No. 36

PHASE

APRIL 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

# REPORT ON THE COOPERATIVE MINERAL EXPLORATION IN THE JALISCO AREA THE UNITED MEXICAN STATES

## PHASE 2

APRIL 1986

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

# PREFACE

At the request of the United Mexican States Government, the Japanese Government planned a mineral exploration program consisting of several survey methods to examine the possibility of the existence of mineral deposits in the Jalisco area located in the central part of the country. The Japanese Government entrusted the execution of the general plan to the Japan International Cooperation Agency (JICA), and in turn JICA entrusted the execution of this survey to the Metal Mining Agency of Japan (MMAJ), since this survey was a professional survey program of mineral exploration.

This year's program is the second year's one. MMAJ organized a survey team of nine members and dispatched it to the area in a period from July 8, 1985 to February 27, 1986.

The field survey was completed as scheduled with the cooperation of the related government agencies of the United Mexican States, especially the Consejo de Recursos Minerales (C.R.M.).

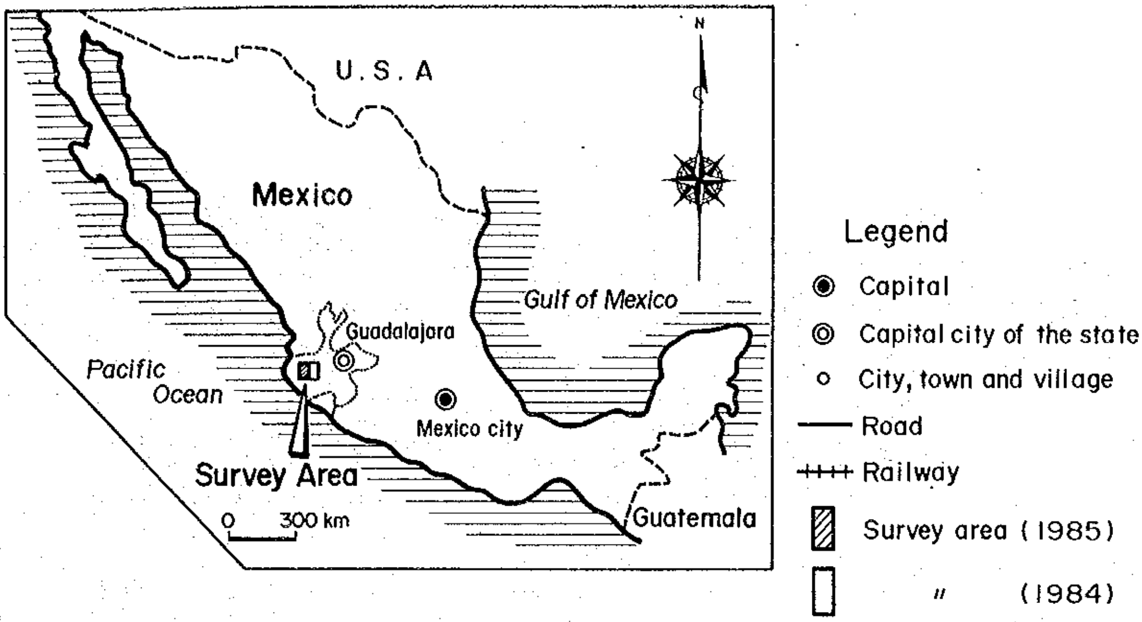
This report is the summary of survey results in the second year and will form a part of a final report.

We would like to express our cordial thanks to the United Mexican States Government Agencies, the Ministry of International Trade and Industry of Japan, the Ministry of Foreign Affairs of Japan, the Japanese Embassy in Mexico and the persons concerned with these agencies.

April, 1986

Keisuke Arita
President,
Japan International Cooperation Agency

Masayuki Nishiie
President,
Metal Mining Agency of Japan



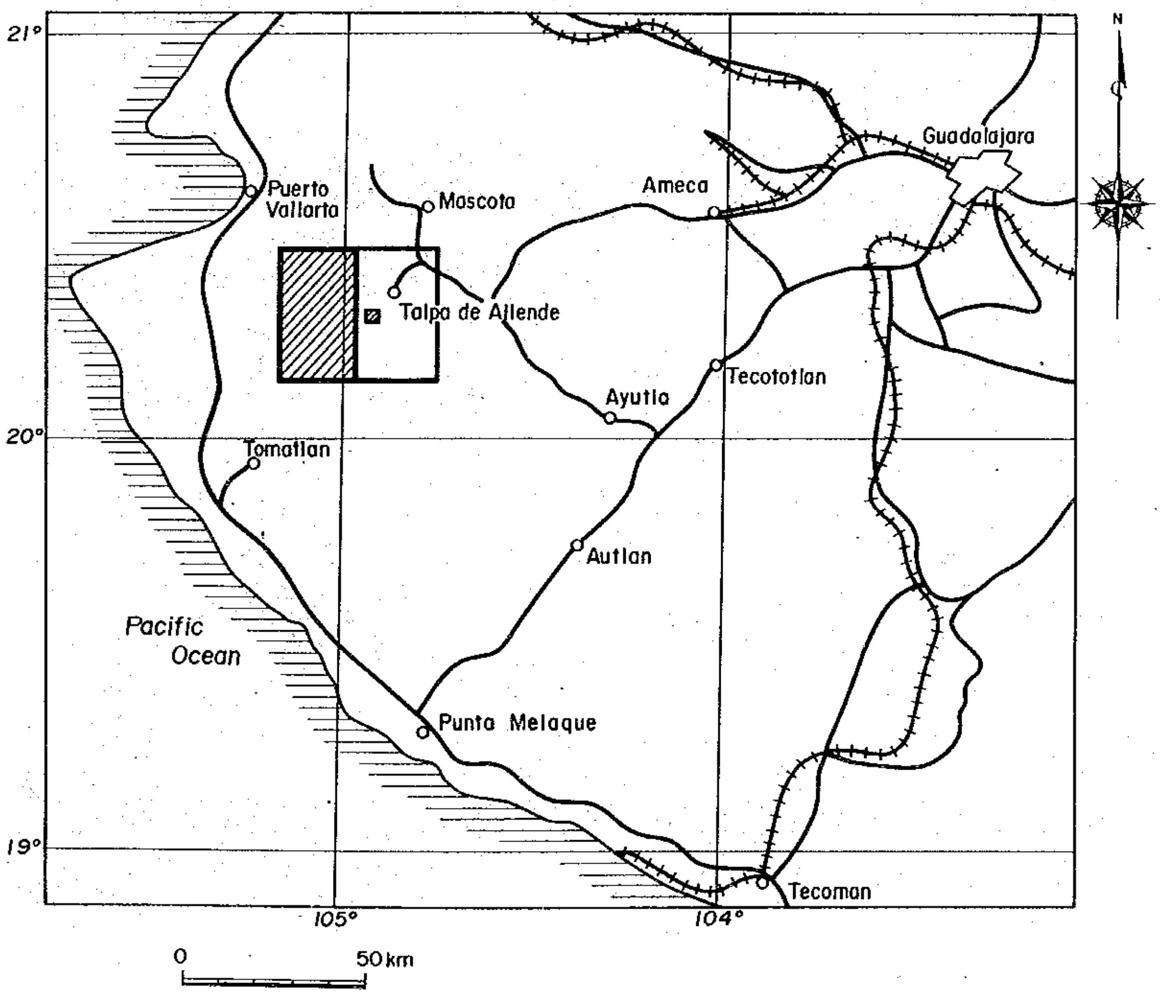




Fig. G-1 Location Map of Jalisco Area

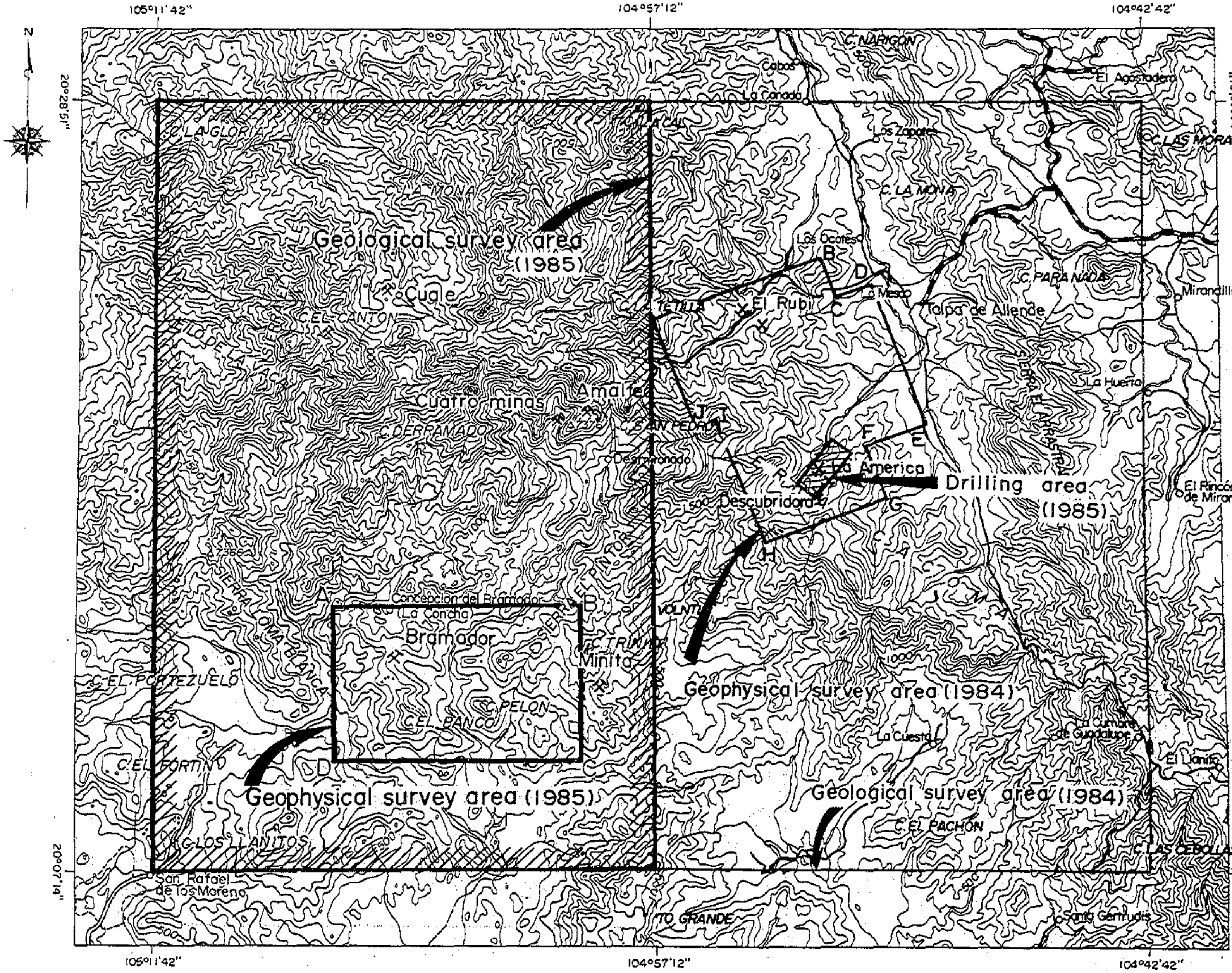



Fig. G-2 Location Map of Survey Area

## SUMMARY

Geological, geochemical (stream sediments), and geophysical (CSAMT method) surveys were conducted in the Western Jalisco area in this phase. The area in which the Jurassic, Cretaceous, Tertiary, and Quaternary System are distributed is located in the intersection of the two major volcanic belts in Mexico, the Sierra Madre Occidental and the Eje Neovolcanico.

The Jurassic System is distributed in the western area, mainly consisting of pelitic schist with minor amount of intercalations of psammitic schist, chlorite schist and sericite schist. The latter two schists might be derived from volcanic rocks. The System is unconformably overlain by the Cretaceous and Tertiary Systems. No significant mineralized zone is observed in the System.

The Cretaceous System is scattered around the area, occupying about 10 per cent of the total survey area, and is important for Kuroko type ores. Main constituent rocks are black shale (Kshl) and dacites (Kdc1-a, -b and Kdc-sh). Kuroko ores are in distribution areas of the latter, suggesting a close relation between them. Dacite dominant areas are the San Juan, Cuale, Amaltea, and La Concha - El Bramador districts, in which Kuroko ores are located.

In the La Concha - El Bramador district, a favourable area for Kuroko exploration, a semi-basin structure with about 10 kilometers diameter is recognized. The basin consists of a combination of synclinorium, trending northwest to southeast, around the San Jeronimo valley. Common species of radiolarias and nannoplanktons of Early Cretaceous age were found in black shales in the overlaying and underlying formations (Kdc-sh and Kshl) of the ore horizon formation (Koh-b). Accordingly it is presumed that the stage of the ore formation is of Early Cretaceous age.

The Tertiary System is distributed in the western highland area, mainly consisting of andesites (Tad1 to Tad4). Welded tuff is seen in the IV-stage andesites (Tad4), therefore it is presumed that geological environment of the stage was transferred from submarine to terrestrial. No significant mineralized zone is seen in the System.

Based on the result of the geological survey, an area of 100 square kilometers in the La Concha-El Bramador district was selected for the geophysical survey (CSAMT method). As a result of the CSAMT survey, low resistivity zones which are possibly related to Kuroko mineralization, were detected. These zones are in distribution areas of the Cretaceous acidic volcanic rocks, and also in or around geochemical anomalous zones of stream sediments. Furthermore the rocks around the zone are subjected to strong alteration.

In the Eastern Jalisco area, a drilling program consisting of five holes, total depth of 1,369.70 meters, was conducted. The area drilled was selected in the La America-Descubridora district based on the results of the first year's geological, geochemical and geophysical (CSAMT method) surveys. As a result of the drilling, no Kuroko ores were found, but useful information relating to Kuroko ores such as submarine paleo-basin structure, extension of the mineralized ore horizon, etc. was obtained.

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# CHAPTER 1 INTRODUCTION

# CHAPTER 1 INTRODUCTION

## 1-1 Purpose of Survey

The purpose of the project is to examine the possibility of the existence of mineral deposits in the Jalisco area by means of clarification of the detailed geological setting with the cooperation of the Consejo de Recursos Minerales (C.R.M).

## 1-2 Outline of Survey

The project, started in 1984, is supposed to conduct for three years, through 1986. In the first year, a geological survey was conducted in an area of 1,000 $km^2$, the east half of the total planned area of 2,000 $km^2$. In this year, geological and geochemical surveys were conducted in the rest of 1,000 $km^2$. In addition an area of 100 $km^2$, which was selected on the basis of the preceding survey results, was geophysically surveyed, then a drilling program consisting of five holes, total depth of 1,369.70 meters, which was planned on the basis of the preceding survey results, was conducted.

The outline of this year's surveys is as follows:

Table 1-1 Outline of Surveys

| Survey Method | Area | Contents |
|---|---|---|
| Geology | 1,000 $km^2$ | 524 km survey route line (scale 1:25,000) |
| Geochemistry (Stream Sediments) | 1,000 $km^2$ | 1,012 samples |
| Geophysics (CSAMT) | 100 $km^2$ | 318 measuring stations |
| Drilling | | 1,369.70 meters (5 holes) |

Table 1-2 Laboratory Tests

| Kind of Tests | Number of Samples | Remarks |
|---|---|---|
| Geological and Geochemical Surveys | | |
| Microscopic Observation of Rock Thin Sections | 50 | |
| Microscopic Observation of Ore Polished Sections | 29 | |
| X-ray Diffraction Test | 332 | |
| Ore Analysis | 35 | Au, Ag, Cu, Pb, Zn |
| Rock Analysis | 34 | $SiO_2$, $TiO_2$, FeO, $Fe_2O_3$, MnO, MgO, CaO, $K_2O$, BaO, $Na_2O$, $Al_2O_3$, $P_2O_5$, LOI |
| Geochemical Analysis (Stream Sediments) | 1,012 | Ag, Cu, Pb, Zn |
| Determination of Fossil | 33 | Nannoplankton, Radiolaria, Foraminifera |
| Drilling Survey | | |
| Microscopic Observation of Ore Polished Sections | 14 | |
| X-ray Diffraction Test | 53 | |
| Ore Analysis | 54 | Au, Ag, Cu, Pb, Zn |

## 1-3 Members of Mission

The members who were involved in the planning, managing, and field survey were as follows:

(1) Planning and Managing

Japanese Members

| | |
|---|---|
| Toshio Sakasegawa | Metal Mining Agency of Japan |
| Kouhei Arakawa | " |
| Takeshi Ogitsu | " |
| Tadaaki Ezawa | " |
| Takashi Kamiki | " |

Mexican Members

| | |
|---|---|
| Ramon Farias Garcia | Director of C.R.M., General |
| Jorge Leipen Garay | Ex-Director of C.R.M., General |
| Luis Brizuela Venegas | Sub-director of C.R.M. |
| Gustavo Camacho Ortega | Chief of Special Investigation Department of C.R.M., Charged in project |
| Cesar J. Villegas Garcia | Chief of Geophysical Exploration Department of C.R.M. |
| Raul Cruz Rios | Sub-Chief of Special Investigation Department of C.R.M., Charged in assistant |

(2) Field Survey Team

Japanese Members

| | |
|---|---|
| Fumio Wada | Dowa Engineering Co., Ltd.<br>(Chief of Mission, General, Geological and Geochemical surveys) |
| Kazuyoshi Masubuchi | Dowa Engineering Co., Ltd.<br>(Geological and Geochemical surveys) |
| Makoto Takeda | "<br>( " ) |
| Yasuo Endo | "<br>(Geophysical survey) |
| Kurae Iwaki | "<br>( " ) |
| Masaru Fujita | "<br>( " ) |
| Masayuki Oshima | "<br>(Drilling survey) |
| Tatsuhiro Aoyama | "<br>( " ) |
| Hisato Kai | "<br>( " ) |

Mexican Members

| | |
|---|---|
| Panfilo Sanchez Alvarado | Special Investigation Department of C.R.M.<br>(Geological and Geochemical surveys) |
| Antonio Gonzalez Ramos | "<br>( " ) |
| Ladislao Segura Garcia | "<br>( " ) |
| Hugo A. Omana Pulido | "<br>( " ) |
| Roberto Ortega Guerrero | Geophysical Department of C.R.M.<br>(Geophysical survey) |
| David Gutierrez Lopez | "<br>( " ) |

# CHAPTER2 GENERAL OUTLINE

# CHAPTER 2 GENERAL OUTLINE

## 2-1 Location and Transportation

The project area is located in Jalisco State, central Mexico, as shown in Fig. G-1. This year's survey area is an area of 1,000 $km^2$, delineated by following four points.

| Point | Latitude | Longitude |
|---|---|---|
| Northwestern Point | 20°28'51" North | 105°11'42" West |
| Northeastern Point | 20°28'51" North | 104°57'12" West |
| Southwestern Point | 20° 7'14" North | 105°11'42" West |
| Southeastern Point | 20° 7'14" North | 104°57'12" West |

An air route and surface road systems are available to reach the City of Guadalajara from the Mexico City. It takes 50 minutes by commercial jet service, and 8 hours by road to travel about 540 kilometers.

It takes about 4 hours to travel 220 kilometers by car from the City of Guadalajara to Talpa de Allende, where our field base camp was set up, and further one hour from Talpa de Allende to the eastern end of the survey area through a rough country road which is only one in service in rainy seasons.

## 2-2 Topography and Climate

The survey area is topographically very rough, locating high steep precipices in some places as high as several tens to one hundred meters.

Generally the eastern to western survey areas are mountainous, and the highest peak is Mt. Torreon, 2,740 meters above sea level. On the contrary the southern to western survey areas are gentle hilly, underlain by granite terrain, and its altitude in the southwestern corner lowers down to 140 meters above sea level.

The climate varies depending upon areas, cool and wet (av. temp. 16°C to 18°C, annual precipitation 1,200 millimeters) in the mountainous areas, predominantly covered by pine trees, and hot and wet (about 24°C in February, 30°C in June to August, annual precipitation 1,200 millimeters in rainy season from June to October) in the lowland areas predominantly covered by semi-tropical vegitation such as citrus fruits and coconuts palm trees.

## 2-3 Industry

Main industries in the area are mining, the Cuale mine, and agriculture, maize, beans, coffee, and stock raising. Sizes of stock farms are generally small, about several tens of cattle. Those of farming are also small, just enough for self-sufficiency.

## 2-4 Mining Industry

The mining industry of Mexico is considerably stagnant as well as other domestic industries, influenced by the worldwide economic depression.

Mexican mineral production in recent years is shown in Table 2-1. There was a decrease in mining exploration in 1984 with most companies operating with greatly reduced budgets and some with decreased staff.

Mining provided 1.3% of the gross national product in 1984. Actually the mining business in Mexico was a bright spot compared with other industries, showing very favourable profits in 1984, but reduced from 1983 due primarily to lower prices for silver and lead. Fluorite and manganese producers exhibited a rebound from the previous two years due to better world markets.

The Cuale mine, one of Kuroko type ore deposits presently being operated in Mexico, is in the area, therefore this area is noticed as one of potential areas for hiden Kuroko type ore deposits. Exploration activity for this kind of ores has not been aggressive at all, because the deposit was fairly recently recognized as Kuroko type one.

In Talpa de Allende, a small milling plant (50 t/day) was constructed to collectively treat copper, lead and zinc minerals from small mines around the town.

Table 2-1 Mexican Mineral Production

(metric tones)

| Mineral | 1980 | 1981 | 1982 | 1983 | 1984* |
|---|---|---|---|---|---|
| Gold | - | - | 6,104 | 6,930 | 6,950 |
| Silver | 1,473 | 1,655 | 1,549 | 1,911 | 2,150 |
| Lead | 145,549 | 157,384 | 145,844 | 167,405 | 182,000 |
| Zinc | 238,231 | 211,629 | 231,910 | 257,444 | 290,000 |
| Copper | 175,399 | 230,466 | 239,091 | 206,062 | 192,000 |
| Molybdenum | - | - | 5,190 | 5,866 | 4,200 |
| Bismuth | 770 | 654 | 606 | 545 | 410 |
| Cadmium | 1,791 | 1,433 | 1,444 | 1,341 | 1,150 |
| Coke | 2,409,000 | 2,425,000 | 2,450,000 | 2,424,826 | 2,450,000 |
| Iron (cont. Fe) | 5,087,000 | 5,293,100 | 5,382,000 | 5,306,343 | 5,570,000 |
| Manganese (cont.) | 160,966 | 208,193 | 183,120 | 133,004 | 163,000 |
| Sulphur | 2,102,000 | 2,077,000 | 1,815,000 | 1,602,029 | 1,750,000 |
| Fluorite | 916,000 | 925,000 | 631,000 | 556,977 | 640,000 |
| Barite | 269,322 | 317,738 | 323,753 | 357,043 | 390,000 |

* Preliminary Estimate (After Mining Annual Review - 1985)

# CHAPTER 3 GEOLOGICAL SURVEY

# CHAPTER 3 GEOLOGICAL SURVEY

## 3-1 Outline of Geology

The survey area is located in the intersection of the two major volcanic belts in Mexico, the Sierra Madre Occidental and the Eje Neovolcanico. The former extends more than 1,000 kilometers along the Pacific Ocean from the border with the U.S.A. to the southeast, and the latter extends about 1,000 kilometers from the State of Nayarit near by the Pacific Coast to the State of Veracruz near by the Gulf of Mexico.

The volcanic activity of the Sierra Madre Occidental started in Oligocene age (33 m.y. Nieto et al., 1981), and that of the Eje Neovolcanico started in Miocene age (Hernandez, 1977). The rocks of the belts are mainly of calc-alkaline rock series (Nieto et al., 1981). It is not clear to which series the rocks belong, because no volcano-stratigraphical and petrographical studies and age determination have yet been conducted.

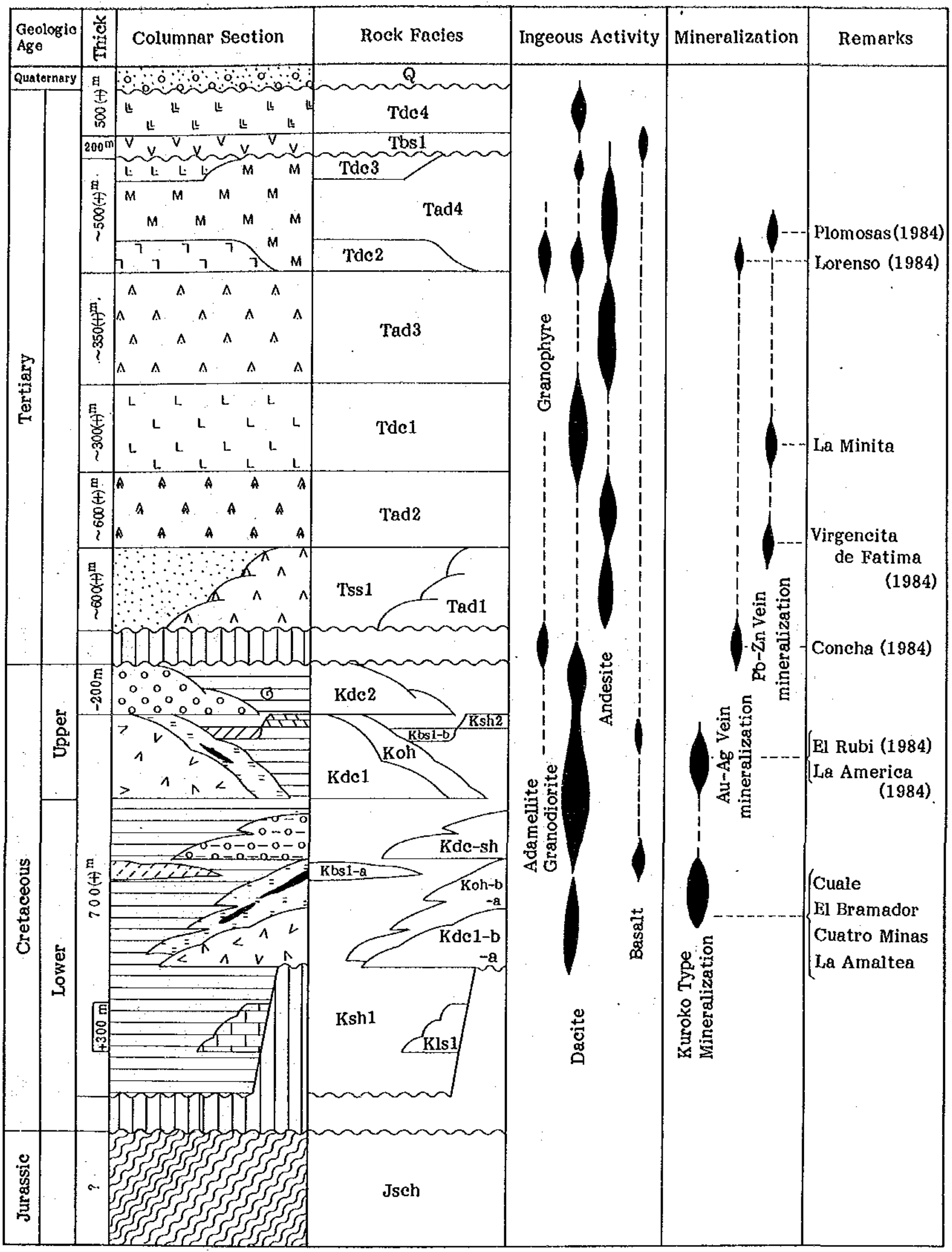
According to Facultad de Ingenieria (1984), volcanic rocks of Sierra Madre Occidental are dominant in the survey area.

Geology of the area is of the basement of the Jurassic metamorphic rocks (Barrocal & Merdoza, 1985), and the overlying Cretaceous, Tertiary, and Quaternary Systems, extending from the last year.

Metamorphic rocks of the basement are distributed extensively north to south in the western survey area. The main constituent rocks are pelitic schist intercalating psammitic schist, chlorite schist, and sericite schist.

The Cretaceous System is distributed in areas around the Cuale mine in the northwestern area and the Amaltea mine in the central east area, and El Bramador to La Concha. The main constituents are dacitic lavas (Kdcl-a, -b) and pyroclastics (Koh-a, -b, Kdc-sh), and black shale (Kshl). The dacite lava (Kdcl-a, -b) shows pale brown to pale green, suffered slightly alteration, and seated as foot walls of the Kuroko ore deposits. The dacitic pyroclastics are of the foot Kuroko ore horizon (Koh-a, -b), and sometimes overlie Kuroko ores as hanging walls. The ore deposits of the Cuale, Amaltea, and El Bramador mines in the area are hosted in the ore horizon (Koh-b). The hanging wall dacitic pyroclastics (Kdc-sh) also overlie the Cuale and El Bramador deposits, therefore it is suggested that Kuroko type ores are very closely associated with such felsic volcanic activities. The black shale (Kshl) shows locally slaty cleavages, but generally are of several centimeters-thick massive beds. Thin layers of basalt lavas and pyroclastics (Kbsl-a) are intercalated in the black shale overlying Kuroko ores (La Crucecita, the eastern survey area). No significant depositional intermission has been noted in the Cretaceous System. The system unconformably overlies the basement metamorphic rocks.

The Tertiary System is extensively distributed in the eastern area. The main constituents are andesites (Tadl 4) with minor sedimentary rocks (Tssl) and dacites (Tdcl). Ages of these volcanic activities are not clear, because no volcano-stratigraphic and age determination data are available. Even the activities were frequently intermitted, no big sign has been noted. The Tertiary System unconformably overlies the Cretaceous System.




Abbreviation

(Jurassic)

Jsch: Metamorphic rocks

(Cretaceous)

| | | |
|---|---|
| Kdc2: | Dacite lava (hanging wall) (1984) |
| Ksh2: | Calcareous shale (1984) |
| Kbs1-b: | Basalt lava-pyroclastics (1984) |
| Koh: | Ore horizon pyroclastics (1984) |
| Kdc1: | Dacite lava dome (1984) |
| Kdc-sh: | Hanging wall dacite-pyroclastics-shale |
| Kbs1-a: | Basalte lava-pyroclastics |
| $Koh_{-b}^{-a}$: | Ore horizon pyroclastics |
| $Kdc1_{-a}^{-b}$: | Footwall dacite |
| Ksh1: | Shale intercalated with sandstone |
| Kls1: | Limestone-marble (1984) |

(Tertiary)

| | |
|---|---|
| Tdc4: | IV-Stage dacite lave (1984) |
| Tbs1: | Basalt lava-pyroclastics (1984) |
| Tdc3: | III-Stage dacite lava (1984) |
| Tad4: | IV-Stage andesite lava-pyroclastics |
| Tdc2: | II-Stage dacite lava-pyroclastics (1984) |
| Tad3: | III-Stage andesite lava-pyroclastics |
| Tdc1: | I-Stage dacite lava-pyroclastics |
| Tad2: | II-Stage andesite lava-pyroclastics |
| Tss1: | Sandstone-conglomerate |
| Tad1: | I-Stage andesite lava-pyroclastics |

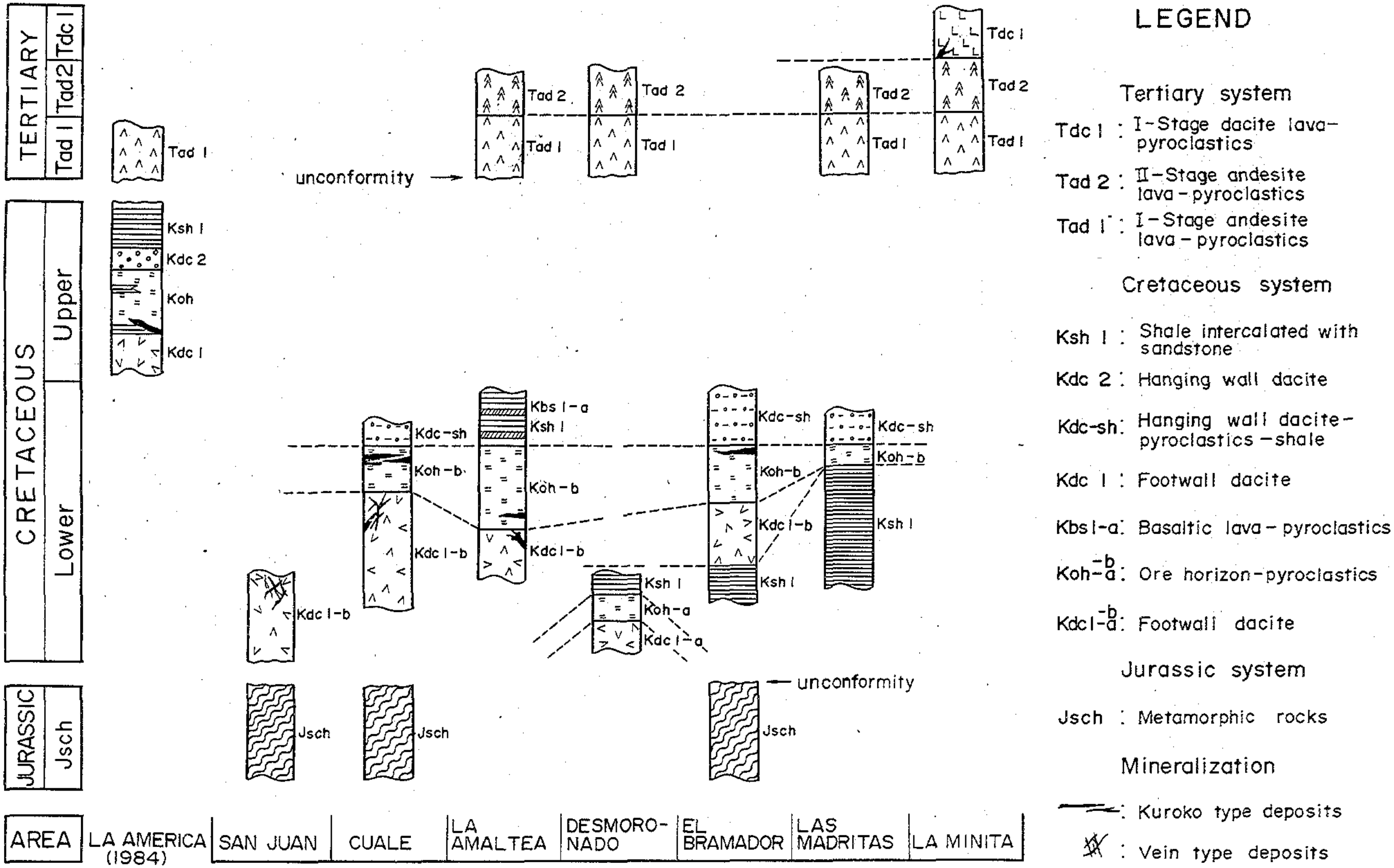
(Quaternary)

Q: Alluvium-Diluvium

Nannoplankton

Fig. 3-1 Generalized Geological Columnar Section of Survey Area

Fig. 3-2 Correlation of Geological Columns of Each Area



## 3-2 Stratigraphy

The rocks in the area are metamorphic rocks of the Jurassic System in the base, overlying shale, sandstone, and volcanic rocks of the Cretaceous System, volcanic rocks, sandstone, and conglomerate of the Tertiary System, and gravel, sand, and clay of the Quaternary System. Some intrusive rocks penetrate above mentioned Systems, specially unknown age granodioritic plutons intrudes in the northern, central, and southwestern areas.

Fig. 3-1 shows its generalized geological columnar section of the survey area.

### 3-2-1 Jurassic System

No stratigraphic succession has been confirmed yet on the metamorphic rocks in the area. However they are similar to rocks defined as Jurassic (Berrocal & Mendoza, 1985).

(1) Metamorphic Rocks (Jsch)

The metamorphic rocks are of oldest in the area.

(Distribution)

The rocks are distributed from the San Juan village in the northwestern area to the Los Caballos de Cabrel village in the southwestern area, north to south.

(Thickness)

No data are available because basal parts of the rocks are not seen.

(Rock Facies)

The System mainly consists of pelitic schist, partly with intercalations of psammitic, sericite, and chlorite schists. Pelitic and psammitic schists are generally black, containing segregating quartz and quartz veinlets, and commonly show micro-folding texture. Under the microscope, quartz, sericite, feldspar, and chlorite are observed. Degrees of recrystallization are generally low, development of schistosity is poor, and semischist is also observed. However, sericite and chlorite schist commonly show well developed schistosity.

(Stratigraphic Relation)

The System is unconformably overlain by the Cretaceous System. Due to the extensive distribution of granodiorite intrusive bodys, no place to reveal the relation to underlain systems is available.

### 3-2-2 Cretaceous System

Judging from the nannoplankton determination study conducted in the two years, it is possible to say that the Cretaceous System in the first year's survey area is of Campanian to Mastrichtian stages (Later Cretaceous Age, 78 to 65 m.y.), on the other hand as mentioned later the Cretacous System in second year's survey are is of Early Cretaceous Age.

Rocks of the System are limestone (Kls1), shale-sandstone (Ksh1), footwall dacite lava (Kdc1-a, -b), dacitic pyroclastics of the ore horizon (Koh-a, -b), hanging wall dacite lava and pyroclastics (Kdc-sh), calcareous shale (Ksh2), and basalt lava and pyroclastics (Kbs1-a, -b). Among them, Kls1 and Ksh2 are distributed only in the last year's survey area, therefore no description is made in this report.

(1) Shale-Sandstone Formation (Ksh1)

The formation is one of main formations in the Cretaceous System, and is very important one because it contains dacite lavas and pyroclastics which are closely related to the genesis of the Kuroko ores. It generally shows very little facies change.

(Distribution)

The formation is mainly distributed in an area from the La Concha village in the southcentral area to the La Maderitas village in the eastern area, and small areas along the San Jose river in the southern area and in the La Crucecita village in the eastcentral area.

(Thickness)

The formation was folded showing general dips of $30^{o}$ to $60^{o}$, but locally disturbed by multi-stage micro-foldings and some shearings. In addition, grading texture to judge bottom-up relation in sandstone beds is poor. Therefore to estimate true thickness of the formation is very difficult. It is assumed that the true thickness of the formation is significantly thinner than its apparent one as seen in examples of other Mesozoic formations, might be 700 meters thick.

(Rock Facies)

The formation generally consists of compact hard black shale. The rock facies are generally homogeneous, but in some places showing a little difference, massive around Las Maderitas and thin alternation of tuff and sandstone being foliated around La Crucecita. Under the microscope, plagioclase, clay minerals, quartz, carbonaceous matter, carbonate minerals, etc. are observed.

(Fossil)

Fossils are poor in the formation, but some radiolarias (Sethocapsa s.p. nassellaria fam. gem. et sp. indet.) are observed in the sample of KM-38 (from El Bramador). This species is common one in Early Cretaceous age.

(Stratigraphic Relation)

The formation unconformably overlies the Jurassic metamorphic rocks, and underlies the I-stage andesites (Tad1) and sandstone-conglomerate (Tss1) of Tertiary age.

(2) Footwall Dacite Lava (Kdc1-a, Kdc1-b)

The lavas are intercalated in the above mentioned shale-sandstone formation (Ksh1), and are thought of submarine volcanic activity. The activity is separated into two stages, older one (Kdc1-a) located in an area from the El Coyulito village to the Trementina valley, and younger one (Kdc1-b) located in areas around the La Concha village, the La Amaltea Mine, the Cuale Mine, and the Blanco valley in the northwestern area. However lithology and rock facies of the both are quite similar.

Even the rocks are intercalated in the shale-sandstone formation (Kshl), the ore horizon pyroclastics (Koh-a, -b) overlie the rocks as a succeeding volcanic activity. The shale-sandstone formation underlie the rocks, and unconformably overlie the basement Jurassic System (Jsch) in the Cuale and La Concha districts.

(Distribution)

The lavas are distributed in areas around the Blanco valley and the Cuale Mine in the northwestern area, the La Concha village to the Los Caballos de Cabrel village in the southcentral area, the La Amaltea Mine in the eastcentral area (up to this all belong to Kdc1-b), and the El Coyulito village (Kdc1-a). Especially the lavas of dacite (Kdc1-b) are distributed in area where they are closely related to the locations of the Kuroko ore deposits.

(Thickness)

Even an accurate measurement of the thickness of the lavas is difficult because of the presence of granodiorite intrusives, it is presumed that the thickness is maximum 500 meters judging from geological cross sections.

(Rock Facies)

The lavas are generally light gray to pale green, aphyric, compact and hard, but in some parts weakly brecciated or semi-massive. Under the microscope, phenocrysts of quartz and plagioclase are occasionally observed, and the groundmass which used to be glassy are strongly silicified resulting unclear texture. Because occurrences indicating parts of lava domes are observed in the field, it is presumed that the lavas would be similar to the lava domes in Japan which are closely related to the Kuroko ores.

(3) Dacitic pyroclastics of Ore Horizon (Koh-a, Koh-b)

The rocks are intercalated in the above mentioned shale-sandstone formation (Kshl), and are very important for exploration purposes because of hosting Kuroko ores. The rocks are closely related to the above mentioned footwall dacite lavas, and overlies them. The rocks accompanied by Kdc1-a and Kdc1-b are named as Koh-a and Koh-b respectively, but both are of similar lithology and rock facies. Therefore there is a possibility that the both are of the same activity.

It is presumed that the genesis of the rocks is of submarine pyroclastic flows, judging from the presence of intercalated shale layers.

(Distribution)

The rocks are distributed in areas around the Cuale Mine, from the La Concha village to the El Bramador village, from the La Amaltea Mine to the La Crucecita village, (up to this Koh-a), and the El Mamey village in the eastcentral area (Koh-b). The rocks would be classified into two activity stages as well as in the case of the footwall dacite lavas (Kdc1-a, -b).

(Thickness)

It is assumed that the thickness of the rocks is about 300 meters judging from the geology around the El Bramador deposits and the La Amaltea Mine.

(Rock Facies)

The rocks are pale green to gray, and mainly consist of fine tuff and lapilli tuff, showing several meters thick alternation with shale beds. The rocks were strongly altered, then the original texture was made very unclear in most cases. The lapilli tuff containing dacite and minor amount of andesite, schist, mudstone, and pumice fragments are noted in some places. Under the microscope, various alteration minerals such as quartz, carbonate minerals (calcite), chlorite, epidote, sericite, etc. are observed.

(4) Basalt Lava and Basaltic Pyroclastics (Kbs1-a)

The rocks are intercalated in the above mentioned shale-sandstone formation (Kshl), but their distribution is very local.

(Distribution)

The rocks are distributed in the area closely relating to the location of the Kuroko type ores around El Rubi deposits in the first year's survey area. In second year's area, they are distributed around La Crucecita where the La Amaltea deposit is in the ore horizon dacitic pyroclastics (Koh-b).

(Thickness)

The rocks are lenticularly intercalated in the shale-sandstone formation (Kshl), and their maximum thickness is about 50 meters.

(Rock Facies)

The rocks mainly consist of dark green to green basaltic lavas and pyroclastics such as fine tuff, generally showing fine grained and compact. The lavas are generally brecciated, but in some parts transforming to massive facies and to doleritic ones. Amygdaloidal textures filled by chlorite are observed in some places. Tuffaceous parts are alternated with shale beds in several meters units, and calcareous in some parts.

Under the microscope, the lavas show subophitic to intersertal textures, consisting of plasioclase, olivine, augite, green amphibole, etc. Generally they were subjected to strong alteration. Chlorite, epidote, and sericite are observed.

(5) Hanging Wall Dacite·Pyroclastics - Shale (Kdc-sh)

The rocks are intercalated in the above mentioned shale-sandstone formation (Kshl), and distributed closely related to Kuroko ores. Therefore it is very important to clarify their distribution for exploration purpose.

The lower parts of the formation mainly consist of shale-pyroclastics alternation, where the formation is separated from the underlying ore horizon formation (koh-b).

(Distribution)

The rocks are distributed in the Cuale and El Bramador districts in second year's survey area, where Kuroko ores underlie. Also these are distributed only in the La America - Descubridora and the El Rubi districts in the first year's area, where Kuroko ores underlie.

(Thickness)

The rocks are intercalated in the shale-sandstone formation (Kshl), and their maximum thickness is estimated as 500 meters.

(Rock Facies)

The rocks consist of lavas and pyroclastics such as fine tuff, tuff breccia, etc. The lavas are located in the bottom of the rock group. It generally shows homogeneous facies, gray to pale gray, compact and hard. It is characterized by the common existence of quartz phenocrysts. Massive and brecciated parts are separated, and rims of fragments of the breccias are occasionally surrounded by limonite and hematite veinlets. Under the microscope, quartz and plagioclase phenocrysts are observed, and the groundmass is glassy, crypstocrystalline and felsic, subjected to strong silicification, consisting of large amount of fine grained quartz, chlorite, and some of clay minerals. The fine tuff and tuff breccia are located in the upper parts of the rock groups, showing grading from the bottom to the top, and alternation of several to several tens meters thick units. Parts of the rocks are very hard to tell apart from the shale in some places, showing pale gray to pale brown.

(Fossil)

Dacitic fine tuff and shale alternate in the formation. Fossils are generally poor in the shale, but nannoplankton is found in the sample of KM-40 from the El Bramador district, and radiolarias in the sample of K-4 from the La Concha district.

The nannoplankton is of Watznaueria barnesae, Cretarhabdus sp. and the radiolarias are of Tricolocapsa(?) sp. These species are common in Early Cretaceous.

### 3-2-3 Tertiary System

The Tertiary System in the area has not measured its age even by age determination or volcano-stratigraphical study.

In the first year's survey, it is clarified that the shale-sandstone formation (Kshl) contains nannonplanktons which belong to species of late Cretaceous age, and is unconformably overlain by the I-stage andesites (Tadl) and the sandstone formation (Tssl), together with the hanging wall dacite and dacitic pyroclastics (Kdc-sh). Therefore it is presumed that the I-stage andesite (Tadl) and the sandstone formation (Tssl) are probably of Tertiary age. This assumption consistents with the general volcanic activity history of the Sierra Madre Occidental and Eje Neovolcanico. The Tertiary System mainly consists of volcanic piles of andesites and dacites. The succession of the piles from the bottom to the top is as follows; I-stage andesites (Tad1), sandstone formation (Tss1), II-stage andesites (Tad2), I-stage dacites (Tdc1), III-stage andesites (Tad3), II-stage dacites (Tdc2), IV-stage andesites (Tad4), III-stage dacites (Tdc3), basalts (Tbs1), and IV-stage dacites (Tdc4). The II-, III-, and IV-stage dacites (Tdc2, Tdc3, Tdc4), and the basalts (Tbs1) are distributed only in the first year's area, then description of them is omitted.

(1) I-Stage Andesites (Tadl)

(Distribution)

The rocks are distributed in areas around the Crucecita valley in the eastcentral area, and from the southeastern part of the Desmoronado valley to the Los Llanos village through the Minita village.

(Thickness)

The maximum thickness of the rocks is about 600 meters in an area around the La Minita village to the Aguacate valley.

(Rock Facies)

The rocks mainly consist of lavas and pyroclastics such as lapilli tuff. The lavas are the most dominant constituent of the rocks, showing dark green to green, brecciated or compact massive. Units of the flows probably are significantly thick, because no flow unit is observed. Under the microscope, porphyritic texture is distinctly observed, and large idiomorphic plagioclase (shorter than 7 mm) and idiomorphic to hypidiomorphic augite (shorter than 5 mm) are observed as well as hypidiomorphic iron minerals (magnetite?) and minor amount of hypersthene (altered to chlorite). The groundmass shows felty texture, mainly consisting of brown glass and very fine grained plagioclase with minor amount of pyroxene and iron minerals (magnetite?).

Alteration minerals such as chlorite, sericite, quartz, etc. are observed. The lapilli tuff is green, intercalated in the lavas, containing dark green to brown andesite fragments, and subjected to alteration stronger than lavas. Plagioclase fragments are also contained in the lapilli tuff, but generally smaller than those in the lavas.

(Stratigraphic Relation)

The rocks unconformably overlie the shale-sandstone formation (Kshl) of the Cretaceous System in the north of La Crucecita.

(2) Sandstone-Conglomerate Formation (Tssl)

The formation is the only one of sedimentary in the Tertiary System. The presence of the formation indicates that distinct recession of volcanic activity occurred during the time.

(Distribution)

The formation is distributed only in an area around the El Coyol de Celi village in the southeastern area.

(Thickness)

Thickness of the formation is about 200 meters in this year's area, on the contrary the maximum about 700 meters in the first year's area.

(Rock Facies)

The formation mainly consists of sandstone and conglomerate, with thin black shale beds and andesite lava flows. The sandstone is gray and massive to layered wacke-like appearent, and well sorted. The conglomerate is gray to brown, and its fragments consist of angular to subangular andesite, dacite, mudstone, basalt, and other silicified rocks. Conglomerate consisting of only limestone is seen in an area northeast of the El Coyol de Celi village, and fossils determined as Amphipyndax(?) sp. Cryptocephalic or Cryptothoracic radiolarias were found in the sample L-44 which was collected from a fragment of the conglomerate. These radiolarias are referred to Cretaceous age, therefore the limestone formation (Klsl) locating in the first year's area is possibly the source of the conglomerate, and the age of the limestone formation is presumed as to Cretaceous as predicted first year.

(Stratigraphic Relation)

The formation gently overlies the I-stage andesites (Tad1), and underlies the II-stage andesites (Tad2).

(3) II-Stage Andesites (Tad2)

(Distribution)

The rocks are distributed in areas around the Los Lobos village and the Pitillo valley in the northern area, the Desmoronado hill in the central area, and the Palosanto hill in the southeastern area.

(Thickness)

Thickness of the rocks distributed in an area around the La Manita village to the Trinidad hill is estimated as 500 to 600 meters.

(Rock Facies)

The rocks mainly consist of lavas and pyroclastics such as lapilli tuff and tuff breccia. The lavas are dark green to dark gray, compact and hard, mainly of medium grained andesite. The lapilli tuff and tuff breccia are dark green to reddish purple, containing mainly andesitic fragments as essential one with minor amount of dacitic fragments as accidental one, appearing subangular. Under the microscope, main constituent minerals of the lavas are plagioclase, potash-feldspar, augite, and iron minerals, with minor amount of glass, showing intergranular texture. Chlorite, epidote, pyrite, etc. as alteration minerals are observed. The lapilli tuff mainly consists of andesite fragments as well as dacitic ones. The groundmass is tuffaceous, consisting of glass together with plagioclase, iron minerals, etc., and alteration minerals such as quartz, chlorite, sericite, and pyrite are observed.

(Stratigraphic Relation)

The rocks conformably overlie the sandstone formation (Tss1) in an area east of El Coyol de Celi, and quasi-conformably overlie the I-stage andesites (Tad1) in an area west of La Minita, but unconformably overlie the shale-sandstone formation (Ksh1) and the hanging wall dacite and dacitic pyroclastics (Kdc-sh) in an area north of La Amaltea.

(4) I-Stage Dacites (Tdc1)

The rocks are of the first felsic volcanic activity in Tertiary age in this area.

(Distribution)

The rocks are distributed in areas around the Trinidad hill to the northwest of the La Minita village and the Desmoronado hill to the northwest of Desmoronado, where are in ridge areas.

(Thickness)

The maximum thickness of the rocks is estimated as about 300 meters.

(Rock Facies)

The rocks mainly consist of lavas and pyroclastics such as fine tuff and lapilli tuff. The lavas are pale gray to pale brown, showing non-porphyritic and porphyritic textures, and generally massive. They generally do not show clear auto-brecciated texture, presumably because of strong alteration. Lapilli tuff and tuff breccia are pale brown to pale gray, and their fragments are of dacite, rhyorite, quartz porphyry, etc. The groundmass is glassy, containing small amount of potash-feldspar. The rocks are subjected to alteration, occurring chlorite, sericite, calcite, quartz, pyrite, etc.

(Stratigraphic Relation)

The rocks conformably overlie the II-stage andesites (Tad2).

(5) III-Stage Andesites (Tad3)

The rocks are thought to be the same volcanic activity as the IV-stage andesites (Tad4), but no definite evidence indicating direct relation between them is seen in the field. Tad3 is distributed in the southern area, and Tad4 is in the northern area.

(Distribution)

The rocks are distributed in areas around La Jabalina, the El Elmitano hill, and other places in the southern area. They overlie the I-stage andesites (Tad1) and the granodiorite (Gd).

(Thickness)

Thickness of the rocks is about 350 meters in the area, but it was estimated as the maximum about 850 meters in the first year's area.

(Rock Facies)

The rocks consist of lavas and pyroclastics such as fine tuff, lapilli tuff, and tuff breccia. The lavas are brown to gray, hard and compact, showing clear brecciated texture. They are characterized by common presence of tabular plagioclase phenocryst. The lapilli tuff and tuff breccia are pale brown to reddish brown, consisting of aggregation of andesitic fragments. The fine tuff is reddish brown to pale gray, fine grained, partially shaly.

(Stratigraphic Relation)

The rocks directly overlie the basement granodiorite (Gd) and I-stage andesite (Tad1). No evidence showing unconformity between the rocks and Tad1 is seen in the field.

(6) IV-Stage Andesite (Tad4)

(Distribution)

The rocks are distributed in areas around the La Virgen valley in the northeastern area and upper stream of the Naranjo valley.

(Thickness)

Maximum thickness of this rocks is estimated as about 500 meters.

(Rock Facies)

The rocks consist of lavas and pyroclastics such as welded tuff, lapilli tuff, and tuff breccia. The lavas are brown to reddish purple, compact and hard, commonly containing about one millimeter long plagioclase phenocrysts. The welded tuff is reddish purple, compact and hard, showing flow structure.

Under the microscope, plagioclase, potash-feldspar(?), some mafic minerals such as pyroxine or amphibole are observed. Very fine grained quartz, epidote, sericite, etc. occur as alteration minerals. The lapilli tuff and tuff breccia are not welded, showing brown to reddish purple, and their fragments consist of andesitic pebbles and poorly vesculated pumices. They are subjected to alteration, occurring micro-grained quartz and sericite.

(Stratigraphic Relation)

The rocks overlie the I- and II-andesites (Tad1, Tad2) and the I-stage dacites (Tdc1), showing no significant depositional gaps between them.

### 3-2-4 Quaternary System

The Quaternary System is distributed in flat areas along the Cuale river and the San Jose river. Unconsolidated sand, gravel ,and clay are main constituents of the System, and they are usually stratiformed. Description of the System is omitted due to the object of the survey.

### 3-2-5 Intrusives

The intrusive rocks are adamellite (Adm), granodiorite (Gd), granophyre (Gph), andesite (Ad), and dacite (Dc). Description of the adamellite is omitted because the rock is only distributed in the first year's area.

(1) Granodiorite (Gd)

(Distribution)

The rock is distributed in areas around El Sestiadero Verde in the northern area, along the Cuale river, around the Cuale village and the Desmoronado-La Concha villages in the central area, and around the El Aguacate-Cabrel-San Miguel villages in the western to southern area. The rock is exposed as a batholith extending outside the survey area.

(Rock Facies)

The rock is gray, compact, hard, and coarse to fine grained granodiorite. Main parts of the rock show equigranular texture. Its principal constituent minerals are quartz, plagioclase, potash-feldspar, biotite, amphibole, and iron minerals (magnetite), and accessary minerals are sphene, apatite, zircon, etc. It is subjected to alteration, occurring chlorite, epidote, quartz, etc.

(Time of Intrusion)

No accurate age of the rock is known because no age determination has been conducted yet. It is presumed that the age of the intrusion is of the Laramide (older than 45 m.y.), because the shale-sandstone formation (Ksh1) of the Cretaceous System was metamorphosed to hornfels phase, and the Tertiary System has not metamorphosed. According to regional classification of the igneous activity by Nieto et al. (1981), the area belongs to an area of the Laramide age, and this classification supports the above mentioned presumption.

(2) Granophyre (Gph)

(Distribution)

The rock is distributed in areas around the La Amaltea and along the Encino river as stocks.

(Rock Facies)

The rock is generally pale brown to gray, compact and hard, appearing 5 to 6 millimeters long columnar plagioclase phenocrysts. Under the microscope, plagioclase, biotite, hornblende, and iron minerals (magnetite) are observed as phenocrysts, and quartz, potash-feldspar, plagioclase, biotite, amphibole, and iron minerals (magnetite) are observed in the groundmass. It shows micrographic and porphyritic texture, and has some facies changes. It is subjected to alteration, sericitization of plagioclase and chloritization of biotite.

(Time of Intrusion)

The rock intruded in the II-stage andesites (Tad2) in the areas around the Derramado hill and the Camacho river, but no clear evidence for the relation between the rock and the later stage rocks than the I-stage dacites (Tdc1) is available. It is suggested that the rock is of shallow intrusion because facies change is very common, and probably belongs to so-called "Tertiary Granite." Therefore its thermal metamorphism would be weak.

(3) Andesites (Ad )

The rocks are classified to two types, (Ad ) and (Ad2). Description of the (Ad2) is omitted in this report because the (Ad2) is distributed only in the first year's area.

(Distribution)

The rocks are distributed in areas around the El Mirador village, north of the La Concha village, and the El Blanco Hill, south of the El Bramador village, in the central area.

(Rock Facies)

The rocks are dark green to dark brown, and hard, having giantic plagioclase phenocrysts resembling to the I-stage andesites (Tad1). Under the microscope, plagioclase, augite, and iron minerals are observed as phenocrysts, and plagioclase, clinopyroxene, iron minerals, glass, etc. are observed in the groundmass, showing porphyritic and intersertal texture. It is subjected to alteration, occurring chlorite, epidote, sericite, calcite, etc.

(Time of Intrusion)

The rocks intruded in the II-stage andesites (Tad2), but no clear evidence for the later stages is available.

(4) Dacite (Dc)

(Distribution)

The rock is distributed in areas along the El Potrero Nuevo river in the northern area, around the La Octotera hill in the central area, and west and south of the Cuale mine in the northwestern area.

(Rock Facies)

The rock is generally gray, compact and massive, containing two to three millimeters long quartz crystals, showing porphyritic texture. It is subjected to alteration, occuring sericite, chlorite, calcite, etc.

(Time of Intrusion)

A part of the rock intruded in the IV-stage andesites (Tad4), therefore it is presumed that the rock is of latest volcanic activity in the survey area.

### 3-3 Geological Structure

Elements concerning the geological structure in the area are different for each geologic domain, the Jurassic, Cretaceous, and Tertiary Systems. Strong and short amplitude folding is very common in the Jurassic and Cretaceous Systems, on the contrary gentle long amplitude folding is dominant in the Tertiary System.

#### Jurassic System

The Jurassic System is unconformably overlain by the Cretaceous and Tertiary Systems. The System is distributed in the northern area, surrounding the San Juan, Cuale, and El Bramador districts. It suggests that the uplift in the western area is greater than that in the eastern area. Such uplift is controlled by a big fault system trending northwest to southeast.

A high order folding system having a half wave length of 120 to 200 meters is commonly observed along the well exposing road connecting the Cuale mine to El Aguacate.

A lower order folding system having a half wave length of 5 kilometers is noted around there overlapping by previously mentioned system. The axis of the latter system trends north to south, gently plunging to the south and forms an open folding.

The dips of the wings of the anticline structure accord with those of the topography.

The position of the Cuale mine corresponds with a anticlinal axis. It is presumed that erosion surface in the northern part is deeper than that in the souther part, accordingly it is judged that the syncline axis pluges to the south.

Direction of joints, form of dragg folding, displacement of segregation quartz veins, grading in sandstone etc, were referred for structure analysis.

Partial strong folding structures, as well as schistosity, are noted specially in pelitic schist in the System.

Generally, the schistosity in slightly oblique to the bedding planes.

#### Cretaceous System

The Cretaceous System is unconformably overlain by the I- and II-stages of Tertiary andesite.

Black shale is subjected to the strongest folding in the area, appearing around the Los Alpes and Delicias deposits. On the other hand, dacite is competent for folding, showing gentle undulation.

Distribution of the System is controlled by a northwest-southeast tectonic line. Dacitic activity occurred in the San Juan, Cuale and Amaltea districts from the northwest to the southeast and amount of uplift decrease to the same direction.

Granodiorite intruded in the middle part between the Cuale and the Amaltea districts, also the II-stage andesite overlies there, therefore relationship between both districts can not see directly. However, geology of the both districts is similar, possibly of a same series. Relationship between the San Juan and Cuale districts is presumed as similar to that.

On the other hand, a semi-basin structure is noted in the El Bramador district, delineated a connecting line, La Concha-Los Caballos de Cabrel-Los Tecomates north. East of Los Tacomates is overlain by the Tertiary andesites. The diameter of the basin is about 10 kilometers north to south. A synclinorium structure, having a northwest to southeast axis, is noted in the La Concha-El Bramador district.

Synclinal and anticlinal axes having an about 600 meters half wave length is in the San Jeronimo valley, plunging to the southeast. Ore horizons in the El Bramador and Cuale-Amaltea districts are possibly correlated with a same stratigraphic position, locating in both wings of a anticlinal structure, being underlain by the dacites (Kdc1-a). A sign of genetical relationship between Kuroko deposits and calderas or special tectonic lines as proposed by Ohmoto (1978) and Scott (1978) is not noted in this area.

**Teritary**

Distribution of the Tertiary System is controlled by amounts of uplift, predominating in the eastern part of the northern area and in the western to eastern part of the southern area.

Folding structue is gentle, and folding axes found in the last years survey area tend to disappear in the area.

Faults located in the area gave dislocation to the Jurassic, Cretaceous, and Tertiary System. Main fault systems are from the older (1) north to south, and north-northeast to south-southwest, (2) east to west, (3) northwest to southeast.

The first one gave dislocation to the Jurassic and Cretaceous Systems in the central area.

The second one gave dislocation to the Tertiary andesite and the granodiorite in the Teosinte district in the eastcentral area and the Las Mostazas district in the southeastern area, but their dislocation is not significant.

The third one is the most dominant one in the area, presenting good continuity and various dislocation.

## 3-4 Mineralized Zone

Various kinds of mineralized zones are distributed in the survey area; Kuroko type ores closely associating with the dacite and dacitic pyroclastics (Kdc1-b, Koh-b) of the Cretaceous System, and copper-lead-zinc vein type ores in the I-stage dacite (Tdc1) of the Tertiary System, etc. However, Kuroto type ores are economically most important in the area, therefore the survey emphasized to evaluate further potential for such type ores.

Kuroko type ores in the area are distributed in following three districts.

(a) Cuale district
(b) El Bramador district

(c) Amaltea district

The Cuale Mine, presently in operation, is in the Cuale district, several tens of old workings are in the El Bramador district and the Amaltea deposit and Cuatro Minas deposit are in the Amaltea district.

### 3-4-1 Details of Mineralized Zone

(1) Cuale Mine (Zimapan Inc.)

The Cuale Mine is located 30 kilometers southeast of Puerto Vallarta, famous resort area facing the Pacific Ocean, and is only one operating mine in the area, also being as a principal mine in the Jalisco State.

Mining activity in the mine started in 1804 at the time of discovery of the La Prieta deposit. Activities of the present owner (Zimapan Inc.) are as follows:

1965: Setting of the mining claims
1972: Detection of the Coloradita, Chivos de Arriba, and Chivos de Abajo anomalies by electromagnetic surveys (TURAM).
1977 to 78:
Drilling of 215 holes (total depth 11,038 meters) finding following ores.

Ore Reserves: 1,471,000 t

| | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) |
|---|---|---|---|---|---|
| Grade: | 1.15 | 169 | 0.34 | 1.27 | 4.89 |

1981: Started operation (January)

Presently the mine produces 21,500 ~ 24,000 tons of ore per month (grade Au: 1 g/t, Ag: 150 ~ 170 g/t, Cu: 0.18%, Pb: 1 ~ 2%, Zn: 3 ~ 4%) by approximately 500 workers. Output and grade of ores from each ore deposit are as follows:

| Ore deposit | Au g/t | Ag g/t | Cu % | Pb % | Zn % | Output t/m |
|---|---|---|---|---|---|---|
| Naricero | 0.24 | 170 | 0.06 | 0.99 | 3.26 | 13,000 |
| Refugio | Preproduction stage | | | | | |
| Socorredora | 0.40 | 250 | 0.21 | 3.15 | 8.10 | Preproduction stage |
| Prieta | 0.95 | 360 | 0.30 | 3.05 | 8.30 | 2,500 to 3,000 |
| Grandeza | 3.50 | 30 | 0.40 | 0.70 | 6.00 | 6,000 to 8,000 |

(a) Mina Naricero (Altitude: 1,860 m)

**Location:**

The deposit, presently main ore source of the mine, is located about one kilometer southwest of the mine office.

**Occurrence:**

The deposit is in the dacitic fine tuff and tuff breccia (Koh-b) underlying the black shale. Thickness of ore horizon is said about 40 meters nearby the deposit (Berrocal & Mendoza, 1985). The deposits are hosted in two horizons in ore horizon and consist of black ore and yellow ore. The massive sulphide ore was brecciated resulting aggregation of several centimeters ore fragments and impregnation, in some places showing veinlets ores. Principal constituent minerals are sphalerite and pyrite, with minor amount of galena, chalcopyrite, tetrahedrite, etc. Main alteration minerals are sericite, chlorite and quartz.

It is judged from the properties and mode of occurrences of the ore minerals that the deposit is of so-called "distal" type, secondary removed and redeposited from its original positions by some actions. In such cases, it is very important to explore "proximal" type ores, original source of this "distal" type ores.

The output from the deposit occupies about 60 percent of the total output of the mine. The grade of ore is as follows:

| Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) |
|---|---|---|---|---|
| 0.24 | 170 | 0.06 | 0.99 | 3.26 |

General strike and dip of the ore horizon (Koh-b) are N20° ~ 40°W and 20° ~ 30° NE and its thickness shows the maximum around Naricero.

Assay results of ores sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| MAR-1 | 0.6 | 405 | 0.14 | 1.87 | 7.08 | Sph-gn-py ore |
| MAR-2 | 2.6 | 3,504 | 0.24 | 7.14 | 23.65 | Kuroko ore |
| MAR-3 | 0.9 | 790 | 0.20 | 0.25 | 0.45 | Py ore |

(b) Mina Socorredora (Altitude: 2,000 m)

**Location:**

The deposit is located about one kilometer west of the mine office.

**Occurrence:**

The deposit is in the alternation of the dacitic tuffs and shale (Koh-b). The deposit consists of an aggregation of independent small deposits, distributing in an oval shape, and is separated into two horizons. A weak zonal distribution of ore minerals, not distinct like in the Coloradita deposit, is noted in the deposit; dominant in sphalerite and galena in the upper layer, and pyrite and chalcopyrite in the lower layer.

Gangue minerals are quartz, barite, gypsum, etc., and principal alteration is silicification, sericitization, and carbonatization.

Size and grade of the deposit are as follows:

| | long axis (m) | Short axis (m) | thickness (m) | | |
|---|---|---|---|---|---|
| Size: | 200 | 100 | 1.5 | | |

| | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) |
|---|---|---|---|---|---|
| Grade: | 0.40 | 250 | 0.21 | 3.15 | 8.10 |

The deposit is now in preproduction stage.

Assay results of ores sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| Soc-1 | Tr | 49 | 0.15 | 8.92 | 23.73 | Kuroko |
| Soc-2 | 0.5 | 117 | 0.05 | 0.41 | 1.76 | Py ore |

(c) Mina Grandeza (Altitude: 2,060 m)

**Location:**

The deposit is located about three kilometers southeast of the mine office, southeast of the Cuale deposit.

**Occurrence:**

The deposit is hosted like stockwork in the footwall dacite lava (kdc1-b). Preferential trend of veinlets consisting the stockwork is not clear.

The scale of the deposit confirmed so far is 125 meters long (maximum), 20 ~ 50 meters width, 70 meters thick.

Main constituent minerals are pyrite and sphalerite, with minor amount of chalcopyrite, galena, bonite, and coveline. Main alteration minerals are sericite and quartz.

The output from the deposit occupies about 30 percent of the total output of the mine.

Presently it is impossible to see its original mode of occurrence of the upper parts of the ores due to erosion. However, it is possible to stratigraphically correlate host rock of the deposit to the footwall dacite of the Cuale deposits, therefore it is suggested that the position of the deposit would be coincident an ore pass zone for forming Kuroko ores, positioning in eruptive center.

It is worth to note that such stockwork overlying massive sulphide deposits generally contain certain amount of gold (Au: 3.5 g/t; Ag: 30 g/t; Cu: 0.40%; Pb: 0.70%; Zn: 6.00%) as the case of this deposit.

Under the microscope, a large amount of sphalertie with minor pyrite, chalcopyrite, bornite, galena, electrum, etc. are observed.

Assay results of ores sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| ORO-1 | 0.8 | 15 | 0.15 | 0.27 | 4.61 | Sph-Py ore |
| ORO-2 | 3.6 | 45 | 0.81 | 1.47 | 38.45 | Sph ore |

(d) Mina Coloradita (Altitude 2,130 m)

**Location:**

The deposit is located about one kilometer north of the mine office.

**Occurrence:**

The deposit is in the alternation of the dacitic pyroclastics and shale (koh-b), specially in the felsic sandy tuff. The deposit consists of two layers, pyritic ore layer mainly consisting of pyrite and chalcopyrite, and overlying black ore layer mainly consisting of sphalerite. Acidic taffaceous sandstone overlying these ore layers contain some impregnated zones of sphalerite, galena, and pyrite, most of parts of which form gossan in the surface. It is said that some of these gossans contain several g/t of gold.

Strike and dip of the layers are N40°W, 20° ~ 40°SW. It is supposed that the deposit is of so-called "proximal" Kuroko type ore formed in the proximity to eruptive center of ore solution judging form the fact that black ore (upper) and pyritec ore (lower) coexist in same palces.

Size and grade of the deposit are as follows:

| | long axis (m) | Short axis (m) | thickness (m) |
|---|---|---|---|
| Size: | 120 | 80 | 1.1 |

| | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) |
|---|---|---|---|---|---|
| Grade: | 1.17 | 75 | 1.33 | 1.81 | 9.79 |

Open pit operation of the deposit terminated in 1984, but gold extraction from the overlying gossan is now under consideration by the operator.

Assay results of ores sampled by the survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| 0-1 | 13.3 | 80 | 0.16 | 0.78 | 0.20 | Gossan |

There are the Prieta deposit and the Refugio deposit which are now under preparation for operation other than above mentioned ore deposits in the mine. It is thought that they are of Kuroko type ores because of being hosted in the ore horizon (Koh-b) as well as the cases of the other deposits.

(2) Bramador Ore Deposits

The deposits are located around the San Jeronimo valley, about two to five kilometers northwest of the El Bramador village. Many old workings are scattered there, aligning northwest to southeast extending for the distance of about 2.3 kilometers. The deposits mainly consists of Kuroko type ores, with minor mercury and gold ores. Bramador ore deposits consist of following each deposit.

| | | |
|---|---|---|
| (a) | La Trozada-E | Mercury deposit |
| (b) | La Castellana | Kuroko type ore |
| (c) | Los Alpes | " |
| (d) | San Jose | " |
| (e) | Delicias - El Rosario | Kuroko type ore(?) - Gold ore(?) |
| (f) | La Colorado | Kuroko type ore |
| (g) | San Pedro - Rey Negro | " |

(a) La Trozada-E (Altitude: 875 m)

**Location:**

Rocks around the old adit are of the ore horizon dacitic pyroclostics (Koh-b), therefore mineral occurrences would be in the formation. Gossan is seen around the adit, then it is presumed that the adit was digged for gossan at that time. Limonite is the main oxidized mineral, remaining small amount of hematite. No sulphide is found there.

Kaolinization is superimposed on the zone of silicification and argillization.

Stratigraphic horizon of the formation around there is correlated with the Kuroko ore horizon, and the position is situated in the northwestern of a series of Kuroko deposits.

However details relating to Kuroko ores are not clear.

Operation history, grade and amount of output of the deposit is not available, even it is said that a distillation furnace was there before. It is presumed that the operation was of very small scale because only one adit is in the level of 875 meters above the sea level and amount of dumps is very small.

| Sample No. | Au g/t | Ag g/t | Cu % | Pb % | Zn % | Remarks |
|---|---|---|---|---|---|---|
| KMO-1 | Tr | 4 | 0.01 | 0.02 | 0.01 | Gossan |

(b) La Castellana (Altitude: 740 m)

**Location:**

The deposit is located about 1.5 kilometers south of the La Concha village, left bank of a tributary of the El Encino river.

**Occurrence:**

Rocks around the adit are of the ore horizon dacitic pyroclastics (Koh-b), fine tuff to lapilli tuff, intercalating brown to dark brown thin shale beds.

Small amount of pyrite dissemination is common in the rocks, but no other sulphides.

No dumps are seen around the adit, accordingly no details are clear. As a result of a X-ray diffraction test, quartz and minor amounts of plagioclase, sericite, and chlorite were detected, accordingly, it is judged that the intensity of the alteration is moderate. Therefore it is thought that the deposit is not located in an area of a mineralized zone.

A sulphide impregnated zone in the ore horizon formation was probably explored at that time.

(c) Los Alpes (Altitude: 740 m)

**Location:**

The deposit is located about 1.7 kilometers south of the La Concha village.

**Occurrence:**

An adit is collapsed. It is said that length of the adit is about 60 meters, dipping about 10 degrees to the end. Judging from rocks and ores scattered there, it is supposed that ores are in altered white shale or dacitic pyroclastics, specially fine tuff (Koh-b).

Ores appear of typical Kuroko, mainly consisting of fine grained pyritic ores and sphalerite-galena-black ores.

Massive ores are dominant but some pyritic ores show compositional banding of galena and sphalerite.

Presumably some zonal distribution is expected in the ore zones, and the deposit is of "proximal" type.

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| KMO-2 | 1.0 | 89 | 0.27 | 19.03 | 28.75 | Kuroko |

Grades of Au and Ag are low compared with those of Pb and Zn.

Under the microscope, large amount of sphalerite, certain amount of galena and pyrite, and minor amount of tetrahedrite are observed. Tetrahedrite tends to occur with galena.

A part of pyrite shows colloform structure. These are very common features in Kuroko type ores.

(d) San Jose (Altitude : 700 m)

**Location:**

The adit of this deposit is located around 1.9 Km south of La Concha village and 150 m west of the aforesaid Los Alpes deposit. The difference in height between the two deposits is 40 m, with San Jose lower.

**Occurrence:**

The adit exists in dacitic pyroclastics (tuff breccia, Koh-b). The vicinity is remarkable in alteration with a glance of lava like rock facies, but weakly altered portions that are locally found are accompanied with accidental breccia, which is considered to be tuff breccia. The ore observed with the naked eye contains only fine particles of pyrite dissemination or somewhat larger particles of pyrite carrying veinlets of quartz, but no sphalerite and galena.

No dump was found around the adit, and any information about the target ore for working was not available. From the location point of view, however, adit has been excavated toward the bottom of Los Alpes deposit that had been worked for Kuroko ore, accordingly the adit seems to aim at the mineralized zone that had developed in the lower part of the stratiform or massive Kuroko type ore. A guide explained that ore of high (gold) silver network or vein had been mined. If the explanation is true, a feature of the Kuroko type ore deposit in this area might be that the deposit is accompanied by mineralization of precious metals under its stratiform deposit (e.g. Grandeza deposit in Cuale deposit group).

(e) Delicias - El Rosario (Altitude: 690 m)

**Location:**

Gossans (Delicias) are found in the right slant of the upper stream of San Jeronimo valley, around 1.8 kilometers south of La Concha village, and a trace of El Rosario mine in the southeast down stream of the same valley. The aforementioned Los Alpes deposit is some 400 m west of these mineralized zones.

**Occurrence:**

The geological feature in the vicinity of Delicica is dacitic pyroclastics in a ore horizon. There is no direct sign of occurrence of a deposit, but compact and massive gossans larger than some 60 m x 300 m are found in the right slope of San Jeronimo valley. Some of these gossans may very rarely contain galena, and they are more compact than usual gossan, of which are the characteristics of massive sulphide origin gossan that Blanchard (1968) has indicated. The gossan consists of quartz and goethite X-ray diffractively, while the compact portion comprises only goethite in appearance. Under the gossan sprawls a mineralized zone containing fine particles of pyrite and small amounts of galena and sphalerite in an unknown dimention. It is reported that Delicias mine was worked with a dressing plant, but the target ore for working is not clear because there is no ore sedimentation remaining at the time of survey. However, adits have been, located in the vicinity of gossans that seem to be origin of Kuroko type ore, and this fact suggests that sulphides were mined from extended zones of this gossan.

This mine is located in a northeast wing of local anticlines that come from Los Alpes deposit.

In El Rosario deposit, which geologically is almost identical to Delicicias deposit, the working target was seemingly the mineralized zone in the footwall rather than massive and stratiform Kuroko type ore, because adits, were excavated toward the footwall, not toward the ore horizon. According to the guide, the working target was gold, which suggests that the precious metal mineralization which is thought to have developed under the Kuroko type deposit in the investigated area mentioned in the paragraph of San Jose deposit may exist in this area.

(f) La Colorada (Altitude: 620 m)

**Location:**

Traces looking like old adits are found along San Jeronimo valley, some 2.1 kilometers south of La Concha village and 250 m southeast of El Rosario deposit.

**Occurrence:**

Though precise positions of old adits cannot be identified, the geological feature around these seeming traces is dacitic pyroclastics (lapilli tuff, Koh-b). A result from X-ray diffraction on samples taken in the vicinity indicates that the area belongs to a quartz-sericite zone, which has subjected to a strong hydrothermal alteration. With the naked eye, there are so many altered portions that identification of the original rock is impossible, and the alteration point of view forces us to believe possibility of existence of a Kuroko type ore in this area. As the time of survey, there is no ore deposition in the area and detailed working is unknown, but it has been told that high grad Kuroko type ore was produced from this deposit.

(g) San Pedro - Rey Negro (Altitude: 500 m)

**Location:**

The position of this deposit is in San Jeronimo valley, around 2 kilometers northwest of El Bramador village.

**Occurrence:**

Reportedly there were ten odd of old adits in this area, but most of their locations are now vague because of collapse. These adits were placed in dacitic pyroplastics (fine tuff, Koh-b) and produced high grade Kuroko type ore, reportedly. Around these old adits, pyrite ore and carbonate rock are mixed in dump, and an analyzed result is as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| KM-16 | 1.2 | 140 | 0.06 | 0.09 | 0.12 | Py ore |
| KM-62 | 0.2 | 10 | 0.07 | 0.43 | 0.20 | Gossan |
| KM-63 | 0.6 | 130 | 0.04 | 2.12 | 3.73 | Py ore |
| KM-64 | Tr | 12 | 0.01 | 0.03 | 0.23 | Carbonate rock |

It is said, however, that high grade Kuroko type ore was once found occasionally in the dump. These old adits have distributed along strikes of dacitic pyroclastics (fine tuff and lapilli tuff, Koh-b), but there is few indication of old workings for the dip direction, which can be understood as showing room for future exploration in the dip direction.

(3) Arriba de San Juan Mineralized Zone (Altitude: 1,600 m)

**Location:**

The mineralized zone is located around the upper stream area of the Blanco valley, about three kilometers from the San Juan village, about 12 kilometers north of the Cuale Mine.

**Occurrence:**

The mineralized zone is in the dacite (Kdcl-b) lithologically similar to the footwall dacite of the Cuale ore deposits. It is impossible to trace the dacite directly from the Cuale mine area, because of erosion, but the dacite stratigraphyically sits in the extension of the footwall dacite horizon in the Cuale mine area.

Ore minerals were completely oxidized to limonite and hematite in the surface, but minor amount of fine grained pyrite disseminated in the rocks is found in some parts of valleys. Some of the hematite is massive and compact, suggesting that the original sulphides of the hematite were very much likely massive. The mineralized zone spread over an area of several hundred square meters around the Blanco valley, and associating alteration zone covers more extensively than the mineralized zone, forming so-called "pervasive" type alteration zone.

From the above mentioned facts, it is presumed that the mineralized zone is correlated to "stringer" ore zone overlying Kuroko type ores, and Kuroko typ ores used to be underlying the stringer ore before they were eroded out.

In spite of strong oxidized and altered zones are distributed there, no old workings and any discovery news of mineral occurrences are known. It might suggest that the erosion occurred down to the deeper part of the formation.

Assay results of an altered rock sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| DA-64 | 0.1 | 2 | 0.02 | 0.01 | 0.03 | Gossan |

(4) La Olla (Altitude : 1,700 m)

**Location:**

The deposit is located in a branch stream of the La Olla valley, about three kilometers north of the Cuale Mine office.

**Occurrence:**

Ore veins are in the footwall dacite (Kdcl-b) altered to pale green to white, underlying the ore horizon of the Cuale deposits. The veins filled fissures in the dacite, trending N30°E, about 50 centimenters in width. Only one trend system of veins exists in the La Olla valley, and silicified zones accompanied by sericitization along the veins are of small size. Fine to medium grained pyrite is an only one ore mineral, and quartz is main gangue mineral. Under the microscope, idiomorphic pyrite with minor amount of galena are observed, and its appearance is likely of "kieslager" type ore.

Because it is presumed that the host rock of the mineralization is the footwall dacite relating to the genesis of Kuroko type ores, there is a possibility that the ore is of same genesis as Kuroko mineralization. However, judging from its only one system and narrow alteration zone, it is more likely of normal vein type ore.

Assay results of the ores sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| HO-1 | 1.6 | 1,518 | 0.03 | 0.58 | 0.24 | Py ore |

High silver contents are characteristic in the ore, and it is worth to study furthermore.

(5) Limoncillo (Altitude: 940 m)

**Location:**

The deposits is located about 3.5 kilometers north of La Concha.

**Occurrence:**

An ore vein is in the andesite (Ad), showing pale green to green, strike and dip of the vein is N40°W, and 20° to the east. Width of the vein is 1.0 to 1.5 meters, and its strike extension length is not clear. This is the only one mineralization in the vicinity.

Principal ore minerals are pyrite, galena, and sphalerite, presenting generally coarse grained. Sulphide minerals were oxidized and altered to hematite and limonite in some parts.

Principal gangue mineral is quartz, with minor amount of calcite.

Assay results of the ore sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| L-22 | 0.1 | 112 | 0.35 | 7.02 | 12.58 | Sph-gn ore |

(6) La Amaltea (Altitude: 2,000 m)

**Location:**

The deposits is located about three kilometers northwest of the Desmoronado village. A road built by Zimapan Inc. reaches to the site, but some repairment is necessary for vehicle traffic.

**Occurrence:**

The deposit is underlain by the dacite disseminated by pyrite, and overlain by the black shale (one to two meters). The deposit consists of black ore and is underlain by silicified ore. The black ore is stratiform, conformably lying with hanging wall and footwall layers. Thickness of the ore varies one to seven meters. Ore minerals are fine grained and compact, and banded textures due to different mineral constituents are observed in some parts. Principal ore minerals are sphalerite, galena, and pyrite, and principal gangue mineral is barite. The silicified ore is characterized by disseminated ore and veinlets in the footwall dacite. Ore mineral is pyrite only, by naked eyes, and accompanied alteration minerals are quartz, sericite, and chlorite. The deposit was operated by Zimapan Inc. during the years from 1967 to 1977, and produced 266,500 tons of ore. Average grade of mined ore is as follows:

| | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) |
|---|---|---|---|---|---|
| Grade | 1 | 154 | 0.97 | 2.6 | 13.6 |

Stoped ores were milled and concentrated in the Rubi concentrator.

Assay results of the ores sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| KM-3 | 3.5 | 145 | 0.46 | 3.81 | 11.20 | Kuroko |
| KM-4 | 2.6 | 50 | 3.69 | 0.12 | 2.70 | Py-Cp-sph ore |
| KMO-3 | 1.0 | 64 | 2.60 | 0.87 | 21.39 | Kuroko |
| WDS-13 | 2.5 | 163 | 0.37 | 5.13 | 22.56 | Kuroko |

(7) Cuatro Minas (Altitude: 1,460 m)

**Location:**

The deposit is located about one kilometers west of the Amaltea Mine, in the right bank of the San Juan valley about 3.5 kilometers northwest of the nearest Desmoronado village.

**Occurrence:**

Host rock of the deposit is grayish white dacite, lithologically similar to the footwall dacite of the Amaltea deposit. Occurrence of the deposit can't be seen due to collapse of the adit, but it is presumed that the deposit is of stockwork type associating with the footwall dacite, extending from the Amaltea mine, judging from information of the geology of the surrounding area, piled ore dumps, and oral story of guide people. It is supposed that Kuroko type mineralization such as the case of the Amaltea deposit might have occurred through ore passess which are presently stockwork parts, judging from the facts of existence of pervasive type alteration, (quartz, sericite, and chlorite?), and partly veinlets of sphalerite and galena rather than pyrite. The deposit was possibly located in a hydrothermal exhalation center. The deposit was mined simultaneously with the Amaltea deposit by Zimapan Inc., but it is said that the amount of mined ore was a little due to its low grade.

Assay results of ores sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| W-1 | 0.8 | 6 | 0.04 | 0.03 | 0.02 | Py imp. ore |
| W-2 | 1.1 | 708 | 0.03 | 2.68 | 7.08 | Sph-gn ore |

## Table 3-1 List of Mineralized Zones

(1)

| No. | Mineralized Zones | Type of Ore Deposit | Occurrence | Remarks |
|---|---|---|---|---|
| 1 | Naricero | Kuroko type | Kuroko and pyrite ore in dacitic tuff - tuff breccia: (Koh-b) | Distal type |
| 2 | Socorredora | Kuroto type | Kuroko and pyrite stratiform ore in dacitic tuffs and shale alteration: (Koh-b) | Proximal type |
| 3 | Nueva Socorredora | Kuroko type | Kuroko and pyrite stratiform ore in dacitic tuffs and shale alternation: (Koh-b) | Proximal type |
| 4 | Grandeza | Au-Ag-Cu-Zn Vein | Stockwork ore in dacitic rocks: (Kdc1-b) | |
| 5 | Coloradita | Kuroko type | Kuroko and pyrite stratiform ore in dacitic tuffs and shale alternation: (Koh-b) | Proximal type |
| 6 | Prieta | Kuroko type | Kuroko and pyrite stratiform ore in dacitic tuffs and shale alternation: (Koh-b) | Proximal type |
| 7 | Refugio | Kuroko type | Kuroko ore in dacitic tuffs and shale alternation: (Koh-b) | |
| 8 | Chivos de Arriba, Abajo, (Rubi) | Kuroko type | Kuroko and pyrite stratiform ore in dacitic tuffs and shale alternation: (Koh-b) | Proximal type |
| 9 | La Trozada-E | Hg deposit | Hg dissemination in dacitic tuffs: (Koh-b) | Kaolinite alteration |
| 10 | La Castellana | Kuroko type | Pyrite straliform ore in dacitic tuffs and shale alternation: (Koh-b) | |
| 11 | Los Alpes | Kuroko type | Kuroko and pyrite stratiform ore in dacitic tuffs: (Koh-b) | Proximal type |
| 12 | San Jóse | Kuroko type | Pyrite dissemination in dacitic tuff breccia: (Koh-b) | |
| 13 | Delicias-Rosario | Kuroko type | Pyrite mineralization in dacitic tuffs: (Koh-b) | Gossan |
| 14 | La Colorada | Kuroko type | High-grade kuroko stratiform ore in dacitic tuffs: (Koh-b) | Proximal type |
| 15 | San Pedro | Kuroko type | Kuroko and oko stratiform ore in dacitic tuffs: (Koh-b) | Proximal type |
| 16 | Arriba de San Juan | Pyrite dissemination | Goethite and hematite after sulfide in dacitic rocks: (Kdc1-b) | Gossan |
| 17 | La Olla | Au-Ag-Qz Vein | Au-Ag-Pyrite mineralization in dacite rocks: (Kdc1-b) | Similar to Kieslager type ore |
| 18 | El Limoncillo | Cu-Zn Vein | Cu-Zn mineralization in andesite: (Ad) | Coarse grained |

| No. | Mineralized Zones | Type of Ore Deposit | Occurrence | Remarks |
|---|---|---|---|---|
| 19 | La Amaltea | Kuroko type | Kuroko and pyrite stratiform ore in dacitic tuffs: (Koh-b) | Proximal type |
| 20 | Cuatro Minas | Kuroko type | Kuroko and pyrite stratiform ore in dacitic tuffs: (Koh-b) | Proximal type |
| 21 | La Minita | Au-Ag-Cu-Zn Vein | Arsenopyrite-pyrite-sphalerite mineralization in dacitic rocks: (Tdc1) | |
| 22 | Los Caballos de Cabrel | Pyrite dissemination | Pyrite mineralization in pelitic schist: (Jsch) | |
| 23 | Jesus Maria | Kuroko type? | Stockwork ore (?) in dacitic rocks: (Kdc1-b) | |
| 24 | Patrocinio | Kuroko type? | Stockwork ore (?) in dacitic rocks: (Kdc1-b) | |
| 25 | San Juan | Au-Ag-Cu-Zn Vein | Sphalerite-pyrite mineralization in dacitic rocks: (Kdc1-b) | Similar to Taro ore |
| 26 | Peregrina | Au-Ag-Cu-Zn Vein | Au-Ag-Cu-Zn mineralization in dacitic tuffs and shale alternation: (Koh-b) | |
| 27 | San Rafael | Au-Ag-Cu-Zn Vein | Au-Ag-Cu-Zn mineralization in dacitic tuffs and shale alternation: (Koh-b) | |
| 28 | La Concha-N | Pyrite dissemination | Pyrite mineralization in dacitic rocks: (Kdc1-b) | |

(8) La Minita (Altitude: 750 m)

**Location:**

The vein deposit is located in the La Minita valley about 1.5 kilometers west of the La Minita village and about 25 kilometers southwest of Talpa de Allende.

**Occurrence:**

The vein is hosted in the dacite (Tdcl) of hard compact pale green to gray. No sufficient information for details is available due to poor outcroping, but it is manifest that the width of the vein is 40 to 60 centimenters, strike is N60°W, dip is about vertical. Ore minerals are chalcopyrite, magnetite, and chalcopyrite, with minor amount of galena and sphalerite. Alteration is of silicification and sericitization.

Assay results of the ores sampled by survey team are as follows:

| Sample No. | Au (g/t) | Ag (g/t) | Cu (%) | Pb (%) | Zn (%) | Remarks |
|---|---|---|---|---|---|---|
| MIN-1 | Tr | 2 | 0.01 | 0.06 | 0.12 | Py-qz ore |
| MIN-2 | 3.4 | 14 | 0.01 | 0.24 | 0.04 | Asp-qz-ore |

(9) Los Caballos de Cabrel (Altitude: 400 m)

**Location:**

The deposit is located about 1.5 kilometers northwest of the Los Caballos de Cabrel village.

**Occurrence:**

The vein is in the schist of the Jurassic System. The schist is of the basement rock in the survey area, and extensively distributed in the northern area. The vein consists of pyrite and limonite, and its average width is about 40 centimeters. Strike and dip of the vein are N50°W and 80° ~ 90° to the southwest. Alteration occurred around the vein is silicification and chloritization.

An adit, 1.5 meters long, is in the outcrop zone of the vein, but detailed information (operation time, grade, etc.) is not available.

### 3-4-2 Comarison of Japanese Kuroko Deposits with Kuroko Type Deposits in the Survey Area

No investigation on ore minerals has been made for the Kuroko type ore existing in the survey area. As microscopic observation was conducted for the ore samples collected during this survey, the Kuroko type ore in the survey area were empared with Japanese Cenozic Kuroko deposits or Mesozoic Kuroko type deposits in combination with other geological modes of occurrence and in relation to the genesis of the deposits in the survey area.

Related Igneous Rock:

In Cuale, El Bramador and Amaltea deposits, galena and sphalerite are principal component minerals. As is usual with the related volcanic rocks of this kind of Kuroko type deposits, acidic calc-alkaline rock series are anticipated (Huchinson, 1973), and the deposits in the survey area are also clearly related with dacite activities. Moreover, the rock series of the volcanic rocks are also highly possible to be of calc-alkaline series as mentioned Chapter 4-2.

Near the areas where the Kuroko type ores exists, granophyre, which is supposed to be the product of the volcanoplutonic activity, exists, and this fact resembles the existence of Ohtaki granodiorite (9.0 m.y. ago; Takahashi & Tanimura, 1980), whose activity was later than the Kuroko formation (15 - 13 m.y. ago, Ohmoto, 1983), in the Hokuroku Kuroko area in Japan, or the existence of Taro type granodiorite in the area of Taro deposits, which are said to be the Mesozoic Kuroko type deposits (Yamaoka, 1983).

Bimodal volcanism, which is one of the features in volcanic activities in the area where Kuroko type ores exist, seems to be noticed in this survey area. However, the degree of volcanic activities in the survey area is far inferior to that of the Hokuroku area, Japan.

Environment of Ore Formation

About the environment of formation of Kuroko type ore in this area, there are few data of foraminifera assemblage, etc., useful for considering about paleobathymetry, submarine paleotopography, etc., at the time of ore formation. However, in the particular areas where Kuroko type ores exist (Cuale, El Bramador and La Amaltea area), the amount of acidic fine tuff or basalts, which seem to suggest the shape of place of ore deposition, increases. If the Japanese Cenozoic Kuroko ore, which was deformed least after formation, is taken as an example, the geological phenomenon as mentioned above suggesting the existence of a basin as a place of ore deposition is noticed frequently (Kumita et al., 1982). Accordingly, the formation of the Kuroko type ores is supposed to have occurred in the submarine basins in the Cretaceous period also in this survey area.

Kind of Ore Minerals

As a result of microscopic observation, it was found that there were only within ten kinds of ore minerals, sphalerite, chalcopyrite, galena, pyrite, bonite, tetrahedrite, arsenpyrite, marcasite, etc., found in this survey area. This number is about a quarter of the number of ore minerals produced in Japanese Cenozoic Kuroko ores. (Yamaoka, 1984). The fact that there are fewer kinds of ore minerals is similar to that in the case of ores produced in Taro deposit.

Barite, calcite, quartz, sericite and chlorite are principal component gangue minerals of Kuroko type ores in the area which are similar to those of Japanese Cenozoic Kuroko ores.

In addition, Kuroko type ores in the survey area seem to be composed of three kinds, Kuroko bed, pyrite bed and siliceous ore, generally, like that of Japanese Cenozoic Kuroko ores.

FeS in Sphalerite

The percentage of FeS in the sphalerite produced in a Cenozoic Kuroko deposit is such an extremely small value as 0.1 mole % (Urabe, 1974). According to microscopic observation, the sphalerite in this area shows a brown color quite similar to the optical properties of the sphalerite produced in the Taro deposit. As this refracted color reflects the amount of solid-soluted iron in sphalerite, the sphalerite in this area is supposed to include the amount of FeS similar to that of sphalerite produced in the Taro deposit, which was estimated by Yamaoka (1983) to be 3 - 21 mole %.

Zonal Texture of Sphalerite

A fine zonal texture is found generally in the sphalerite produced in Japanese Cenozoic Kuroko ores, but this zonal texture has not been found in the sphalerite produced in the Kuroko type ores in the survey area. This characteristic is common to sphalerite produced in the Taro ore.

It is unclear whether the zonal texture existed or not primarily.

"Chalcopyrite Disease" in Sphalerite

The "chalcopyrite disease" (Barton, 1978) also found generally in Japanese Cenozoic Kuroko ores is not at all found in the sphalerite in this area, which means that there was no process of replacement after the growth of the host sphalerite. Also in this point, the sphalerite in this area is similar to that produced in the Taro ore (Yamaoka, 1983).

Existence of "Telescoped Ore"

Japanese Cenozoic Kuroko ores produce high temperature type minerals such as molybdenite, etc., but on the other hand, also produce low temperature type minerals such as argentite, showing the characteristic of subvolcanic type telescoped ore. However, the Kuroko type deposits in this area do not contain high temperature minerals as mentioned above, being different from Cenozoic Kuroko ores also in this point and rather similar to the Taro ore.

In addition to the above, the colloform texture and gangue minerals are found in common regardless of difference in time and place. Table 3-2 shows the characteristics of the minerals. More similar points are noticed between the ore produced in the Kuroko type ores in the survey area and the ore produced in the Taro deposit in the same Mesozoic era.

Kuroko type ores in first year's survey area probably formed at the late Cretaceous, on the other hand, these in second year's survey area possibly at the early Cretaceous judging from the determination of nannoplanktons and radiolarias.

This difference of formation era of Kuroko type ores would be attributed to the facts that Kuroko formation is closely involved in the volcanism related to global tectonics (Cathles et al., 1983) and volcanic front of the Cretaceous in the area probably migrated from west to east (Damon et al., 1981).

Table 3-2 Comparison of Mineralogical Features of Kuroko Type Ores

| Deposits | | I | II | III |
|---|---|---|---|---|
| Numbers of Ore Minerals | | Approx. 10 species | Approx. 10 - 15 species | Approx. 40 - 50 species |
| FeS in Sphalerite | | 3 - 4 mole %(?) | 3-21 mole%[1)] | Approx. 0.1 mole%[2)] |
| Banded Sphalerite | | Not Observed | Not Observed | Common |
| Chalcopyrite disease in Sphalerite | | Not Observed | Not Observed | Common |
| Colloform and framboidal texture | | Common | Common | Common |
| Telescoped ore | | Not Observed | Not Observed | Observed |
| Gangue minerals | Barite | Common | Not Observed | Abundant |
| | Calcite | Minor | Common | Minor |
| | Sericite | Common | Common | common |

I: Cuale, El Bramador and La Amaltea Deposits
II: Taro Deposit (Japanese Mesozoic Kuroko Type Deposit)
III: "Kuroko" Deposits in Hokuroku District, Akita, Japan
(Japanese Cenozoic Kuroko Deposits)

1): Yamaoka (1984)
2): Urabe (1973)

## 3-5 Survey on Alteration Zone by X-ray Diffractometry

It is well known that some alteration mineral zoning exists in country rocks of Kuroko type ore deposits, associating with their genesis. The alteration occurs by reaction between host rocks and hydrothermal solution (ore solution) during its moving in the rocks. Zoning of alteration minerals, some cases, extends beyond hanging wall rocks (Utada et al., 1981, 1983), therefore, it is sometimes possible to evaluate potential for Kuroko type ore deposits applying such fact. This feature is known not only in cases of Cenozoic Kuroko ores in Japan, but also in cases of Middle Jurassic to Archaozoic massive sulphide ores in Canada (Urabe et al., 1983), therefore it is suggested that the feature is common to all cases of this type of ores everywhere. In this survey, the dacite lavas and dacitic pyroclastics (Kdc1-a, Kdc1-b, etc) which are closely related to the Kuroko type mineralization in the area are investigated from the alterational point of the view.

### 3-5-1 Measuring Condition

| | | |
|---|---|---|
| Instrument | : | Rigaku Denki Ltd. - Geiger Flex 2078 |
| Target | : | Cu |
| Filter | : | Ni |
| Voltage | : | 30 kV |
| Current | : | 15 mA |
| Full Scale | : | 2,000 c.p.s |
| Time Constant | : | 1 sec |
| Slit System | : | 1 deg/0.3 mm |
| Scanning Speed | : | 2°/min |
| Chart Speed | : | 20 min |

### 3-5-2 Method of Analysis

Mineral contents detected by X-ray diffraction chart are represented as relative quantity ratios using quartz index by mean of the Hayashi's method (1979). The quartz index means a percentage of the maximum X-ray intensity of certain mineral in a sample, Im (c.p.s), in the maximum X-ray intensity of a pure quartz, Iq (c.p.s), measured under the exactly same condition.

$$\text{Quartz Index (Q.I.)} = \frac{Im}{Iq} \times 100$$

When the first peak is scaled out, in case of quartz measuring, the first peak (3.33Å)values are estimated from the second peak (4.27Å) values, peaks used for each minerals are as follows:

| | | | | | |
|---|---|---|---|---|---|
| Quartz | : | 3.33 Å (101) | Pyrophyllite | : | 3.05 Å (006) |
| | : | 4.27 Å (100) | Epidote | : | 2.90 Å (113) |
| Plagioclase | : | 3.21 Å (002) | Geothite | : | 4.11 Å (110) |
| Albite | : | 3.20 Å (002) | Amphibole | : | 2.55 Å (002) |
| Potash feldspar | : | 3.24 Å (040) | Limonite | : | 4.11 Å (110) |
| Sericite | : | 9.93 Å (002) | Kaolinite | : | 7.18 Å (001) |
| Chlorite | : | 7.19 Å (002) | | | |
| Calcite | : | 3.04 Å (220) | | | |
| Dolomite | : | 2.91 Å (104) | | | |
| Pyrite | : | 2.71 Å (200) | | | |

Sericite/Montmorillonite (mixed layer) : 9.8 ~ 14.0 Å (002)
Chlorite/Montmorillonite (mixed layer) : 7.3 ~ 8.5 Å (002)

### 3-5-3 Alteration Mineral

Primary and alteration minerals caught in the area are as follows.

| | | |
|---|---|---|
| Silica Mineral | : | Quartz |
| Feldspar | : | Plagioclase, (Albite),<br>Potash Feldspar |
| Clay Minerals | : | Sericite, Chlorite, Sericite/Montmorillonite (mixed layer)<br>Montmorillonite, Chlorite/Montmorillonite (mixed layer)<br>Kaolin, Pyrophyllite |
| Carbonate Minerals | : | Calcite, Dolomite |
| Others | : | Epidote, Pyrite, Goethite, Limonite, Amphibole |

Quartz was caught in the all specimens. Plagioclase (Albite) was almost completely altered to other minerals nearby known ore deposits.

Sericite occurs most commonly among clay minerals belonging to 1M, 2M, 1M + 2M types, however the relation to the ore mineralization are not clear.

Chlorite commonly occurs subsequent to sericite among clay minerals. This is a very common mineral in Kuroko ore alteration environment. It is well-known fact that this chemical component changes for outer shell zones or surrounding areas of Kuroko ores (Izawa et al., 1978, Urabe and Scott, 1982 - A). Chlorite abundant in magnesium generally occurs in outer shell zones of Kuroko ores, rather than in surrounding areas. According to the result of the study on chlorite occurred in the area by mean of the Oinuma's method (Oinuma et al., 1972), the chlorite is relatively dominant in iron, and seldom occurs in outer shell zones of Kuroko ores.

Sericite/montmorillonite and chlorite/montmorillonite were detected in a few samples in the areas far several kilometers from known ore deposits.

Kaolin was detected in many samples but relations to Kuroko ores are not clear.

Goethite and limonite were detected in some samples from areas along the upper stream of Blanco valley, but seldom from other areas.

Calcite, dolomite, pyrophyllite, epidote, amphybole, pyrite etc. were detected in quite few samples.

### 3-5-4 Alteration Zone

Based on the alteration minerals occurred in the most samples in some amount, referring to Utada et al. (1981) and Honda et al. (1979), alteration zones were classified as follows:

| | | |
|---|---|---|
| Zone I | : | Quartz + Potash feldspar + Sericite |
| Zone II | : | Quartz + Sericite |
| Zone III | : | Quartz + Chlorite + (Sericite) + (Potash feldspar) |
| Zone IV | : | Quartz + Kaolin + (Potash feldspar) + (Sericite) + (Chlorite) |
| Zone V | : | Quartz + Plagioclase (Albite) + (Potash feldspar) + (Sericite) + (Chlorite) |

Note: Minerals in blankets are of small amount.

In this zoning, Zone V is possibly of diagenesis, and others are of hydrothermal. It is suggested that, among them, Zones I and II are probably situated in centers of alteration halos.

Alteration patterns in Cuale district, El Bramador district and others were investigated aplying the above mentioned zoning.

(1) Cuale District

Fig. 3-3 shows alteration zoning in this district. Most of the ore deposits are located in Zone I and II, therefore, it is suggested that Kuroko ores are closely related to intensity of alteration. And it is possible that Zone IV located in the southern district is due to the intrusion of dacite (Dc). In northern district, Zone V, which means the weak alteration, is extensively distributed. This is probably of diagenesis.

(2) El Bramador District

Fig. 3-4 shows alteration zoning in this district. Most of the ore deposits in the district are located in Zone II, and it is suggested that ore deposits distribute close relation to alteration zoning. However, the zone I, which seems to be the most intense alteration zone, is located sporadically at the area of 3 km x 3 km in the southern district. Though there is not any known ore deposit in this Zone, it is recognized that high potential for hidden ore deposits exist in the Zone, and that further detailed studies is required to be conducted for it.

(3) La Amaltea - La Crucecita District

In this district, the Cuatro Minas and La Amaltea deposits are located, but only small Zone I are associated with these deposits. The other areas belong to Zone V, therefore it is said that the alteration in the district is rather weak.

(4) Arriba de San Juan District

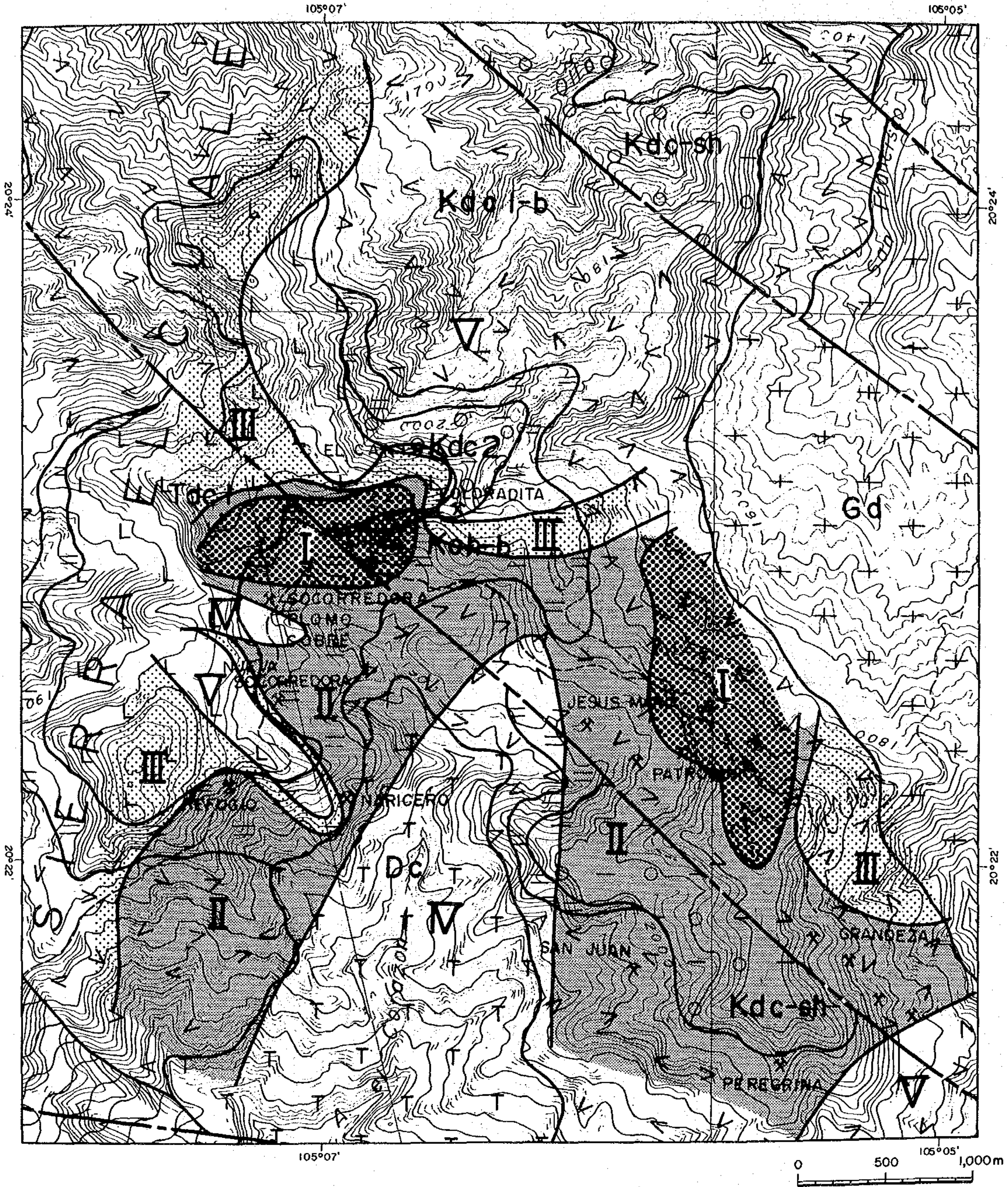
Dacite lavas (Kdc1-b) located in this district completely change to altered white rocks. According to the results of the X-ray diffraction test, plagioclases of the rock completely decompose and produce sericite. Goethite and limonite also were found in samples from an area of 0.5 km x 2 km. It is possible that the latter minerals were altered from some sulphide minerals by weathering.

(5) Desmoronado South District

Only 16 samples were studied by X-ray diffraction method, and details of alteration pattern in this district are not clear. Sericite was detected in most of samples, but relicts of plagioclase are also observed. The alteration in the district is weak even suffering some hydrothermal alteration, so it is judged that the district is of low potential for Kuroko type ores from alterational point of view.

(6) Others

X-ray diffraction test was conducted for some parts of dacite intrusives (Dc), but clay minerals were rare in the rocks, leaving large amount of fresh plagioclase.




## LEGEND

**Tertiary System**

- Tdc1 — I-Stage Dacite-Pyroclastics

**Cretaceous System**

- Kdc-sh — Hanging Wall Dacite-Pyroclastics-Shale
- Koh-a — Ore Horizon Pyroclastics
- Kdcl-a — Footwall Dacite
- Kshl — Shale Intercalated with Sandstone

**Jurassic System**

- Jsch — Metamorphic Rocks

**Intrusives**

- Dc — Dacite
- Gph — Granophyre
- Ad — Andesite
- Gd — Granodiorite

Fault

**Alteration Zones**

- I : Quartz + K-feldspar + (Sericite)
- II : Quartz + Sericite
- III : Quartz + Chlorite + (Sericite) + (K-feldspar)
- IV : Quartz + Kaolinite + (K-feldspar) + (Sericite) + (Chlorite)
- V : Quartz + Plagioclase (Albite) + (K-feldspar) + (Sericite) + (Chlorite)

Fig. 3-3 Distribution of Alteration Zones in Cuale District

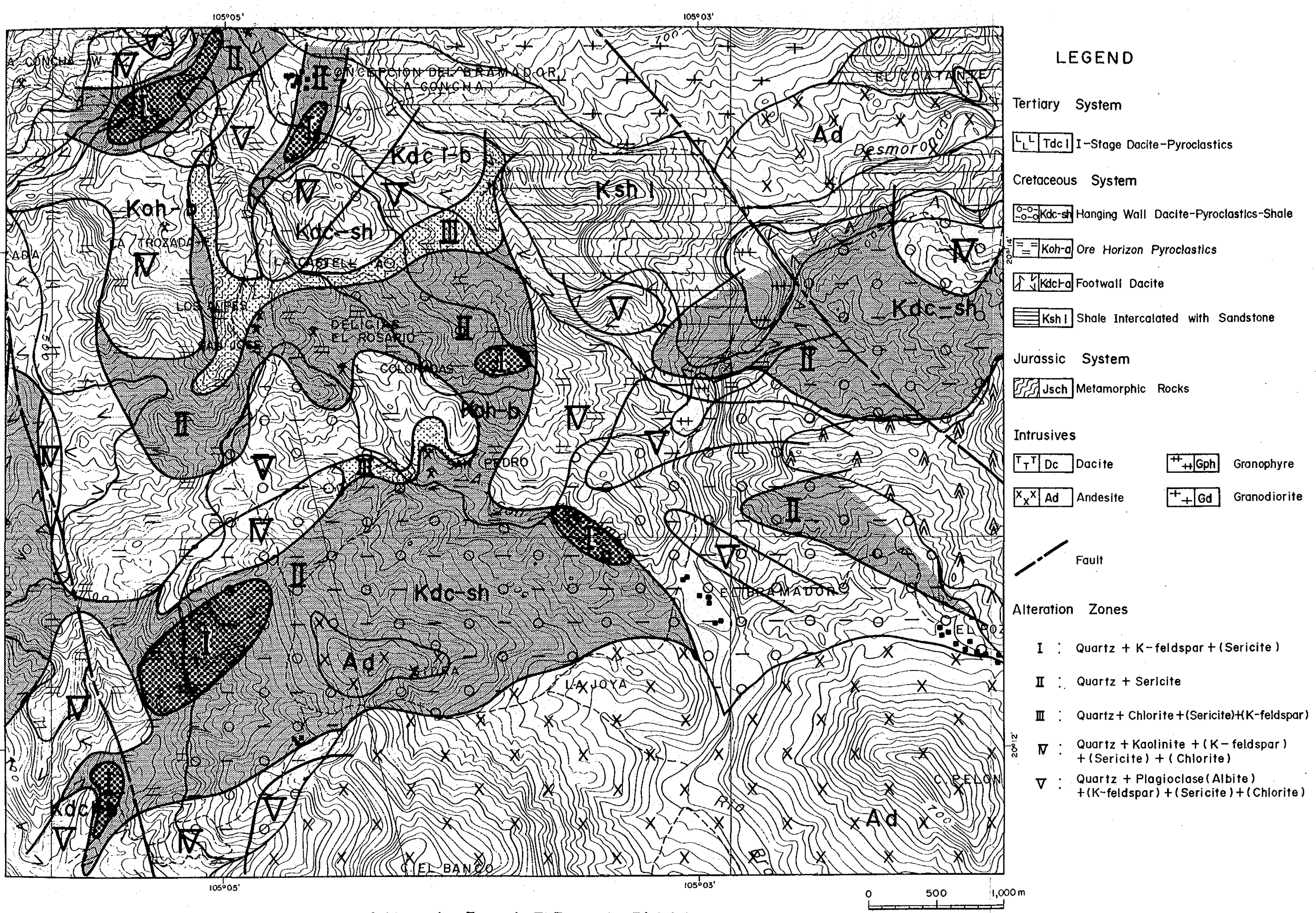



Fig. 3-4 Distribution of Alteration Zones in El Bramador District