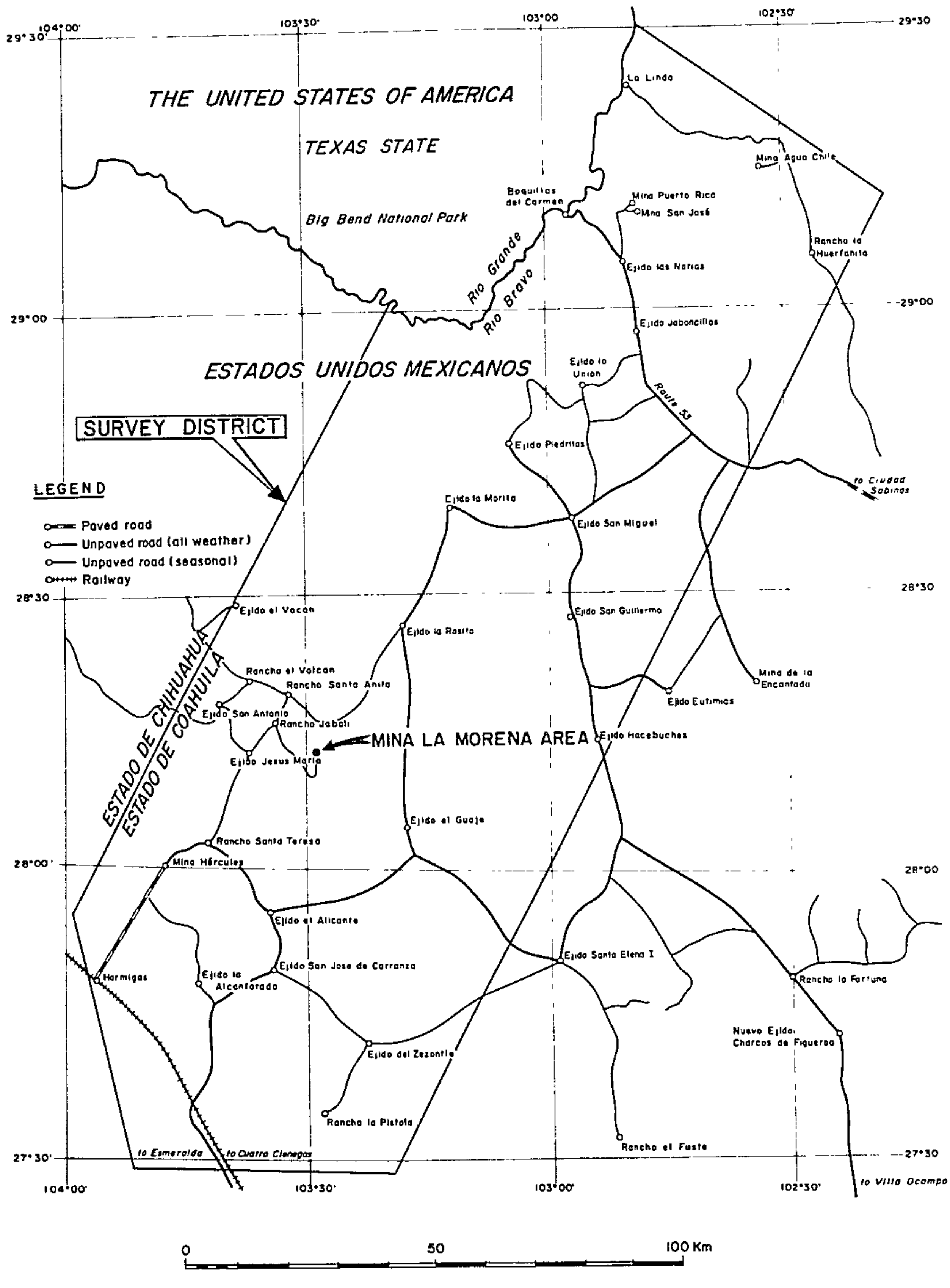


Fig.2 LOCATION MAP OF THE SURVEY AREA



SUMMARY

The present phase survey, comprising the detailed surface geological survey in an area of 6.25 km^2, the geophysical survey of IP method with 34.9 total line-kilometers and the diamond drilling with 1,240.90 m total length, was conducted in and around Mina la Diana in the Mina la Morena area which had been recommended as the most promising target for further exploration after the comprehensive investigation on the survey results up to the third phase.

As the results of this phase survey, various important data regarding the mineralization of this area were obtained. Those are summarized as follows:

Geology and Ore Deposits

The survey area is located in and around an anomalous topographic hollow on the southwestern wing of the Sierra la Morena anticrinorium which is inferred to have been formed in the principal folding stage (45 to 35 x 16^6 K-Ar age, middle Eocene to early Oligocene) of the Laramide orogeny, and is composed of limestone-predominant calcareous sedimentary rocks of the Aurora formation which belongs to the Albian stage of earlier Cretaceous.

These calcareous sedimentary rocks were affected by the Laramide orogeny, subsequent tectonic movements and intrusive igneous activity structurally, resulting in complicated structures of folds and fractures.

A concealed igneous rock intruded into the Aurora formation presumably in Neogene age, and brought thermal metamorphic zones composed of skarn minerals-bearing recrystallized zone, saccharoidal recrystallized zone and fine-grained recrystallized zone from inner to outer showing a eccentric zonal arrangement.

It is also inferred that this area was subjected to the younger regional stress resulting in "younger fractures" within the thermal metamorphic zone at the end of the intrusion, and that the hydrothermal mineralization at the end of the intrusive igneous activity took place along these fractures.

Mineralization in this area is relatively intensive and mostly of vein filling and replacing the NE-SW fractures in the Aurora formation. Manto-type bonanzas controlled by the bedding planes and pelitic calcareous layers are also locally observable. These ore deposits in this area are characterized by relatively high grade of silver and copper, and poor in lead and zinc, so that these ore deposits might be properly referred as hydrothermal silver-bearing copper deposits of vein-type, showing a peculiar phase of non-ferrous metallization of the vein-type in the project district where it shows relatively high grade of lead and zinc generally. The distribution of ore deposits in this area is limited in a belt of 900 m wide on the rim of the thermal metamorphic zone.

From the relative abundance of the metallic elements such as Ag, Cu, Pb and Zn, a zonal arrangement of ores is recognized, in which very high Cu zone defined by $Cu/(Pb+Zn) \geqq 3$, high Cu zone by $Cu/(Pb+Zn) \geqq 1$ and high Zn zone by $Cu/(Pb+Zn) < 1$ are arranged from inner to outer. The zonal arrangement of ores does not correspond with that of thermal metamorphism. The very high Cu zone is located in and around the distribution of the sericite-qartz rock. Most of the ores which have the significant metal contents of $100\ g/t \leqq Ag$ and/or $0.1\% \leqq Cu$ occur within the thermal metamorphic zone, of which high-grade ores of copper and zinc (more than 1% each) are mostly localized in the high Cu zone.

Under the environment of semi-arid climate, these ore deposits are strongly subjected to supergene alteration represented by oxidation, and are exposed as iron oxides-predominant oxidized ores. Oxidation is recognized even in the depth of 300 m or more. In some parts, however, where gypsum occurs abundantly to enclose the sulfide minerals, primary sulfide ores still remain. Secondary enrichment and remarkable leaching of metallic elements in shallow depth zones are locally recognized, but the secondary removal of major metallic elements due to supergene alteration is estimated to be minor.

Problems for Future Exploration

All of the ore deposits and showings recognized in this area by the exploratory works up to the present survey are considered to be hydrothermal vein-type deposits in the calcareous sedimentary rocks of the Aurora formation. It is certain, however, that the La Peña and the Cupido formations lie beneath the area. The La Peña formation is porous and dominant in pelitic sedimentary rocks, while the Cupido formation is assumed to provide some favorable conditions for mineralization, because the majority of silver-bearing lead-zinc vein-type deposits in this district occur in it. From these features, it is presumable that some bonanzas could be formed in the above two formations, especially in the Cupido formation. Information on the mineralization in the above two formations is considered to be most important for evaluation of the ore deposits in this area.

Although the concealed igneous rock is considered to be one of the most important factors to control the mineralization in this area, the skarnization due to the igneous rock is very weak in the Aurora formation as far as the available data indicate. It possibly suggests that the volatile elements derived from the concealed igneous rock were mostly consumed to form skarn in the underlying Cupido formation. This problem should be solved in near future.

Future Exploration

As far as the horizon of the Aurora formation is concerned, the following areas should be drilled to make clear the distribution of the sericite-quartz rocks and the mineralization in them, and to confirm the lower continuance of known ore bodies, that is, (1) the lower part of the skarn minerals-bearing recrystallized zone, (2) the eastern part of the thermal metamorphic zone, (3) the mineralized zone and veins of NE2, NE3 and NE4 in the northeastern part of the thermal metamorphic zone, (4) N4 mineralized zone in the northern part of the thermal metamorphic zone, and (5) the chargeability anomaly of P.

For the exploration of deeper horizons of the La Peña and the Cupido formations, the area where the Kau I unit is exposed as widow is considered

to have advantage from view of the depth to the above-mentioned formations, where the top of the Cupido formation is estimated to be reachable at the depth of approximately 300 m from the surface. In the southwest of the area, however, it is estimated to be much deeper and a depth of about 600 to 800 m would necessary.

For future exploration as mentioned above, it is necessary to consider that various structures concerning the mineralization in this area, such as concealed intrusive igneous rock body, thermal metamorphic zone, mineralized zone, etc. tend to plunge to the northwest or north-northwest, and that the ore deposits in this area are probably formed under the same activity of mineralization as those located to the north of the area such as Mina la Morena and Mina el Refugio. Also the electric potential method using drill holes would be useful to obtain the structural information of the ore bodies.

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INTRODUCTION

1. PURPOSE OF SURVEY

This project, started in 1975, is now in its fourth phase corresponding to the final stage.

The main purpose of the present survey was to make clear the geological details of the thermal metamorphic zone including the mineralized zone of Mina la Diana in the Mina la Morena area ranked as the most promising area by summarizing the results of various surveys from the first to third phase, and was to examine the possibility of development.

2. REASONS FOR SELECTING THE SURVEY AREA

Based on the results of various surveys from Phase I to Phase III, eight areas were selected as to be explored, among which the thermal metamorphic zones of El Volcan, south Sierra de Cruces and Mina la Morena areas were high-ranked. These thermal metamorphic zones have never been prospected systematically in spite of occurrence of prominent mineralization and high possibility of blind ore deposits. Particularly this area showed specially high outcrop grades of silver and copper, and the result was thought to have great effect to the exploration of other areas. Therefore, this area was selected as a target of survey in this phase.

3. OUTLINE OF THE SURVEY AREA

[Location and Access]

This area has a rectangular shape which occupies 6.25 km^2 in area binding the four points of 1 to 4 as shown in Table G-1, and is in the Sierra la Morena located in the southwest of the project district.

Table G-1 Location of the survey area

Corner	UTM coordinates	
	E	N
1	649,690	3,124,286
2	647,295	3,125,892
3	645,944	3,123,903
4	648,344	3,122,284

A road is running through the north and the west of the area from Ejido la Rosita, via Rancho Santa Anita, Rancho el Jabali and Ejido Jesus María, to Mina Hércules. Rancho el Jabali near the survey area can be reached in two hours and a half from Ejido la Rosita, and in an hour and a half from Mina Hércules by car.

However, the road is narrow and in bad condition, and is often interrupted during the rainy season. From Rancho el Jabali to the survey area, it takes about 30 minutes by car through the road of 4 m in breadth and about 11 km in extension newly constructed for the present survey.

[Topography and Vegetation]

This area is located in the middle north of the Sierra la Morena and mostly lies on a cuesta of the southwestern wing of the Sierra la Morena anticlinorium. This area is characterized topographically by central hollow, comparatively steep mountains of relative height up to about 200 m surrounding the hollow, and steep cliff characteristic to cuesta having the relative height of about 300 m on the northeast of the area.

The vegetation consists of scattered growth of xerophytes such as short thorny shrubs of *Fabaceae,* plants of *Agave,* evergreen shrubs of *Tribuleae,* cactuses and so on.

4. DETAILS OF SURVEY WORKS

The present survey comprises the geological survey, geophysical survey and diamond drilling. Type, quantity and term of the field works are shown in Table G-2 together with the number of engineer engaged. Also type and quantity of the laboratory works are given in Table G-3.

Prior to the field works, construction of roads in and around the survey area, and building of a wooden house (floor area : 50 m^2) for a base camp were executed.

Table G-2 Type, quantity and term of the field works

Type of works	Quantity	Term	Member	
			Japanese	Mexican
Geological survey	6.25 km^2	Jun. to Dec.,1978	4	4
Geophysical survey	34.9 line-km (by I.P.)	Jun. to Aug.,1978	1	2
Diamond drilling	1240.90m, 5 holes	Jul. to Nov.,1978	3	2
Road construction	11.0 km	Jun., 1978		
House construction	1 house (50m^2)	Jun., 1978		

Table G-3 Laboratory examination

Type of examination		Quantity			Place of work
		Geological survey	Geophysical survey	Diamond drilling	
Chemical analysis of rock sample		2			Japan
Chemical analysis of ore sample		104 samples 680*[1] elements		94 samples 746*[2] elements	Mexico and Japan
Microscopic observation of thin section		27		25	Japan
Microscopic observation of polished section		16		17	Japan
X-ray powder diffraction		5		8	Japan
K-Ar age determination		2			Japan
EPMA	Sample	6		9	
	Spot analysis	22 spots		18 spots	
	Line scanning	3 lines			Japan
	Characteristic X-ray image	2 scenes		2 scenes	
Measurement of resistivity and frequency effect			23		Japan

Remarks : *[1] : including 183 elements reanalized,
*[2] : including 166 elements reanalized.

The geological survey was conducted on a scale of 1 : 1,000 along the gephysical survey lines spaced 100 m apart from each other and the additional lines lying in the extention of main lines and between the main lines. Important outcrops were also sketched in details. The results were arranged and compiled on the topographic map of a scale of 1 : 2,000 prepared by the simple surveying carried out at the time of surface survey.

The geophysical survey comprises the electrical exploration of IP method under the specifications of 23 survey lines of the planned length of 1.5 km each, line spacing of 100 m, point spacing of 100 m, electrode interval coefficient of n = 4 with the dipole-dipole configuration. Results were summarized on the topographic map of a scale of 1 : 5,000 having been prepared in Phase III.

Diamond drilling machine of Tone TGM-5A was used in the diamond drilling, and five holes were drilled by all-coring wire line method. The total drilling length reached up to 1,240.90 m.

5. MEMBERS

Personnel engaged in the project are as follows:

Japanese counterparts

a) First Mission
(Conference for this year's program)

Mitsuru Suemori	(Japan International Cooperation Agency)
Tsuyoshi Konno	(Metal Mining Agency of Japan)
Kenji Sawada	(ditto)
Yukio Harada	(Metal Mining Agency of Japan, Representative of Mexico Office)
Motomu Kiyokawa	(Metal Mining Agency of Japan)

b) Second Mission (Field survey)

Motomu Kiyokawa	(Head of the Mission, geologist, Metal Mining Agency of Japan)
(Geological survey)	
Hiroshi Miyajima	(Geologist, Metal Mining Agency of Japan)
Akio Abe	(ditto)
Tetsuo Sato	(ditto)

(Geophysical survey)

Takao Ogawa	(Geophisicist, Metal Mining Agency of Japan)

(Diamond drilling)

Hisao Ataku	(Drilling engineer, Metal Mining Agency of Japan)
Suekichi Kikuchi	(ditto)

Mexican counterparts

Guillermo P. Salas	(Director General del CRM)
José L. Lee Moreno	(Gerente, Gerencia de Estudios Especiales del CRM)
Mauricio de la Fuente D.	(Gerente, Gerencia de Geofisica del CRM)
Gustavo Camacho Ortega	(Jefe de Departamento Estudios Regionales del CRM)

(Geological survey)

Panfilo Sanchez Alvarado	(Geologo, Departamento de Estudios Regionales del CRM)
Hector Perez Martinez	(ditto)
Miguel A. Olvera Cano	(ditto)
Gerardo Gonzalez Faustino	(ditto)

(Geophysical survey)

Gilberto Paredes R.	(Geofisico, Gerencia de Geofisica, CRM)
Mario Alvear Vigueras	(ditto)
Jesus Garcia Pineda	(ditto)

(Diamond drilling)

Javier R. Rodoriguez Hernandez	(Sabinas Office, CRM)
Eligio Arellano Vasques	(ditto)

6. ACKNOWLEDGEMENTS

The writers are mostly grateful to Dr. Hideo Takeda associate geologist of CRM, dispatched from Geological Survey of Japan by JICA, for his kind support and useful information. Ing. Esteban Lerma, mine manager of Mina Hércules, is also thanked for his support and help to the field survey.

PART I

GEOLOGICAL SURVEY

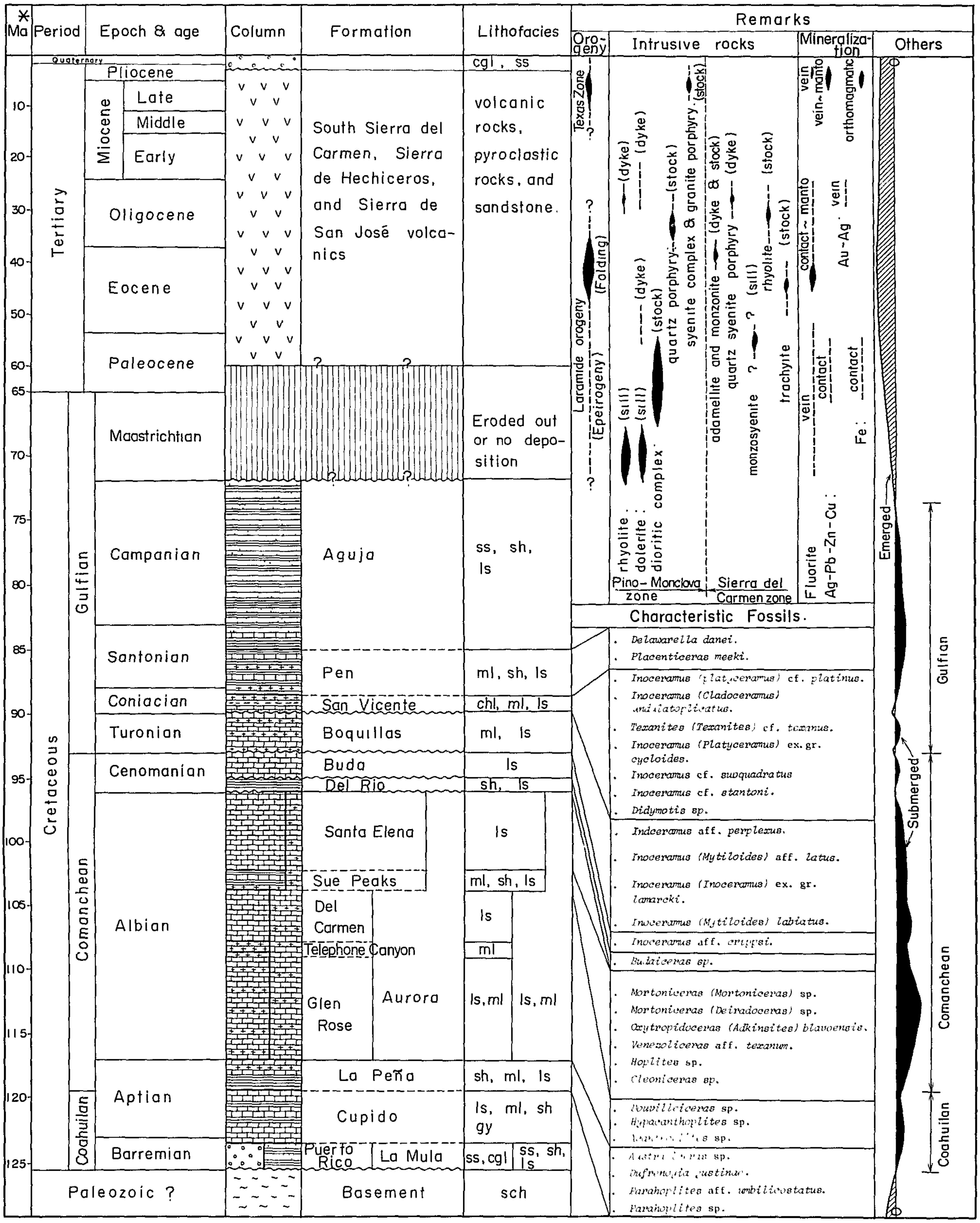
1. OUTLINE OF GEOLOGY

The project district lies north of the Sabinas Bay of late Jurassic, located northeast of the Mexican geosyncline, which is a miogeosyncline formed after the Nevadan orogeny. The basement consists of low-grade crystalline schist considered to have been metamorphosed in Palaeozoic. Cretaceous sedimentary rocks cover the basement with clino-unconformity and are thickly distributed over the whole district. Calcareous rocks predominate in the Cretaceous system. It is also the district where volcanic rocks were active in some parts during Tertiary. From late Cretaceous to early Palaeogene, it was influenced by the Laramide orogeny and was formed into blocks by the folded mountain ranges having characteristic assymmetrical folds and also by the accompanying fold-faults. In Neogene, the district was further subjected to block movements under the influence of the Texas zone. Accompanying these orogenies and volcanic activities, igneous rocks of various lithologic characters and modes of occurrence intruded in the period from late Cretaceous to late Tertiary, particularly in the northern part of the district. Fractures and dome structures formed by these tectonic movements and intrusive igneous activities often provided favorable spaces for fluorite, silver-bearing copper-lead-zinc, gold and silver, and iron mineralization, and many mines and mineral showings of various modes of occurrence and kinds of minerals are distributed throughout this district. These features are summarized in the schematic geological column of Fig. I-1.

The survey area of Phase IV is in the southwestern part of the project district. Cretaceous system is broadly and thickly distributed in and around the area, while Tertiary volcanic rocks of the lower Sierra de Hechiceros volcanics are distributed to the north of the area. The Cretaceous system in and around the area consists of several formations, namely, La Mula and Cupido formations of Coahuila series, La Peña, Aurora, Sue Peaks, Santa Elena, Del Rio and Buda formations of Comanche series, and Boquillas formation of Gulf series, among which only the Aurora formation is distributed within the area.

Intrusive rocks are relatively scarce in and around the survey area, with only a few dolerite dikes having been confirmed in the Sierra la

Fig. I-1 Schematic geological column of the survey district



Remarks : cgl : conglomerate, ss sandstone, sh shale, ls limestone, ml marl, chl chalk, sch schist
*: Different time scales are used for Tertiary (Hardenbol & Berggren, 1976) and for Cretaceous (Armstrong & McDowall, 1977).

Morena and two stocks of quartz porphyry showing K-Ar age of 35×10^6 years occurring at Cerro Blanco located about 10 kms east-northeast of the area. Also a concealed acidic intrusive rock body is assumed to lie underneath a relatively large recrystallized zone within the area, which was thought to have intruded during the age from late Miocene to Pliocene.

The area and its surroundings structurally belong to the Pino-Monclova zone as defined during Phase II. The NW-SE system fold structure and compressive fold-faults (thrusts) formed by the Laramide orogeny are well developed here. Major folds are the Sierra la Morena anticlinorium that forms the Sierra la Morena (the survey area is located at the southwestern wing of this fold) and the Palo Blanco syncline distributed to the southwest of it, while the major fold-faults are the Mina la Morena fault and El Refugio fault at the foot of the steep slope of the cuesta topography in the north of this area. In addition to these NW-SE system faults, many small NW-SE faults and folds are recognized in the area, though their dislocation and deformation are relatively minor.

Besides the ore showings located around Mina la Diana which are the object of the present survey, vein-type ore deposits are distributed in the vicinity of Mina la Morena and Mina el Refugio which lie along the above-described thrust faults.

2. GEOLOGY AND STRUCTURE

2.1 Cretaceous System

The Cretaceous system distributed in this area is composed of the Aurora formation of the Comanche series belonging to the lower Cretaceous system.

The Aurora formation mainly consists of limestone. The thickness of the formation in this area is about 837 m or more, divided into 15 units of Kau I to Kau XV in ascending order according to their lithofacies. In the geological profile, however, lower units of the Aurora formation of about 150 m thickness are thought to exist beneath Kau I, which are put together in Kau O. This division was made with the consideration to such factors as the volume ratios of marl and calcareous shale, the stratigraphic features of limestone, geological structures, etc., but it was extremely difficult to trace each unit which closely resembled each other in lithofacies on the ground surface, because of a recrystallized zone distributed in the center of the area, and also because of dislocation due to small faults.

The Kau O unit is estimated to be about 150 m thick. Since it crops out only in the flank of an escarpment on the north side of the Sierra la Morena and none within the area, its lithofacies are not clear. According to the results of Phase III, however, it mainly consists of medium-to thin-bedded dark gray limestone which becomes marly at the upper part and also accompanied with thin layers of marl.

The Kau I unit is estimated to be about 40 m thick. Its upper part crops out as window in the flank of the southwestern slope of the dividing ridge in the southeastern part of the area. The lower part of this unit forms a steep cliff on the southeastern slope of the dividing ridge and mainly consists of thick-to medium-bedded gray limestone, while its upper part forms a more gentle slope and mainly consists of medium-bedded gray limestone intercalated with thin layers of marl.

The Kau II unit is about 10 m thick and crops out on the southwestern slope of the dividing ridge. It consists of relatively thick-bedded gray limestone, and is grayish brown in color near the recrystallized zone and

mineralized zone. It is cliff-making and easily traceable.

The Kau III unit is about 24 m thick, and is distributed as window in the upper part and at the foot of the southwestern slope of the dividing ridge together with Kau I and Kau II. This unit lies below the steep cliff formed by Kau IV which is described later, and forms a gentle slope with poor outcrop. It mainly consists of thin-bedded dark gray marl and calcareous shale accompanied with thin-bedded gray limestone. Around the recrystallized zone and mineralized zone, it is brown in color and strongly stained by iron oxides.

The Kau IV unit is estimated to be about 125 m thick and widely distributed to the east of the fault which runs across the center of the area in the NW-SE direction. This unit is characterized by thick-bedded massive gray limestone. At the lower part particularly, it is thick-bedded and often forms steep cliffs. It also shows the stylolite structure. In its upper part, however, it is slightly thinner-bedded than the lower part and forms slightly rounded ridges. The bedding planes are generally uneven and irregular. In the thermal metamorphic zone at the center of this area, this unit consists of white massive saccharoidal limestone, and is penetrated by green copper-bearing calcite-quartz veinlets and iron oxide veinlets.

The Kau V unit about 12 m thick is distributed in belts on the central, northern and southern parts of the area. This unit mainly consists of thin-bedded dark gray marl with intercalation of calcareous shale and thin-bedded limestone. This unit is sometimes replaced by large calcite crystals together with the upper part of Kau IV. These parts composed of coarse-grained calcite are stained as a whole by brown iron oxides as well as the parts within the recrystallized zone.

The Kau VI unit is about 63 m thick, mainly consists of medium-to thick-bedded gray limestone, and is distributed in the northern part of the survey area, in the vicinity of the base camp, and in the middle south of the area. Being cliff-making, the unit forms stepped topography. It is accompanied with thin marl in its upper part, which is changed into white saccharoidal limestone near the base camp.

The Kau VII unit is about 7 m thick and is distributed in the north, center and middle south of the area. The unit mainly consists of marl having low resistivity against erosion and, in general, has very few outcrops. In the northern part of the area, hematitied pyrite veins of a relatively small scale, occurring in bedded form, are frequently distributed in this unit and in its vicinity, while in the south of the base camp, this unit is replaced by coarse-grained calcite.

The Kau VIII unit is estimated to be about 155 m thick, and mainly consists of dark gray limestone. It is found frequently cropping out in the syncline in the northern part of the area, in the flank of the northeastern slope of the NW-SE directing mountain range to the north-northwest of the base camp, and also along the slope of the mountains in the southern part of the area, forming rather steep slopes. This unit mainly consists of medium-to thick-bedded dark gray limestone, and at least three repetitions from thick-bedded to medium-bedded limestone are observable. A small amount of marl is intercalated in the medium-bedded sections.

The Kau IX is about 35 m thick, and consists predominantly of marl. In addition to frequent outcropping in the middle and upper parts of the northeastern slope of the mountain range to the north-northwest of the base camp, it is also distributed in blocks further toward the southeastern direction. Topographically, it has low resistivity against weathering and erosion so that a gentle slope is formed. It mainly consists of thin-bedded dark gray marl and accompanied with thin-bedded calcareous shale and dark gray limestone. On the ground surface the unit is also accompanied with dissemination of hematitized pyrite less than 1 mm in grain-diameter and clot-formed aggregate of fine-grained pyrite. Large calcite crystals occur in and below this unit which is distributed to the south of the recrystallized zone forming the topographic hollow in the center of the area, where brown-color staining of iron oxides is significant.

The Kau X unit is estimated to be about 85 m thick and is mainly distributed in the southwestern part of the area. It is cliff-making and mainly consists of thick- to medium-bedded dark gray limestone accompanied

with thin marl in the medium-bedded limestone, and the grading from thick-bedded limestone to medium-bedded limestone is repeated at least twice. Cube-shaped pyrite of sedimentary origin with a grain size of around 1 mm and clot-formed aggregate of fine-grained pyrite are also observed, but these are completely altered to hematite on the ground surface. Also, small amounts of sand pipe-like trace fossils and miliolids are found.

The Kau XI unit is about 6 m thick, consisting of thin-bedded dark gray marl and thin-bedded limestone, and is distributed in the southwestern part of the area.

The Kau XII unit is estimated to be about 45 m thick, mainly consisting of dark gray limestone with well-developed medium to thick bedding. It is mainly distributed on the southwest of the area.

The Kau XIII unit is estimated to be about 15 m thick, and distributed on the southwest of the area. It mainly consists of dark gray marl with intercalation of medium- to thin-bedded limestone.

The Kau XIV unit is estimated to be about 50 m thick and mainly consists of thick- to medium-bedded dark gray limestone. It is distributed on the southwest of the area.

The Kau XV unit is distributed only in limited localities on the southern border of the survey area, so that its thickness there can not be determined. Thickness of about 15 m or more is estimated here. This unit consists of dark gray limestone.

As previously mentioned, the Kau 0 to Kau XV units were classified lithostratigraphically mainly based on such key factors as volumetric ratio between terrigeneous fine clastics and biogeneous pelagic calcareous sediments, features of stratification, etc. The even-numbered units are those which mainly consist of limestone, while the units with the odd numbers mostly consist of sedimentary rocks rich in terrigeneous fine clastics such as marl and calcareous shale. The even-numbered unit changes gradually to the odd-numbered one, and the thickness of such a cycle ranges between 35 m to 70 m, the most frequent being around 50 m. Also the parts from Kau 0 to Kau I and from Kau VIII to

Kau XV tend to be relatively abundant in terrigeneous fine clastics, while that from Kau II to Kau VII tends to be abundant in biogeneous pelagic sediments. Such phenomena are inferred to represent either the longer cycle of the periodical changes in the hinterland which supply terrigeneous fine clastics as observed in the Glen Rose formation distributed in the north of the project district, or the protracted changes in the sedimentary environment of the Aurora formation, despite the fact that the environment in which the Aurora formation was accumulated is considered to be of a relatively stable oceanic nature.

The Aurora formation distributed in this area contains little fossils. It only contains small amounts of *Bivalvia* sp., sand pipe-like trace fossils and miliolids, and does not produce any large fossil to permit the age determination.

2.2 Intrusive Rocks

Dikes of dolerite and decite occur within the area. Also blind intrusive body of acidic plutonic rock is assumed to exist underneath the recrystallized zone at the center of the area.

(1) Dolerite

This rock intrudes as two small dikes of the NS direction at about 30 m southeast of a hill of 1,595.8 m high located southwest of the base camp, and at about 150 m north of the same hill. The former is traceable as long as about 180 m, while the latter only about 10 m. Both have widths of 1 m or less.

These dikes closely resemble in lithofacies each other, and comprise weakly carbonatized gray porphyritic igneous rock megascopically. Microscopically this rock is altered olivine-pyroxene delerite containing phenocrysts of altered plagioclase, and pseudomorphs after olivine and pyroxene replaced by chlorite and carbonate. Groundmass comprises plagioclase with alkali-feldspar rim, altered olivine and opaque mineral, and shows intergranular texture. As alteration products, sericite, chlorite, carbonate minerals, iron-oxides and quartz are found; also a small amount of biotite occurs secondarily, which

indicates that the dikes were subjected to thermal metamorphism by the concealed intrusive rock described later as well as hydrothermal alteration accompanying mineralization.

A sample obtained from the dike southeast of the 1,595.8 m hill showed K-Ar age of 20 x 16^6 years. Since the effect of thermal metamorphism is possible in the sample besides being subjected to carbonization and silicification, it is highly probable that the dike might actually be much older.

(2) Dacite

This rock crops out as a small dike of the NW-SE direction in the saddle of a small hill about 450 m northwest of the base camp.

Megascopically it comprises porphyritic rock of fluidal texture of graysh white in color. Also phenocrysts of quartz, plagioclase, hornblende, etc. are recognized. Microsopically, pheocrysts of quartz, plagioclase, potash feldspar, hornblende and magnetite are recognized, of which feldspars are partly sericitized. The core of hornblende phenocryst is altered to oxy-hornblende, iddingsite and chlorite, and the rim of the crystal is changed into opacite. The groundmass shows fluidal texture weakly and consists of lath-shaped plagioclase, apatite, fine-grained magnetite and glass extremely devitrified and changed into quartz and plagioclase. As secondary minerals, a small amount of carbonate minerals and quartz occur in the groundmass. It is hornblende-bearing dacite.

It is relatively fresh in appearance and inferred not to have been subjected to thermal metamorphism.

(3) Concealed Intrusive Igneous Rock

The survey of Phase III revealed the possibility of concealed acidic intrusive rock, considered to have intruded sometime during late Miocene to Pliocene below the thermal metamorphic zone distributed at the center of this area. Because of the maximum horizontal width of the thermal metamorphic zone around the intrusive rock

bodies in the adjacent areas, such as Sierra de Cruces complex, El Volcan granite porphyry, Cerro Chalio complex, Cerro la Vasca complex, Cerro de Minerva complex, etc., the maximum depth of the apex of the concealed intrusive rock body in this area was at first assumed to be 250 m. After the survey of this phase, however, the intrusive rock body having been assumed was recognized neither on the ground surface nor in the drill holes of maximum depth of 302.25 m. Therefore, the thermal metamorphic zone around the assumed intrusive rock body in this area is inferred to be developed upwardly much more than laterally.

As mentioned later, mineralization in this area is assumed to have been formed under the hydrothermal process caused by this concealed intrusion, and to have been controlled structurally by the concealed intrusive rock body. It was unable, however, to confirm its direct bearing on mineralization. Because no anomaly was shown on the concelaed intrusive rock body by the aeromagnetic survey of Phase I, this intrusive rock was assumed to be granitic. Since dolerite is subjected to thermal metamorphism, and shows the K-Ar age of 20 x 10^6 years, it is possible that the age of its intrusion may date as far back as to early Miocene.

(4) Sericite-Quartz Rock

This rock, encountered by DDH-M2 and DDH-M5 at the depths of 125.40 m and 147.50 to 156.75 m, respectively, occurs as mineralized fragments with diameter of 10 cm or less in quartz-cacite veins.

The rock of this kind found by DDH-M2 occurs as fragments in oxidized ore stained strongly by green copper, consists mainly of quartz and sericite, is strongly disseminated by hematite after pyrite and is stained by green copper.

The sericite-quartz rock of DDH-M5 is encountered at the depths of 147.50 m, 151.05 m, 152.85 m and 156.75 m occurring in four ore veins of the depth intervals of 147.25 to 147.85 m, 150.90 to 151.20 m, 152.55 to 153.10 m and 156.45 to 157.05 m, respectively, which are characterized by abundance of sericite.

The 147.50 m sample shows remarkably porphyritic structure represented by euhedral to subheral short prismatic crystals or spherulitic aggregates, and is dissemunated by fine-grained sulfide minerals. Microscopically, this rock is composed mainly of quartz and sericite. Sericite replaces the short prismatic to lath-shaped mineral assumed to originally be feldspar, fills the interstices of quartz grains, or occurs as spherulitic aggregates.

The samples collected at the depths of 151.05 m, 152.85 m and 156.75 m are comparatively coarse-grained and leucocratic, accompanied with sericite abundantly, and disseminated strongly by sulfide minerals such as pyrite and others. Although these rocks are so strongly altered and mineralized as to lose the original structure, sericite occurs as aggregates assumed to be pseudomorphous after phenocrystic feldspar, suggesting that the rocks would be of igneous origin.

Being unconfirmed, therefore, the sericite-quartz rock in question is possibly of igneous origin. This rock is found only in the mineral veins filling the young fractures, and restricted to occur within the skarn minerals-bearing recrystallized zone at the center of the thermal metamorphic zone. Also it is accompanied with high-grade ores of silver and copper in its hanging wall side as mentioned later. From these features, this rock is considered to be important for the further exploration in this area.

2.3 Structure

This area is located at the southwestern wing of the Sierra la Morena anticlinorium of NW-SE trend formed during the folding stage of the Laramide orogeny. While the second-to third-order fold structures develop approximately in the same direction as the above-mentioned first-order structure, there is another NE-SW system fold structure which passes from the Arroyo los Barriles through the west of the base camp, orthogonally crossing and deforming the foregoing fold structures. As the second-order structure of the NW-SE system, there is a pair of syncline

and anticline developed in the northern part of the survey area and near a creek which runs northwesterly from about 1 km northwest of the base camp. Another pair of syncline and anticline is observed about 600 m and 800 m to the southwest of the base camp. The third-order structures of the NW-SE system are the three pairs of syncline and anticline observed betwen the above-mentioned pair of folding that develops in the northern part of the survey area and in the creek northwest of the base camp, as well as another pair of syncline and anticline southeast of the base camp. As for fold structures of the NE-SW system, there is, in addition to the foregoing one that passes from the Arroyo los Barriles to the west of the base camp, a pair of syncline and anticline that provides plunge to the second- and third-order NW-SW system fold strucutes in the northern part of the area. Although the Aurora formation in this area is deformed in a complex way by these fold structures, the deformation in general is small except in the northern part of the area where the second- and third-order NW-SE system folds develop, and the Cretaceous system as a whole forms a monoclinal structure dipping at 10° to 15° to the southwest and shifts to the Palo Blanco syncline that lies southwest of the area.

Faults recognized in this area run in two different directions of NW-SE system and NE-SW system. Though the NW-SE system faults are not many, there are some like the fault that passes from about 150 m southwest of the base camp to the west bank of the creek northwest of the base camp having an estimated dislocation of one hundred and several tens of meters, and these, in general, have good continuity. Meanwhile, the NE-SW system faults in general are fractured with small dislocation and lack continuity, but they are distributed more frequently compared with the NW-SE system, particularly on the southwestern and northeastern sides of the thermal metamorphic zone distributed in the center of the area. These faults have dislocation estimated between several to several tens of meters, and are filled or replaced by calcite veins and hematite-calcite-quartz veins. While these relatively prominent faults are confirmed to have relatively good continuity as veins outside the thermal metamorphic zone, they often become obscure inside the thermal metamorphic zone. On the other hand, many calcite-quartz veinlets dis-

seminated with pyrite and accompanied with green copper stains occur to fill the minor fissures within the thermal metamorphic zone.

These NW-SE system and NE-SW system faults are inferred to have been formed as compression and tension fractures respectively, perpendicular and parallel to the axis of principal compressional stress in the Laramide orgeny. They were deformed subsequently in a complex manner by stresses which produced the NE-SW system folds and also by the intrusive igneous activities. In parts were strongly affected by thermal metamorphism due to intrusive igneous activities, these faults and fractures were filled with calcite.

3. METAMORPHISM, ALTERATION AND MINERALIZATION

3.1 Metamorphism

(1) Distribution of thermal metamorphic zone and metamorphic minerals

As frequently mentioned, right in the center of this survey area is a thermal metamorphic zone of oval shape having a major axis of about 2.4 km in the NE-SW direction and minor axis of about 1.5 km with its center located in the anomalous topographic hollow.

This thermal metamorphic zone consists of a core with a major axis of about 1.7 km and minor axis of about 1.1 km, its center being slightly biased toward southeast, and which is mainly composed of saccharoidal limestone (hereinafter referred to as the saccharoidal recyrstallized zone), and a weakly recrystallized zone surrounding the saccharoidal recyrstallized zone with a width of 80 m to 400 m (hereafter referred to as fine-grained recrystallized zone).

The thermal metamorphism observed in these recrystallized zones is mostly recrystallization of calcareous sedimentary rocks partly accompanied with skarnization. In a zone between the base camp and its southwest where small hills are distributed, vein-formed garnet and large porphyroblastic garnet occur. Also wollastonite, hedenbergite and actinolite are observable in the zone, and coarse-grained calcite and strong silificication are recognized, confirming that thermal metamorphism and hydrothermal alteration are most predominant in the zone (hereinafter referred to as skarn mineral-bearing recrystallized zone). In addition to the above, very small amounts of diopside and epidote occur in a pool within the saccharoidal recrystallized zone in the flank of the southwestern slope of the saddle-shaped divining ridge in the northeastern corner of the area. In dolerite and others which richly contain Fe, Mg and Al, biotite occurs as a thermal metamorphic mineral.

Judging from the mineral assemblage in each of these thermal metamorphic zones, it is presumed that the grade of metamorphism in the zones had risen sufficiently hgih as to allow amphibolite

facies to occur in the skarn mineral-bearing recrystallized zone and epidote-amphibolite facies in the saccharoidal recrystallized zone.

Also quartz, actinolite, chlorite, etc. which partly occur along cleavages and cracks in garnet are considered to have been formed retrogressively by the hydrothermal process following thermal metamorphism.

(2) Zonal arrangement of metamorphic zones

The fine-grained recrystallized zone, saccharoidal recrystallized zone and skarn mineral-bearing recrystallized zone which are observed in the thermal metamorphic zone are distributed in such a way that those having higher metamorphic grade are enclosed by those of lower metamorphic grade concentrically with the centers biased toward southeast. Therefore, the change from the metamorphic zone to the non-metamorphic zone is particularly pronounced in the southeastern side of the thermal metamorphic zone. Such a phenomenon is considered to reflect the mode of occurrence of the concealed intrusive rock that has direct bearing on the formation of the thermal metamorphic zone, and it is assumed that either the tongue of the intrusive rock is rising into the lower part of the skarn mineral-bearing recrystallized zone or the intrusive rock itself is dipping toward north-northwest.

3.2 Alteration

Since this area is covered entirely with a thick sequence of calcareous sedimentary rocks, wall rock alteration due to metallization is hardly recognized, but sericite, chlorite, carbonate minerals, quartz, etc. occur in dolerite, while quartz, carbonate minerals, sericite and, in rare instances, jasperoid occur in metalliferous veins. Alterations most widely recognized in all of the dikes, metalliferous veins and wall rocks are carbonitization and silicification. Carbonatization frequently occurs as coarse-grained calcite veins replacing and filling the pelitic limestone beds, faults and fractures, and as veinlets over the

whole area. Silicification is always observed in metalliferous veins, and particularly prominent among the small hills that extend southeast of the base camp, where quartz-calcite veins frequently occur.

Silicification, carbonitization, chloritization, sericitization and other sorts of alteration are considered to have taken place during the hydrothermal stage of the intrusive igneous body which is assumed to lie below and have close bearing on the formation of ore deposits in this area. Since the wall rock mainly consists of calcareous sedimentary rocks and is subjected to strong weathering which produced natrojarosite and hydroxides of iron, besides the distribution of altered zones being limited locally, it is quite difficult to establish the guide for mineral exploration taking the distribution of altered zones as a main key.

3.3 Mineralization

Many oxidized ore deposits and showing composed mainly of hematite are distributed in this area, and there are some traces of past exploration or development of small scale at Mina la Diana, at about 300 m east and at about 800 m southwest of the base camp and also in the vicinity of DDH-M2, all of them having been abandoned at present.

These deposits and showings are of vein- to manto-type controlled mainly by the NE-SW system (and partly the NW-SE system) faults, fracture zones, fissures, bedding planes, etc., and are distributed within 900 m from the outer rim of the above-mentioned thermal metamorphic zone. Their density of distribution reflects that of faults, fracture zones and fissures that existed prior to thermal metamorphism or mineralization. They appear most frequent in the northeastern and southwestern parts of the thermal metamorphic zone. Also some significant influence of their relative position to the thermal metamorphic zone is recognized. In other words, they occur with less density in the saccharoidal recrystallized zone where the fractures might possibly have been closed during the stage of thermal metamorphism, while they occur with greater density on its outer rim, in the fine-grained recrystallized zone, in the neighboring non-metamorphic part and also in the skarn mineral-bearing recrystallized zone. The density tends to decline gradually as

apart from the thermal metamorphic zone and, on the whole, appear more frequently on the northwestern side of the thermal metamorphic zone. Furthermore, the scale of metalliferous veins is influenced by their relative position to the thermal metamorphic zone and is in general correlated to the density of distribution.

Major ore deposits and showings will be described according to their geographical distribution, which have been grouped as follows in relation to the thermal metamorphic zone:

(1) Northern part of the thermal metamorphic zone,
(2) Northeastern part of the thermal metamorphic zone,
(3) Eastern part of the thermal metamorphic zone,
(4) Skarn mineral-bearing recrystallized zone,
(5) Southwestern part of the thermal metamorphic zone and
(6) Southern part of the thermal metamorphic zone (refer to PL.I-5).

(1) Northern part of the thermal metamorphic zone

Many small lenticular hematite veins and layer-formed hematite veins are distributed in the fine-grained recrystallized zone and non-metamorphic part at the fold in the northern part of the area. Of these, N1 to N8 are of relatively large scale.

N1 extends about 140 m in the N55°E direction and is traceable as a calcite-quartz vein, and accompanied with lenticular hematite vein 0.8 m wide and around 20 m long penetrated by calcite veinlets. The grade of a channel sample (10A) of this hematite vein was Ag : tr, Cu : 0.08%, Pb : 0.02%, Zn : 0.08%.

N2 is a manto-type ore body of about 1 m thick that replaced thin-bedded limestone and mainly consists of hematite. Mineralization is observed over a range of 40 m x 40 m. Around the ore body are many hematite veinlets and hematite-calcite-quartz veinlets steeply dipping and striking in N20-60°E. The grade of a chip sample (C11A) was Ag : 7.2 g/t, Cu : 0.17%, Pb : 0.02%, Zn : 0.44%.

N3 comprises calcite-quartz vein that fills a fracture zone traceable for an extension of about 200 m in the N45°E direction. It is accompanied

with lenticular hematite-calcite veins 0.3 m to 0.8 m wide and 10 to 20 m long. In the southwestern extension of this fracture zone, lenticular hematite ores of 0.3 m to 1 m long are distributed intermittently for about 300 m. Altogether, the mineralized zone is about 500 m long. A chip sample (G29A) from the lenticular ore body in the southwestern extension showed Ag : 0.9 g/t, Cu : 0.09%, Pb : 0.003%, Zn : 0.13%.

N4 is a mineralized zone accompanied with green copper showings, and crops out over a range of 140 m x 140 m, in which the thin-bedded pelitic limestone about 15 m thick is selectively mineralized. At the western tip of the mineralized zone, several hematite-quartz-calcite veins of striking to N40°E, dipping at 70°E, having the width of about 0.5 m and accompanied with green copper minerals occur in the brecciated part about 10 m wide. Reddish brown gossan of iron hydroxides is seen over the entire mineralized zone. Also silicification and argillization are recognized, and staining of green copper accompanies along the lattice-like calcite-quartz veinlets. At the lower extreme of the mineralized zone is an intensely oxidized argilliceous part which distincly delineates the boundary of the underlying non-mineralized limestone. A chip sample (C13A) accompanied with green copper shows a grade of Ag : 65.7 g/t, Cu : 3.11%, Pb : 0.02%, Zn : 2.21%, while a chip sample (E23A) of oxidized iron in vein shows a grade of Ag : 10.0 g/t, Cu : 0.05%, Pb : 0.02%, Zn : 0.33%.

N5 is a vein-type ore body in the N40°E direction that is partly accompanied with manto-like section. It comprises 3 streaks of veins of 1.2 - 0.9 m wide and 20 - 80 m long filling the fracture zone of about 1 m wide, and manto-like bonanza of 0.5 m thick (10 x 15 m) spreading along the limestone bedding. The ore consists of hematite, calcite and quartz. Although the ore is recognized only within the above range, a coarse-grained calcite vein continues for about 60 m in its northeastern extension. A channel sample (C9A) taken from the manto-like bonanza shows a grade of Au : 0.8 g/t, Ag : 11.5 g/t, Cu : 0.05%, Pb : 0.052%, Zn : 0.092%.

N6 to N8 are manto-type ore bodies that replace the pelitic part intercalated in limestone. They have strike and dip of N75-85°E and 20°N, respectively, and are distributed over the range of 150 m x 50 m. N6 has a maximum thickness of 2 m, N7 of 0.5 m and N8 of 0.8 m. All consist of iron oxides rich in hematite, accompanied by small amount of calcite.

(2) Northeastern part of the thermal metamorphic zone

Many veins of relatively high grades such as the deposits of Mina la Diana occur in the faults and fracture zones in the southwestern slope of the dividing ridge which forms the northeastern rim of the thermal metamorphic zone. Of these, the relatively long and dominant deposits are NE1 to NE4. These deposits mainly occur in the fine-grained recystallized zone.

NE1 is a mineralized zone which extends for about 600 m, occurring in a relatively large fault-fracture zone of about 20 m wide which delineates the northwestern corner of the anomalous topographic hollow in the central part of this area. Since the central part is covered by talus, mineralization there is not known in detail, only observable for about 250 m in the northern part and for about 50 m in the southern part. In the northern part, echelon veins of more than 15 small ore bodies (each ore body is about 0.5 m to 2.0 m wide and 10 to 20 m long) are observed, which comprise fissure-filling hematite-calcite-quartz veins. The grades of chip samples taken from these ore bodies are shown in Table I-1. In the southern part, a hematite-calcite vein of about 2 m wide and about 70 m long, consisting mainly of hematite is recognized, and the analytical results of a chip sample (G28A) taken from its outcrop show Au : 1.0 g/t, Ag : 12.2 g/t, Cu : 0.02%, Pb : 0.004%, Zn : 0.02%.

Table I-1 Analytical results of ores from the NE1 mineralized zone

Sample no.	Au g/t	Ag g/t	Cu%	Pb%	Zn%	Remarks
E22A	tr	3.0	0.06	0.01	0.23	Dip & strike: N30°W· 90° 2(W)x10(L)m
G34A	0.8	0.7	0.14	0.03	0.47	Dip & strike: N18°W· 60°SW 2(W)x10(L)m
G72A	0.6	189.8	0.02	0.01	0.01	Dip & strike: N30°W· 90° 4(W)x60(L)m

NE2 is a mineralized zone about 80 m wide and about 200 m long, accompanied with many hematite-calcite-quartz veins that fill the fracture zone of about 60 m wide near the NW-SE system fault. Each ore body is 0.5 m to 4 m wide and 10 to 30 m long, and many veins, striking to N30°E and dipping at 90°, occur in four belts. The ore is rich in hematite and accompanied with calcite and quartz, but no copper mineral is recognizable megascopically. The grades of chip samples taken from its outcrops are shown in Table I-2.

Table I-2 Analytical results of ores from the NE2 mineralized zone

Sample no.	Au g/t	Ag g/t	Cu%	Pb%	Zn%	Remarks
G30AP	1.5	15.3	0.04	0.004	0.08	Manto, dip & strike: N10°E·17°E,0.7(T)x 3(L)m
G31A	1.8	91.8	0.13	0.01	0.02	Vein, dip & strike: N30°E·90°, 0.4(T)x 5(L)m
G32A	tr	4.4	0.03	0.004	0.03	Vein, dip & strike: N30°E·90°, 4(T)x 10(L)m

NE3 is a vein that composes the deposit of Mina la Diana, traceable for an extension of 350 m toward the northeast from to east of its mining concession mark. This vein fills and replaces the fault-fracture zone in the N40°E-70°E direction, branching off plural veins in echelon, in parallel, or in feathery forms in accordance with the irregular changes of the fracture zone and fault. It is often observed spreading into manto-form along the bedding planes and pelitic layers, but in the topographically lower part, it crops out as a comparatively distinct vein of about 1 m wide. Its southwestern extension is not clearly defined. Mineralization is mainly observed in the fault clay zone within the fracture zone. Although very little replacement of host rock is seen both inside and outside of vein, the whole fracture zone on the ground surface is sometimes changed into hematite-rich ore, indicating that there was a secondary enrichment of supergene origin. The ore is rich in hematite and is accompanied with small amount of calcite and quartz, while green copper minerals occur in druses and porous parts. As ore minerals, native copper, native silver, cerargyrite-bromyrite, tenorite, cuprite and green copper minerals are found microscopically in addition to hematite. Assay values of chip samples taken from this vein are shown in Table I-3.

Table I-3 Analytical results of the NE3 metalliferous vein

Sample no.	Au g/t	Ag g/t	Cu%	Pb%	Zn%	Remarks
C19A	2.5	131.4	4.79	0.0075	0.83	Iron oxide ore with green copper mineral
C20A	1.5	131.4	4.92	0.70	0.39	Stock ore
C21AT	1.5	441.8	5.44	0.37	0.22	Compact hemalite ore
C22A	1.5	43.8	1.55	0.32	1.32	Compact hematite jasper
A8105APE	3.1	9,090.1	16.06	0.16	0.19	Green copper-rich ore

NE4 is a calcite-quartz vein along the fault traceable from the flank to the peidmont of the southwestern slope of the dividing ridge for an extension of about 450 m, but its continuity in the southwestern end is not clear. Within this calcite-quartz vein are hematite-calcite-quartz veins of 0.3 m to 2 m wide and 5 to 30 m long, found sporadically either as parallel veins or isolated veins. Green copper minerals are also found in veins in the piedmont, its assay value being Ag : 394.2 g/t, Cu : 25.00%, Pb : 0.012%, and Zn : 0.51%.

(3) Eastern part of the thermal metamorphic zone

A mineralized zone (E) of about 100 m wide and 350 m long is recognized extending in the N50°E direction from a small shaft and tunnel about 300 m east of the base camp to the prospecting road to its northeast. This mineralized zone consists of numerous parallel hematite-calcite-quartz veins accompanied with green copper showings and also numerous parallel calcite-quartz veins subjected to iron oxide staining, and accompanied with manto-like deposists in part. As many as 15 veins are metalliferous, and the scale of each ore body recognized on the ground surface varies widely between 0.3 m to 4 m wide and between 10 m to 120 m long. Most of the veins strike in N30 to

50°E and dip vertically or steeply toward west. They mainly consist of iron oxides such as hematite and limonite, in which green copper minerals are visible megascopically. Under the microscope, hematite, cuprite, tenortie and green copper minerals (mainly conichalcite) are recognized. As gangue minerals, calcite, quartz and gypsum are present. Willemite and zinc arsenate minerals such as austinite were found in cores of diamond drilling performed near this mineralized zone. Assay values of samples taken from this mineralized zone are shown in Table I-4.

Table I-4 Analytical results of ores from the eastern mineralized zone

Sample no.	Au g/t	Ag g/t	Cu%	Pb%	Zn%	Remarks
A8098A	1.1	545.4	7.90	0.029	19.50	Sampled from an ore stockpile
A8099A	0.6	413.9	1.68	0.027	4.30	
A8147A	tr	59.3	7.71	0.0027	21.75	Green copper mineral-rich ore
A80910APE	tr	27.9	8.03	0.019	0.25	Sampled from an ore stockpile
A8141A	1.9	13.4	0.17	0.004	0.08	Banded limonite
A8142A	tr	69.6	0.38	0.01	0.04	Banded limonite
A8143A	0.5	43.5	0.15	0.02	0.04	Porous calcite
A8101A	tr	27.9	5.83	0.041	0.72	Sampled from an ore stockpile
A8102AP	-	8.0	0.81	0.05	0.31	Dip & strike: N45°E·60°NW 2(W) x 30(L)m
A8103APE	2.0	545.4	2.40	0.16	2.08	
C5A	0.9	4.8	0.02	0.02	0.01	4(W) x 30(L)m
G67A	2.9	56.2	0.083	0.016	0.37	N45°E·90°, 1.5(W) x 20(L)m
G69A	0.5	15.3	0.13	0.01	0.31	N45°W·90°, 0.6(W) x 20(L)m

(4) Skarn minerals-bearing recrystallized zone

Within the skarn minerals-bearing recrystallized zone which extends from a small hill where the base camp is located to a small hill about 200 m west-southwest are more than 15 hematite-calcite-quartz veins of NE-SW system forming a mineralized zone of about 150 m wide and about 350 m long. Many of the veins strike N30 - 50°E and dip toward northwest at 70° to 85°, but some of the veins are seen to cross the above showing the strike and dip of N10°W·90° or to form mano-like deposits. The scale of each ore body is mostly in the range of several tens of centimeters wide and several tens of meters long, but some can be traced for several meters in width and some 100 m in length. These are characterized by intense silicification and often accompanied with garnet, wollastonite, actinolite and other skarn minerals. Ores on the ground surface mainly consist of oxidized ores with green copper stains. Microscopically, hematite, cuprite, tenorite, native copper, conichalcite, etc. are identified. Turquoise-like amorphous green copper is also present. As gangue minerals, calcite, quartz, fluorite and gypsum are recognized besides garnet, wollastonite, actinolite and other skarn minerals. Sericite, chlorite and other hydrothermally produced minerals are also present. As will be described later, veins were intersected by DDH-M1, DDH-M2 and DDH-M5 performed in this mineralized zone. In addition to pyrite, pyrrhotite, chalcopyrite, tetrahedrite, polybasite, kobellite, galena and other primary sulfide minerals, secondary sulfide minerals such as chalcocite, covelline and acanthite, elementary mineral such as native copper, halogenide minerals such as cerargyrite-bromyrite, silicate minerals such as chrysocolla and arsenate minerals such as conichalcite and mimetite were also found. In core samples obtained by drilling, siderite and jasperoid were found in addition to the above-described minerals. Table I-5 shows the analytical results of surface samples.

(5) Southwestern part of the thermal metamorphic zone

In the area between the southwestern rim of the thermal metamorphic zone and its southwestern non-metamorphic part where

Table I-5 Analytical results of ores from the skarn mineral-bearing recrystallized zone

Sample No.	Au g/t	Ag g/t	Cu %	Pb %	Zn %	Remarks
A7274APE	0.5	255.6	8.16	0.024	0.21	Massive, 2(W)x2(L)m
A8081A	tr	21.7	0.95	0.01	0.03	Network, 2(W)x20(L)m
A8091A	0.8	133.9	2.01	0.013	0.044	Vein,1(W) x 4(L)m, channel sampling (W: 0.5m)
A8092A	2.6	62.7	0.24	0.013	0.18	Channel sampling (W: 1m)
A8093A	5.8	131.2	4.53	tr	0.067	Green copper mineral-rich ore
A8094A	1.2	108.7	0.06	0.01	0.03	Hematite-calcite ore
A8095APE	1.6	757.6	5.57	0.0093	1.050	Stocked ore
E3A	-	5.0	0.04	0.03	0.04	Vein, 0.5∿0.9(W)x70(L)m iron oxide ore
G13A	tr	3.0	0.13	0.004	0.02	Iron oxide ore with green copper mineral
G87A	tr	27.5	0.05	0.003	0.02	Iron oxide ore with quartz vein
G3A	1.3	131.4	4.40	0.014	0.22	Stocked ore
G5A	tr	4.5	0.08	0.004	0.02	Vein, 0.5(W)x20(L)m, dip & strike: N55°E·90°
G80A	2.4	117.2	2.46	0.011	0.021	Vein, 0.1(W)x1.5(L)m, dip & strike:N50°∿60°E·90°, Green copper mineral-rich ore
G83A	tr	2.3	0.91	0.011	0.021	Iron oxide ore with green copper mineral
G82APT	tr	28.6	0.32	0.01	0.02	Vein, 0.1(W)x1.5(L)m, dip & strike: N82°E·65°E, iron oxide ore with skarn minerals
G85AP	0.5	12.7	0.42	0.001	0.21	Vein, 2.5∿3(W)x70(L)m, dip & strike: N50°E·90°, iron oxide ore with green copper mineral
G86AT	9.7	18.8	0.45	tr	0.25	Vein, 0.3(W)x8(L)m, dip & strike: N50°E·90°, skarn vein with iron oxide

many faults occur, there exist many vein-type and manto-type oxidized ore deposits controlled by faults, fracture zones, fissures and bedding planes, of which major ones are SW1 to SW8.

SW1 is a manto-type deposit filling and replacing a thin-bedded pelitic limestone bed intercalated in the thick-bedded limestone. Its outcrops are recognized intermittently over a range of 70 m x 150 m. The deposit strikes to N10°E, dips 10°W, and has the maximum thickness of 1 m. On its foot-wall side is an intensely oxidized calcite layer of about 1 m thick, around which several short hematite-calcite veins about 10 cm wide are recognized striking to N40°E and dipping steeply. The ore is rich in black and compact hematite, and accompanied with calcite veinlets and quartz. Assay result of a channel sample taken from an outcrop was Au : 1.8 g/t, Ag : 14.5 g/t, Cu : 0.08%, Pb : 0.03%, and Zn : 0.16%.

SW2 is a mineralized zone extending for about 350 m, and is represented by hematite-calcite-quartz and calcite veins aligned in the N25°W direction. It consists of several calcite veins and intermittent hematite-rich calcite-quartz veins. Many of the veins are of small scale ranging from 10 cm to 50 cm, but locally some are as large as 4 m wide near the pelitic rocks. Assay result of samples taken from this mineralized zone are shown in Table I-6.

Table I-6 Analytical results of ores from the SW2 mineralized zone

Sample no.	Au g/t	Ag g/t	Cu%	Pb%	Zn%	Remarks
E13A	-	10.0	0.02	0.06	0.02	Manto, dip & strike: N80°E·20°SE, iron oxide ore 1(W)x5(L)m
E18A	-	3.0	0.01	0.002	0.05	Vein, dip & strike: N40°E·90°, iron oxide ore, 3.5(W)x10(L)m
E20A	tr	0.6	0.02	0.03	0.01	Vein, dip & strike: N55°E·90°, iron oxide ore, 0.5(W)x2(L)m

SW3 is a calcite-quartz vein filling the fracture zone traceable for an extension of about 200 m. It consists of several veins running parallel and partly being accompanied with hematite-calcite-quartz veins of 0.7 m to 1 m wide and about 20 m long with strike and dip of N30-60°E and 90°. A sample taken from an outcrop of this vein shows a grade of Ag : 7.2 g/t, Cu : 0.17%, Pb : 0.02%, Zn : 0.44%.

SW4 is a vein filling a steeply dipping fault in the N65°E direction, accompanied with intermittent three ore bodies about 1 to 2 m wide and 20 to 40 m long. Mineralization is observed for an extension of 200 m. The ore mainly consists of hematite, and accompanied with calcite and quartz. Assay result of a sample (G38A) taken from an outcrop is Ag : 6.0 g/t, Cu : 0.05%, Pb : 0.01%, Zn : 0.03%.

SW5 is a calcite-quartz vein confirmed to have a strike length of about 250 m, striking to N40°E and dipping steeply toward northwest. The width of the vein varies from 0.5 m to 1 m. Hematite-rich sections of around 1 m wide and 20 m long are observed locally.

SW6 is a calcite-quartz vein accompanied partly with hematite that fills a brecciated fault zone in the N60°E direction. It can be traced intermittently over an extension of about 500 m. Sections rich in hematite are observed in the range from the fine-grained recrystallized zone to the non-metamorphic part, which partly shows traces of small-scale exploration. The ore mainly consists of hematite and is accompanied with calcite and quartz. A sample (G25A) collected near an old prospect shows an assay value of Ag : 1.4 g/t, Cu : 0.02%, Pb : 0.004% and Zn : 0.01%.

SW7 is a vein that fills and replaces the steeply dipping brecciated fault zone striking to N55°E, partially showing manto-like form along bedding plane in thin-bedded limestone. Outcrops of the vein can be traced continuously along the fault for an extension of about 400 m. In places where the vein is within the fine-grained recrystallized zone, the vein is around 1 m wide and rich in calcite and quartz. Within the non-metamorphic part, however, the vein

width sometimes reaches to a maximum of 6 m, and the ore becomes rich in hematite. The ore consists of hematite, calcite and quartz, and yellowish brown flaky natrojarosite occurs in places exposed to intense weathering. The analytical results of samples taken from this vein are shown in Table I-7.

Table I-7 Analytical results of ores from the SW7 vein

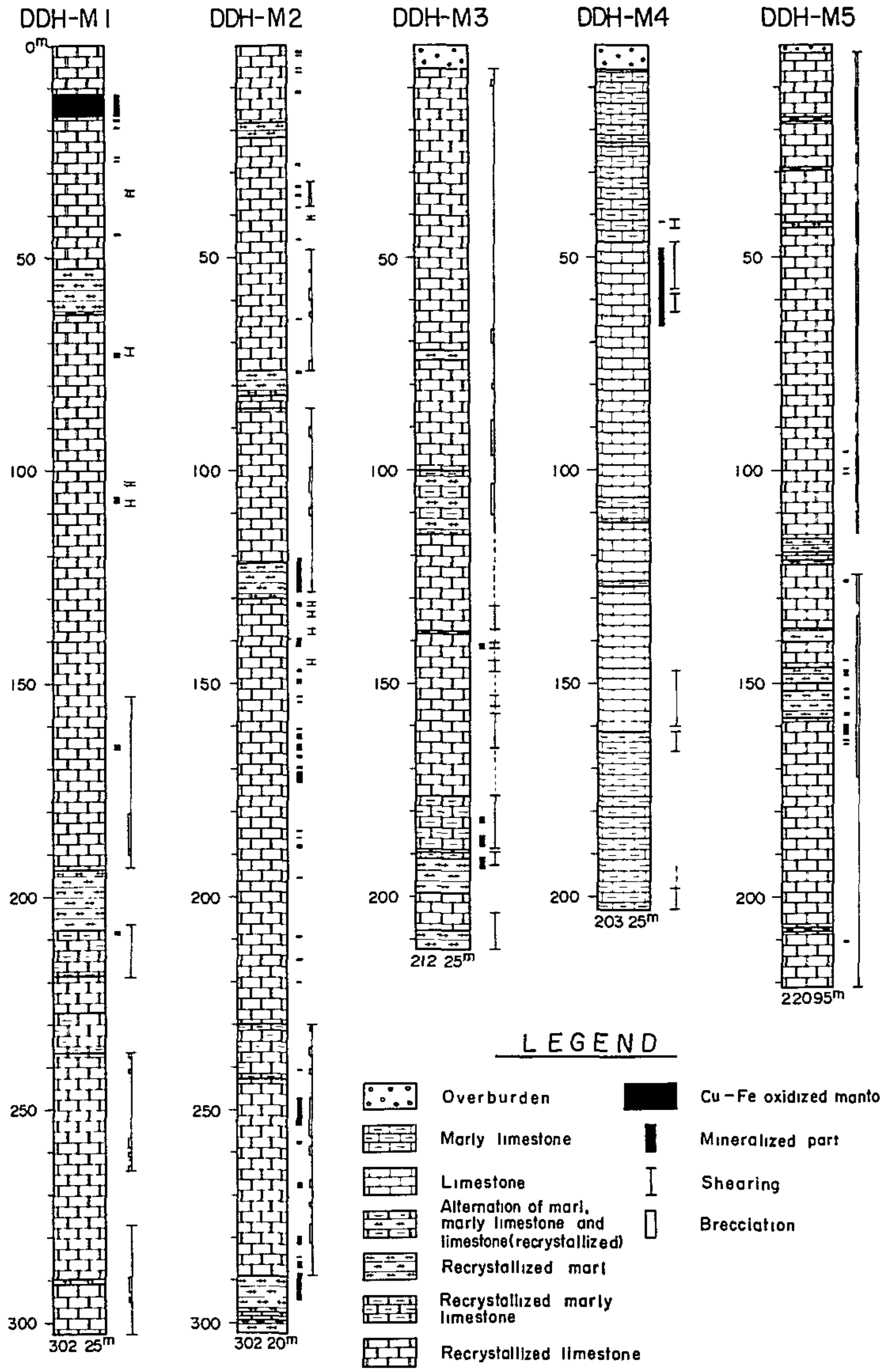
Sample no.	Au g/t	Ag g/t	Cu%	Pb%	Zn%	Remarks
E35A	tr	tr	0.0009	0.005	0.0078	Manto, dip & strike: N50°E·20°SE, iron oxide ore
E32A	tr	1.7	0.01	0.01	0.03	Vein, iron oxide ore
C8A	tr	2.4	0.15	0.02	0.04	Vein, iron oxide ore
G45A	0.4	6.1	0.04	0.03	0.04	Manto, iron oxide ore
G44APX	tr	27.5	0.05	0.01	0.03	Manto, jarosite
A8031A	tr	206.5	0.02	0.01	0.02	Vein, limonite

SW8 is a vein filling the fracture zone assumed to continue for an extension of about 350 m, and crops out for about 100 m in the southwestern part and about 50 m in the northeastern part. Both show traces of prospecting by small shafts and trenches. Outcrops in the southwestern part consist of hematite-calcite-quartz network veinlets, accompanied with green copper stains, filling minor fissures in the fracture zone of about 3 m wide, which is relatively rich in quartz. The assay value of a sample (C7A) taken in this part is Ag : 4.3 g/t, Cu : 0.64%, Pb : 0.03%, Zn : 0.04%. Outcrops in the northeastern part consist of hematite-rich oxidized ore of about 2 m wide, and branch off to two veins. Assay value of a sample (E7A) on an outcrop which is considered to be its extension shows a grade of Au : 0.5 g/t, Ag : 197.1 g/t, Cu : 2.98%, Pb : 0.018% and Zn : 4.06%.

(6) Southern part of the thermal metamorphic zone

Although no prominent mineralization is recognized in the southern part of the thermal metamorphic zone, localized mineralization is observed in the calcite-quartz vein (S1) filling the fault breccia zone of 2.5 m to 3.5 m wide, and being traceable intermittently for an extension of 300 m along the fault that crosses the southern rim of the mineralized zone in NE-SW direction. Mineralized part is 0.2 m to 2 m wide and 20 - 40 m long, strikes to N50-55°E, and dips 60°SE-60°NW. The ore consists of hematite, calcite and quartz. Assay value of a sample (A7311A) taken from an outcrop is Ag : 1.6 g/t, Cu : 0.21%, Pb : 0.01%, Zn : 0.04%.

Fig. I-2 Compiled core-log



4. GEOLOGY OF DRILL HOLES

As a part of the present phase survey, diamond drilling of 5 holes, totaling 1,240.90 m in length was performed. The results obtained from the drill cores are summarized in the geological log of drill holes on the scale of 1 : 200 (PL. III-2-(1) to (2)) together with various data of laboratory examination. Also location of each drill hole is shown is PL. III-1.

4.1 Geology and Structure of Drill Holes

4.1.1 DDH-M1 Drill Hole (Depth : 302.25 m, Vertical)

This drill hole is located about 50 m west-northwest of the base camp within the skarn minerals-bearing recrystallized zone, and its drilling was planned mainly to investigate the lower extension of the mineralized vein cropping out near the drilling site.

Geology observed in this hole is described here in detail with the correlation to the surface geology as follows:

<u>0.00 - 53.00 m</u> :

This section consists of white to light brown saccharoidal limestone, accompanied with a very small amount of acicular to granular hematitized-pyrite dissemination. It is of medium to thick-bedded limestone, occurring bedding planes at intervals of 0.1 m - 1 m (average about 0.3 m), with stylolite structure in part. Also, very thin oxidized, brownish, argillaceous layers are intercalated along the bedding planes and stylolite structures. The angles between bedding planes and a plane perpendicular to the drilling direction (hereinafter called the "apparent dip"; however, it will be simplified as "dip" in the case of a vertical drilling hole) range from 10° to 20°, mostly being approximately 15°. The section corresponds to the Kau VI unit.

Fissures are relatively scarce in this section from where mostly cylindric cores are obtained. Brecciated parts filled with calcite are, however, found between 34.10 m and 35.20 m, and open cracks heavily stained with iron oxides and green copper are also recognized in part.

As will be described later, prominent oxidized ores with distinct green copper occur between 12.05 m and 17.55 m.

<u>53.00 - 63.90 m</u> :

This section comprises brown to grayish white marl intercalated with saccharoidal limestone. Marl is difficult to distinguish from limestone, since it is recrystallized to saccharoidal, but it is recognizable by its characteristic foliated texture of iron oxide, which occur microscopically with pooled or lenticular quartz along the lamina.

Bedding planes intercalated with very thin argillaceous layers are observed in every 0.1 m to 0.4 m interval with dips of 10° to 20°. This section corresponds to the Kau V unit.

Although fissures are generally scarce in this section from where mostly cylindric cores are collected, at the depths of 53.10 m and 57.10 m, dogtooth or translucent-interstitial calcite veins about 5 cm in width and dipping 60° are observed, and also there are some streaks of calcite veinlets dipping sharply by about 75° with hematitized-pyrite dissemination.

<u>63.90 - 193.60 m</u> :

This section consists mainly of light brown to white saccharoidal limestone disseminated with a very small amount of fine-grained cubic pyrite and acicular aggregates of very fine-grained pyrite. These disseminated pyrite are oxidized and altered into hematite in the most parts and others except the part between 74.25 m and 76.20 m where fissures are extremely scarce and where they remain as pyrite. Also, where there are open cracks with distinct iron oxides stain as in between 71.80 m and 73.25 m, the limestone is stained entirely by iron oxides to show brownish color. Microscopically, a saccharoidal limestone at the depth of 86.60 m showed mostly suture-bound calcite (approximately 0.2 mm in diameter) with a small amount of sheaf-formed to acicular hedenbergite, actinolite, quartz and sericite.

Bedding planes develop every 0.2 m to 1.5 m with dips of 15° to 30°, mostly being about 20°. Calcite veins with hematitized-pyrite dissemination and dogtooth calcite frequently occur along the bedding planes. There

are also thin brown, oxidized, argillaceous beds. Stylolite structure is also observed. This section corresponds to the Kau IV unit.

In the part between 63.90 m and 152.50 m, the drilling cores are mostly cylindrical, and show scarcely open cracks but in the parts from 102.35m to 103 m, from 106.85 m to 107.20 m and distinctly disseminated parts by iron oxides mentioned above, open cracks with green copper minerals are observable and from these parts fragmental drilling cores are obtained. In addition, irregular networks of dogtooth calcite veinlets are generally developed all over the section, dipping mostly by 60° to 80°, but any mineralization is not observed with them.

The section between 152.50 and 193.20 m as a whole is severely fractured, and brown, dogtooth calcite occurs in minor fissures developping in parallel or networks. Fracturing is particularly remarkable between 180.00 - 190.00 m where limestone is fragmented to form a brecciated zone. Interstices of breccias are filled with brown dogtooth calcite, and also weak silicification is recognized. In the druses of dogtooth calcite, translucent to white calcite occurs but not mineralized. Although this section is severely fractured and brecciated, the drilling cores are mostly cylindrical in shape since interstices are filled and cemented by calcite. Open cracks are, however, observed in the parts of 158.50 - 160.30 m, 164.50 - 165.70 m, 170.90 - 173.05 m and 189.40 - 190.00 m, where the cores are fragmental in part, and conspicuously stained by dark-brown iron oxides.

193.60 - 218.25 m :

This section is composed of thermally metamorphed marl and limestone.

Marl is mostly found between 193.60 m and 207.60 m, and is difficult to distinguish from limestone because of recrystallization, but it is characterized by the banded iron-oxides stain along the laminae. It is also partly accompanied with a soft argillaceous bed about 20 cm thick. Bedding planes are observed every 5 to 20 cm interval, and thin argillaceous layers stained by iron oxides are also intercalated.

Limestone is abundant between 207.60 - 218.25 m, and is recrystallized to saccharoidal.

The bedding planes occur at intervals of 30 cm dipping by 5° - 10°. In this section, fracturing is rather weak, particularly in the part between 193.60 m and 207.60 m where marl is predominant, but in the part between 207.60 m and 218.25 m where limestone is predominant, brown dogtooth calcite veinlets occur in parallel to in networks form, and a small amount of translucent calcite also occurs in its druses. In rare instances, hematitized-pyrite calcite veinlets accompanied with green copper stain with a dip of about 60° cut these calcite veins. Cores are mostly short-prismatic or cylindric in shape, but where open cracks develop as in between 217.50 - 218.25 m, the cores are also fragmental.

This section is considered to correspond to the Kau III unit, and the boundary between this section and the overlying Kau IV unit is transitional.

218.25 - 302.25 m :

This section mainly consists of brown to grayish white massive saccharoidal, recrystallized limestone, marly limestone occurs in the parts of 226.90 - 236.25 m and 282.75 - 284.25 m, and argillaceous marl also in the part of 289.80 - 290.30 m.

As a whole, bedding planes are not so distinct, particularly in the part consisting mainly of limestone, but thick beddings of about 0.5 m to 1.5 m are observed. While marl and marly limestone parts show thin to medium beddings of about 5 - 30 cm in thickness dipping by 20° to 25°, intercalating thin argillaceous layers stained by iron oxides.

Fissures scarcely occur in the parts of 218.25 - 236.60 m and 266.45 - 277.00 m, and occur a few streaks for each meter of slightly irregular-formed veinlets of dogtooth calcite dipping by 45° - 85°. Rarely, hematitized-pyrite calcite veinlets with green copper stain (which have a comparatively straight plane dipping by about 70°) cut these calcite veinlets mentioned above.

In the section other than the above, many fissures in parallel to networks formed are distributed and are cemented by brown dogtooth calcite, suggesting that the fracturing process had probably been strong. Particularly in the parts of 236.60 - 236.90 m, 240.25 - 240.65 m, 257.60 -

258.00 m, 259.50 - 260.40 m, 260.90 - 261.45 m, 265.50 - 266.40 m, 289.20 - 293.25 m and 294.20 - 295.40 m, brecciated zones cemented by dogtooth calcite are well developed. Mineralization is recognizable only in very limited parts as hematitized calcite veins accompanied with green copper stain and dipping by 60° - 70°, however, it occurs neither in the fractured parts nor in the brecciated parts as in the non-fractured parts.

This section is considered to correspond to the upper part of Kau O and Kau I.

4.1.2 DDH-M2 Drill Hole (Depth : 302.20 m, Direction : S35°E Inclination : -80°)

This hole is located near the access road about 200 m to the west-southwest of the base camp and was purposed mainly to investigate the lower extensions of the skarn minerals-bearing recrystallized zone accompanied with garnet veins, the hematitized calcite vein rich in quartz occurring to the east of the drill site, and also the intrusive igenous rock inferred to be concealed below.

0.00 - 76.40 m :

This section consists mainly of saccharoidal recystallized limestone, intercalating recrystallized rock assumed to be marl in the part of 18.00 - 21.60 m.

The limestone is white to grayish white in color and saccharoidal, but it is light pinkish-brown in color where it is partly stained by iron oxides. Microscopically, it is composed of a lot of suture-textured calcite (0.1 mm or finer in size), interstitial aggregates of calcite about 0.6 mm in size (with a diameter of about 3 mm) are observed, and minor granular hematitized pyrite (0.02 mm).

The recrystallized rock assumed to be marl has foliated bands stained by iron oxides which are thought to have occurred along the laminae. Although the original rock cannot be identified because of strong recrystallization, microscopically, it consists mainly of an elongated arrangement of calcite with suture-bound texture (0.04 to 0.01 mm in

size) along the laminae, a small amount of pooled quartz and fine-grained cubic pyrite (mostly hematitized, with diameter of about 0.1 mm) disseminations, more over it resembles the rock assumed to be marl in DDH-M1 hole, so that this part is regarded as recrystallized marl.

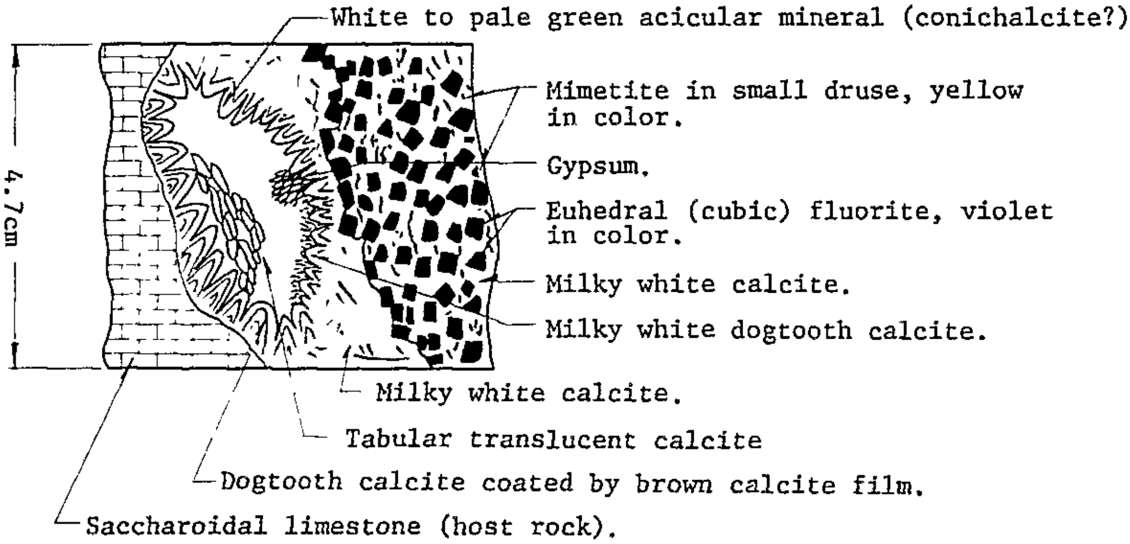
Development of stratification in the limestone part is rather weak suggesting to be thickly bedded. In the part assumed to be marl, however, bedding planes occur by an interval of 5 to 30 cm with apparent dip of 30° in parallel with laminae, intercalating thin argillaceous beds which is strongly stained by iron-oxides.

In the section of 0.00 to 48.00 m, irregular to networks calcite veinlets and hematite-calcite-(fluorite) veins are recognized, in which the former is cut by the latter and is assimilated to the host rock to become obscure the boundary suggesting to be subjected to thermal metamorphism. The latter is frequently accompanied with green copper stain and shows a distinct boundary between the host rock. In the parts 27.75 - 28.50 m and 25.95 - 26.05 m, calcite veins about 5 to 10 cm wide with many druses are also observed. Although fractures and mineralized veins (will be described later) are found in this section, they are not frequent so that cores are mostly good cylindric in shape. The cores, however, are sometimes fragmental in places subjected to iron oxides staining as in the parts of 32.00 - 38.15 m and 40.25 - 40.90 m.

Compared to the above described section, the section from 48.00 to 76.40 m is rather strongly fractured and rich in parallel to network calcite veinlets of irregular pattern. Particularly a part from 48.30 to 52.20 m is penetrated by a prominent calcite vein about 1.5 m thick with an apparent dip of about 70°. Those parts of 52.90 - 53.20 m, 57.25 - 59.90 m, 62.70 - 63.35 m and 76.00 - 76.40 m are distinctly brecciated fracture zones, also a part from 64.25 to 64.65 m are limonite veins. Although this section is rather severely fractured, most of the fractures are cemented by calcite, and cylindric cores are obtained. Fragmental cores, however, are also obtained in the above-stated limonite veins and the parts of 62.90 - 63.35 m and 71.70 - 74.00 m.

The chip sample collected from the above-mentioned prominent calcite vein (50.15 m in depth) is, megascopically, rich in fluorite, calcite and mimetite. On the rim of the vein, dogtooth calcite (of about 0.5 cm) coated by brown calcite film are recognized, and is covered by milky white to translucent tabular calcite with a well-developed C-plane. Gypsum occurs at the last stage. The part composed of fluorite, mimetite and calcite penetrates the above milky white calcite part. The details are given in Fig. I-3.

Fig. I-3 Geological sketch of core (depth 50.15m)



The sample is microscopically composed mainly of subhedral calcite accompanied by euhedral fluorite, interstitial quartz, gypsum, mimetite, zoisite, siderite, barite(?) and willemite. Also by X-ray powder diffraction, fluorite, mimetite, calcite, montmorillonite, (quartz) and (hydrated halloysite) were identified.

The above section corresponds to the Kau VI unit.

76.40 - 85.50 m :

This section consists of recrystallized marl and limestone. Marl is mostly observed in the part from 76.40 to 82.40 m and limestone in the part from 82.40 to 85.50 m.

Marl is recrystallized and shows light brown to grayish brown in color with conspicuous brownish iron oxides stain along the laminae. The apparent dips of the laminae and bedding planes are 25° - 30°, and very thin argillaceous layers stained by iron oxides are intercalated along the bedding planes in alternations of 10 - 30 cm. Fissures are scarce as a whole, but open cracks are found between 70.80 and 77.25 m.

Limestone is light brown to white in color and saccharoidal with stratification of 5 - 20 cm, and is interbedded with very thin oxidized, argillaceous layers along the bedding planes, which have apparent dips of 20° - 30°, corresponding to the dip of the overlying marl.

On the whole, minor fissures occur rather frequently, filled and cemented by dogtooth calcite veinlets. Open cracks accompanied with iron oxides stain are observable between 82.40 m and 83.85 m.

This section is considered to correspond to the Kau V unit.

85.50 - 229.75 m :

This section mainly consists of relatively thick-bedded limestone, intercalating what is assumed to be marl in the depth from 121.60 m to 130.00 m.

The limestone is white to partly light brown in color and saccharoidal, is disseminated by hematitized fine-grained pyrite, and is accompanied with a large garnet porphyroblast of 5.5 cm in diameter which occurs at the depth of 156.60 m. Bedding is relatively thick (10 to 50 cm thick). Microscopically, it is completely recrystallized and consists mainly of calcite of 0.01 - 0.02 mm in size (rarely about 1 mm) with suture-bound texture containing a small amount of quartz (below 0.3 mm) and hematitized pyrite (below 0.2 mm) scattered sporadically.

The part assumed to be marl is brownish light gray in color and thin-bedded of 5 - 15 cm thick, having relatively distinct foliation and being slightly argillaceous.

The apparent dips of the bedding planes and laminae are 20°- 25°, mostly being about 20°.

The upper part of this section (up to the depth of 128.50 m) is comparatively fractured and partly-brecciated, particularly in 89.50 - 92.35 m, 98.90 - 105.10 m and 108.40 - 110.60 m. Most of these are filled with brown to white dogtooth calcite and are recoverable as cylindric cores. But in the parts of 95.50 - 96.25 m, 103.40 - 105.25 m, 108.30 - 116.60 m and 120.50 - 128.50 m open cracks stained by iron oxides and mineralized parts accompanied by green copper are observed, from where fragmental cores are obtained. The chip sample (at the depth of 125.40 m) collected from the mineralized part between 120.50 m and 128.50 m contained sericite-quartz rock regarded as of igneous origin (to be described later).

The lower part (128.50 - 229.75 m) of this section is relatively poor in dogtooth calcite veins, but many mineralized veins accompanied by comparatively prominent primary sulfide ores (to be described later) occur. Cores recovered from this section are generally cylindrical in form except in the parts of 130.80 - 131.05 m, 135.05 - 134.15 m, 136.75-138.50 m, and 144.35 - 145.50 m where open cracks are frequent and the cores are fragmental.

This section is considered to correspond to the Kau IV unit.

229.75 - 242.60 m :

This section consists of strongly fractured saccharoidal limestone. Since a rather large amount of argillaceous substances are seen in the interstices of breccias and fissures, it is assumed to be recrystallized argillaceous or marly limestone, however, the original structure is not clear because of strong fracturing and recrystallization. Fracturing with brecciation is severe particularly in the parts of 230.35 - 231.00 m, 235.40 - 237.10 m and 240.20 - 241.20 m, but the fractured and brecciated parts are generally cemented by white to brown calcite, and cores are mostly cylindrical in shape.

Mineralization in this section is weak, and is recognized only as iron oxides stain in open cracks in general, but a iron oxides vein about 14 cm wide occurs between 240.20 m and 240.40 m.

This section is considered to correspond to the Kau III unit.

242.60 - 289.10 m :

This section lies within the severely fractured zone continued from the above described section. It comprises white to pale brown saccharoidal limestone which in general is intensely fractured and partly brecciated. Very weak dissemination of fine-grained hematitized pyrite and its acicular aggregates, is observed in the limestone, but the original rock structure as well as stratification is not distinct.

Brecciation is remarkable particularly in the parts of 247.00 - 247.90 m, 248.60 - 249.40 m, 250.15 - 250.50 m, 251.45 - 253.60 m, 254.10 - 256.10m, 258.55 - 258.90 m, 259.15 - 259.50 m, 260.00 - 260.40m, 266.30 - 266.80 m, 267.05 - 268.35 m, 271.65 - 272.15 m, 276.55 - 276.85 m, 277.60 - 277.95 m and 279.30 - 281.10 m, where the limestone is crushed into fragments of several millimeters to several centimeters. These brecciated and fractured parts are cemented by brown dogtooth calcite, and the cores are mostly cylindrical. But many open cracks stained by iron oxides are also found, from where fragmental cores are obtained.

Mineralization in this section is very weak, and mostly occurs as secondary staining in the above-mentioned parts abundant in open cracks.

This section is assumed to correspond to the Kau I and II units.

289.10 - 302.20 m :

This section consists mainly of marl with stylolite structure, also with some limestone.

The marl is brown, weakly recrystallized and argillaceous, and is mainly found in the parts of 289.10 - 297.45 m and 299.00 - 302.20 m where stratification and stylolite structure are observable in interval of 3 - 15 cm. Also along those, thin oxidized brown argillaceous layers are intercalated.

Limestone bed is intercalated in the above marl between 297.45 m and 299.00 m, and is saccharoidal, accompanied with fine-grained hematitized pyrite dessemination.

The bedding plane, although not distinct due to its rough surface, seems to have an apparent dip of about 20°.

Fracturing is weak in general, but a few minor fissures filled with dog-tooth calcite veinlets occur at a depth of 297.45 m and below. No mineralization is recognized.

This section is assumed to correspond to the Kau 0 unit.

4.1.3 DDH-M3 Drill Hole (Depth 212.25 m, Vertical)

This hole was drilled mainly for the purpose of investigating the extension of the mineralized zone with old prospecting pits that is located about 300 m east-northeast of the base camp.

<u>0.00 - 5.50 m</u> :

The section between 0.00 m and 4.75 m comprises surface soil rich in fresh limestone pebbles of gray to dark gray, and the interstices of pebbles are filled mainly by humic soil and grayish clay.

The section between 4.75 m and 5.50 m comprises mainly brown, oxidized limestone breccias of about 5 cm in maximum diameter, and the interstices are filled by brown clay. This section is the weathered zone just above the bedrock.

<u>5.50 - 100.00 m</u> :

This section consists mainly of limestone, intercalating a marly part between 71.90 and 74.20 m.

The limestone is weakly recrystallized, and is light grayish brown in color being subjected to iron oxides stain. The grade of recrystallization and decolorization is lower than the DDH-M1 and DDH-M2 drill holes. Because of overall fracturing, stratification and other structures are not distinct, but it is assumed to be of relatively thick-bedded limestone.

The marly part (between 71.90 and 74.20 m) is intensely stained with iron oxides and is brownish gray with a tinge of pink, and stratification is comparatively well developed with a dip of about 20°.

This section is intensely fractured on the whole and partly accompanied with brecciated zones. Many of these fractures are filled by brown dogtooth or white calcite, and many of the cores are in good cylindric form, but open cracks stained by iron oxides are found in part and so the cores are fragmental in this case.

Brecciated parts exist in 8.40 - 8.60 m, 9.55 - 9.65 m, 67.15 - 69.90 m, 79.85 - 80.60 m, 87.75 - 88.00 m, 89.40 - 93.35 m and 94.30 - 96.50 m, while comparatively prominent calcite veins develop in 14.25 - 16.20 m, 18.50 - 20.55 m, 34.20 - 34.50 m, 35.00 - 35.25 m, 36.85 - 37.30 m, 50.20 - 52.90 m, 58.05 - 58.60 m, 64.80 - 66.70 m, 73.80 - 74.80 m, and 79.85 - 80.90 m. Many of the calcite veins and veinlets consist of brown dogtooth calcite, and in the druses of those and in some of the fissures, white calcite occurs. Also, at the depth of 80.85 m, radial to white pulverulent barite occurs replacing the calcite vein. Although there are prominent fractures with calcite veins filling them, and metallization is hardly found in this section.

This section corresponds to the Kau IV unit.

<u>100.00 - 115.00 m</u> :

This section consists of marl and limestone. The marl is seen between 100.00 - 101.10 m, brownish gray in color and recrystallized weakly. Stratification is not distinct and the marl occurs in massive form.

The limestone is light brown in color and recrystallized weakly. Fine stratifications of 5 to 20 cm exist with intercalation of marl beds of 1 - 3 cm thick stained strongly by brown iron oxides. The apparent dip of the bedding planes are about 20°.

This section is slightly fractured on the whole, but severe fracturing accompanied with brecciation is found particularly between 103.20 - 110.30 m, where the fissures and interstices of breccias are filled by brown dogtooth calcite and white calcite. The white calcite mainly occurs in druses. Cores are mostly cylindrical, but are fragmental between 110.90 - 111.40 m, where open cracks exist.

This section corresponds to the Kau III unit.

115.00 - 176.20 m :

This section consists mainly of limestone accompanied partly with marly parts.

The limestone is brownish gray and very fine-grained saccharoidal, and is stained by hematitized pyrite very slightly on the whole. Stratification and stylolite structure occur every 5 - 30 cm, along which intensely oxidized brown argillaceous layers about 1 cm wide are often intercalated. The dip of the bedding planes is about 20°.

The marly part occurs between 137.60 - 138.20 m. It is brownish dark gray and very fine-grained saccharoidal, and is weakly disseminated by hematitized pyrite. Foliated iron oxide stains are observed throughout this part.

Minor fissures cemented by dogtooth calcite are found throughout the section, but especially the intervals of 131.60 - 137.25 m, 140.40 - 141.55 m, 144.50 - 145.40 m, 146.35 - 147.30 m, 153.00 - 155.40 m, 157.10 - 163.20 m, 164.00 - 165.50 m and 174.00 - 176.20 m are extremely fractured, and also brecciated in part. Many of these fractures are cemented by brown dogtooth calcite, and the cores are cylindrical, but open cracks exist in part where the cores are fragmental. Between 140.50 - 141.45 m, mineralization accompanied with green copper occurs (to be described later).

This section corresponds to the Kau I and Kau II units.

176.20 - 212.25 m :

This section corresponds to the geological unit summarized as Kau 0 in the geological profile and consists of argillaceous limestone, limestone and marl. This section divides, according to lithofacies and its occurrence, into the upper part (176.20 - 198.90 m), the middle part (198.90 - 207.70 m) and the lower part (207.70 - 212.25 m).

The upper part (176.20 - 198.90 m)

This part consists of argillaceous limestone, limestone and marl, and is intensely stained by iron oxides.

The argillaceous limestone occurs in 176.20 - 188.65 m and 189.25 - 190.80 m as severely fractured breccias. The breccias consist of weakly recrystallized argillaceous limestone, and their interstices are filled with brown oxidized clay and brown to white calcite. Because of the intense fracturing, stratification and other structures are not clear, but it has stylolite structure in part and also intercalations of argillaceous layers (1 to 5 cm thick) subjected to intense staining by iron oxides, all of which show a dip of about 20°.

Limestone occurs between 188.65 - 189.25 m. It is light brown and very fine-grained saccharoidal. Stratification are observed in every 7 to 10 cm, and along the bedding planes, very thin oxidized argillaceous layers are intercalated. Stylolite structure is also observable.

Marl is recognized in the part of 190.80 - 198.90 m, showing characteristic foliated structure of iron oxides along the laminae. Microscopically, this marl at the depth of 197.25 m consists mainly of fine-grained (about 0.01 mm) calcite accompanied with a small amount of larger-size calcite (about 0.2 mm), quartz, hematitized pyrite and black carbonaceous material. Larger-size calcite, quartz and hematite are arranged in pooled to foliated form along the laminae and black carbonaeous material also occurs in foliated form. The distinct foliations observed megascopically are probably formed by the arrangements of these minerals. In the parts of 190.80 - 195.00 m and 197.70 - 198.90 m, this rock is intensely oxidized and brown in color as a whole, while between 195.00 - 197.70 m, oxidation becomes slightly weaker and is restricted along the laminae where the color is brownish gray. The laminae in many cases show dips of around 20°, but in strongly fractured parts such as between 190.80 - 192.45 m, they sometimes dip by about 30°. This marl is very similar lithologically to the rock near the bottom of DDH-M2 hole which was correlated to the Kau O unit.

<u>The Middle part</u> (198.90 - 207.70 m)

This part consists of light brown micro-saccharoidal limestone, in which fine-grained hematitized pyrite dissemination is recognized. Stratification develops every 10 to 40 cm, accompanied by stylolite structure and

dipping by about 20°. Along these, very thin argillaceous beds stained by brown iron oxides are intercalated. The part of 203.75 - 207.70 m is strongly fractured with many irregular minor fissures which are filled and cemented by dogtooth calcite veinlets.

The Lower part (207.70 - 212.25 m)

This part comprises marl with extreme foliated iron oxides stain along the laminae, just like the marl in the upper part. Being heavily stained by iron oxides all over, it is of brownish color. The stain is strong particularly near the bedding and laminated planes.

The dips of bedding and laminae are approximately the same, dipping sharply by about 50°. The section is fractured entirely, and white calcite veins are seen in 210.60 - 210.85 m and 211.30 - 212.00 m.

4.1.4 DDH-M4 Drill Hole (Depth 203.25 m, Vertical)

This hole was drilled mainly to investigate the structures lying beneath the prominent IP anomalies recognized along the picket-lines L-A and L-B by preliminary interpretation of the IP electric survey, and also the relevance of these anomalies to mineralization.

0.00 - 5.90 m :

This section, which is the surface soil, abounds in fresh, small breccias of limestone with humic soil and clay.

5.90 - 23.25 m :

This section consists of drak gray to gray fresh fine-grained limestone, many of which are somewhat marly and dark-colored, with dissemination of fine-grained pyrite assumed to be of sedimentary origin. Its mode of occurrence is massive with relatively poor stratification, sporadically intercalating thin, black carbonaceous material beds 1 to 5 cm thick and thin marl beds which dip by 10° to 20°.

On the whole, fissures are scarce, appearing with a frequency of only one or two for every meter and with a dip of 60° to 70°. They are mostly filled with veinlets of white calcite and sometimes by black carbonaceous material. No mineralization occurs at all.

This section corresponds to the Kau X unit.

23.25 - 46.50 m :

This section mainly consists of fresh and slightly marly dark gray limestone, intercalated with many black carbonaceous material layers of 0.1 - 1 cm in thickness as segregate veinlets or as beds. The limestone has dissemination of fine-grained pyrites and small nodular to lenticular aggregates of fine-grained pyrites, both assumed to be of sedimentary origin.

Stratification is well developed in general, and thin to medium stratifications occurring in thicknesses of 5 to 15 cm and 10 to 30 cm are seen in 23.25 - 32.25 m and in 32.25 - 46.50 m respectively, the dips of bedding planes ranging between 10° and 20°.

In 23.25 - 41.25 m, the rock is quite fresh with few fissures, with the exception of very minor white calcite veins (dipping by 60° to 70°) occurring in part. But in 41.25 - 43.00 m, a decolorized and oxidized part accompanied with white calcite veins occurs, where a precipitation of yellowish brown to reddish brown iron oxides is noticeable, around which white calcite veinlets occur rather frequently. Although such altered parts occur partly, the majority of the cores throughout this section are good cylindrical in shape.

This section corresponds to the Kau IX unit.

46.50 - 161.25 m :

This section mainly consists of limestone, accompanying marly limestone in 106.40 - 112.25 m and in 125.90 - 127.20 m.

With the exception of the marly limestone parts, limestone is predominant throughout this section. Although the parts in 46.50 - 57.50 m and 58.65 - 62.75 m are decolorized and altered, the section for the most part is composed of fresh, grayish white, fine-grained compact limestone, and a very small amount of fine-grained disseminated pyrite of sedimentary origin are observed.

The limestone has medium to thick stratifications of 0.2 to 1.5 m thick, and in the part of medium stratification, black carbonaceous material layers of less than 1 cm in thickness and thin marl beds are intercalated dipping by about 15°. Stylolite structure is common in the limestone.

Development of fissures is weak, with the exception of the above-mentioned decolorized and altered parts, and then only one or two white calcite veins occur for every meter dipping steeply by 60° - 70°. In 46.50 - 57.50 m and 58.65 - 62.75 m, however, fissures are comparatively well developed. Particularly in 46.50 - 57.50 m, fissures are remarkably developed with brecciated zones in part, and white calcite veins of several millimeters to 10 and several centimeters fill and cement these fractures. The limestone around these fissures is decolorized and partly oxidized. Also, many closed networks of minor fissures that have become brown by oxidation are seen in 146.80 - 159.90 m, and the limestone around these has a tinge of very light brown.

Marly limestone is dark gray, fine-grained and compact, and is alternating with thin layers of black carbonaceous material of 1 to 5 cm in thickness. Stratifications are medium to thin and the bedding planes are dipping by 10° to 15°. Very few fissures are found.

This section corresponds to the upper part of the Kau VIII unit.

<u>161.25 - 203.25 m</u>:

This section is black to dark gray in color, and mainly consists of thin to medium stratified (5 - 30 cm) marly limestone relatively rich in carbonaceous material of about 0.5 to 4 cm in thickness. A very small amount of disseminated pyrites of sedimentary origin is recognized throughout.

The bedding planes are concordant with the overlying strata with dips of 10° to 15°.

Regarding fissure, in 161.25 - 167.25 m, some network to parallel veinlets of white calcite of 0.1 - 0.5 mm in thickness are observed, in 167.25 - 193.00 m, few fissures occur and only one or two fine veinlets of white calcite per every meter are observed and in 193.00 m - 198.00 m, the

rock is somewhat fractured, many veinlets of white calcite occur along bedding planes or filling network fissures and decolorization of rock and staining by iron oxides are prominent. In 198.30 - 203.25 m, development of fissures is comparatively strong and many irregular network veins of white calcite occur, some of which are nearly as thick as 10 cm. The cores recovered are almost cylindric.

This section is considered to correspond to the Kau VIII unit.

4.1.5 DDH-M5 Drill Hole (Depth : 220.95 m, Direction : N55°W, Inclination : -55°)

This hole was drilled in order to investigate, from all three dimensions, the size and mode of occurrence of the mineralized zone confirmed by the DDH-M2 hole.

<u>0.00 - 1.90 m</u> :

This section comprises surface soil layer, which is composed of pebbles of limestone and brown humic soil in 0.00 - 1.10 m, and graveles of limestone and calcite vein accompanied by brown clay in 1.10 - 1.90 m.

<u>1.90 - 116.05 m</u> :

This section mainly consists of thermally metamorphosed limestone, accompanied by recrystallized rocks which are assumed to be marl.

The limestone is white to light brownish gray in color and saccharoidal, in which dissemination of small amounts of hematized fine-grained pyrites and acicular aggregates (within 1 mm in length) of fine-grained pyrite are observed. Because of strong recrystallization, its stratification is not clear, but oxidized thin beds of brown clay, stylolite structure, thin beds replaced by iron oxides and calcite are found in part, all having apparent disp of 15° - 20°. It is assumed to be thick-stratified massive limestone.

The recrystallized rocks assumed to be marl occur in 16.90 - 18.00 m, 28.60 - 29.50 m, 41.70 - 44.15 m and 46.95 - 50.40 m. These are light brown, slightly argillaceous recrystallized carbonate rocks which are assumed to be recrystallized marl or marly limestone. Compared to

limestone, dissemination of hematized fine-grained pyrites and acicular aggregates of fine-grained pyrites are observed slightly more frequent, and stain of iron oxides is more conspicuous. Stratification is formed by thin to medium beds of 5 to 20 cm thick and their apparent dip is 15° to 20°.

In this section, fissures filled by white calcite and brown dogtooth calcite, and also fracture zones accompanied by brecciated parts are quite notable. Fracturing and brecciation are strong especially in the parts of 1.90 - 23.65 m, 25.60 - 27.90 m, 33.50 - 34.00 m*, 37.40 - 37.65 m*, 37.40 - 37.65 m*, 37.85 - 38.35 m*, 38.95 - 43.70 m, 43.95 - 45.45 m, 46.95 - 47.30 m, 49.00 - 51.35 m, 53.05 - 54.40 m, 55.30 - 55.75 m, 56.00 - 56.10 m, 56.55 - 56.90 m, 58.20 - 58.40 m, 58.75 - 59.35 m$^+$, 61.20 - 61.35 m, 63.35 - 64.10 m, 65.05 - 65.40 m, 67.00 - 69.00 m, 70.15 - 70.75 m, 73.45 - 74.65 m, 75.25 - 75.95 m, 76.20 - 76.65 m, 77.35 - 81.50 m, 81.90 - 82.95 m, 83.75 - 83.90 m, 86.55 - 87.15 m, 88.55 - 88.80 m$^+$, 91.65 - 92.50 m, 93.25 - 95.85 m^x, 96.15 - 99.75 m, 100.10 - 100.35 m, 100.70 - 101.35 m^x, 102.10 - 103.20 m$^+$, 103.50 - 104.15 m, 105.35 - 106.40 m, 106.90 - 107.40 m, 109.70 - 111.15 m$^+$ and 112.00 - 114.90 m. In the parts listed above, the parts which are not marked represent the brecciated fracture zones filled by white or brown dogtooth calcite, while those with asterisks (*) represent white calcite veins, those with plus sign (+) the fracture zones filled by brown calcite veinlets and those marked (x) the brecciated fracture zones accompanied by mineralization. These numerous fissures or fracture zones show distinct contacts with the host rock, and their apparent dips range between 45° and 85°, most of them being 60° to 75°. Besides these prominent fractures, there are many irregular network veinlets of dogtooth calcite, and straight veinlets of calcite (1 - 5 mm in width) with the sharp dip (apparent dip of 70° - 80°) which cut across the former and are accompanied with dissemination of hematitized pyrites and green copper stains. Calcite that occurs in large quantities in the structures above-mentioned comprises white calcite or brown dogtooth calcite and when both coexist, the latter is usually found covering or cutting the former.

This section corresponds to the Kau VI unit. Incidentally, there is possibility that a part of the brecciated zone developed in 1.90 - 23.65m corresponds to the lower bottom of the Kau VII unit.

116.05 - 122.05 m :

This section consists of recrystallized rocks assumed to be marl and of thermally metamorphosed limestone.

The recrystallized rocks assumed to be marl occur in 116.05 - 118.95 m and in 120.85 - 122.05 m. The rock in 116.05 - 118.95 m is light brown, slightly argillaceous and recrystallized. While the rock in 120.85 - 122.05 m is brown, argillaceous recrystallized and with the characteristic foliated texture due to iron oxides. In both rocks there are dissemination of hematitized fine-gained cubic pyrites or acicular aggregates of fine-grained pyrites. These rocks are probably marl having been recrystallized.

Limestone occurs in 118.95 - 120.85 m and is saccharoidal, in which a very small amount of hematitized pyrite dissemination is observed.

Because of recrystallization throughout the section, its stratification is not very clear, but brown thin beds of clay with an apparent disp of about 10° and stylolite structure are found in part.

Network or parallel veinlets filled by brown dogtooth calcite and straight calcite veinlets accompanied with dissemination of hematitized pyrites are observed rather frequently, and also in 118.70 - 118.90 m, there is a white calcite vein with an apparent dip of about 50°.

This section corresponds to the Kau V unit.

122.05 - 220.95 m :

This section mainly consists of thermally metamorphosed limestone, partly intercalating recrystallized rocks assumed to be marl. And there are sericite-quartz rocks assumed to be igneous rock in the ore vein parts.

The limestone is light brown to white in color and saccharoidal, and weak dissemination of fine-grained hematitized pyrites of cube or acicular aggregate are observed throughout the rock. At the depth of 125.75 m, large garnet porphyroblasts occurs. Because of recrystallization, its

stratification is unclear, but clay beds of 0.5 - 1 cm thick stained intensely by iron oxides and stylolite structure are observed in part, all with apparent dips of 15° to 20°. It is presumed to be medium- to thick-stratified limestone.

The recrystallized rocks assumed to be marl occur in 136.95 - 139.90 m, 146.10 - 149.85 m, 151.45 - 158.10 m and 207.15 - 207.85 m. Recrystallized rocks seen in these parts are somewhat argillaceous and saccharoidal in appearance, and accompany dissemination of fine-grained hematitized cubic pyrites and distinct iron oxides stain. Foliated bands stained by iron oxides along laminae are characteristic.
These rocks have relatively well-developed stratification and often intercalates brown thin beds of clay with apparent dips of 15° to 20°.

The sericite-quartz rocks are found in the veins at the depths of 147.50 m, 151.05 m, 152.85 m and 156.75 m. This rock at the depth of 147.50 m is siliceous and has distinct porphyritic texture by sericitized minerals (feldspar?) which are megascopically euhedral to subhedral prismatic or spherulitic in form. And also dissemination of pyrite and emplectite or wittichenite is observed in the rock. Microscopically, it consists of quartz, sericite and opaque minerals, accompanying a small amount of apatite, fluorite and adularia. Quartz occurs as anhedral crystal of around 1mm in diameter, and shows suture texture. Sericite occurs either filling interstices of quartz or replacing short prismatic (around 0.3 mm) to lath-shaped (0.1 - 0.4 mm) feldspar-like minerals, and sometimes occurs as specks (around 0.02 mm) within quartz. Adularia occurs mainly filling fissures and is fresh. This rock is assumed to be intensely altered acidic igneous rock.

Sericite-quartz rocks that occur at the depths of 151.05 m, 152.85 m and 156.75 m are megascopically fine-grained holocrystalline leucocratic rocks, accompanying a large quantity of sericites. Short prismatic feldspar-like minerals replaced by sericite are also observed in part. And there is strong dissemination of pyrite, emplectite or wittichenite(?) and polybasite throughout the rocks. Since the rock is intensely mineralized and fractured, the texture of igneous rocks is not clear even under microscope, but there are glomeroporphyritic quartz grains with

suture texture in part of the quartz grains within the veins. These are corroded and accompanied by specks of sericite. These rocks are assumed to be a holocrystalline acidic igneous rock like aplite.

In this section there are many white calcite or brown dogtooth calcite veins filled with pyrite, quartz, calcite and gypsum and fracture zones with brecciation, and ore veins exist mostly in the depth of 144.05 - 163.80 m (will be described later). Fracture zones with brocciation exist mainly between 124.10 - 171.90 m, and the major ones occur in 124.10 - 131.20 m, 144.05 - 144.45 m^x, 146.85 - 147.85 m^x, 149.85 - 151.20 m^x, 151.85 - 153.10 m^x, 156.45 - 157.35 m^x, 159.20 - 161.60 m^x, 162.80 - 163.80 m^x and 164.20 - 171.90 m, where they are filled and replaced by dogtooth calcite, white calcite and ore veins. Among these, the ones marked with x are the ore veins or fracture zones with ore veins. Besides these major structures, minor network or parallel fissures are relatively well developed.

From the depth of 171.90 m to the bottom of the hole (220.95 m), network or boxwork fissures filled by brown dogtooth calcite and veinlets of several millimeters to 10 cm wide exist notably. They are partly brecciated, indicating that there was intense fracturing. In this part, only a small amount of white calcite occurs in the druses of brown dogtooth calcite veins.

This section corresponds to the Kau IV unit.

4.2 Metamorphism, Alteration and Mineralization in Drill Holes

4.2.1 Metamorphism

The three holes, DDH-M1, DDH-M2 and DDH-M5, were drilled within the recyrstallized zone with skarn minerals where recrystallization and hydrothermal alteration were proved to be most prominent as a result of the surface geological survey. In these three holes, DDH-M2 and DDH-M5, were drilled near the outcrop of the garnet vein. Meanwhile, DDH-M3 hole was drilled at the eastern margin of the saccharoidal recrystallized zone, and DDH-M4 hole was drilled in the non-metamorphic part located to the south of the thermal metamorphic zone.

(1) DDH-M1, DDH-M2 and DDH-M5 Drill Holes

Calcareous sedimentary rocks found in these three holes are altered into saccharoidal limestone due to thermal metamorphism, and then the structures such as bedding and laminae and microfossils were often destroyed as a result, which often made identifying the original rock difficult. The grain size is generally coarse, about 0.1 to 0.2 mm in case that the original rock is limestone, and is a slightly finer 0.1 mm or less in case that the original rock is marl. There is no change of grain size of recrystallization by depth in DDH-M1 and DDH-M5 holes, but near the bottom of DDH-M2 hole, the grain size is slightly finer than upper part.

Skarnization is generally weak and hedenbergite, wollastonite, diopside, garnet, epidote, zoisite, and actinolite occur locally. Skarn minerals other than garnet are not recognizable megascopically, they are only found in very small amounts in thin sections, and they mostly occur in and around the ore veins.

Garnet is seen in both DDH-M2 hole (at the depth of 156.50 m) and DDH-M5 hole (at the depth of 125.75 m), occurring as large porphyroblasts of about 5 cm in diameter. The garnet in these holes is brown to yellowish brown and has a well-developed zonal structure. These garnets are fractured and along the fissures of garnet, pyrite, calcite, quartz, gypsum, fluorite, etc. occur either as veinlets or as dissemination. Since these are altered and large quantities of

iron oxides and other altered minerals occur, they are assumed to be of the andradite type. Incidentally, the depth where skarn minerals were microscopically identified are at 86.60 m in DDH-M1 hole, at 50.15 m, 156.50 m and 164.80 m in DDH-M2 hole and at 125.75 m in DDH-M5 hole.

(2) DDH-M3 Drill Hole

The rocks of this hole consist of micro-saccharoidal recrystallized calcareous sedimentary rocks, in which no skarn mineral was recognized at all.

(3) DDH-M5 Drill Hole

The rocks of this hole as a whole consist of fresh calcareous sedimentary rocks, and are not affected by thermal metamorphism.

4.2.2 Alteration

(1) Alteration in the Thermal Metamorphic Zone

Drill holes of DDH-M1, DDH-M2, DDH-M3 and DDH-M5 performed within the thermal metamorphic zone show alterations such as carbonitization, silicification, sericitization, chloritization, argillization, etc. Of these, carbonitization and silicification are commonly observed in these four holes. Sericitization is particularly prominent in parts where sericite-quartz rocks assumed to be igneous rock are found, such as in DDH-M2 hole (at the depth of 125.40 m), DDH-M5 hole (at the depth between 147.50 - 156.75 m), accompanying dissemination of pyrite, emplectite or wittichenite(?), and also weak chloritization in part. Argillization occurs mainly along the bedding or stylolite structure and is also relatively distinct in calcareous sedimentary rocks such as marl rich in fine terrigenous clastics. Oxidized brownish clay is recognizable megascopicaly, and montmorillonite, hydrated halloysite and others were identified by X-ray diffraction.

With the exception of argillization, these alterations occur only in the fracture zones accompanying ore veins and white calcite, and

also within the calcareous sedimentary rocks nearby these zones. These alterations do not spread widely in the host rock, which indicates that such alterations are closely related to mineralization. However, argillization is observed fairly spreading in the pelitic calcareous sedimentary rocks in DDH-M1 hole (between the depths of 289.80 - 290.30 m) and elsewhere.

Chlorite, calcite, quartz, iron oxides, pyrite, sericite and others occurring in the cracks of large porphyroblasts of garnet indicate that the garnet produced during the skarn stage was retrogressively altered during the hydrothermal stage, a fact that is especially important in determining the stage of mineralization in this area.

(2) Alteration in the Non-metamorphic Zone

The rocks of the DDH-M4 hole performed in the non-metamorphic area to the south of the thermal metamorphic zone comprise mostly fresh limestone, but in the places where fissures were relatively developed well and many white calcite veins occur, such as in the depth of 41.25 - 43.00 m, 46.50 - 57.50 m, 58.65 - 62.75 m, and 193.00 - 198.30 m, the calcareous sedimentary rocks were decolorized as a whole and turned into yellowish brown or reddish brown due to iron oxides stain, and also weak argillization exists in these places. These alterations are particularly prominent near the fissures and calcite veins, and there are some places in which the alterations are supposed to be spreading along bedding planes. There is no prominent mineralization in these altered zones but because of the fact that limestone is fresh on the surface, the altered zones are controlled by fissures and distribution of calcite veins and others, the alterations in these places are thought to have been brought about by hydrothermal process.

4.2.3 Mineralization

(1) , DDH-M1 Drill Hole

Mineralization in this hole occurs as manto or vein at 12 locations between 12.05 m and 209.50 m. The modes of occurrence, scales, core recovery and results of laboratory works are summarized in Table I-8. In further descriptions, the vein numbers indicated at the left of the above table will be quoted.

M1-1 Ore Body (Depth : 12.05 - 16.65 m) :

This ore body consists mainly of oxidized ores accompanied by prominent green copper stainings, and occurs replacing the saccharoidal recrystallized limestone. Although the ore body bounds on its hanging wall with rugged and irregular boundary and occasionally penetrates the hanging wall as veinlets along the fissures, the boundary is on the whole almost horizontal. Its margin on the foot wall side is clearly bounded from the host rock by an almost horizontal bedding plane, suggesting that the ore body is presumably of the manto-type.

This ore body is divisible from its appearance, into the following 5 sections: 1) between 12.05 and 13.35 m, where it is rather porous and rich in iron oxides and white calcite, 2) between 13.35 and 13.70 m, where it is porous and very rich in green copper minerals, 3) between 13.70 and 14.60 m, where it is rather compact and rich in iron oxides and slightly silicified, 4) between 14.60 and 15.55 m, where it is compact, notably silicified and consists mainly of iron oxides with breccias of the host rock recognizable in part and 5) between 15.55 and 16.65 m, where it is compact and accompanied by large quantity of green copper.

From the results of microscopic observations of typical samples collected from these sections excluding section 4), the mineralized parts of 1) to 4) are inferred to consist mainly of secondary minerals restructured from the original ore composition by supergene alteration. This is inferred from the fact that: iron oxide minerals scarcely occur as pseudomorphs after primary sulfides but

Table I-8 Analytical results of ores from DDH-MI drill hole

Vein No.	Interval (m)	Length (m)	Width (m)	Incli-nation	Core-recovery(%)	Chemical analysis									Ore minerals	Gangue minerals	Remarks
						Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	As(%)	Cd(%)	Hg(g/t)	Co(%)			
MI-1	12.05～13.35	1.30	4.60	0°	83.0	0.4	36.8	0.14	0.02	0.07	-	-	-	tr	*hm-gt	*qz-ca-fl	Manto
	13.35～13.70	0.35				8.7	121.9	4.08	0.02	0.34	2.39	0.03	1.6	tr	*hm-gt-py-cp-cn-gr·cu	*qz-fl	
	13.70～14.60	0.90			90.0	4.8	70.3	0.97	0.01	0.17	1.40	0.01	1.1	tr	hm-gt-cn-gr·cu	qz-ca	
	14.60～15.50	0.90				0.7	234.4	1.36	0.021	0.19	1.52	0.02	2.9	tr	*hm-gt-ce?	*qz-ca	
	15.50～16.65	1.15			88.7	1.4	328.1	6.80	tr	0.20	2.62	0.001	2.7	tr	*hm-gt-py-cp-ac-cc-cv-ct-tn-cn-gr·cu	*qz-ca	
	Average of 12.05～16.65	4.60	4.60	0°	87.2	2.2	161.3	2.51	0.013	0.17	1.96	0.012	2.2	tr			
MI-2	16.95～17.55	0.60	0.05	75°	100	1.4	210.9	4.99	0.01	0.11	0.20	0.03	0.72	tr	hm-gt-cn-gr·cu	qz-ca	*gr·cu-stained* vein
MI-3	19.40～19.75	0.35	0.03	90°	100	tr	17.0	0.25	0.01	0.11	-	-	-	tr	hm-gt-cn		*cn-stained crack*
MI-4	26.25～27.75	1.50	1.50	15°	36.7	3.9	46.9	0.97	tr	4.20	1.47	0.04	0.85	tr	gt	ca	*Manto?*: porous limonite
MI-5	44.30～44.90	0.60	0.01	90°	100	0.8	12.7	0.36	0.02	0.03	-	-	-	tr	hm-cn		*cn-stained* crack
MI-6	72.60～73.20	0.60	0.005	80°	100	tr	11.3	0.24	0.01	0.07	-	-	-	tr	gt		gt-cn-stained cracks
MI-7	106.75～107.20	0.45	0.01	75°	100	tr	2.8	0.11	0.02	0.04	-	-	-	tr	gt-hm-cn	ca	Oxidized vein
MI-8	158.50～158.90	0.40	0.05	75°	75.0	0.4	76.4	0.20	0.01	0.05	-	-	-	tr	gt-hm	ca	Limonite-stained fractured zone
MI-9	159.45～160.35	0.90	0.01	90°	83.0	tr	2.8	0.11	0.01	0.04	-	-	-	tr	gt-hm		Limonite-stained crack.
MI-10	164.50～165.70	1.45	0.05	85°～90°	100	tr	2.8	0.06	0.01	0.07	-	-	-	tr	gt-hm	ca	Porous iron oxide vein
MI-11	170.90～172.00	1.10	0.005	85°～90°	90.9	tr	2.3	0.14	0.01	0.11	-	-	-	tr	gt	ca	Iron oxide-stained cracks
MI-12	208.50～209.50	1.00	0.005	65°～90°	100	tr	2.3	0.29	0.01	0.05	-	-	-	tr	hm-gt-(cn)	ca	Oxidized vein
MI-13	209.50～211.45	1.95	0.005	65°～90°	100	0.4	1.6	0.05	0.01	0.03	-	-	-	tr	gt		Iron oxide-stained crack.

Note: hm: hematire, gt: goethite, py: pyrite, cp: chalcopyrite, cn: conichalcite, gr·cu: green copper, ce: cerargyrite, tn: tenorite, ac: acanthite, cc: chalcocite, cv: covelline, ct: cuprite, qz: quartz, ca: calcite, fl: fluorite. Asterisk shows that the minerals are identified under the microscope.

mainly colloform structures; few quartz occur in the mineralized part; calcite and iron oxide minerals occur paragenetically in concentric form; and quartz fragments are found. It is also inferred that the mineralized parts in section 5 is composed of the primary minerals that were altered while retaining their original textures. Restructuring of the original ore texture by the supergene process occurs in greater extent in ores that are closer to the ground surface, although such restructuring seems to take place mostly inside the ore body.

Ore minerals identified from this ore body are pyrite, hematite, goethite, chalcopyrite, chalcocite, covelline, acanthite, native copper, tenorite, cuprite and conichalcite. Calcite, quartz and fluorite are contained as gangue minerals.

M1-2 Ore body (Depth : 16.95 - 17.55 m) :

This ore body comprises a vein which fills a rather irregularly winding fissure with a dip of about 75°, and consists mainly of oxidized minerals with prominent green copper staining. Primary sulfide minerals which were altered mainly into hematite and limonite fill fissures about 3 to 5 cm wide and are accompanied by such gangue minerals as calcite and quartz. Secondary copper minerals such as conichalcite, turquoise-like amorphous green copper minerals and others occur mainly within the limestone wall rock. Also, translucent granular polyhedric calcite occurs in druses of the vein.

As this ore body is located directly below the M1-1 ore body and is likewise very rich in copper, it is assumed to be the root of the M1-1 ore body.

Veins M1-3 (Depth : 19.40 - 19.75 m), M1-5 (Depth : 44.30 - 44.90 m) and M1-7 (depth : 106.75 - 107.20 m) :

These are small-scale oxidized ore veins 1 to 3 cm wide, intensely stained by green copper and which fill fissures dipping steeply by 75 - 90° in the saccharoidal limestone. The ores mainly consist of hematitized cubic pyrite accompanied by calcite, (quartz) and (fluorite)

as gangue minerals. Green copper minerals occur mainly as films along fissures. These lack commercial value as ore deposits.

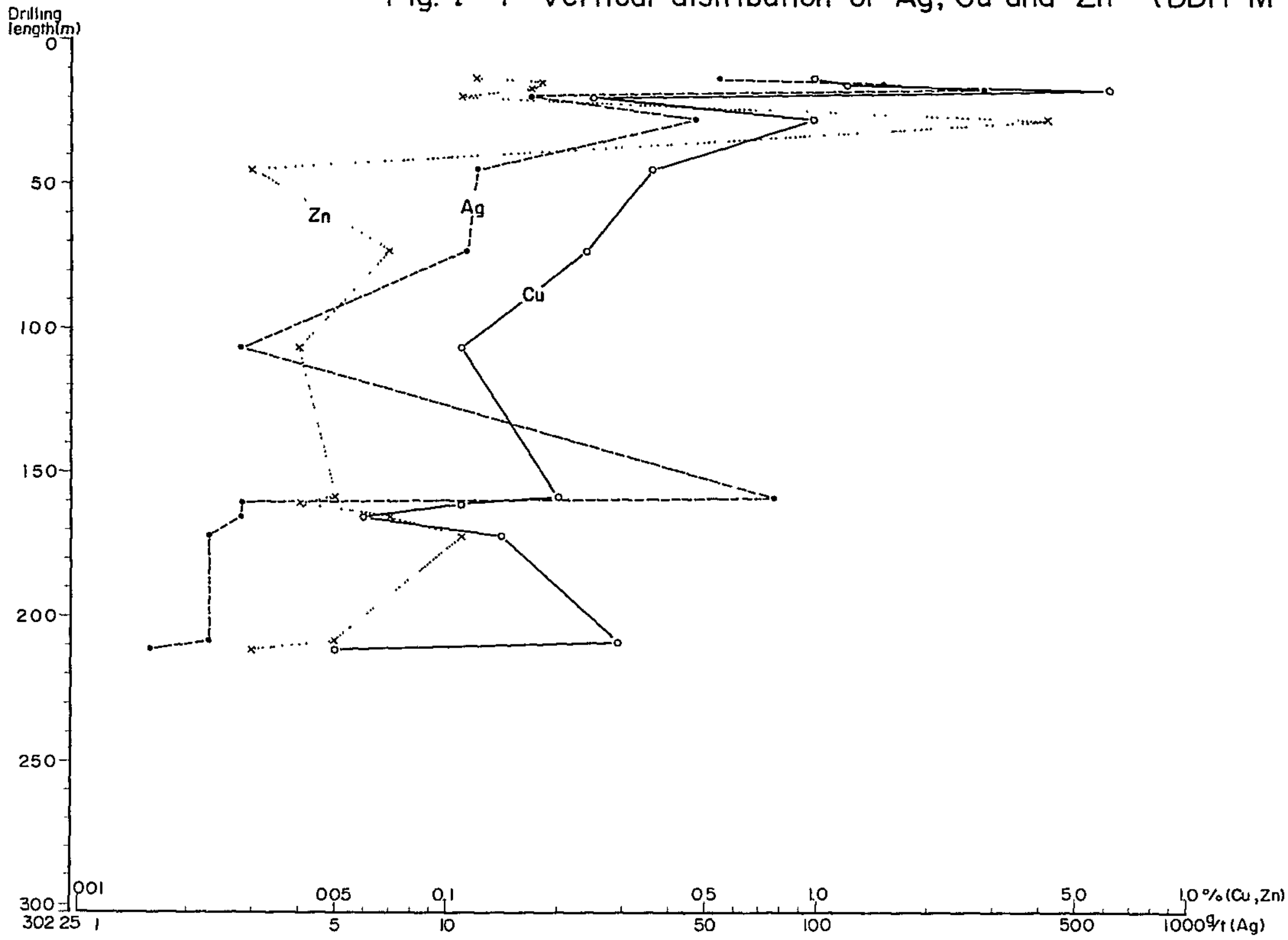
M1-4 Ore Body : (Depth : 26.25 - 27.75 m) :

Since the core recovery at this ore body was a meager 36.7%, the ore condition is not clearly definable, but the cores recovered consist mainly of porous and fragile iron oxides (mainly limonite) subjected to intense oxidation and leaching by ground water. Although the form of the ore deposit is not clear, it is assumed to be of the manto-type since the surfaces of limestones that lie above and below this ore body are strongly oxidized and both dip by about 15°. No dissemination of green copper minerals is macroscopically recognizable in this ore body.

Veins M1-6 (Depth : 72.60 - 73.20 m), M1-8 (Depth : 158.50 - 158.90 m), M1-9 (Depth : 159.45 - 160.35 m), M1-10 (Depth : 164.50 - 165.70 m), M1-11 (Depth : 170.90 - 172.00 m) and M1-12 (Depth : 208.50 - 211.45 m) :

These veins mainly fill the steeply dipping fissures in the saccharoidal limestone and the minor fissures in fracture zones. Most of them are small-scale veins less than 5 cm wide. Ores consist of strongly oxidized and stained calcite-(quartz) veins containing hematitized cubic pyrite, with frequent extending of iron oxide dissemination to the inside of host rocks but any green copper is hardly accompanied. Since the veins are small in scale and contain little metals, they have little economic value as ore deposits. Besides these rather prominent veins, veinlets less than 0.5 cm wide which fill steep-dipping fissures are observed sporadically throughout the entire section. These are calcite-(quartz) veinlets with dissemination of hematitized iron-bearing sulfide minerals. They are frequently accompanied by green copper mineral stains near hematite. These veinlets are so small in scale that they are considered not to have economic importance.

Fig. I-4 Vertical distribution of Ag, Cu and Zn (DDH-M I)



Characteristics of Mineralization in the DDH-M1 Hole :

Of analyses performed for each mineralized part described above, changes in the grades of silver, copper and zinc according to their depths are shown in Fig. I-4. Since host rocks become mixed in the analytical samples when the vein widths are less than 5 cm, the waste ratio for each vein width was calculated, then converted into each modified grade.

Similar assay charts which appear later all give the modified grades after corrections were made in the same manner.

As apparent from Fig. I-4, the mineralized zones in this hole have relatively high copper contents, and most of them show higher copper contents than zinc. Also relatively prominent mineralization occurs in places shallower than 27.75 m. Although many fissures and fracture zones also occur below that depth, most of those are filled by brown dogtooth calcite and mineralization is only found along minor fissures.

(2) DDH-M2 Drill Hole

More than 40 veins (some of these are manto-like) are observed in this hole between the ground surface and the depth of 24.40 m, while well-developed cracks disseminated strongly by iron hydroxides are observed between 240.40 and 294.25 m. Between 0.00 and 138.50 m and also between 222.45 and 302.20 m, these veins are intensely oxidized and consist mainly of oxidized ores, but between 138.50 and 222.45 m they characteristically accompany gypsum as gangue mineral and contain ores rich in primary sulfide minerals. The modes of occurrence, scales, core recovery and results of laboratory examinations of these many veins are summarized in Table I-9, and changes in the grades of silver, copper and zinc according to the drilling length are shown in Fig. I-5. The vein numbers listed at the left of this table are used in most of subsequent descriptions.

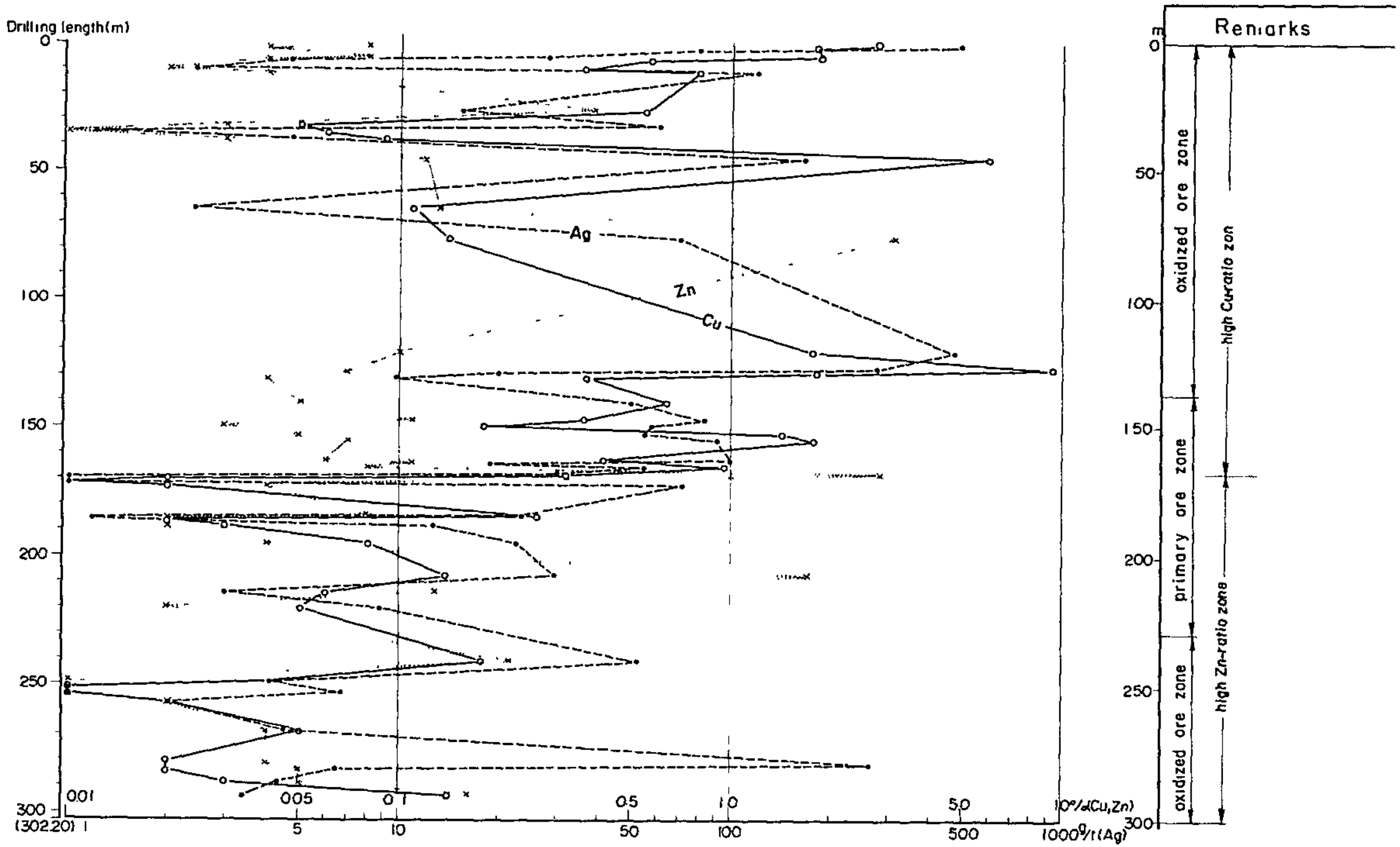
These many veins are briefly grouped into types of A to F as described below according to their modes of occurrence, mineral assemblages and the grades of their metal contents. The drilling lengths generally increase from A to F.

Table I-9 Analytical results of ores from DDH-M2 drill hole

Vein No.	Interval (m)	Length (m)	Width (m)	Incli-nation	Core recovery(%)	Assay Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	As(%)	Cd(%)	Hg(g/t)	Co(%)	Ore minerals	Gangue minerals	Remarks
M2-1	1.10~ 1.45	0.35	0.005	70°	100	tr	65.1	0.37	0.01	0.01	-	-	-	tr	hm-gt-cn-gr·cu	ca	Veinlet
M2-2	2.20~ 2.35	0.15	0.01	85°	100	tr	20.6	0 48	0.01	0.01	-	-	-	tr	ditto	ca	ditto
M2-3	5.00~ 5.25	0.25	0.005	85°	100	tr	tr	0.25	0.01	0.01	-	-	-	tr	ditto	ca	ditto
M2-4	5.90~ 6.25	0.35	0.01	85	100	tr	1.2	0 15	0 01	0.01	-	-	-	tr	hm-gt-cn	ca	Limonite-stained veinlet
M2-5	10.54~ 10.70	0.16	0 02	60°	100	tr	1.2	0.18	0 01	0.01	-	-	-	tr	hm-gt-cp-cn	ca	Veinlet
M2-6	10.80~ 11.10	0.30	0.01	60°	100	tr	26.6	0.21	0.003	0.01	-	-	-	tr	hm-gt-cn	ca	ditto
M2-7	27.75~ 27.92	0.17	0.06	55°	100	tr	15.7	0.55	0.01	0.39	-	-	-	tr	hm-gt	ca-ba	Vein
M2-8	32.85~ 33.25	0.40	0.20	45°	100	tr	60.5	0.05	0.02	0.03	-	-	-	tr	hm-gt	ca-qz	Porous, iron-oxide vein
M2-9	35.08~ 35.45	0.37	0.03~0.05	70°	100	tr	1.2	0 06	0.01	0.01	-	-	-	tr	gt	ca-qz	ditto
M2-10	37.90~ 38.05	0.15	0.15	50°	100	1.4	4.7	0.09	0 03	0.03	0.17	0.001	1.6	tr	gt	ca-qz	ditto
M2-11	45.45~ 45.80	0.35	0.20	60°	100	0.7	168.7	6.18	0 04	0.12	0.98	0.002	20.0	tr	hm-gt-cn	ca-qz	Vein
M2-12	64.25~ 64.65	0.40	0.30	50°	87.5	tr	2.4	0 11	0.02	0.13	-	-	-	tr	hm-gt	ca-qz	Porous, iron-oxide vein
M2-13	76.40~ 77.10	0.70	0.50	45°	31 4	0.4	70.0	0.14	0 02	3.14	1.14	0.07	2.3	tr	hm-gt-(cn)	ca	Vein
M2-14	85.50~ 85.70	0.20	0.15	45°	100	-	-	-	-	-	-	-	-	tr	hm-gt-(cn)	fl-ca-qz	Vein same as No.11
M2-15	86.00~ 86.05	0.05	0 05	20°	100	-	-	-	-	-	-	-	-	tr	ditto	ca-qz	Manto, ore is same as No.11
M2-16	86.85~ 86.95	0.10	0.03	70°	100	-	-	-	-	-	-	-	-	tr	ditto	ditto	Oxidized vein with green copper
M2-17	118.35~119 55	1.20	0.60	60°	17.7	-	-	-	-	-	-	-	-	tr	ditto	ditto	ditto
M2-18	120.50~121.60	1.10	networks		27.3	1.3	147.6	1.78	0.03	0.10	0.36	0.003	30.0	tr	hm-gt-gr·cu	qz-ca-fl	Petwork vein ?
	121 60~124.80	3.20	2.26	45°	9.5	tr	76.2	0.36	0.02	0.05	-	-	-	tr	gt	ca-qz	Strongly oxidized porous vein
	Average of 120 50~124.80	4.30	3.00	45°	14.0	8.3	94.5	0 72	0 02	0.06	-	-	-	tr			
M2-19	124.95~127.75	2.80	"	"	19.6	2 6	274.1	9.45	0 03	0.11	1.19	0.001	44.9	tr	*hm-gt-cn-gr·cu-(py)	*ca-qz-sr	Gn.cu-stained fracture zone filled with veins
	127.75~128.50	0.75	0.40	60°	100	tr	20.0	1.82	0 002	0.07	0.05	0.002	2.2	tr	ditto	ditto	ditto
	Average of 124.95~128.50	3.55	1.80	60°	36.6	2.1	220.4	7 83	0 024	0.10	0.95	0.001	35.9	tr			
M2-20	130.80~131 45	0.65	0.02	60°	100	tr	9.7	0.37	0.004	0.04	-	-	-	tr	hm-cn-gr·cu	ca	Veinlets
M2-21	139.50~141.15	1.65	0.30	80°	39.4	tr	50.0	0.65	0 02	0.05	0.12	0.001	2.4	tr	py-hm-gt-gr·cu	fl-qz-ca	Veins
M2-22	146.45~146.80	0.35	0.35	20°	100	tr	83.3	0.36	0 01	0.11	-	-	-	tr	py	qz-ca-gy	Manto
M2-23	148.70~149.90	1.20	0 60	60°	100	tr	15.7	0.18	0.01	0.03	-	-	-	tr	py	qz-ca-gy	Vein
M2-24	152.65 152.85	0.20	0.05	70°	100	tr	55 0	1.46	0.02	0.05	0.17	0.001	0.63	tr	py-ko ?	qz-ca-gy-ga	Vein
M2-25	154 00~154.30	0.30	0.15	45° 70°	100	0.9	90.0	1.78	0.02	0.07	0.20	0.0004	0.84	tr	py	qz-ca-gy	Vein
M2-26	160.50~160.90	0.40	0.20	60°	100	tr	33.3	0.67	0 01	0.05	-	-	-	tr	py-ko ?	qz-ca-gy	Vein
M2-27	161.65~162 70	1.05	0.52	60°	100	tr	100.0	0 42	0.01	0.06	-	-	-	tr	*py-ko?-gl	qz-ca-gy	Vein
	162 70~163.80	1.10	0 55	60°	100	tr	27.8	0.77	0 003	0.11	-	-	-	tr	ditto	qz-ca-gy	Vein
	Average of 161 65~163.80	2.15	1.07	60°	100	tr	62.9	0.60	0.006	0.09	-	-	-	tr			
M2-28	164 20~165.75	1 55	0 78	60°	100	0.7	55.0	0.97	0 02	0.08	0.19	0.001	6.7	tr	*py-cc-(ko?)	*qz-ca-fl-gy-at	Vein
M2-29	167.80~168.20	0.40	0.20	60°	100	0.7	30.0	0.32	0.02	2.81	1.43	0.005	0.09	tr	py-hm-gt	qz-ca-gy	Strongly oxidized vein
M2-30	169.30~170.0	0.70	0.18	75°	100	tr	1.0	0.02	0.01	0.16	-	-	-	tr	py-hm-gt	qz-ca-gy	Vein
M2-31	170.65~171.25	0.60	0.10	70°	100	tr	1.0	0.01	0.01	0.05	-	-	-	tr	py	qz-ca-gy	Vein
M2-32	172 15~172.80	0.65	0.08	70°	100	0.5	70.8	0 02	0 01	0.04	-	-	-	tr	py	qz-ca-gy	Two veins
M2-33	183.90~184.30	0.40	0.15	70°	100	1.0	6.2	0 07	0.01	0.02	-	-	-	tr	py	qz-ca	Vein
M2-34	185.77~185.97	0.20	0.03	70°	100	tr	1.2	0.02	0 003	0.02	-	-	-	tr	py	ca-gy	Vein
M2-35	187.85~188 10	0.25	0.05	65°	100	tr	12.5	0.03	0.01	0.02	-	-	-	tr	py-(ko?)	qz-ca-gy	Vein
M2-36	195 05~195.22	0.17	0 018	70°	100	tr	6.2	0 04	0.01	0.02	-	-	-	tr	*py-(ko?)-hm-gt	*ca-qz-gy-ba	Vein
M2-37	207.95~208.20	0.25	0.02	70°	100	0.7	15.0	0 07	0.02	0.90	0.02	0.01	0.46	tr	py-hm-gt	ca-gy	Vein
M2-38	214 30~214.80	0.50	0.05	85°	100	tr	3.0	0.06	0 01	0.13	-	-	-	tr	*py-hm-gt	*qz-ca-fl-gy	Vein
M2-39	219.60~220.00	0.40	0.03	85° 90°	100	tr	8.9	0.05	0.01	0.02	-	-	-	tr	*py-cc-cp-hm-gt	*qz-ca-fl-gy	Vein
M2-40	240.20~240.40	0.20	0.14	45°	100	1.1	53.2	0.18	0.02	0.23	-	-	-	tr	hm-gt	ca	Vein
	247.00~249.00	2.00			100	tr	4.1	0.03	0 01	0.01	-	-	-	tr			Iron oxide stained
M2-41	249.00~251.00	2.00	fractured zone		100	tr	2.8	0.01	0.01	0.01	-	-	-	tr	hm-gt		Fracture zone
	251.00~253.60	2.60			100	tr	6.9	0.01	0.01	0.01	-	-	-	tr			
	Average of 247.60~253.60	6.60	6.60		100	tr	4.8	0 02	0.01	0.01	-	-	-	tr			
M2-42	257.20~257.70	0.50	fractured zone		100	tr	2.0	0 02	0.01	0.02	-	-	-	tr	hm-gt		Fractured zone, disseminated by hematite after pyrite.
M2-43	267.00~268.35	1.35	ditto		100	tr	4.5	0.05	0.02	0.04	-	-	-	tr	hm-gt		ditto
M2-44	279.40~281.30	1.90	ditto		100	tr	263.2	0.02	0.02	0.04	-	-	-	tr	hm-gt		ditto
M2-45	284.00~284 30	0.30	ditto		100	tr	6.5	0.02	0.03	0.05	-	-	-	tr	hm-gt		ditto
M2-46	286.45~288.05	1.60	ditto		100	tr	4.3	0.03	0.03	0.05	-	-	-	tr	hm-gt		ditto
M2-47	289.10~294.25	5.15	ditto		100	tr	3.4	0.14	0.03	0.16	-	-	-	tr	hm-gt		ditto

Note hm hematite, gt· goethite, cn conichalcite, gn·cu: green copper, cp. chalcopyrite, py: pyrite, ko: kobellite,
gl: galena, cc: chalcocite, ca: calcite, ba: barite, qz: quartz, fl: fluorite, sr: sericite, gy: gypsum, at: actinolite,
wo· wollastonite, g3: garnet.
Asterisk shows that the minerals are identifi under the microscope.

Fig. I-5 Vertical distribution of Ag, Cu and Zn (DDH-M2)



(Note) Assay values which were obtained from drill cores comprising veinlets thinner than 5cm are corrected to ore's values using waste ratio

A-Type Veins :

M2-1, M2-2, M2-3, M2-4, M2-5 and M2-6 veins encountered between 0.00 and 11.10 m belong to this type. In addition, four smaller ones are found between 0.00 and 13.15 m.

These veins fill relatively straight fissures dipping by 60 to 85° developed in the saccharoidal recrystallized limestone, with vein thicknesses varying from 2 to 0.5 cm for M2-1 through M2-6 and from 0.1 to 0.5 cm for those of smaller scales. The ores consist of the pseudomorph after iron-bearing sulfide minerals (altered into hematite and limotite of cubic or irregular shape), calcite and (quartz), while green copper mineral staining of a rather substantial quantity is found around the pseudomorph after hematitized iron-bearing sulfide minerals. Although most pseudomorphs after iron-bearing sulfide minerals are assumed to be pyrite, chalcopyrite is also assumed to have existed since a small amount of it is recognized in rare occasions in the cores of pseudomorphs having irregular shapes. Green copper minerals consist mainly of conichalcite, with turquoise-like ones in part, and dissemination of these is more notable in the saccharoidal limestone than in the veins, and also prominent in the M2-1 through M2-3 veins that are closer to the ground surface. The intensity of dissemination decreases as the depth increases, showing a gradual transition to the B-type ores rich in black iron oxides as described later.

Although these veins have relatively high copper contents, their economic value is low because of the smallness of their scales.

B-Type Veins :

M2-7, M2-8, M2-9, M2-10 and M2-11 veins encountered between 13.13 and 64.65 m, and M2-40 between 240.20 and 240.20 m belong to this type.

These veins mainly consist of black to dark brown iron oxides (mostly limonite) of boxwork or sponge structure. Their modes of occurrence are not clarified because the core recovery was low in some parts due to fragility, and particularly very few cores were

receovered from their contacts with the host rock; but they are assumed to be veins which filled fissures or fracture zones with lesser apparent dips of 45 to 70°. As already mentioned, ores consist of iron oxides, accompanied by a small amount of calcite and quartz as gangue minerals, and are seemingly quite porous. These are extremely leached, oxidized ore minerals mostly with low silver, copper and zinc contents.

C-Type Ore Bodies :

M2-11, M2-13, M2-14, M2-15, M2-16, M2-17, M2-18, M2-19 and M2-20 ore bodies encountered between 45.45 and 138.50 m belong to this type.

These ore bodies are mostly veins that replace and fill fissures and fracture zones of apparent dips from 45 to 70°, but there are some manto-like ore bodies like M2-15 which occur along the bedding and also some ore bodies of irregular forms like the upper part of M2-18 (120.50 - 121.60 m) and M2-19 which fill and replace network fissures and beddings.

The ores, in appearance, are similar to those in the lower part (14.60 - 16.65 m) of the M1-1 ore body in the DDH-M1 hole, and consist of oxidized ores with prominent green copper staining, and are characterized by their high copper grades.

The ore at 125.40 m used for microscopic observations in thin sections and polished sections was intensely disseminated macroscopically by euhedral hematitized pyrite of 0.1 to 1 cm size and cubic or irregular-shaped, fine-granular iron-bearing sulfide minerals, with prominent overall green copper mineral dissemination of conichalcite, chrysocolla or turquoise-like amorphous copper minerals. Also, some small fragments of sericite-quartz rock disseminated by hematitized sulfide minerals are recognized. Under the microscope, ore minerals such as hematite, geothite, pyrite, conichalcite, chrysocolla(?) are recognized, of which hematite and geothite occur either as pseudomorph after pyrite or colloform banding, while pyrite occurs as a relic in its pseudomorph. As gangue

minerals, flaky sericite and mosaic quartz (1 mm ±) are mostly found, with a small amount of chlorite and calcite. Sericite is seen mainly occurring within the mosaic aggregates of quartz or occurring paragenetically with quartz, and also around and within pseudomorph after pyrite. The rock fragments containing lots of sericite occurring paragenetically with quartz in gangue minerals resemble those in the DDH-M5 hole, and are highly likely to be fragments of aplitic, acidic igneous rocks.

Among these ore bodies are relatively prominent ore veins more than 20 cm wide, such as M2-11, M2-13, M2-17, M2-18 and M2-19; particularly the last three, where the mineralized zones reach 6 m in width and which have high silver and copper grades in the parts accompanied by what are to be igneous rocks, are among the most important in appraising the ore deposits in this area.

D-Type Veins :

M2-21, M2-22, M2-23, M2-24, M2-25, M2-26, M2-27 and M2-28 encountered between 138.50 and 165.75 m belong to this type.

These are mostly veins rich in primary sulfide minerals which fill and replace fissures and fracture zones with apparent dips mostly around 60° but some with 45 to 80°. The manto-like ores are also found along the bedding, like M2-22. Besides these, several minor ones less than 1 cm wide with apparent dips of 60° to 80° are also found.

Excepting the manto-like ones, most of the veins contact with the host rock with some complicated boundaries caused by frequent encroaching of sulfide minerals upon the host rock or by occasional caputuration of brecciated host rock into the veins. The manto-like ones are rather clearly bounded on the host rocks.

Ores consist mainly of coarse-grained pyrite (several millimeters to several centimeters). Also sheaf-formed kobellite(?) and galena occur paragenetically with pyrite or in the gangue. Pyrite (particularly the coarse-grained) is mostly fractured, and hematitized either along the fracture plane or along the surface of the

crystals, while fine-grained pyrite in some of the veins is found completely replaced by hematite and other iron (hydro-)oxides. Microscopically, kobellite(?) is found embayed by pyrite or isolated in the gangue as acicular or sheaf-formed aggregates and, from its mode of occurrence, is considered to have become crystallized later than pyrite. Also, chalcocite, as one of the secondary sulfide minerals, is also found occurring paragenetically with iron (hydro-)oxides of colloform texture in the relatively more oxidized veins at 164.80 m. As gangue, quartz, calcite, gypsum, fluorite and a very small amount of actinolite occur filling the interstices of ore minerals like pyrite.

Although no significant difference in appearance is recognizable macroscopically between the ores in these veins and those in the E-type veins described in the next paragraph, analytical results show that most of these ores can be differentiated from the latter by their higher copper grade and lower zinc grade, and also for having significantly different distribution of Ag-Cu-Zn ratio, as will be described later.

Most of the D-type veins are more than 20 cm wide. M2-27 and M2-28 in particular are noteworthy, having confirmed vein widths of about 80 cm to 1 m and relatively high copper contents of 0.6% to 1.0%.

E-Type Veins :

M2-29, M2-30, M2-31, M2-32, M2-33, M2-34, M2-35, M2-36, M2-37, M2-38 and M2-39 veins encountered between 167.80 and 222.55 m belong to this type. Besides these relatively prominent veins, several smaller ones less than 2 cm wide are also recognized in this section.

These veins mainly fill and replace fissures and fracture zones having apparent dips of 60 to 90° (mostly around 70°) developing in the saccharoidal limestone. Very coarse-grained pyrite (several centimeters large) is often recognized in these veins, and the boundary between these and the host rock is irregular because of frequent encroaching of pyrite upon the host rock in a complicated manner.

Macroscopically, ores resemble the D-type veins described earlier, and mostly consist of coarse-grained fractured pyrite. In M2-35 and M2-36 a very small amount of kobellite-like minerals accompany pyrite. In M2-39 very small amount of pyrrhotite, chalcopyrite and chalcocite are observed as inclusions in pyrite under the microscope. The sample from the depth of 222.40 m contains tetrahedrite, acanthite and covelline besides those sulfides described above. Pyrite is oxidized along its fractures and margins to yield iron (hydro-) oxides such as hematite and geothite, etc. Gangue minerals are mainly quartz, calcite and gypsum. A small amount of fluorite and barite is also recognized.

These veins seem to have low economic value since their vein widths are less than 20 cm and their grades are low, but there are possibilities that these veins in their lower extensions may have transformed into the D-type veins. This is one of the questions that remains to be clarified by future exploration.

F-Type Veins :

M2-41, M2-42, M2-43, M2-44, M2-45, M2-46 and M2-47 found between 247.00 and 294.25 m belong to this type. These veins consist of iron hydroxides that stain open cracks of irregular network in the fracture zones, partly accompanied by brecciated zones, filled and cemented by dogtooth calcite. Ores consist of black to dark brown limonite which fill minor fissures and are considered to be secondary oxidized ores precipitated from the ground water that leached the overlying mineralized zone. Although very rarely some parts show high silver grade, the metal contents are, on the whole, low, so that these veins have little commercial value as ore deposits.

Characteristics of Mineralization in the DDH-M2 Hole :

In this hole, veins of A, B, C and F types mainly consisting of oxidized ores and veins of D and E types mainly consisting of primary sulfide ores are found.

The differences among the A, B, C and F type veins are considered to reflect the difference in the manner in which the veins were altered by supergene process. Of these, the A and C types are considered to have less migration of elements and are characterized by their high copper grade, being particularly significant in M2-19 which accompanies sericite-quartz rock that are assumed to be of igneous origin. The B-type veins are extremely leached and have generally low metal grades, and are characterized generally by having higher copper grade than zinc. The F-type veins mainly consist of secondary minerals with low metal grades, and their zinc grades are generally lower than their copper grades.

Of the D- and E-type veins, which are mainly composed of primary sulfide ores, the D-type veins show relatively high copper and silver grades but low zinc contents while the E-type veins show the opposite tendency.

A look at the entire hole, where the boundary which divides the D- and E-type veins is somewhere between 165.75 and 167.80 m (we will establish the borderline at 167 m), shows that copper and silver grades are high in the upper (shallower) part and low in the lower (deeper) part, while the zinc grades, despite great variations, tend to be high in the lower (deeper) part and particularly in the E-type veins. This borderline is assumed to correspond with the underground extension of the borderline which divides the mineralized zone rich in copper and the mineralized zone rich in lead and zinc, as classified by the zonal arrangement of deposits (to be described later).

(3) DDH-M3 Drill Hole

Many fracture zones with brecciated parts and fissures are found in this hole, most of which are filled by brown dogtooth calcite, but some with white calcite. Although the entire hole is intensely oxidized, mineralization is observed only locally. Major mineralized zones are shown in Table I-10 together with the modes of occurrence, core recovery and the results of laboratory examinations, etc.

Table I-10 Analytical results of ores from DDH-M3 drill hole

Vein No.	Interval (m)	Length (m)	Width (m)	Incli-nation	Core recovery(%)	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	As(%)	Cd(%)	Hg(g/t)	Ore minerals	Gangue minerals	Remarks
M3-1	140.50~141.45	0.95	0.45?	60°?	57.9	0.9	20.0	1.14	0.01	10.10	4.2?	0.08	0.17	*hm-gt-wl-au-cn-gr·cu	*qz-ca	Brecciated zone filled with hematite-calcite-green copper veinlets.
M3-2	181.30~182.50	1.20	fractured zone		87.5	0.7	2.4	0.01	0.01	0.15	-	-	-	gt	ca	Limonite-stained fractured zone
M3-3	185.70~188.20	2.50	brecciated zone		50.0	tr	2.9	0.02	0.004	0.16	-	-	-	gt	ca	Brecciated zone stained by limonite
M3-4	190.80~191.80	1.00				tr	0.6	0.05	0.003	0.11	-	-	-	gt	ca	ditto
	191.80~192.80	1.00	ditto			1.0	2.9	0.05	0.01	0.12	-	-	-	gt	ca	ditto
	192.80~193.40	0.60				0.7	15.0	0.49	0.02	0.90	0.80	0.01	0.17	gt	ca	ditto
	Average of 190.80~193.40	2.6				0.55	4.8	0.15	0.01	0.30						

Note: hm: hematite, gt: goethite, wl: willemite, au: austinite, cn: conichalcite, gr·cu: green copper, qz: quartz, ca: calcite.
Asterisk shows that the minerals are identified under the microscope.

Table I-11 Analytical results of ores from DDH-M4 drill hole

Vein No.	Interval (m)	Length (m)	Width (m)	Incli-nation	Core-recovery(%)	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Ore minerals	Gangue minerals	Remarks
M4-1	41.40~41.95	0.55	sheared zone	?	100	tr	0.8	0.004	0.01	0.009	gt	ca	Brecciated and bleached limestone with calcite veinlets stained by limonite slightly.
M4-2	47.85~48.20	0.35	ditto	?	100	tr	3.3	0.01	0.01	0.03	gt	ca	ditto
	48.20~50.00	1.80	ditto	?	100	tr	1.2	0.01	0.01	0.02	gt	ca	
	50.00~51.50	1.50	ditto	?	100	tr	0.8	0.01	0.01	0.04	gt	ca	
	51.50~53.00	1.50	ditto	?	100	tr	0.5	0.01	0.01	0.02	gt	ca	
	53.00~54.50	1.50	ditto	?	100	tr	3.8	0.003	0.01	0.01	gt	ca	
	54.50~56.00	1.50	ditto	?	100	tr	5.4	0.002	0.02	0.01	gt	ca	
	56.00~57.50	1.50	ditto	?	100	0.5	2.1	0.002	0.01	0.02	gt	ca	
	Average of 47.85 to 57.50	9.65	ditto		100	tr	2.3	0.006	0.01	0.02			

Note: gt: goethite, ca: calcite.

M3-1 Vein (Depth : 140.50 - 141.45 m) :

This vein consists of fragile oxidized ores. The mode of occurrence is not clear due to low core recovery, but judging from the condition of nearby fissures and the mode of occurrence of ores in the vein, it is assumed to be a vein about 45 cm wide filling and replacing a brecciated fracture zone with a dip of about 60°.

The ores consist of iron (hydro-)oxides, accompanying weak green copper staining, and also many fragments of recrystallized limestone. According to the results of microscopic observation of the sample taken from 141.00 m, extremely fractured pyrite replaced by iron (hydro-)oxides (hematite, geothite, etc.), fractured ameba-shaped quartz and unhedral granular calcite, etc. are recognized. Oxidized mineral forming a well-developed mesh structure presumably of sphalerite origin is also found along with granular to hexagonal prismatic willemite, granular austinite, calcite, iron (hydro-) oxides, etc. while iron (hydro-)oxides, radial aggregates of conichalcite, amorphous green copper minerals and others fill the cells. Iron (hydro-)oxides that are assumed to be pseudomorph after pyrite frequently form atoll to ring structure together with green copper minerals and other minerals.

This mineralized zone with a vein about 45 cm wide and very high zinc grade rates particular attention.

M3-2 (Depth : 181.30 - 182.50 m), M3-3 (Depth : 185.70 - 188.20 m) and M3-4 (Depth : 190.80 - 193.40 m) :

These are somewhat argillaceous mineralized zones with intense iron oxides staining found mainly in the fractured or brecciated zones of marly limestone, accompanying white calcite veins in M3-3 and M3-4. However, the shape of each mineralized zone is not clearly definable.

The ores are somewhat argillaceous and mainly consist of iron hydroxides, with calcite as gangue. Overall metal grades are low, but they are characterized by their remarkably high zinc contents in relative terms.

They have little commercial value as ore deposits.

Characteristics of Mineralization in the DDH-M3 Hole :

A mineralized zone composed of oxidized ores with relatively high zinc grade is seen in this hole.

(4) DDH-M4 Drill Hole

This hole is situated in the non-metamorphic, fresh limestone zone. On the whole, mineralization is weak, but in addition to the showings given in Table I-11, some showings are also observed between 190.00 and 198.30 m.

These showings are seen in the weakly brecciated parts where many white calcite veins occur, and are characterized by the decolorized calcareous sedimentary rocks, iron hydroxides staining and locallized weak pyrite dissemination, all of which are presumed to have occurred by alteration at the farthest end of the range subjected to hydrothermal process which caused mineralization. Although there is nothing in these showings that can be called ore, their assays tend to have relatively high zinc values when compared with copper values.

These showings are assumed to have been formed during the hydrothermal stage, but their ore grades are low and they do not seem to have any commercial value as ore deposits.

(5) DDH-M5 Drill Hole

Veins comprising 15 relatively prominent streaks of oxidized ores and other veins accompanying primary sulfide ores are found in this hole. There are also a few minor veins less than 2 cm wide, and weak fluorite mineralization is found occurring within white calcite veins in the relatively shallow places of this hole. Since we have already touched on fluorite mineralization in the preceding paragraphs on geology and structure, we will only deal with oxidized ores and veins accompanied by sulfide ores here.

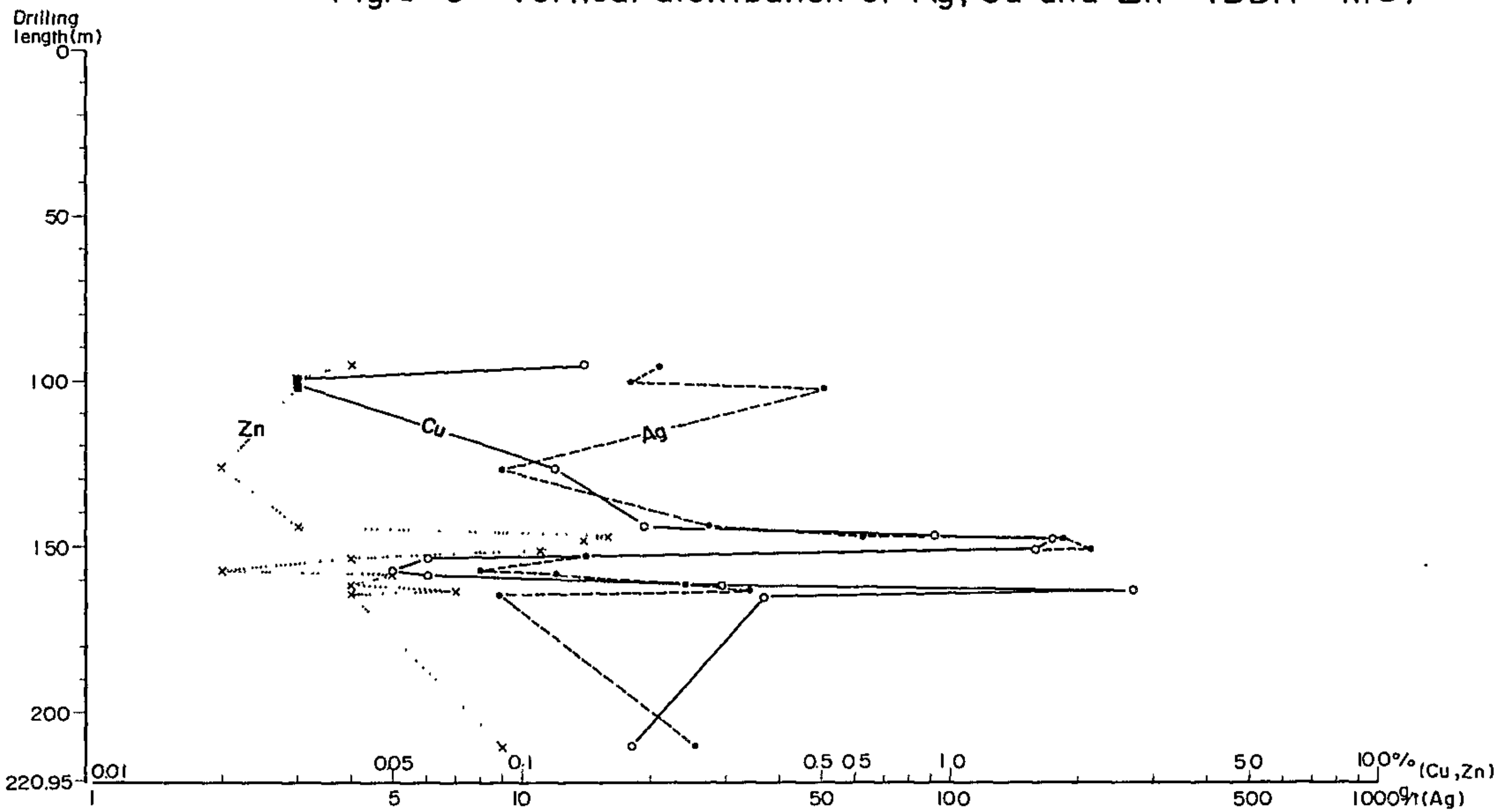
The modes of occurrence, scales, core recovery and the results of laboratory examinations are summarized in Table I-12. Changes in

Table I-12 Analytical results of ores from DDH-M5 drill hole

Vein No.	Interval (m)	Length (m)	Width (m)	Incli-nation	Core recovery(%)	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	As(%)	Cd(%)	Hg(g/t)	Ore minerals	Gangue minerals	Remarks
M5-1	95.25∿ 95.85	0.60	0.40	45°	25.0	tr	22.2	0.14	0.03	0.04	-	-	-	hm-gt	qz-ca-fl	Vein
M5-2	99.30∿ 99.60	0.30	0.20	30°	33.3	tr	18.1	0.03	0.01	0.03	-	-	-	hm-gt	qz-ca	Vein
M5-3	100.70∿101.10	0.40	0.30	30°∿45°	50.0	tr	50.8	0.03	0.004	0.03	-	-	-	hm-gt	qz-ca	Vein
M5-4	125.55∿126.05	0.50	0.03∿0.05	50°	100	tr	9.0	0.12	0.01	0.02	-	-	-	*py-(ko?)-hm-gt	*qz-ca-fl-gy-ga	Vein
M5-5	144.05∿144.22	0.17	0.025	60°	100	tr	18.1	0.13	0.004	0.02	-	-	-	py-(ko?)-hm-gt	qz-ca-gy	Vein stained by green copper
M5-6	146.85∿147.00	0.15	0.002	60°	100	tr	62.5	0.92	0.01	0.16	0.13	0.002	6.6	py-hm-gt	qz-ca	ditto
M5-7	147.25∿147.85	0.60	0.05∿0.07	20°∿65°	100	tr	93.7	0.89	0.02	0.07	0.20	0.001	6.8	*py-cp-th-ac-ko?-cc-cv-hm-gt	*qz-ca-fl-gy	ditto
M5-8	150.90∿151.20	0.30	0.15	20°∿60°	100	tr	214.8	1.60	0.02	0.11	0.13	0.001	5.8	*py-hm-(ko?)	*qz-ca-gy	ditto
M5-9	152.55∿153.10	0.55	0.30	60°	100	tr	14.1	0.06	0.01	0.04	-	-	-	*py-(ko?)-hm-gt	*qz-ca-gy-fl	Weakly oxidized vein
M5-10	156.45∿157.05	0.70	0.60	60°∿15°	100	tr	8.1	0.05	0.01	0.02	-	-	-	*py-(ko?)-hm-gt	*qz-ca-gy-fl	Manto? ∿ vein
M5-11	157.20∿157.35	0.15	0.15	20°	100	tr	12.1	0.06	0.01	0.05	-	-	-	ditto	ditto	ditto
M5-12	159.20∿161.60	2.40	1.60	45°	41.7	tr	24.2	0.29	0.02	0.04	-	-	-	hm-gt	qz-ca-fl-gy	Oxidized vein
M5-13	162.80∿163.10	0.30	0.07	70°	100	tr	34.0	2.70	0.01	0.07	0.22	0.003	29.5	hm-gt-gr·cu	qz-ca-fl-gy	ditto
M5-14	163.50∿163.80	0.30	0.08	75°	0.50	tr	8.9	0.37	0.01	0.04	-	-	-	hm-gt	qz-gy	ditto
M5-15	209.80∿210.25	0.45	fractured zone		100	tr	8.5	0.06	0.05	0.03	-	-	-	hm-gt	qz-ca	Oxidized fractured zone

Note: hm: hematite, gt: goethite, py: pyrite, ko: kobellite, cp: chalcopyrite, th: tetrahedrite, ac: acanthite, cc: chalcocite, cv: covelline, gr·cu: green copper, qz: quartz, ca: calcite, fl: fluorite, ga: garnet, gy: gypsum.
Asterisk shows that the minerals are identified under the microscope.

Fig. I-6 Vertical distribution of Ag, Cu and Zn (DDH - M5)



(Note) Assay values which were obtained from drill cores comprising veinlets thinner than 5cm are corrected to ores' values using waste ratio.

the grades of silver, copper and zinc according to the depth are illustrated in Fig. I-6. For convenience's sake, the vein numbers at the left of Table I-12 will be quoted in most of subsequent descriptions.

Based on their modes of occurrence, mineral assemblages and assays, these veins can be divided into three groups: veins between 95.25 and 101.10 m, between 125.55 and 157.35 m, and between 159.20 and 210.25 m.

Veins between 95.25 and 101.10 m :

M5-1 (Depth : 95.25 - 95.85 m), M5-2 (Depth : 99.30 - 99.60 m) and M5-3 (Depth : 100.70 - 101.10 m) belong to this group. Also, a few minor veins with similar mineral assemblage but with vein widths less than 2 cm are found between 95.25 and 125.00 m.

These veins are mostly oxidized ores that are composed mainly of iron hydroxides, but because of poor core recovery of 25 to 50% due to fragility of the ores, their shapes have not been confirmed. However, judging from the conditions of some of the cores in which the contacts with the host rock remain or the internal structure of the veins are evident, they are considered to be veins that fill and replace fissures having apparent dips of 30 to 45°.

Cores from the veins resemble the "B-type" veins of the DDH-M2 hole in appearance, and consist mainly of boxwork or sponge-like, porous brown to dark brown iron hydroxides (mainly geothite and partly hematite). Based on their modes of occurrence and because hardly any green copper minerals are recognizable in the ores macroscopically, the veins in this section are considered to be ores oxidized and leached intensely. A small quantity of quartz, calcite, fluorite and others are also recognized as gangue minerals.

Since these veins consist mainly of extremely leached ores, their metal contents are low, but they are relatively prominent in terms of width, ranging from 20 to 40 cm.

Veins between 125.55 and 157.35 m :

Eight veins rich in primary sulfide ores accompanying gypsum are distributed in this interval.

These veins fill and cement fissures and fracture zones having apparent dips of 50 to 60°, and the hanging sides of these veins bound on the brown oxidized clay beds which have apparent dips of around 20°. Many of these veins apr - to be of manto-type.

Ores consist mainly of coarse-grained, fractured pyrite, with a small amount of sheaf-formed kobellite(?). Also, quartz, calcite, fluorite, gypsum, sericite and other gangue minerals are recognizable macroscopically. Pyrite is oxidized along the cracks and its margin, and many are altered into hematite, geothite and other iron (hydro-)oxides, while gypsum mainly occurs filling druses and minor fissures developed inside the ores. As already stated, sericite occurs in large quantity in the veins between 147.50 and 156.75 m that are accompanied with fragments assumed to be of igneous rock.

According to the results of microscopic observation of samples collected from M5-7 and M5-8 at 147.50 m and 151.05 m respectively, the modes of occurrence of ore minerals are as follows: pryrite occurs in large quantity; kobellite and acanthite are embayed or enclosed by pyrite paragenetically; pyrrhotite and chalcopyrite are included in pyrite; tetrahedrite replaces acanthite vermicularly or penetrates acanthite as microveinlet; chalcocite, covelline and cerargyrite(-bromyrite) occur secondarily around chalcopyrite; polybasite is included vermicularly in pyrite; iron (hydro-)oxides such as hematite, geothite, etc. occur along the margin of pyrite. As for chalcopyrite, besides the occurrences mentioned above, some are found penetrating acanthite as microveinlet or coexisting with quartz.

Macroscopically, kobellite(?) is seen in the samples taken from veins M5-9 through M5-11, but in the sections examined microscopically, only oxidized pyrite is recognizable, with such gangue minerals as quartz, calcite, gypsum, fluorite, sericite, etc.

Of all these veins, M5-7 through M5-11, are accompanied with sericite-quartz rocks that are assumed to be igneous rocks. These are considered to correspond to the extended parts of the mineralized zones M2-18 and M2-19 in the DDH-M2 hole where the same rock fragments are found.

Since some of these veins are about 60 cm wide or show copper grade of 1.6%, the veins M5-7 through M5-11 are considered important in evaluating the ore deposits in this area.

Veins between 159.20 and 210.25 m :

Four veins, M5-12 through M5-15 belong to this group. Of these, M5-12 through M5-14 occur closely to each other in 159.20 - 163.80 m.

These veins consist of oxide ores oxidized extremely. Although the core recovery were low in M5-12 and M5-14 due to many fragile ores, good cores were recovered from the contact zones between the veins and the host rock, and from the appearances of these cores, these veins are assumed to fill fissures and fracture zones having apparent dips of 45 to 75°.

Ores consist mainly of yellowish brown to dark brown iron (hydro-) oxides rich in geothite, with some porous and extremely leached ores and ores accompanied by weak green copper staining.

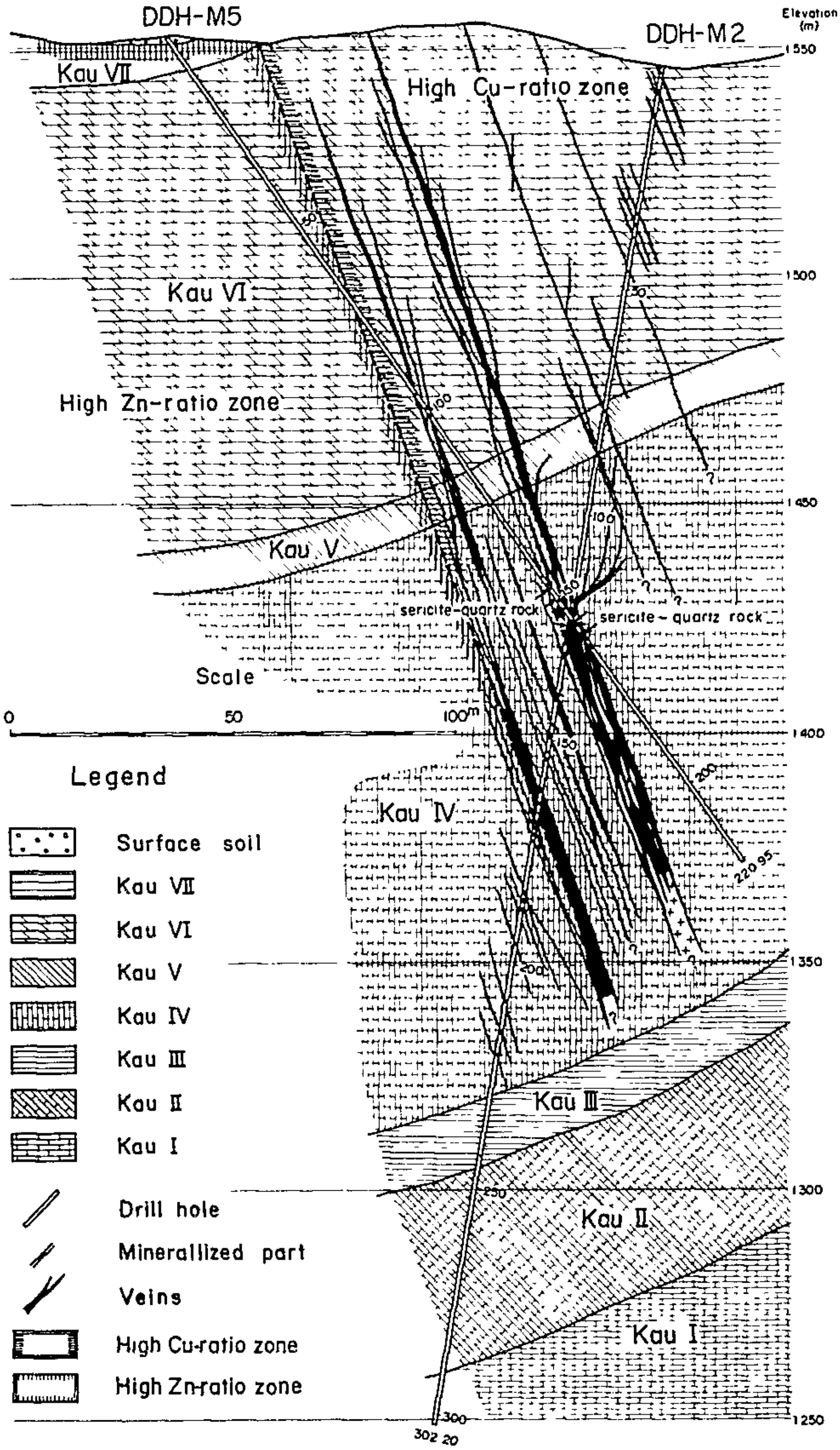
M5-12 through M5-14 which are found close together are considered to be veins similar to M5-7 through M5-11, but are oxidized and leached. As some of them are prominent veins of about 1.6 m wide, they rate special attention.

Characteristics of Mineralization in the DDH-M5 Hole :

The ores having higher copper grades than zinc are found in this hole. The ore grades are higher in the veins around the depth of 150 m where fragments of what are assumed to be igneous rocks occurs as the same case as in the DDH-M2 hole.

Fig. I-7 shows an estimated profile of geology and ore veins inferred from the evidences in the drill holes of DDH-M2 and DDH-M5.

Fig.I-7 Geological profile of DDH-M2 and DDH-M5



5. SOME ASPECTS ON CALCITE AND SKARN MINERALS CONCERNING TO MINERALIZATION

5.1 Calcite

As revealed by the drilling of DDH-M1, DDH-M2, DDH-M3 and DDH-M5, most of fractures within the thermal metamorphic zone are cemented by dogtooth calcite which is not associated with mineralization. On the other hand, platy to granular white calcite occur in metalliferous veins, in fluorite-calcite veins and in the altered zone of the DDH-M4 drill hole which cut the fractures cemented by the dogtooth calcite, and have no relations with them. From the fact, it is inferred that there were, at least, two stages of calcite crystallization. The crystallization of dogtooth calcite is assumed to have taken place during the last stage of thermal metamorphism before the mineralization since it is observable only in the thermal metamorphic zone. The white calcite, however, is closely associated with hydrothermal minerals such as fluorite, quartz and sulfide minerals, and is one of the principal gangue mineral itself, so that it is inferred to have been brought by hydrothermal process with mineralization. The fractures filled with the latter are probably formed during the hydrothermal stage posterior to the thermal metamorphism (hereinafter it is referred as "younger fractures" and other fractures which are cemented by dogtooth calcite in the thermal metamorphic zone as "older fractures").

5.2 Skarn Minerals

As confirmed by the geological survey and by the diamond drilling, very weak skarnization is recognized in the central part of the thermal metamorphic zone, and some skarn minerals such as large porphyroblastic garnet, minor hedenbergite, diopside?, wollastonite are observable. These skarn minerals are mostly altered in the hydrothermal stage retrogressively, especially garnet is altered to iron oxides, calcite, etc. and is also penetrated by some hydrothermal veinlets along small cracks. Mineralization accompanied with skarnization, however, is not recognized, consequently the mineralization recognized in this area are considered to have taken place in the hydrothermal stage.

It is, however, presumed as a possibility that volatile derived from the igneous rock were mostly consumed in the Cupido formation (the most favorable horizon for silver-bearing base metal mineralization in the project district) and could not reach up to the Aurora formation.

6. SUPERGENE ALTERATION AND SECONDARY ENRICHMENT

Ore deposits of this area are, as mentioned previously, intensely oxidized under semi-arid environment, and almost of all ore deposits crop out as oxide ore veins. According to the results of the drilling, the effect of supergene alteration extends as deep as 300 m from the surface, but in some parts where veins are characteristically accompanied with gypsum and in case of ore minerals are surrounded by quartz, sulfide minerals are still preserved.

Associated with these supergene alterations, leaching and secondary enrichment are frequently observed in ore bodies, but secondary dispersion of major metallic elements such as Ag, Cu, Pb and Zn except Fe is rather weak and these elements migrate less than several centimeter in distance. Although strongly bleached porous oxide ores are sometimes recognized within ore bodies, leaching of major metallic elements is inferred to be comparatively small since most of the secondary minerals occur only in and arround iron oxide psuedomorphs after primary minerals. Secondarily enriched ores are sometimes recognized immediately below the strongly oxidized and leached ores (the M1-1 ore body in DDH-M1 and the NE3 vein).

The relatively small migration of major elements by supergene alteration is presumably attributable to small precipitation and to abundant association of carbonate minerals.

As secondary minerals, native copper, cuprite, tenorite, chalcocite, conichalcite, turquoise-like amorphous green copper, malachite, native silver, acanthite, cerargyrite, austinite, willemite, mimetite, etc. are identified.

7. RATIOS OF MAJOR METALLIC ELEMENTS AND ZONAL ARRANGEMENT OF ORE DEPOSITS

7.1 Ratios of Major Metallic Elements

The relation between mineralization and geological structure is examined by the analytical data of ore samples.

In this case, at first, triangular diagrams of 10Ag - Cu - (Pb + Zn) (Fig. I-8) was prepared using the analytical data of 104 surface samples, then the relation between the chemical characteristics of each sample and its locality was traced.

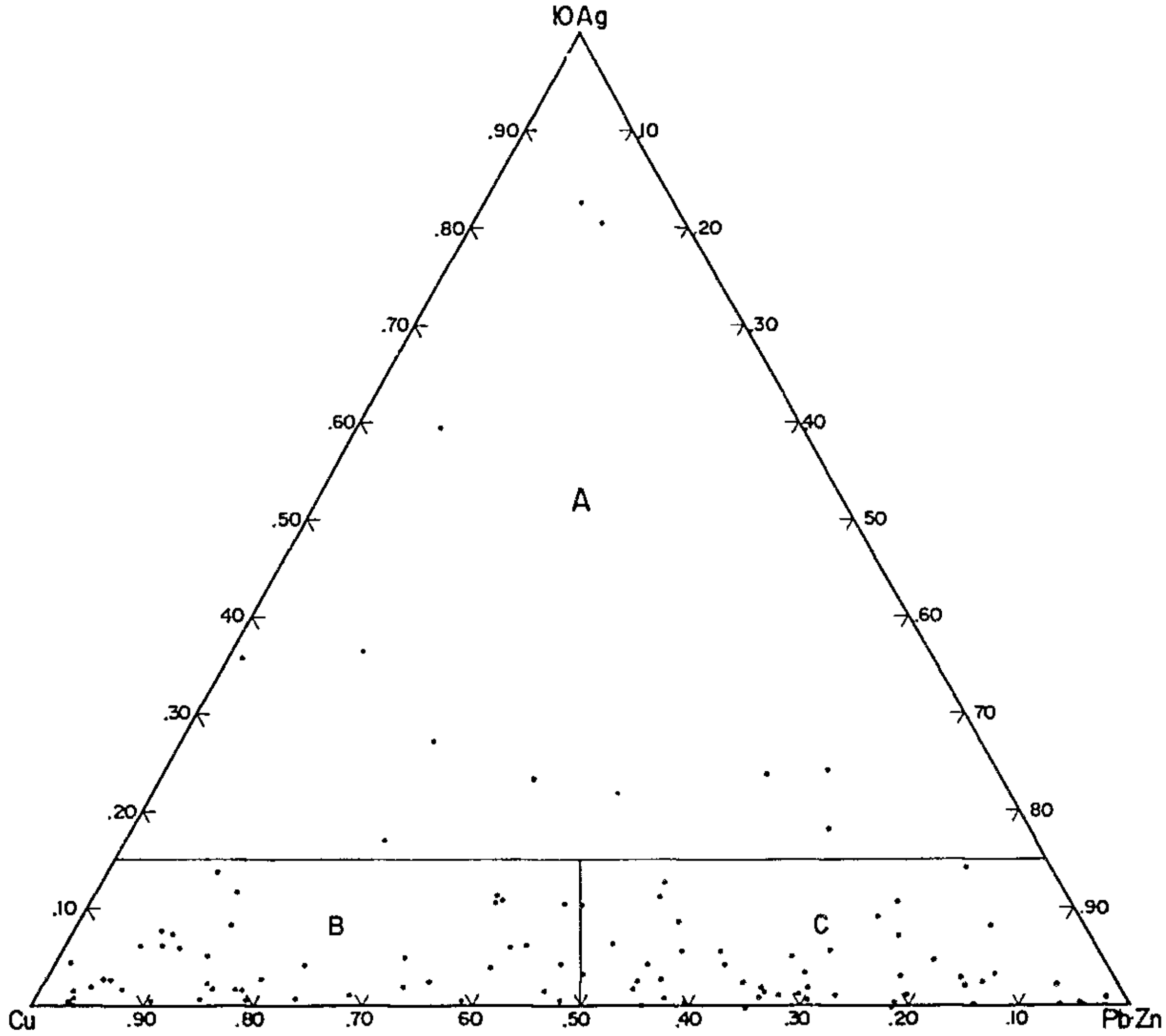
For 80 drill core samples, the relation between the depth and the ratios of 10Ag, Cu and Zn elements to the total (10Ag + Cu + Zn) of each sample was investigated (Fig. I-9). For the subsurface smaples, when two analytical results obrained from the same ore body, they are treated as one and the assays were averaged for convenience of plotting. Pb was not used because of its small variation and extremely low value. Fig. I-10 was prepared to examine the difference between sulfides-rich ores and oxide ores.

7.1.1 Major Metallic Element Ratios of Surface Samples and Their Distribution

Fig. I-8 shows following tendencies, each of which can be geologically interpreted as follows:

(1) Many samples have 10Ag ratio of 0.15 or less, while 12% samples of the population are scattered in the territory of 10Ag ratio of higher than 0.15 (hereinafter called high Ag-ratio sample). These high Ag-ratio samples were obtained from the thermal metamorphic zone and its vicinity, but the location is not related to the zonal arrangement of the thermal metamorphic zone. Most of high Ag-ratio samples are those taken from veins occurring in major faults and prominent veins. It is interpreted for this tendency that thermal metamorphism and mineralization are presumably independent each other.

Fig. I-8 10Ag-Cu-Pb·Zn diagram



A: high Ag-ratio ore B: high Cu-ratio ore C: high Zn-ratio ore

Fig. I-9 Vertical distribution of elemental ratios ($\frac{10Ag, Cu, Zn}{10Ag+Cu+Zn}$)

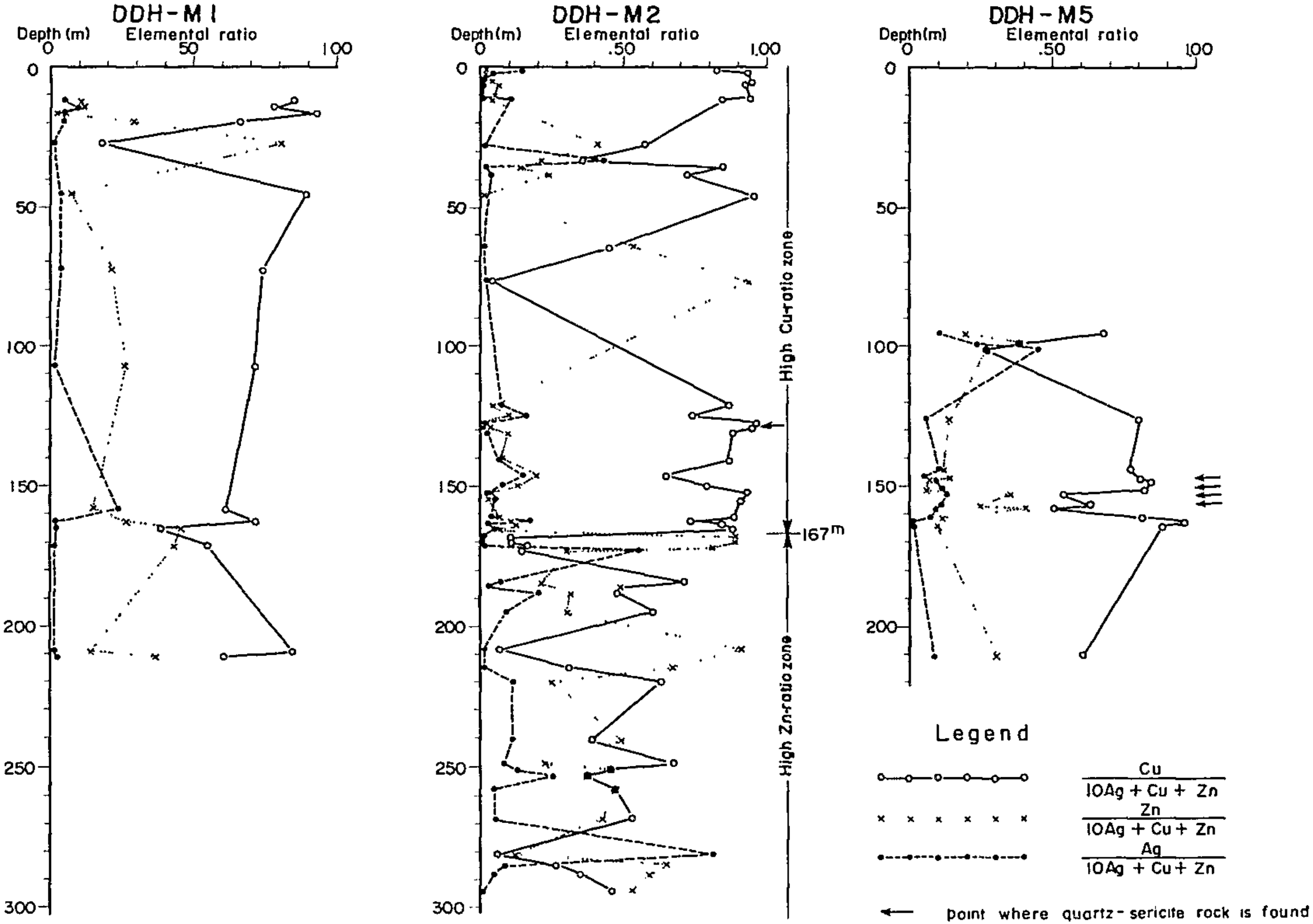
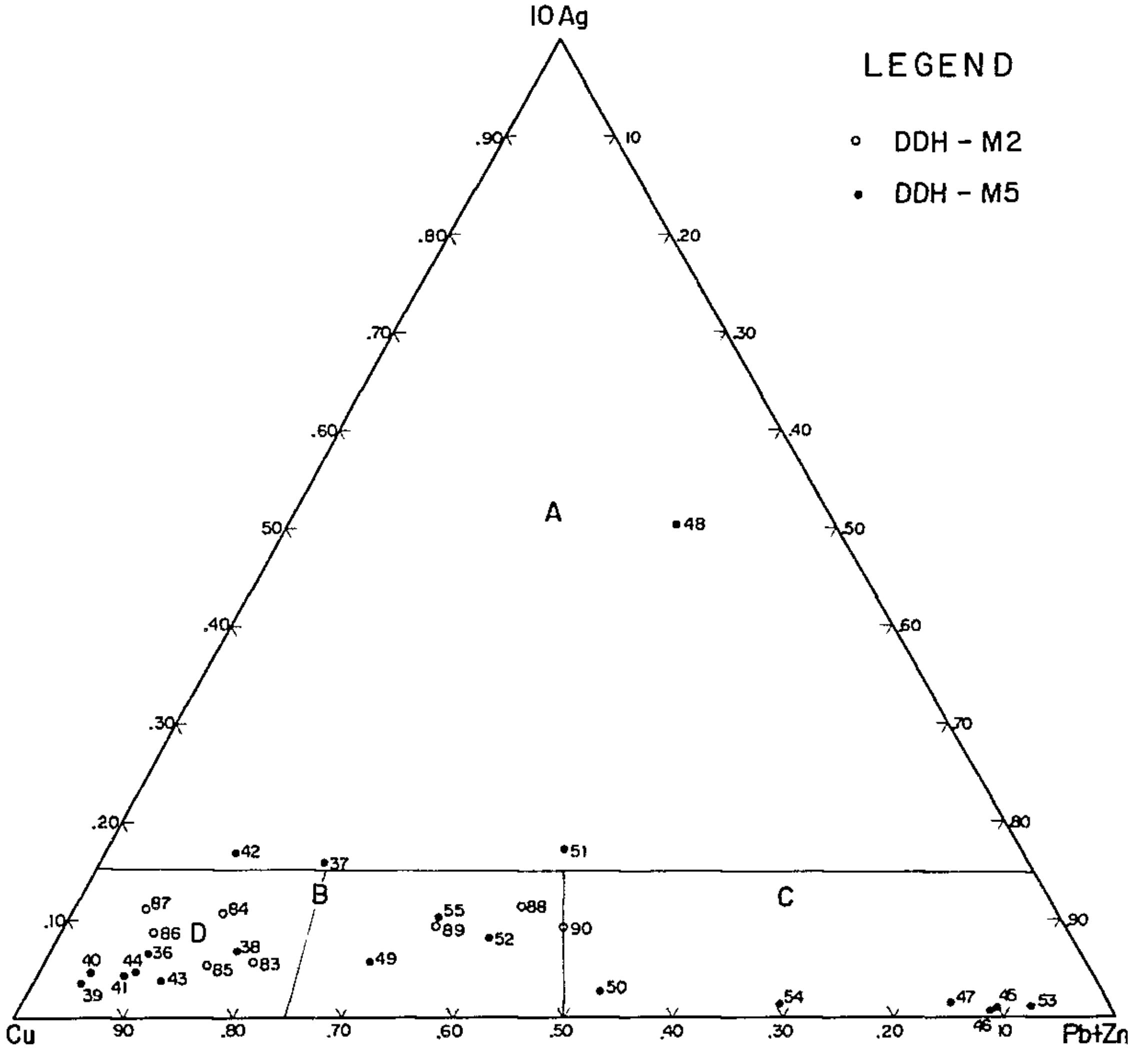


Fig.I- 10 10Ag-Cu-Pb+Zn diagram of sulfide-rich ores (DDH-M2 & DDH-M5)



A high Ag-ratio ore, B high Cu-ratio ore, C high Zn-ratio ore, D: Very high Cu-ratio ore.

Figures correspond to the serial numbers in the APX. III - I.

(2) Samples with less than 0.15 10Ag-ratio show a continuous distribution pattern with respect to Cu and Pb + Zn ratios, and neither concentration nor absence of any paticular ratio was found. However, the ground distribution of samples showing Cu/(Pb+Zn) of 1 or higher (hereafter referred as high Cu-ratio sample) reveals that the majority of them are located in the range from the skarn mineral-bearing recrystallized zone to the northeastern part of the thermal metamorphic zone (this range is hereinafter referred to as high Cu-ratio zone while the surrounding range of it is hereinafter referred to as high Zn-ratio zone).

(3) The high Cu-ratio samples distributed outside of the high Cu-ratio zone are those collected from veins occurring in the major faults. Further saying, the high Cu-ratio samples distributed outside of the thermal metamorphic zone are those taken from the veins which fill the major faults. These major faults, with one exception, are traceable into the thermal metamorphic zone.

7.1.2 Major Metallic Element Ratios of Subsurface Samples and Their Distribution

On Fig. I-9, following tendencies are recognized and are considered geologically as following:

(1) Eleven samples belonging to the high Ag-ratio occupy about 13% of the population. Of these, four samples are rich in primary sulfide minerals while seven are extemely oxidized and leached. No paticular correlation was found between the locations of the samples and the geological situation.

(2) Cu/Zn ratio is generally alter than 1 for most of the samples collected from both of the DDH-M1 and DDH-M2 drill holes. This corresponds to the fact that both drill holes were localized in the high Cu-ratio zone on the surface and that the high Cu-ratio zone continues downword to the bottom of these drill holes.

(3) DDH-M2 drill hole is localized in the high Cu-ratio zone, consequently the line showing the Cu ratio follows a relatively stable pattern

from the ground surface to the depth of 167 m, except in extremely leached parts, indicating that this section is in the high Cu ratio zone.

(4) In the section deeper than 167 m in the DDH-M2 drill hole, however, the above pattern of comparatively stable Cu ratio is not observed, and Cu/Zn ratio fluctuates widely to values of lower than 1. The section deeper than 167 m is presumably the high Zn-ratio zone. It is inferred that the depth of 167 m is a border of two zones dipping at 65° to 70° to the north-northwest relating to the zoning on the surface and the dip corresponds approximately to those of veins.

(5) Very high Cu-ratio sections are found in the DDH-M2 (depth from 120 to 167 m) and DDH-M5 (depth from 120 to 165 m) drill holes, in which quartz-sericite rock assumed to be igneous rock are observable, indicating close relation between the quartz-sericite rock and mineralization.

7.1.3 Major Metallic Element Ratios of Sulfide-Rich Ores

(1) Samples having Cu/(Pb+Zn) ratio of lower than 1 are those mostly taken from the section deeper than 167 m of DDH-M2 which belongs to the high Zn-ratio zone, and the 10Ag ratio in these samples is also lower than 0.03.

(2) Samples having Cu/(Pb+Zn) ratio of 1 or alter are those mostly collected from the high Cu-ratio zone. 10Ag ratio of these high Cu-ratio samples ranges from 0.03 to 0.18, and is significantly different from that of the high Zn-ratio samples. This tendency is also observable in the high Cu ratio samples from the high Zn-ratio zone, suggesting that silver has more close relation with copper than lead and zinc.

The fact that such decline on 10Ag ratio in the high Zn-ratio samples is not recognized in the surface samples is assumed to indicate that silver, lead and zinc are hardly leached than copper by supergene alteration.

(3) With the respect of Cu/(Pb+Zn) ratio, samples rich in sulfide minerals have a characteristic tendency of concentration to a high Cu-ratio area, peculiar to the very high Cu-ratio area (Cu/(Pb+Zn)>3) on the graph, comparing with surface samples. This is assumably attributable to the location of the most samples from the high Cu-ratio zone.

(4) Very high Cu-ratio samples above-cited are located in sections from 139.50 to 165.75 m in the DDH-M2 drill hole and from 125.55 to 151.20 m in the DDH-M5 drill hole (hereinafter this zone is referred as very high Cu-ratio zone). Both the sections are distributed near by the sericite-quartz rock assumed to be igneous, especially on the foot-wall side.

(5) Although there are some exceptions, as a whole, the sulfide-rich samples have similar patterns of major metallic element ratios which substantiates the fact that migration of major metallic elements due to supergene alteration was not large.

7.2 Zonal Arrangement of Ore Deposits

Following zonal arrangement of ore deposits is inferred from the relationship between the major metallic element ratios and geological structure. (Refer to PL. I-5)

(1) The mineralized zone having very high Cu ratio occurs in the underground of the skarn minerals-bearing recrystallized zone (in and around the sericite-quartz rock).

(2) The mineralized zone having high Cu ratio encloses the above-mentioned very high Cu-ratio zone, and developes mainly on the surface within the saccharoidal recrystallized zone in the eastern half of the thermal metamorphic zone, and the underground extension of this zone reaches the depth of 167 m in the DDH-M2 drill hole with a dip between 65° and 70° to the northwest. Since high Zn-ratio samples mainly occur in the section deeper than 141 m in the DDH-M3 drill hole, it is assumed that the above zone dips approximately at 45° to the northwest in this neighborhood.

As a whole, the distribution of this mineralized zone on the surface is concordant with the distribution of the thermal metamorphic zones, but a oblique corossing with the latter is also seen at the southern end and in the northeastern part of this mineralized zone.

(3) The high Zn-ratio zone is mainly found within the theremal metanorphic zone and its periphery, and its distribution ranges over 900 m outward from the rim of the thermal metamorphic zone.

(4) Isolated high Cu-ratio zones also occur within the high Zn-ratio zone where relatively prominent mineralization is accompanied, such as N4 mineralized zone and veins occuring in the major fracture zones.

(5) Distribution of high Ag-ratio samples seems to have no relation with the zonal arrangement of thermal metamorphic zone, however, most of the veins containing high Ag-ratio samples occur in major fractures or by the site of them and is distributed within the range of 300m outward from the rim of the thermal metamorphic zone.

7.3 Ore Grade and Zonal Arrangement of Ore Deposits

The assay values of samples collected from the many ore deposits have distinct relation with the zonal arrangement of ore deposits and the thermal metamorphic zone as follows:

(1) Most of the ores showing more than 100 g/t of silver and 0.1% of copper, zinc and lead are distributed within the thermal metamorphic zone.

(2) Most of samples from the surface having more than 1% of copper are distributed within the high Cu-ratio zone.

(3) In the drill holes, it is recognized that relatively high-grade ore mentioned in (1) occur in the veins localized in the limited range from nearby the sericite-quartz rock to their hanging side, frequently showing 1% or more of copper and 100 g/t or more of silver.

(4) The high Zn-ratio zone of the DDH-M2 drill hole is widely fluctuating in base metal contents. The copper grade is mostly 0.01 to 0.02%, and the silver grade is mostly below 70 g/t, while the zinc grade reaches rarely as much as 2.8% but mostly 0.3% or less.

8. STRUCTURE CONTROL OF ORE DEPOSITS

The ore deposits distributed in this area are structurally controlled by the older fractures (cemented by dogteeth calcite), the concealed intrusive igneous body with the thermal metamorphic zone, and the younger fractures.

8.1 Structure Control by the Older Fractures

The older fractures are considered to be formed principally by the main folding of the Laramide orogeny, subsequently complicated by the tectonic movements, then converted to tensional fractures by the intrusive igneous activity. Trends of these fractures are dominant in NE-SW and NW-SE systems, especially the former is remarkable.

These fractures are considered to have served as important spaces for precipitating ore solution at the margin and the surroundings of the thermal metamorphic zone.

The older fractures are well developed at the southwestern part and at the area ranging from the eastern to northeastern parts of the thermal metamorphic zone, especially it is conspicious at the northeastern part which is located in the vicinity of the major fold-faults around the area such as the Mina la Morena and the El Refugio faults, occurring relatively prominent veins and mineralized zones which trend mainly NE-SW direction such as veins of NE1 through 4 and SW1 through 7 and mineralized zones.

8.2 Structure Control by the Thermal Metamorphic Zones

Within the thermal metamorphic zone, especially in the saccharoidal re-crystallized zone, most of the older fractures are considered to have been cemented by dogtooth calcite during the late stage of the thermal metamorphism, so that notable veins and mineralized zones assumably do not occur, except the area where the younger fractures were formed.

But the distribution range of mineralized zones are obviously affected by the thermal metamorphic zone and the concealed igneous rock as mentioned previously.

8.3 Structure Control by the Younger Fractures

As discussed previously, it is inferred that the younger fractures trending mainly NE-SW were formed in the stage after the cementation of the older fractures by dogtooth calcite. Also it is assumed that the formation of the younger fractures were continued to the mineralization stage, because pyrite crystal of the mineralized veins occurring in the younger fractures are frequently crushed and the cracks of pyrite are completely filled again with gangue minerals.

It is considered that the tectonic movement forming the younger fractures brought reactivation of the older fractures and resulted in the formation of favorable loci for ore deposition in the margin and periphery of the thermal metamorphic zone, and in the center of the thermal metamorphic zone older fractures had been closed already by the dogtooth calcite, yonger fractures were newly formed and provided important loci for ore deposition.

9. CONSIDERATION

It is clarified that the hydrothermal silver-bearing copper ore deposits of vein-type related closely to the intrusive rock of Neogene are distributed in the limestone-predominant calcareous sedimentary rocks of the Aurora formation in this area.

These ore deposits occur mainly in the NE-SW trending fractures which have been formed by the Laramide orogeny and complicated by the subsequent tectonic movement.

These ore deposits occur mostly as veins, however, sometimes they form manto-formed bonanzas. The ores are characterized by relatively high grade in silver and copper and low grade in lead and zinc.

While as the results of this phase survey, various important data regarding the mineralization were obtained, some of important factors to be elucidate for evaluation of economic potential to the ore deposits are still in pending.

Those ploblems summarized below should be solved by the further investigation in near future.

(1) Distribution and mode of occurrence of the sericite-quartz rock, which is assumed to be closely related to the mineralization and is highly mineralized in general.

(2) The lower extension of the main ore deposits in the horizons of the La Peña and the Cupido formations.

The La Peña formation has a thickness of about 100 m and is rich in pelitic rocks. The Cupido formation is underlain beneath the La Peña formation and is probably the lowermost horizon of calcareous sedimentary rocks of this area. Also the formation has intercalations of evaporite layers. It is considered to be favorable horizon for ore deposition since the majority of silver-bearing lead and zinc ore deposits of vein-type occur within this formation. Intersecting these horizons, various structures are developed in the area, and the mineralization reached up to the Aurora formation along the structures. Consequently it might be expected to have

some bonanzas at the horizons of the above two formations, especially within the Cupido formation. It is thought that elucidation of mode of mineralization within the above two horizons gives an important factor for the study of economic evaluation of the area.

(3) Although the fact that the concealed intrusive igneous rock is considered to be one of the most important factors of structure control of ore deposits in this area, skarnization is extremely weak and is not associated with any mineralization so far as present geological data indicate. The reason is probably that the volatile elements of the skarn stage had been mostly consumed at the deep, especially within the Cupido formation which is probably the first horizon of calcareous sedimentary rocks for the ascending volatite elements.

(4) Ore deposits in this area were probably formed under the same activity of mineralization as those located to the north of the area such as Mina la Morena and Mina el Refugio. Detailed exploration, however, has not yet covered the border zone between those mines and this area.