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

PHASE 1

MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

At the request of the United Mexican States Government, the Japanese Government has developed a plan to carry out various surveys concerning mineral resources exploration, including geological survey etc., to investigate the possibility of mineral resources existing in the Jalisco district in the central part of Mexico and has entrusted Japan International Cooperation Agency with the execution of the plan. Japan International Cooperation Agency has again entrusted the Metal Mining Agency of Japan with the execution of this survey, because the contents of this survey, which are the surveys of geology and mineral resources, belong to a specialized field.

In FY1984, the first year of this survey project, the Metal Mining Agency of Japan organized a survey team of six members and dispatched it to the district in a period from August 26, 1984 to January 25, 1985.

The field survey was completed as scheduled with the cooperation of the related government agencies of the United Mexican States, especially the Mineral Resource Council.

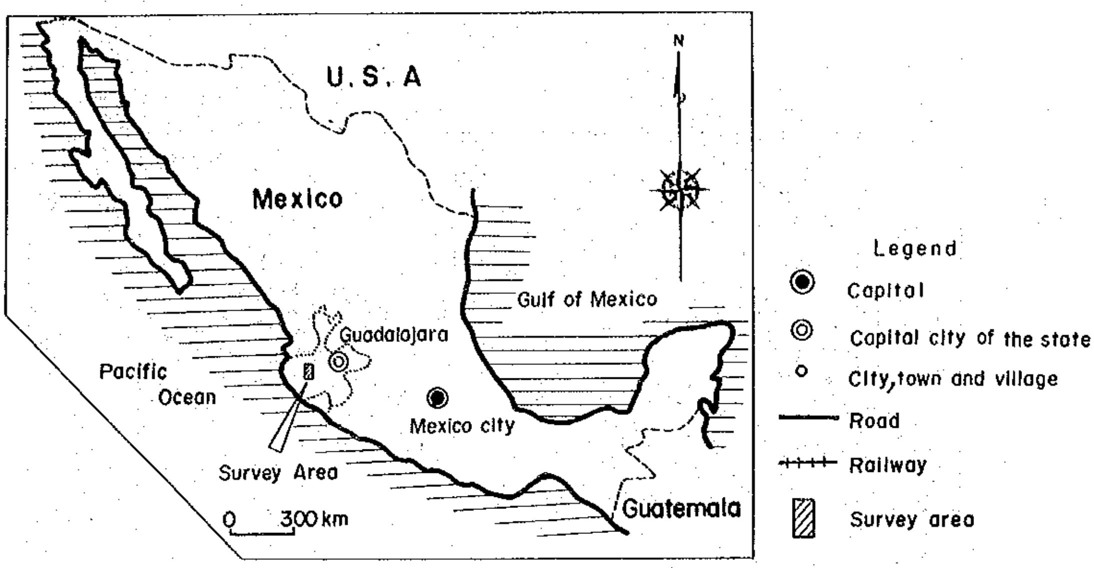
This report is the summary of survey results in the first year and will form a part of a final report.

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.

March, 1985

Keisuke Arita
President,
Japan International Cooperation Agency

Masayuki Nishiie
President,
Metal Mining Agency of Japan



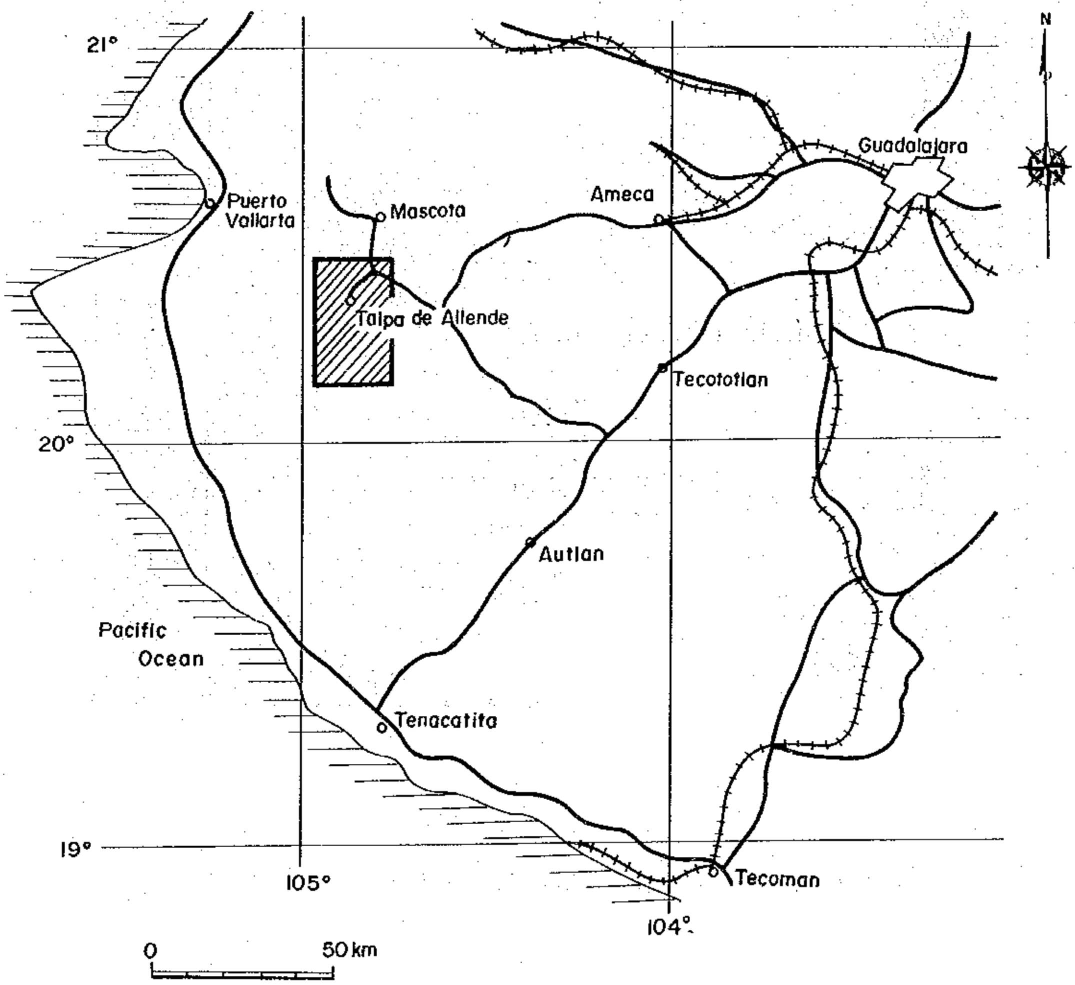


Fig. G-1 Location Map of the Survey Area (A)

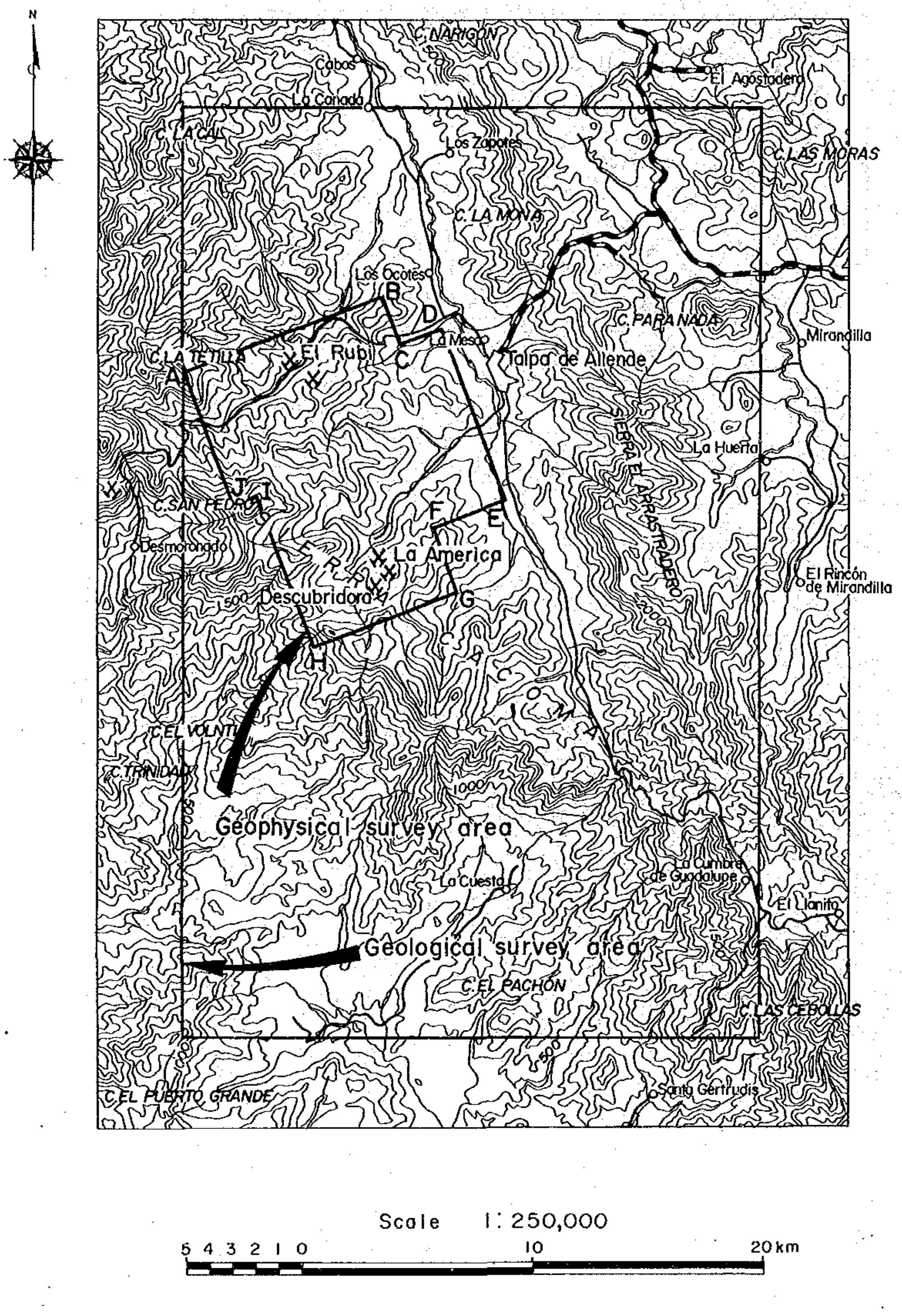


Fig.G－2 Location Map of the Survey Area (B)

SUMMARY

The survey area in the first year is located at the intersection of Sierra Madre Occidental with Eje Neovolcanico, and is widely covered with the Tertiary volcanic rocks.

The Cretaceous system in the survey area is unconformably covered with the Tertiary system, and is very important because it is an embed formation of a Kuroko type deposit despite of its so small size less than 5% of the survey area.
The main stratum of the formation is constituted with black shale (Ksh_1) that intercalates sandstone and a small amount of calcareous shale (Ksh_2).
The sedimentary rocks had been folded with a various degrees, and lie roughly in a direction from the northeast to the southwest with 30^o -60^o dips. However, a two-storied structure can be presumed because of the relation of the sedimentary rocks with the hanging wall dacite (Kdc_2), and the dip of the enveloping surface of the sedimentary rocks is considered to be so much gentler than the above mentioned one.
An opened syncline is estimated in the zone between Toledo River and Aranjuez River. According to the judgment on nannoplanktons included in the black shale existing in the vicinity of the ore horizon in the middle basin of Toledo River, it can be concluded that the stage belongs to Campanian to Maastrichtian Stage (78 to 65 m.y. ago) of the Upper Cretaceous.

On the other hand, the Tertiary system mainly consists of andesites and dacites, and covers a large part of the survey area. Welded tuffs are found in IV-stage andesites (Tad_4) which are predominant in the region ranging from the north to the middle of the survey area, and this fact suggests that a circumstance of the volcanic activity had moved from the submarine to the subaerial during a period in which the activity had shifted from III-stage andesites (Tad_3) to IV-stage andesites (Tad_4).
These volcanic rocks lie in approximate north-to-south strikes, and there are additional east-to-west strikes in the southern part.

In La America-Descubridora area and El Rubi area, Kuroko type deposites are embedded in an intimate time and space relation with acidic volcanics of the Cretaceous system.
The deposit groups in both areas, despite of an about 10 km distance between them, are understood to roughly belong to the same horizon in geological and structural aspects.
A geophysical exploration (by CSAMT method) was carried out on a 122 km^2 where a previous geological study had suggested the presence of ore horizons. As a result, in La America-Descubridora area, three low resistivity zones were detected to be hopeful to explore Kuroko type deposits.
These zones are located in the north wing of an upheaval of acidic volcanics which have a strong relation of origin with Kuroko type deposits, and are expected spreads of ore horizon tuffs (Koh) and foot wall dacites (Kdc_1), and also the presence of Kuroko type deposits.

Geochemical explorations on stream sediments and studies of alteration minerals have also indicated that these low resistivity zones can be evaluated to be hopeful for exploration of Kuroko type deposits.

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CHAPTER 1 INTRODUCTION

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1-1 Purpose of Survey

The project aims at exploration of Kuroko type deposits in Talpa de Allende area, Jalisco State, the United Mexican States, under cooperation of the Consejo de Recursos Minerals (referred to as C.R.M. hereinafter) of the United Mexican States.

In this year, geological survey and geochemical explorations on stream sediments were carried out on the whole survey area (1,000 km^2). In addition, based on results from geological studies in about four weeks, a 122 km^2 zone was picked out as one which has a high probability of existence of Kuroko type deposits, and then geophysical surveys (by CSAMT method) were put into practice at the site to select zones for geophysical surveys (by SIP method) and drilling explorations in the coming year.

1-2 Outline of Survey

The project basically continues three years through 1986, taking this year (1984) the first one. During the term, the whole 2,000 km^2 target area is subjected to exploration of Kuroko type deposits by means of geological surveys, geochemical explorations including sampling of stream sediments, geophysical survey (by CSAMT and SIP methods) and drilling explorations.

Items of survey in the current year are shown in Table 1-1.

Table 1-1 Kind of Works

Item	Area	Remarks
Geological and geochemical survey	1,000 km^2	500 km of geological survey route
Geophysical survey	122 km^2	377 stations

Table 1-2 Laboratory Examination

Kind of Examination	Number of samples	Remarks
Microscopic observation of rock thin sections	33	
Microscopic observation of polished ore sections	21	
X-ray powder diffraction	90	
Chemical analysis of ores	33	Au, Ag, Cu, Pb, Zn
Chemical analysis of rocks	102	Whole rock, 13 elements
Chemical analysis of stream sediments	1,505	Ag, Cu, Pb, Cu

1-3 Members of Mission

To promote the projects, the following persons have attended the arrangements for survey planning and cooperation, and the field survey.

Survey planning and cooperation (Japan side):

Tooru Miura	Metal Mining Agency of Japan
Makoto Ishida	"
Takeshi Ogitsu	"
Ken Nakayama	"
Yoshiyuki Kita	"
Yasuo Endoo	"
Masatake Kitajima	Japan International Cooperation Agency
Masaaki Katoo	"
Komao Hosaka	Mining Sect., Agency of Natural Resources and Energy, MITI

Survey Planning and Cooperation (Mexico side):

Jorge Leipen Garay	Directer of C.R.M., General
Gustavo Camacho Ortega	Chief of Special Investigation Department of C.R.M., Charged in project
Raul Cruz Rios	Sub-Chief of Special Investigation Department of C.R.M., Charged in assistant

Field Survey (Japan side):

Fumio Wada	Dowa Engineering Co., Ltd. (Chief of Mission, General, Geological survey, Geochemical exploration)

Minoru Yoshikawa	Dowa Engineering Co., Ltd. (Geophysical exploration)
Akira Fukunaga	" (")
Kazuyoshi Masubuchi	" (Geological survey, Geochemical exploration)
Makoto Takeda	" (")
Masaru Fujita	" (Geophysical exploration)

Field Survey (Mexican side):

Panfilo Sanchez Gonzalez	Special Investigation Department of C.R.M. (Geological survey, Geochemical exploration)
Ladislao Segura Garcia	" (")
Antonio Gonzalez Ramos	" (")
Roberto Ortega Guerrero	Geophysical Department of C.R.M. (Geophysical exploration)
David Gutierrez Lopez	" (")
Apolinar Zumaran Gastor	" (")
David Ventura Lopez	" (")
Jesus Garcia Pineda	" (")

CHAPTER2 GENERAL OUTLINE

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2-1 Situation and Traffic

The survey area is situated in the Talpa de Allende District of the State of Jalisco in the central part of the United Mexican States as shown in Fig. G-1. The area to be surveyed in this fiscal year is 1,000 km^2 bounded by the following four points.

Northwest End	North Latitude:	20°28'51"	West Longitude:	104°57'12"
Northeast End	"	20°28'51"	"	104°42'42"
Southwest End	"	20°7'14"	"	104°57'12"
Southeast End	"	20°7'14"	"	104°42'42"

The traffic by air and land routes from Mexico City, the capital of Mexico, to Guadalajara City is as follows.

(1) Air Route:

The straight line distance between the two cities is about 450 km, and it takes 50 minutes for a jet liner. Many flight services of Aero Mexico and Mexicana de Aviacion are available every day very conveniently.

(2) Land Route:

It is the most convenient to go via the completely paved Pan American Highway (National Highway Route 15) and it takes eight hours to go a distance of 540 km. Further, it takes four hours to get to Talpa de Allende, which was the base of the survey this time, 220 km distant from Guadalajara city. The road of 100 km between Guadalajara city and Ameca town has been well-paved, but the remaining 120 km road consists of a blacktopped part (100 km) and an unpaved part (20 km). The unpaved road which begins at a point 20 km from Talpa de Allende is always in a very bad condition both in rainy and dry seasons. There is one oil station in Talpa de Allende town.

The area for geophysical exploration is an area of 122 km^2 encircled by the following points of coordinates. The origin of the coordinate system was placed on the southwestern end of the survey area (Fig. G-2).

Corners	Coordinates X	Y
A	0	28,850
B	8,488	31,883
C	9,183	30,003
D	11,095	30,675
E	13,833	23,283
F	10,613	22,042
G	11,650	19,263
H	5,474	16,963
I	3,050	23,425
J	2,100	23,075

2-2 Topography and Climate

The topography of the survey area is characterized by the Arrastradero range about 2,000 m above sea level, which consists of Tertiary volcanic rocks and run almost from north to south and the Cacoma range which is in the NW-SE direction and obliquely intersect with the former. Near the ridgelines of the above-mentioned mountains, precipices of tens of meters to a hundred meters are frequently seen. Talpa de Allende, the base of this survey, is situated in a basin, which has developed along the River Talpa flowing through the survey area from the south to the north, and is 1200 m above sea level. On the other hand, La Cuesta area, which is in the southern part of the survey area and has an altitude reduced to about 500 m, consists of Tertiary volcanics and granites and leads to the coastal plain that has developed on the coast of the Pacific Ocean.

The climate can be classified into three types roughly depending upon altitudes.

(1) Mountainous zone:

The vegetation in this zone is characterized by growing conifers and cool climate is dominant all through the year.

(2) Talpa de Allende basin:

Subtropical plants such as oranges, bougainvillea and palm trees are prevalent. The mean annual temperature is 18 - 20°C and the annual rainfall exceeds 1200 mm. The rainy season lasts from June to October, and the maximum monthly rainfall in this season amounts to 340 - 350 mm. The temperature in January is the lowest, about 15 - 16°C, and that in May to June is the highest, about 20 - 21°C.

(3) La Cuesta area in the southern part of the survey area:

The vegetation here is much in common with that in the Talpa de Allende area. The annual rainfall is about 1,200 mm, and the mean temperature in the period of June to August, the hottest season, reaches 28 - 29°C. Even in February, the coldest time, the temperature is 23 - 24°C and it is warm.

2-3 Industry

According to the results of the latest census (about 1979), the population of Talpa de Allende is said to be 6,000, but a large population has been flowing in from the surrounding villages and the present population is supposed to be 10,000. The main industries of this area are stock-farming, cultivation of corn, adzuki, etc., and commerce. Stock-farming and agriculture both include private land owners and egida tareo engaged in work using the land distributed from the Federal-owned land or the land expropriated from individuals. In the stock-farming industry, there are few stock-farm owners who breed more than 1,000 cattles, and most of the pastures are the medium to small ones. The productivity of agriculture is low because of the out-of-date irrigation facilities and agricultural technology, and small scale farmers who can barely support themselves occupy most part of the farmers.

The main activiteis of commerce are the collection and distribution of goods for the residents in Talpa de Allende and the surrounding villages, and the dealing with visitors to festivals held by the catholic church in the town. We heard that the festivals in September and March were famous and there were many visitors also from other states.

2-4 Mining Industry

Being serioucsly influenced by the worldwide economical depression, the mining industry of Mexico is considerably stagnant at present similarly to the domestic economic condition. This stagnation is reflected on the recent mining statistics. Although Mexico is still maintaining its position as the world's largest silver producing country, there are only four minerals whose production quantities were increased than those in the previous year (1982) among twelve principal metallic and nonmetallic minerals as shown in Table 2-1. This tendency is thought to continue also in this year, which is in the long houring of metal prices at low levels and domestic and foreign economical stagnation.

Among the four minerals whose production quantities increased, three minerals are those of silver and accompanied lead and zinc. To the causes of their increase, the newly developed Real de Angel Mine (production 10,000 t/day) in Zacatecas State is contributing greatly.

The main reasons for the large drop of copper production are the closing of medium and small mines and the production cutback of large scale mines (La Caridad Mine, Cananea Mine, etc.) compelled by the metal price hanging down. The influence of the strike in the Cananea Mine, which lasted for eight weeks, cannot be ignored either.

In this stagnant atmosphere of the mining industry, its influence is appearing gradually on exploration activities, resulting in the suspension of the C.R.M.'s exploration project, stoppage of Bethlehem Steel's exploration activities in Mexico, substantial retreat of the Alfa Group from the exploration of nonferrous metallic minerals, etc.

On the other hand, Jalisco state, in which the current survey area is situated, has been explored by C.R.M., and the Barqueno Mine (disseminated and stock-work type gold ore deposit in Tertiary andesite), which is now proceeding to the stage of production, is famous. Cuale Mine, situated at a distance of 15 km to the west of the survey area is the sole active Kuroko mine in Mexico.

There is a high possibility of the existence of Kuroko type ore deposits, but current mining activities cannot be said active, partly because of the delayed recognition of some ore deposits distributed in this area as massive sulphide ore deposits.

In Talpa de Allende, there is a small dressing plant (50 t/day) which was constructed to collectively treat copper, lead and zinc minerals mined in small mines around the town. Presently, test processing of Barqueno ores is being carried out by C.F.M. (Comision de Fomento Minero).

Residents in and near Talpa de Allende are highly interested in mining.

Table 2-1 Mexican Mineral Production (Tons)

Mineral	1979	1980	1981	1982	1983*
Silver	1,537	1,473	1,655	1,549	1,900
Lead	173,455	145,549	157,384	145,844	167,000
Zinc	245,477	238,231	211,629	231,910	257,000
Copper	107,109	175,399	230,466	239,091	205,000
Bismuth	754	770	654	606	550
Cadmium	1,778	1,791	1,433	1,444	1,340
Coke	2,589,000	2,409,000	2,425,000	2,450,000	2,425,000
Iron (contained Fe)	4,041,000	5,087,000	5,293,100	5,382,000	5,310,000
Manganese (contained)	177,359	160,966	208,193	183,120	134,000
Sulphur	2,025,000	2,102,000	2,077,000	1,815,000	1,600,000
Fluorite	875,000	916,000	925,000	631,000	560,000
Barite	151,162	269,322	317,738	323,753	360,000

* Preliminary estimate

(After Mining Annual Review - 1984)

CHAPTER 3 GEOLOGICAL SURVEY

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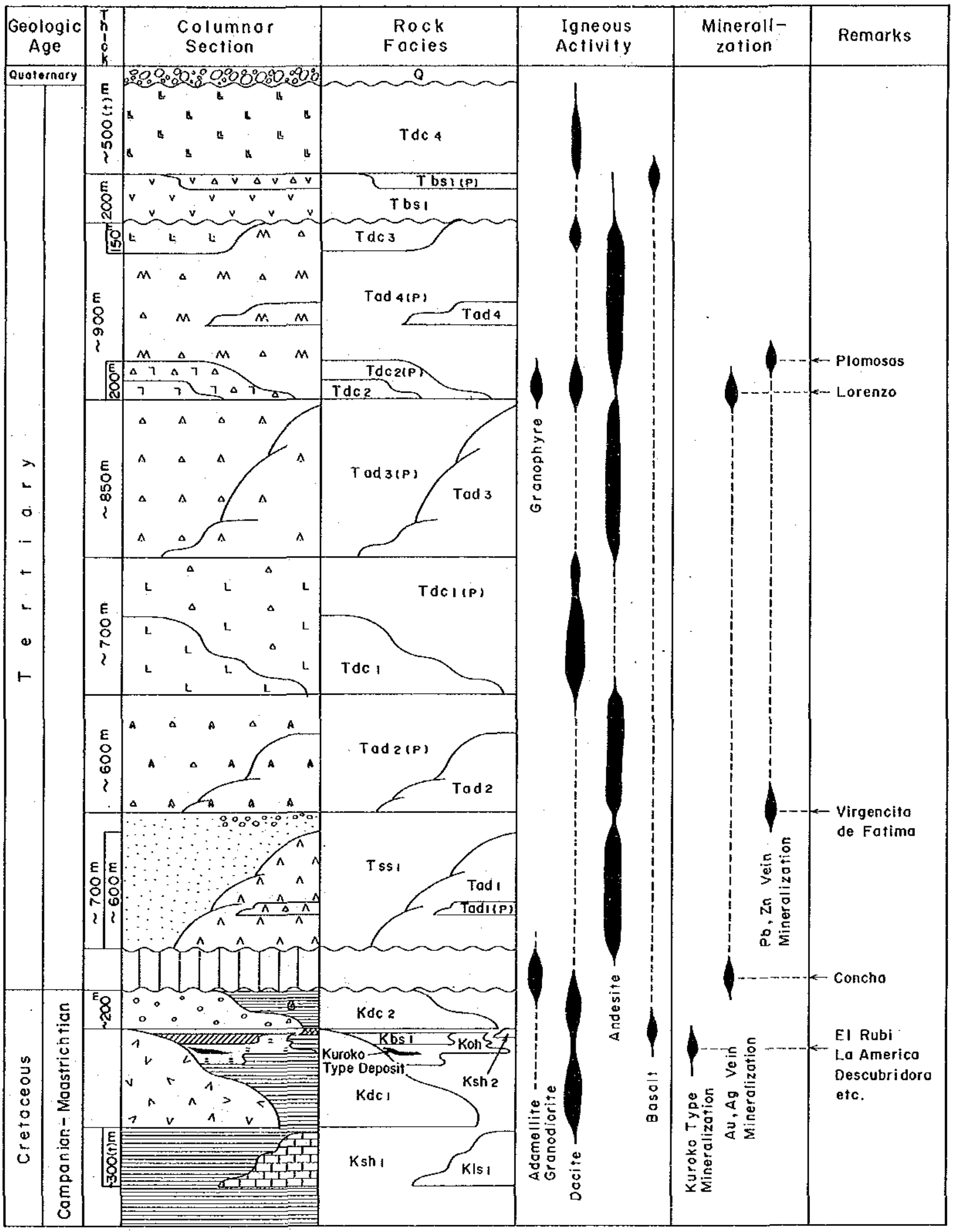
3-1 Outline of Geology

The survey area is situated in the intersection of the Sierra Madre Occidental, a great volcanic range which runs in the NW-SE direction along the coast of the Pacific Ocean over a length of more than 1,000 km from the border with the United States of America in the north, with the Eje Neovolcanico, which has an extension of about 1,000 km from the Nayarit State on the coast of the Pacific Ocean to the Veracruz State on the coast of the Gulf of Mexico in a range from N.L. 19° to N.L. 21°. These two zones are the representative volcanic zones in Mexico, and according to Nieto et al. (1981), the volcanic activity of the Sierra Madre Occidental is supposed to have started in the Oligocene (33 million years ago). On the other hand, the first volcanic activity of the Eje Neovolcanico is said to have started in the Miocene (Hernandez, 1977). The two volcanic zones both seem to be constructed mainly of calc-alkaline rock series (according to Nieto et al., 1977). To find which of the two zones the Tertiary volcanics distributed in the survey area belong to, a volcanostratigraphical survey, the measurement of their absolute ages and a petrological investigation are required, and this is the subject to be studied later.

The Cretaceous system in the survey area, which are covered unconformably by the I-stage andesites (Tad_1) and the sandstone formation (Tss_1) of the Tertiary period, are distributed in the form of Fenster along the Toledo River in the northwestern part of the survey area and the Aranjuez River in the western part. Although the area of their distribution is less than 5% of the survey area, they are important, because they are the strata containing Kuroko type deposits. The main rocks which compose the system are black shale (Ksh_1) intercalating sandstone and intercalated calcareous shale (Ksh_2) although the amount of the later is small. Although the black shale shows the development of slaty cleavages locally, it is constructed of a single layer of several centimeters thick generally. From the fact that no occurrences showing clear depositional discrepancy are found in the Cretaceous system, it is supposed that there is a conformable depositional relation between the lower and the upper layers. In the La America - Descubridora area and El Rubi area where the existence of the Kuroko type deposits has already been known, dacite lava forms the hanging and foot walls of the Kuroko type deposits, suggesting a close relationship between the activities of these acidic volcanic rocks and the Kuroko type deposits.
The sedimentary rocks have received folding, although to different degrees, and usually show a strike almost in the NE-SW direction and a dip of 30° - 60°. From the relationship with the hanging wall dacite (Kdc_2) of the Kuroko type deposits, a two-storied structure is anticipated and the enveloping surface shown by the sedimentary rocks is supposed to have a far gentler dip. A gently-sloped open syncline structure is supposed to exist between the Toledo River and the Aranjuez River.
According to the results of study the nannoplanktons found in the black shale (Ksh_1) near the ore horizon in the basin of the Toledo River, it has been concluded that this stage belongs to the Campanian to Maastrichtian stages (78 - 65 million years ago) of the Upper Cretaceous.

The distribution of sedimentary rocks (Tss_1) has also been noticed in the Tertiary system, but this system is composed mainly of andesites and dacites. The time of activity of these volcanic rocks is unclear, because there is no example of volcano-stratigraphical survey and the measurement of absolute age. However, no big activity discrepancy is noticed in the Tertiary System except the dormant periods existing



Abbreviation
(p) Pyroclastics

(Cretaceous)

- K dc2 : Dacite lava (Hanging wall dacite)
- K sh2 : Calcareous shale
- K bs1 : Basaltic lava- pyroclastics
- K oh : Ore horizon pyroclastics
- K dc1 : Dacite lava dome (Foot wall dacite)
- K sh1 : Shale intercalated with sandstone
- K ls1 : Limestone- marble

(Tertiary)

- T dc4 : IV- Stage dacite lava
- T bs1 : Basalt lava - pyroclastics
- T dc3 : III- Stage dacite lava
- T ad4 : IV- Stage andesite lava - pyroclastics
- T dc2 : II- Stage dacite lava - pyroclastics
- T ad3 : III- Stage andesite lava - pyroclastics
- T dc1 : I -Stage dacite lava - pyroclastics
- T ad2 : II -Stage andesite lava - pyroclastics
- T ss1 : Sandstone - conglomerate
- T ad1 : I -Stage andesite lava - pyroclastics

(Quaternary)

- Q : Alluvium Diluvium

- ∂ : Nonnoplankton

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

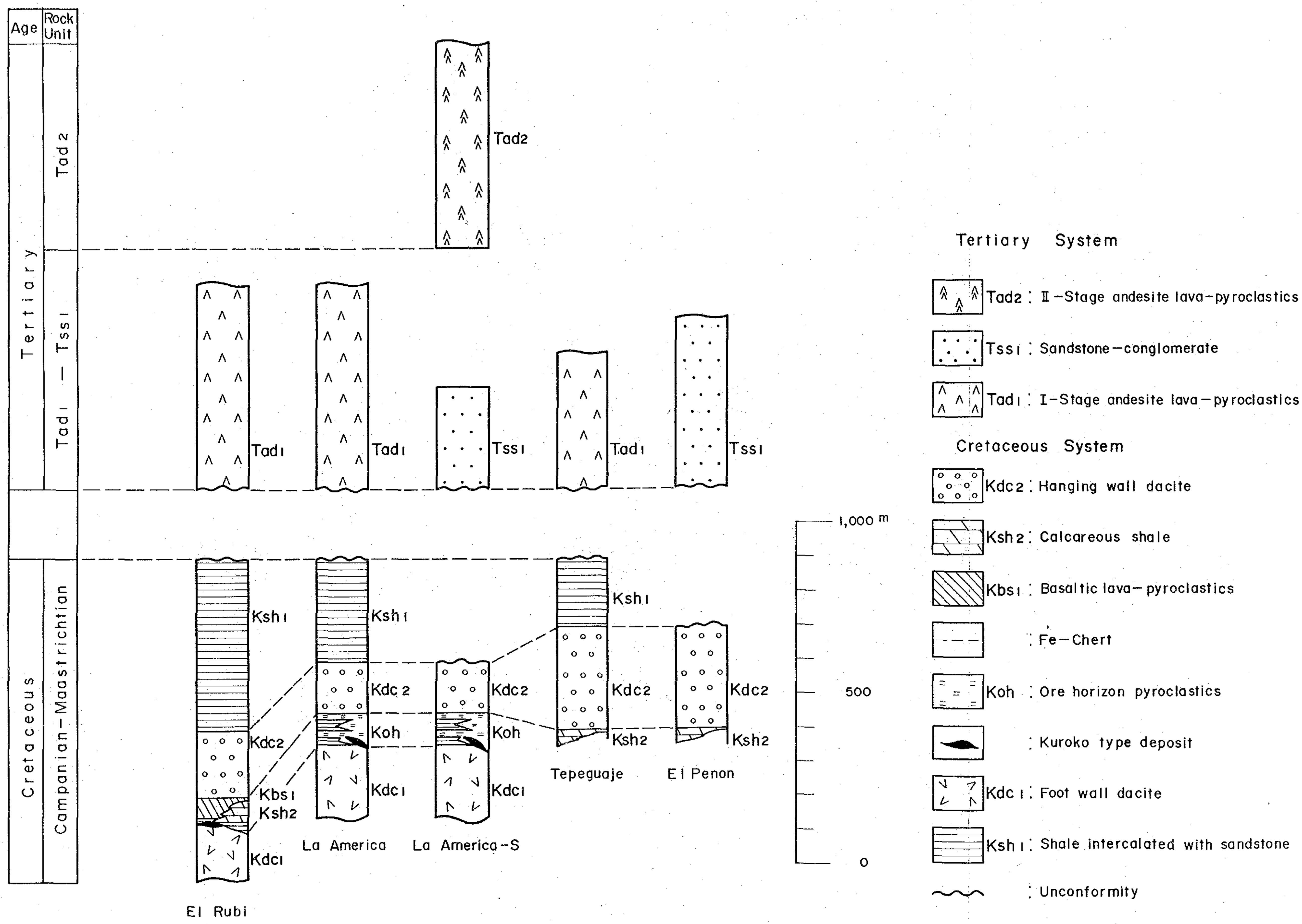


Fig. 3-2 Geological Column of La America and El Rubi Area

between the I-stage andesites (Tad_1) and the II-stage andesites (Tad_2), and between the basalts (Tbs_1) and the III-Stage dacite (Tdc_3) - IV-Stage andesites (Tad_4). The change of the arena of volcanic activities during the transition period between the III-stage andesites (Tad_3) predominant in the southern part of the survey area and the IV-stage andesites (Tad_4) predominant in the northern to central part can be supposed from the appearance of welded tuff in the latter (Tad_4). These volcanic rocks have a strike almost in the N-S direction in the northern part of the survey area, and in the southern part, another stike in the E-W direction are added to the above.
Concerning the alteration of the volcanic rocks, the II-stage andesites (Tad_2) distributed in the Cornadero valley in the northern part of the survey area and in the Monte Grande area in the middle part have received propylitization all over, but the hydrothermal alteration of volcanic rocks later than that is local and in a lower degree.

In the survey area, Kuroko type deposits exist in a close time and space relationship with acidic volcanic rocks in the Cretaceous system. Kuroko type deposits have been found in the La America-Descubridora and El Rubi areas, and especially in the case of the former, many old drifts, where the same type deposits were mined, are distributed in the fine tuff and lapilli tuff (Koh) of ore horizon. Although the deposits in the two areas are about 10 km apart from each other, the deposits are judged to be existing in the same horizon from the resemblance of the hanging wall and foot wall of the Kuroko type deposits and their positions of geological structure.

3-2 Stratigraphy

The rocks distributed in the survey area consist of the shale, sandstone and volcanic rocks of the Cretaceous, the volcanic rocks, sandstone and conglomerates of the Tertiary and intrusives intruding into these rocks. The Quaternary system has developed in the topographical lowlands along the Talpa River and in the southern part of the survey area.
In La Cuesta area in the southern part of this survey area, granodiorite-adamellite of an unknown age have developed.

3-2-1 Cretaceous System

For the Cretaceous system in this survey area, no survey has been carried out which can determine its stratigraphy. As a result of inspecting the nannoplaktons in the black shale samples collected during this survey near La Yerba Buena and Toledo villages in the basin of the Toledo River, it was concluded that the system was the upper Cretaceous (Campanian - Maastrichtian stages, 78 - 65 million years ago).

(1) Limestone Layer (Kls_1)

Whether this layer is the oldest one or not is unclear, because its area of distribution is different from that of other Cretaceous formation. However, the layer was assumed to be a member of the Cretaceous system, because it has received thermal effect by the granodiorite, which is regarded to be a product of the Mexican orogeny (Jurissic - Tertiary periods).

(Distribution)

The limestone is distributed in small scale near San Agustin in the southwestern part of the survey area. The center of the distribution forms a sharp hill and the NW portion is bounded by a fault which contacts with III-stage andesites (Tad_3). The SE part is bounded by granodiorite and has changed to marble completely.

(Thickness)

The thickness of the layer cannot be measured as the bottom of the layer has not yet been confirmed. However, it has been confirmed that even the exposed part alone has a thickness of about 300 m.

(Rock Facies)

In this layer, massive dark grey limestone is recognized locally, but the limestone has changed into recrystallized massive white marble generally.

In the limestone, there are no intercalated layers such as shale and sandstone.

(2) Shale (Sandstone) Layer (Ksh_1)

This is a layer which forms the main part of the Cretaceous system distributed in the Toledo River and the Aranjuez River basins. This is important because it contains Kuroko type deposits and has a common rock facies all over with only local difference between the upper and lower parts.

(Distribution)

This is distributed along Toledo River and Aranjuez River basins in the northwestern part of the survey area, being covered unconformably by the I-stage andesites (Tad_1) and the sandstone (Tss_1) which are supposed to be those of the Tertiary period. The principal exposed parts can be observed along the road leading from Las Jicamas village to La Yerba Buena village via the El Rubi Mine, along the valley running from Aranjuez village to San Isidro in the basin of the Aranjuez River and in the Capulinera valley, etc.

(Thickness)

This has received folding and often shows dips of 30^o - 60^o, and higher order folds or disturbed zones are also found. As there are few examples of the graded bedding of sandstone which will serve for judging normal and reverse depositional relations, there is a problem in calculating the thickness of the layer using only field dips. Especially, from the fact that the general dip of the hanging wall dacites (Kdc_2) in the La America - Descubridora area and the El Rubi area, which are intercalated in this layer, is far gentler than the dip of this layer, a kind of two-storied structure can be supposed. Accordingly, compared with its apparent thickness, the true thickness of this layer should be reduced greatly like that of other Mesozoic formations. Although its accurate thickness cannot be calculated as its bottom has not been confirmed, its thickness to the ore horizon is supposed to be about 1,000 m in the thickest part. The total thickness of exposed parts becomes about 700 m when the above-mentioned two-storied structure is taken into account. Calcareous shale (Ksh_2) is intercalated in this layer and its thickness is about 60 m in the confirmed part.

(Rock Facies)

This layer consists mainly of compact and hard black shale. Although a uniform facies is observed all over the area, a certain degree of facies change is also noticed. In the mass to the north of the Toledo village in the Toledo River basin or in the La Yerba Buena village in the same basin, a thin single layer has developed, showing phyllitic facies. On the other hand, the Capulinera valley in the Aranjuez River basin, the single layer increases its thickness and becomes rather massive. Near the Descubridora deposit, black shale is found which is microscopically rich in carbon matters and includes more calcite and opaque minerals (pyrite) than other shale. Sandstone of a thin bedding is often intercalated in this layer, but it was not so useful for stratigraphical judgement because of its poor development of graded bedding. A calcareous shale (Ksh_2) which looks like shale is also intercalated. Microscopically, plagioclase, quartz, volcanic lapilli (andesite lapilli), etc., are contained, and sericite can be also observed. Locally, facies, which can be called calcareous sandstone, also exist.

(Fossils)

This layer contains few fossils, and very little nannoplanktons were observed in the shale collected in the two areas below.

Actual collection sites, nannoplankton species and their estimated age are as follows.

Collection site: North of La Yerba Buena Village (MJ-3)

Nannoplankton species:

- Watznaueria barnesae (Black) Perch-Nielsen
- Cretarhabdus Crenulatus (Baramlette and Martini) Thierstein
- Zygodiscus elegans Gartner
- Arkhangerskiella Cf. Parca Stradner
- Zygodiscus Sp. indet.
- Cretarhabdus Sp. indet.

Collection site: North of Toledo (G-13)

Nannoplankton species:

- Watznaueria barnesae (Black) Perch-Nielsen
- Cretarhabdus Crenulatus (Baramlette and Martini) Thierstein
- Arkhangerskiella Cf. Parca Stradner
- Zygodiscus elegans Gartner

From these combinations, the stage of this layer is exstimated to range from Campanian to Maastrichtian stage (upper Cretaceous period: 78 - 65 million years).

Although these sample collection sites were limited to the Toledo River basin, there is also a high possibility that the Cretaceous system in the Aranjues River basin is compared to the same stage as it is thought to be stratigraphically the same due to the syncline structure concealed between the two areas.

(Stratigraphical Relationship)

This layer is covered unconformably by the I-stage andesites (Tad_1) supposed to be that of the Tertiary system and wacke sandstone (Tss_1).

(3) Foot Wall Dacite (Kdc_1)

This rock is the product of the oldest volcanic activity which can be observed in this survey area and is intercalated in the above-mentioned shale and sandstone strata (Ksh_1).

(Distribution)

This dacite is distributed in a close relationship with the Kuroko type deposit contained in this survey area. As actual distribution places, narrow outcrops are found only near the tunnel of the La America Mine and on the northern side of the El Rubi tunnel. In the El Rubi area, the development of dacite towards the north is interrupted by the intrusion of granophyre, and in the La America area, the dacite is covered by the tuffs (Koh) of ore horizon and the hanging wall dacites (Kdc_2), and the state and form of its development can rarely be observed directly. However, in the El Rubi area, an occurrence that can be regarded as a lava dome can be observed. Also in the La America area, the lava dome like form agrees best with the field occurrence when the underground and surface geological features are considered together. From these facts, the foot wall dacite in the two areas is supposed to take a lava dome like form similar to that of Japanes Cenozoic Kuroko deposits.

(Thickness)

The thickness of this dacite cannot be measured as its bottom has not been confirmed. Although no clue for estimating the thickness was obtained, the scale of this is shown on the geological section based on estimation.

(Rock Facies)

The two formations are distributed about 10 km apart from each other, but the facies in the El Rubi and La America areas resemble each other closely. The facies in the two areas are both macroscopically aphyric, compact and hard. However, the rocks in the La America area are green and show a weak brecciated structure, while those in the El Rubi area are greyish white and more massive. Microscopically, the rocks of the two areas have a cryptocrystalline texture and are very much alike except for a small difference that a small amount of quartz phenocrysts is found in the La America area rocks but not in the El Rubi area rocks. Their groundmass is thought to have been glassy, but has been changed into fine quartz and clay minerals (sericite or chlorite) by the alteration.

The dissemination of pyrite is prevalent in La America area, but it is rarely seen in El Rubi area.

(Stratigraphical Relation)

This formation is considered to be the product of a submarine volcanic activity occurred in a certain stage of the depositional time of the shale layers (Ksh_1) in the upper Cretaceous, but its relation with lower layers cannot be observed in the fields and is unclear. From the field occurrence of this formation, it is supposed that a dome-up movement, which was noticed in the Uchinotai deposit, Kosaka by Hashiguchi (1983), occured, and this formation seems to contact with the pyroclastics (Koh) of ore horizon and the shale and sandstone layer (Ksh_1) in a peneconformable relationship locally.

(4) Pyroclastics of Ore Horizon (Koh)

This layer comprises fine acidic tuff mainly, but acidic lapilli tuff is also intercalated in the La America Mine. As this formation has a characteristic facies in the shale and sandstone layer (Ksh_1), it is suitable for a key bed, but since its distributed areas are limited as described below, it could not be used widely.

(Distribution)

This formation is distributed only in the La America-Descubridora area. The distribution form, covered mainly by handing wall dacites (Kdc_2), shows a kind of Fenster. However, from the fact that the geology in La America and Descubridora tunnels is occupied by this formation almost entirely, its distribution area is thought to extend greatly. Intercalated shale is also observed, so this formation is thought to have been formed as submarine pyroclastic flow deposits. In this case, pyroclastic flow usually fills basins, and from the fact that the place of forming a Kuroko type deposit is also supposed to be a basin, the distribution of this formation becomes important in exploring Kuroko type deposits.

(Rock Facies)

This formation comprises mainly hard fine tuff of green. In La America and Descubridora tunnels, there are places where this formation shows a felsite like facies because of its very high hardness. Lapilli tuff is found in La America tunnel and on a part of its surface, and from the extension of attenuated pumice, its rough strike and dip can be supposed. Microscopically, quartz, carbonate mineral (calcite), chlorite, sericite, etc., have been produced by the alteration and the texture of the original rock has been nearly eliminated, but the original rock is judged to be acidic pyroclastics owing to the clear facies difference from intercalated shale.

(Thickness)

As there are few outcrops at which the relation of this formation with lower layers can be observed, its accurate thickness cannot be estimated. In the exposed part of the foot wall dacite (Kdc_1) near the La America tunnel, this formation has been attenuated. On the other hand, the thickness increases gradually around the Descubridora deposit. From the fact that the folding type of this layer is different from that of the hanging wall dacite (Kdc_2), which covers this layer, a two-storied structure can be supposed, and the real thickness of this layer, which is an incompetent layer, is supposed to be smaller than the apparent thickness. When the relationship between the field distribution range and the hanging wall dacite (Kdc_2) is taken into account, the thickness of this layer is estimated at 100 m approximately.

(Stratigraphical Relation)

This layer contacts with the lower foot wall dacite (Kdc_1) in a peneconformable relation.

(5) Basaltic Tuff-Lava (Kbs_1)

(Distribution)

While the fine tuff of the ore horizon is distributed only in the La America-Descubridora area, the distribution of these rocks is limited to the neighborhood of the El Rubi deposit. Stratigraphically, it is intercalated between the hanging wall and foot wall dacites, accordingly, it corresponds to the fine tuff at the ore horizon in the La America-Descubridora area. Both have a feature of uneven distribution. This layer also gives a clue to the estimation of a paleotopographic shape similarly to the tuff of the ore horizon. Because of its relation with the place of deposition, its distribution is important for the exploration of the Kuroko type deposit.

(Thickness)

When directly in contact with foot wall dacite (Kdc_1), this layer is attenuated, but the maximum thickness of this layer is estimated to be about 50 m.

(Rock Facies)

This layer mainly comprises basaltic tuff, which is generally compact and fine. Small spots of epidote are sometimes found visually. Brecciated lava facies often changes to a massive facies, resulting in dolerite. Microscopically, this is holocrystalline, has a subophitic texture and consists of plagioclase, olivine, augite, hornblend, etc. Chlorite and epidote have been produced by alteration.

(Stratigraphical Relation)

This layer contacts with the shale (sandstone) layer (Ksh_1) conformably and with the foot wall dacite (Kdc_1), in a peneconformable relationship locally.

(6) Hanging Wall Dacite (Kdc_2)

This rock is thought to be the final product of a volcanic activity cycle related with the formation of Kuroko type depsoit, which has developed from the foot wall dacite (Kdc_1).

(Distribution)

This layer is distributed only in La America-Descubridora and El Rubi areas, where the existence of Kuroko type deposits is known. In the former area, this rock is distributed in a zone from the southwest of the Descubridora tunnel to the Capulinera valley to the northeast of the La America tunnel with a stretch almost in the NE-SW direction. In the case of the latter, this layer is observed in a zone from the mass to the northwest of El Rubi tunnel to the right bank of Los Espinos valley.

Most of the Kuroko type deposits in the survey area exist below this rock, accordingly, it is important in exploration.

(Thickness)

As this layer is a competent layer, it shows only the folding of lower order, and there is no need to estimate a real thickness from the apparent thickness, different from the shale (sandstone) layer (Ksh_1). Although the thickness of this layer cannot be determined accurately due to the fact that it is covered by wacke sandstone (Tss_1), which is supposed to belong to the Tertiary system, and erosion, the thickness can be estimated to be about 200 m.

(Rock Facies)

This layer shows a rather uniform facies all over. It looks grayish white and is characterized by quartz phenocrysts, which are found universally. It is compact and hard, and can be divided into massive parts and brecciated parts. In the boundary between each breccia, the veinlets of limonite or hematite have sometimes developed. Microscopically, this layer has a cryptocrystalline texture which consists of coroded subhedral-xenomorphic quartz (at a 1 mm diameter or smaller) and euhedral and prismatic plagioclase (at a 2 mm length or smaller). The groundmass is glassy but comprises a large amount of fine quarts, chlorite and other clay minerals generated by alteration.

(Stratigraphical Relation)

This layer is covered unconformably with the sandstone layer (Tss_1) described later. In the valley near La America it is underlaid with the pyroclastics (Koh) of the ore horizon in the form of a kind of decollement, due to the difference in their folding types.

3-2-2 Tertiary System

The Tertiary system in the survey area is not determined from the results of volcanostratigraphical survey and absolute age measurement but the I-stage andesites (Tad_1) and the sandstone layers (Tss_1) which cover the shale (sandstone) layers (Ksh_1) and the acidic volcanics (Kdc_2) of the upper Cretaceous period unconformably afterwards are assumed as the Tertiary system. No controverysy was noticed between this assumption and the history of the general volcanic activity of the Sierra Madre Occidental and the Eje Neovolcanico.

The Tertiary system was formed mainly by the volcanic activities of andesites and dacites. On the basis of the mutual depositional relationships, rock facies, etc. It is classified into ten groups as follows:

(1) I-stage Andesites (Tad_1)

These rocks are distributed mainly in the Cerro El Pintor and San Pedro masses which lie between the Toledo River and the Aranjuez River. It is also found to the north of La Yerba Buena and around Murgia and Platanito in the south-western part of the survey area.

(Thickness)

These rocks have developed most in the area around Cerro El Pintor and San Pedro and its thickness is estimated to be about 600 m.

(Rock Facies)

These rocks are composed of lavas and lapilli tuff. The lavas occupy most part of these rocks and show a dark green-green brecciated or compact massive appearance. Lava flow units, which are seen in later period andesites (for example, Tad_4), are not noticed, and a lava flow unit itself seems to be considerably thick. Microscopically, development of a porphyritic texture is observed, large euhedral plagioclase (7 mm long or less) and euhedral-subhedral augite (5 mm long or less) are seen, and in addition, subhedral iron mineral (magnetite) and a small amount of hyperthene (altered to chlorite) are also seen. The groundmass, which shows a pilotaxitic texture, consists mainly of brown glass and fine plagioclase and accompanies a small - very small amount of pyroxene and iron minerals (magnetite). Chlorite, sericite, quartz, etc., have been produced by alteration.

The lapilli tuff assumes a green color and is intercalated into lava flows. Macroscopically, it contains dark green-brown andesite lapilli, and its alteration is stronger than the lavas. The plagioclase contained in the tuff tends to become finer than that in the lava.

(Stratigraphical Relation)

These rocks cover the shale (sandstone) layer (Ksh_1) of the Cretaceous system with dip-unconformity in the Pena Blanca valley and the Tepozanes valley to the south of Toledo. In the south-western part of the survey area, the depositional relation of these rocks with lower layers is unclear, because the lowermost part of this layer has not yet been confirmed.

(2) Sandstone Layer (Tss_1)

This layer is the only layer which comprises mainly sediments among the Tertiary system in the survey area. From the existence of this layer, it is understood that there was a clear dormant period of volcanic activities between the activities of the I-stage andesites (Tad_1) mentioned before and the volcanic activities after them.

(Distribution)

This layer seems to be exposed or concealed over a wide area extending from the neighborhood of Cerro El Pintor, which seems to be the northern limit, to the Agua Fria valley in the southwestern part of the survey area. The typical distribution of this layer on the surface is found in from the east of La America deposit to the San Quiteria village.

(Thickness)

This layer is considered to have a maximum thickness in the Santa Quiteria area, where its lowermost and uppermost parts can be confirmed, which is estimated to be about 700 m.

(Rock Facies)

This layer comprises mainly wacke sandstone, in which grey massive bedding has developed, but compact black shale is also intercalated in the lower part of this layer. Intercalated andesite lava is also found in the upper part. The sandstone shows rather good sorting and is composed of various rock fragments microscopically, among which andesite lapilli seem to be dominant. In addition to plagioclase, quarts and epidote with sizes of about 1 mm, muddy rock is also contained. In some upper part of this layer, conglomerate has developed, which assumes a brown color visually and contains andesites of angular-subangular, dacite, altered rock whose original rock is not evident, etc. The conglomerate in the Agua Fria valley is very hard and oxidized.

(Stratigraphical Relation)

This layer unconformably covers the hanging wall dacite (Kdc_2) in the La America-Descubridora area, and the shale (sandstone) layer (Ksh_1) near the Capulinera valley to the northeast of La America. In Cerro El Pintor, it covers the I-stage andesites (Tad_1) with a gentle dip. As it is intruded by massive andesite (Ad_1) which much resembles the I-stage andesites (Tad_1), it cannot be thought that there was a long time interval between the two (i.e. Tad_1 and Tss_1).

(3) II-stage Andesites (Tad_2)

These rocks are distributed independently in the Cornadero valley in the northwestern part, in the Santa Quiteria - Monte Grande villages in the central part and in the La Huerta stream basin at the south end of the survey area. Therefore, the mutual depositional relation of these independent portions cannot be determined, but they were united into the same group in this survey in consideration of the similarity of their facies, the relationship with their upper and lower layers, etc.

(Distribution)

In addition to the three areas mentioned above, which are the representative distribution areas, these rocks are also distributed along the valley from the Agua Fria stream basin to Platanito in the southwestern part of the survey area.

(Thickness)

In the Santa Quiteria - Monte Grande area, where the lowermost and the uppermost parts of these rocks were confirmed, its thickness was measured to be about 600 m. In the Cornadero stream basin and the La Huerta stream basin, the lowermost part of these rocks has not yet been confirmed and rocks have received block movement caused by faults, therefore, it was unable to determine the thickness of rocks.

(Rock Facies)

These rocks consist mainly of andesitic lapilli tuff and andesite lava.

These rocks in the Cornadero stream basin consist of altered andesite lava which assumes dark green - purplish red colors and lapilli tuff of the same quality. Almost the whole part of this area except for the mountain top is composed of altered andesites with the same facies. Microscopically, the lapilli tuff contains subangular andesites, the groundmass is tuffaceous, and fine plagioclase and iron minerals in addition to glass are observed. Chlorite and calcite have been produced by alteration.

Also in the Santa Quiteria - Monte Grande area, these rocks have the same composition of rocks as that in the Cornadero stream basin, but the lapilli tuff includes fine grains more. In this area, alteration and pyritization is stronger than that in other areas. Microscopically, these rock consist of volcanic fragments (most part is andesite, but other rocks also seem to be included) plagioclase, iron minerals and glass, and contain quartz, chlorite, sericite, pyrite, etc., resulting from alteration.

In the La Huerta stream basin, lava flows seem to be dominant compared with the above-mentioned two areas.
Macroscopically, these rocks assumes a dark grey - dark green color and contain a high percentage of compact medium grain andesite. Microscopically, it has an intergranular texture and consist of plagioclase, K-feldspar, augite, iron minerals and a small amount of glass. By alteration, chlorite, epidote, pyrite, etc., have been produced.

In addition to the above, these rocks in the Agua Fria stream basin and near Platanito are composed mainly of dark green-purplish red lapilli tuff - fine tuff.

(Stratigraphical Relation)

Although the depositional relation of these rocks with lower layers cannot be observed in the Cornadero stream basin, it is supposed that these rocks cover granodiorite, which are widely distributed from La Cuesta to Soyatan, unconformably in the La Huerta stream basin near the southern end of the survey area. In other areas, these rocks cover sandstone (Tss_1) in a conformable relationship.

(4) I-stage Dacites (Tdc_1)

These rocks represent the first acidic volcanic activity of the Tertiary in the survey area.

(Distribution)

These rocks are distributed from the east and the west sides to the foot of the Arrastradero mountain range which passes the eastern part of the survey area from the north to the south. These rocks in the El Rincon valley in the northern part and that in the Puerto del Diablo valley in the southern part show difference in their facies, but they were compared as the same layer, because they are of the same rock composition and of the stratigraphical position in which they appear are similar. In the Cacoma range which crosses the survey area from NW to SE, these rocks have not been found.

(Thickness)

As these rocks are covered by the Quaternary system or have been dislocated by faults on the west side of the Arrastradero range, and as it is covered unconformably by basalt lava (Tbs_1) on the east side of the range, it is difficult to calculate the accurate thickness of these rocks. On the geological sections, the maximum thickness of this layer is estimated to be about 700 m.

(Rock Facies)

The facies of these rocks can be roughly classified into three, corresponding to the distribution areas respectively.

In the El Rincon valley in the northern part, the facies containing greyish white-light brown aphyric dacite and that containing quartz phenocrysts are dominant. As a whole, much massive rock is contained and the autobrecciated texture has become unclear probably because of strng alterations. However, as the mode of distribution of these rocks seems to be conformable with upper layers (IV-stage andesites, Tad_4), we regarded the facies of these rocks as lava facies.

In the Tierra Coloradas area, on the other hand, pyroclastics are dominant. Rocks show a light brown color, and on a fresh surface, a breccia structure is found, and quartz, biotite, etc. can be observed macroscopically, although in small quantities. However, the structure and texture of these rocks have been made unclear generally by strong weathering, and the veinlets and the spots of iron oxides are often contained. Microscopically, the representative tuff in this area shows a vidroclastic texture and comprises mainly dacitic glass fragments but also contains a small amount of pumice, plagioclase, quartz, iron minerals, biotite, etc. The tuff has been oxidized generally and assumes a reddish brown color. The alteration is weak and only a small amount of clay minerals have been produced. Near the uppermost part of this layer, a section which can be called muddy tuff is also intercalated.

In the Puerto del Diablo valley, these rocks have a light brown flow structure, in which compact dacite dominates.

(Stratigraphical Relation)

The relation of these rocks with the lower sandstone layers (Tss_1) has not been noticed directly in the fields, but these rocks are supposed to cover the lower layers in a conformable relation from the distribution form of these rocks.

Concerning the depositional relation with the III-stage andesites (Tad_3), with which these rocks contact in a relation of fault near Bella Vista in the central part of the survey area, the III-stage andesites (Tad_3) are supposed to be representing a volcanic activity preceding to and followed by that of IV-stage andesites (Tad_4) from the viewpoints of facies and distribution, therefore, the III-stage andesites are supposed to be an activity later than these rocks.

(5) III-stage Andesites (Tad_3)

These rocks are supposed to belong to a series of volcanic activites together with the IV-stage andesites (Tad_4) described later and to be the product of an activity earlier than that of Tad_4. The distinction of the two was made by considering whether the activity arena of each belongs to a sea area or a land area. Intercalated stratified fine tuffs often found in these rocks suggest that the activity of these rocks occurred mainly in the sea area. The facies of these rocks are also similar to those of the IV-stage andesites (Tad_4).

(Distribution)

These rocks are distributed over an area from the Agua Fria stream basin in the southern part to the western foot of the Cacoma range in the eastern part of the survey area. In the Cacoma range, which has a steep geographical form, these rocks often form waterfalls. In the southern part, these rocks are a formation which occupies the largest distribution area.

(Thickness)

The thickness of these rocks is maximum near Cerro El Dinero and estimated to be about 850 m but tends to decrease as these rocks stretch southwards.

(Rock Facies)

There are a part where lava flows dominate and a part where lapilli tuff-tuff breccia dominate.

In the area around the Agua Fria valley in the southwestern part of the survey area, light brown lapilli tuff - tuff breccia (small quantity) dominate. In the field, it is sometimes difficult to identify volcanic lapilli macroscopically, but on a cutting section, brown-grey andesite lapilli assemblages can be noticed clearly. A greyish white fine tuff formation (several meters in width) is intercalated in these layer, but it did not serve for the analysis of the general geological structure as its strike and dip vary greatly.

In these rocks at the western foot of the Cacoma range in the southeastern part of the survey area, lava flows dominate. Macroscopically, these rocks are brown-grey and compact, show a brecciated structure clearly and are characterized by prismatic plagioclase phenocrysts contained universally.

Although the facies in the southwestern part differ from those in the southeastern part as described above, these two independently distributed sections were lumped together into the same rock formation because of their stratigraphical relations with the II-stage andesites (Tad_2) and the fact that they are essentially the same kind of andesites.

(Stratigraphical Relation)

Although a direct depositional relation with the sandstone layer (Tss_1) or the II-stage andesites, which are the lower layers, was not found, they are thought to have a conformable depositional relation since no geological occurrence suggesting an unconformable relation is not noticed near their boundary. These rocks are supposed to be abutting at a gentle angle with the granodiorite (Gd), which is distributed from the north to the west of La Cuesta, when judged from their distributional relation.

(6) II-stage Dacites (Tdc_2)

(Distribution)

These rocks are distributed in small scales from the mountain ridge to the south of the Descubridora deposit to Cerro El Aguaje.

(Thickness)

These thickness are estimated to be about 200 m.

(Rock Facies)

These rocks are composed mainly of brown-yellowish brown dacitic lapilli tuff. Locally, volcanic lapilli having a flow structure are found and a small amount of poorly vesculated pumices are also contained. As dacite boulders containing quartz phenocrysts are found up the Monte Grande stream, lava facies development is supposed in the lower portion.

(Stratigraphical Relation)

These rocks cover the III-stage andesites (Tad_3) below conformably.

(7) IV-stage Andesites (Tad_4)

These rocks are the effusives by the andesitic activity in the latest stage in the survey area.

(Distribution)

They are the main component rocks of the Arrastradero range which runs from the northeastern end to the southeastern end of the survey area. The same rock formation is distributed also in a range from Los Ocotes in the north to the northwest mass.

(Thickness)

The maximum thickness is found near Puerto del Talpa and estimated to be about 900 m.

(Rock Facies)

Although these rocks are distributed extensively, its facies are found to be in common except for local changes. These rocks consist of lava flows, welded tuff and non-welded lapilli tuff and tuff breccia, which assume a brown-purplish red color and contain compact plagioclase of about 1 mm long universally. Microscopically, the welded tuff contains plagioclase, K-feldspar and mafic minerals (pyroxene, hornblend,), and fine quartz, epidote, sericite, etc., have been produced as secondary minerals by alteration. The non-welded tuffs contain fine quartz, a small amount of sericite (flaky, fine) and iron minerals in addition to andesitic lapilli and poorly vesculated pumice.

Although these rocks have been dislocated by faults in some place, it generally forms steep cliffs along the ridgeline of the Arrastradero range and can be traced from the north to the south in the survey area with the help of its characteristic outcrop occurrence. In the upper to the middle part of these rocks to the east-southest of Talpa de Allende, dacite lava was observed, but it was included in these rocks as it is distributed scatteredly in small scales with a thickness below 10 m.

(Stratigraphical Relation)

These rocks are in a conformable relation with the I-stage dacites (Tdc_1) and the III-stage andesites (Tad_3).

(8) III-stage Dacite (Tdc_3)

(Distribution)

This rock is distributed in small scales in the crests of the Arrastradero range to the west of Tierra Coloradas. Its relationship with the dacite lava intercalated in the upper-middle part of the IV-stage andesites (Tad_4) is unclear.

(Thickness)

A thickness of about 150 m was measured.

(Rock Facies)

This layer comprises dacite lava with a brown-greyish white flow structure. Macroscopically, the layer appears to have been subjected to hydrothermal alteration, but X-ray diffractometrical study suggests that it was merely subjected to diagenesis.

(Stratigraphical Relation)

This rock covers the IV-stage dacites conformably.

(9) Basalts (Tbs_1)

These rocks are the sole basalt lava in the Tertiary system in the survey area.

(Distribution)

These rocks are distributed from Los Ocotes to the basin of the Talpa River, both in the northern part of the survey area, and from the eastern foot of the Arrastradero range to the basin of the Mascota River and its tributaries. In each area, these have a distribution characteristic of having filled up topographical lowlands.

(Thickness)

Although its accurate thickness is unclear, because its lowermost bottom has not been confirmed, its maximum thickness is estimated to be about 200 m from the geological cross section.

(Rock Facies)

Macroscopically, these rocks are constructed of yellowish brown-grey compact vesculated lava and basaltic fine tuff.

They both show extremely gentle dips and are regarded to represent activities after folding movement, in which lower layers took part.

Microscopically, olivine and a small amount of augite are observed in the form of phenocrysts, and the groundmass shows a holocrystalline intergranular texture and consists of feldspar, olivine, augite, iron mineral (magnetite) and apatite. A part of the olivine has been changed to an iron mineral (hematite) by oxidation.

(Stratigraphical Relation)

These cover lower layers, the I-stage dacites (Tdc_1) and the IV-stage andesites, with dip-unconformity.

(10) IV-stage Dacite (Tdc_4)

This rock is the product of the final volcanic activity in the survey area.

(Distribution)

This composes the geology of Cerro Para Nada at the eastern end of the survey area. Its area of distribution is small, covering an area of 3.5 km from E to W and 2.5 km from N to S.

(Thickness)

As this rock forms a lava dome, whose underground shape cannot be confirmed not to say of its lowermost part, the thickness of rock cannot be calculated. The thickness on the surface at Cerro Para Nada amounts to 500 m approximately.

(Rock Facies)

This rock is grey compact vesculated glassy dacite. From the shape of the exposed part, this is judged to be a lava dome.

(stratigraphical Relation)

This rock is supposed to be the product of an activity later than that of the basalts (Tbs_1). No occurrence suggesting a noticeable interval of activities between both rocks was observed.

3-2-3 Quaternary System

The Quaternary system is distributed in the flat part of the basin of the Talpa River and the mountain foot in the middle to northern part of the survey area, and in the southern part, in the La Quebrada stream basin and the Los Otates stream basin from La Curesta southwards. This system comprises mainly a gravel layer of a poor degree of consolidation and has been stratified in most cases.

The details of the Quarternary system are omitted in consideration of the purpose of this survey.

3-2-4 Intrusives

The intrusives include five kinds of rocks, adamellite (Adm), granodiorite (Gd), granophyre (Gpy), andesites (Ad_1 and Ad_2) and dacite (Dc).

(1) Adamellite (Adm)

(Distribution)

This is distributed in granodiorite (Gd) in a range of 2.5 Km x 5 Km around Centinela at the southern end of the survey area. It is unclear whether these two kinds of rocks are the separate rock bodies of different intrusion time or the same rock body of facies changed.

(Rock Facies)

Macroscopically, this rock is a compact, hard, and medium grain holocrystalline rock in which pink K-feldspar is conspicuous. Microscopically, it has a equigranular texture and contains quarts, K-feldspar, plagioclase and biotite as principal minerals, and sphene and apatite as accessory minerals. By alteration, biotite has been changed into chlorite, K-feldspar and plagioclase into clay minerals, and small quantities of epidote and quartz have been produced.

(Intrustion Time)

The intrusion time is unclear as the measurement of absolute age has not been carried out. However, when it is assumed that this rock is essentially the same rock body as granodiorite, the intrusion time of this rock can be supposed from the results of survey for the whole neighborhood of this area carried out in the past. According to the igneous activity classification by Nieto et al. (1981), this area belongs to the igneous activity area of the laramide phase, therefore, this rock is supposed to have intruded at that time.

(2) Granodiorite (Gd)

(Distribution)

This rock is a batholith exposed over an area of more than 5 km in width and more than 15 km in length with a stretch almost in the NE-SW direction from the northeast of La Cuesta in the southern part to the southern end of the survey area. As similar rock is exposed also at the western end (to the west of Cerro San Pedro) of the central part of the survey area, this granodiorite is supposed to be the basement rock in these areas.

(Rock Facies)

Macroscopically, this rock is grey, compact and hard medium-fine grain granodiorite. Microscopically, it shows an equigranular texture and contains quartz, plagioclose, K-feldspar, biotite, hornblend and an iron mineral (magnetite) as principal minerals, and sphene, apatite and zircon as accessory minerals. The K-feldspar assumes a xenomorphic form, filling the intergranular of plagioclase, biotite and hornblend, and a part of biotite has been altered to chlorite.

(Intrustion Time)

The intrusion time cannot be determined in detail as the measurement of absolute age has not been carried out, but the possibility of intrusion in the laramide phase can be supposed. If the intrusion of this granodiorite is assumed to be in this phase, it agrees with the fact that limestone has changed to marble and the Tertiary system contacting directly with this rock is in an unmetamorphosed state.

(3) Granophyre (Gph)

(Distribution)

A stock-shaped exposed part of this rock is observed in the area around Tescalama Dos to the north of the El Rubi deposit. This rock of the same facies is also distributed in the north of Los Ocotes and at the southeastern foot of Cerro San Pedro in small scales.

(Rock Facies)

Macroscopically, white short plagioclase prisms of 5 - 6 mm in size are observed in compact light brown rock. In the Los Majadas valley, however, the facies change into fine grains. Microscopically, euhedral plagioclase and a small amount of biotite are contained as phenocrysts. The groundmass shows a coarse granophyric texture, and quartz, K-feldspar, plagioclase, biotite, an iron mineral (magnetite) and apatite are observed. The plagioclose has been changed to sericite, and the biotite to chlorite by alteration.

(Instrution Time)

In the Las Majadas valey, the granophyre seems to have given a weak thermal effect to the II-stage andesites (Tad_2), but in the III-stage andesites (Tad_3), the existence of thermal effect is unclear. However, judging from its form of distribution, it is supposed to have intruded also into the III-stage andesites (Tad_3). This rock belongs to shallower intrusive, showing facies changes, and to rock species which seldom give a clear thermal aureole to intruded rocks.

(4) Andesites (Ad_1, Ad_2)

(Distribution, Facies, Intrusion Time)

The andesite (Ad_1) is distributed in Cerro El Pintor and Cerro San Pedro with a close relation with the I-stage andesites (Tad_1). As its facies, which contain characteristic plagioclase megacrysts, look like those of the I-stage andesites (Tad_1), its intrusion time is supposed to be not so apart from the I-stage andesite activity.

The andesite (Ad_2) is a dark green compact and massive fine-medium grain andesite, distributed in the southern neighborhood of Monte Grande. As this rock also has similar facies to the surrounding II-stage andesites (Tad_2) essentially, it is supposed to have intruded immediately after the II-stage andesite activity.

Both andesites (Ad_1 and Ad_2) have stock like forms.

(5) Dacite (Dc)

(Distribution, Facies, Intrusion Time)

This rock forms dacite stocks found concentratedly in the Los Encinos area at the northeastern end of the survey area. It is grey, compact, massive and glassy, and also contains vesculated parts. In facies, it is similar to the IV-stage dacite distributed in the southern part of this area. It intrudes the IV-stage andesites (Tad_4).

3-3 Geological Structure

Various elements about the geological structure observed in the survey area are different between the Cretaceous system and the Teriary system. The severe folds, which are observed in Cretaceous sediments, are not found in the Tertiary system, which shows gentle folds generally.

(Cretaceous System)

As the Cretaceous system in the survey area is covered unconformably by the I-stage andesites (Tad_1) and the sandstone layer (Tss_1) of the Tertiary, so that the Cretaceous system is exposed limitedly and the geological structure of this system cannot be interpreted completely. Also in the Cretaceous system, sediments and ore horizon pyroclastics take part in folds in the field and assume various strikes and dips as shown in Fig. 3-3.

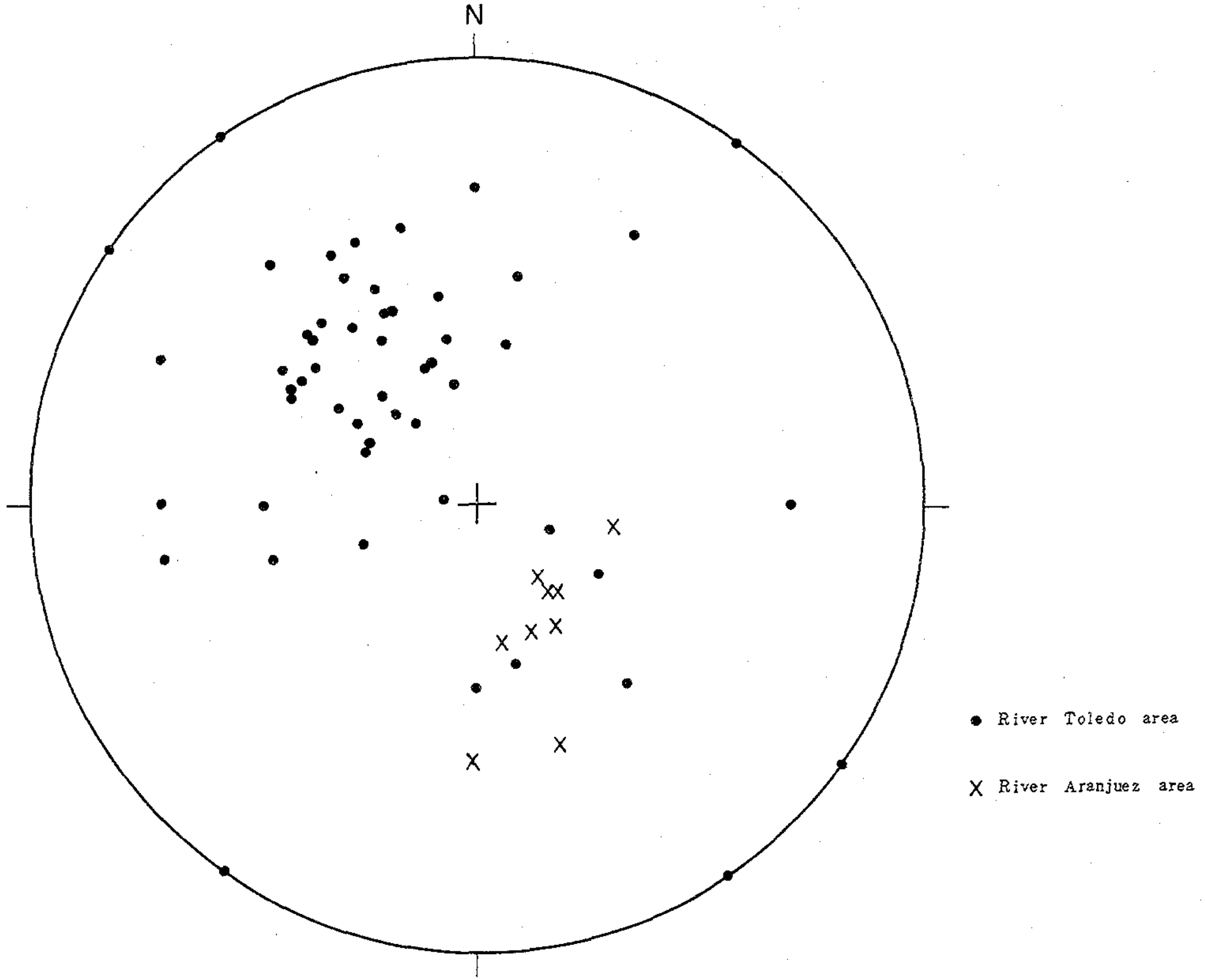


Fig. 3–3 Stereo Net Projections of Poles of Bedding Planes in Shale—Sandstone (Ksh_1)
(Projections on Lower Hemisphere)

On the other hand, the hanging wall dacite (Kdc_2) shows an extremely gentle dip generally in the investigation of the depositional relation of its bottom surface with ore horizon pyroclastics (Koh), the distribution form in the valley near the La America tunnel and interpretation on the geological cross section. A similar relation is found between the shale (Ksh_1) and the hanging wall dacite (Kdc_2) in the El Rubi area. Accordingly, it can be supposed that a kind of two-storied structure exists between the sediments (Ksh_1) - the ore horizon pyroclastics and the hanging wall dacite (Kdc_2). Conceptually, it can be understood that the dip of the hanging wall dacite (Kdc_2) corresponds to the dip of an enveloping surface which envelops the crest or the trough of the shale and the sandstone (Fig. 3-4). By understanding thus, the distribution of the same tuff over a length of about 400 m in the Descubridora tunnel can be explained although various dips are observed on the surface of the mine. In other words, it is suggested that the strata as a whole has a far gentler dip than the apparent dip. From the above, the structure of the hanging wall dacite (Kdc_2) is very important for understanding the entire image of the geological structure in the survey area. Also in the El Rubi and the La America-Descubridora areas, the dip of the hanging wall dacite (Kdc_2) shows the same dip direction as that of sediments respectively (southeastern dip in the El Rubi area and northwestern dip in the La America area). The strike of the folding axis, which is supposed to be concealed below the I-stage andesite (Tad_1), cannot be defined as a single direction from the fact that the poles of strike and dip are scattered as shown in Fig.3-3, but a southeastern plunge of the axis can only be noticed. In the El Rubi area, the hanging wall dacite (Kdc_2) changes its direction to east-west strike and the south dip in the north of the El Rubi tunnel by the influence of foot wall dacite (Kdc_1) doming up. Near the La America deposit, the hanging wall dacite (Kdc_2) is included in anticlinal zone structurally, and it is highly possible to extend to the Capulinera valley in the northeast when judged from the strike and dip shown by the shale (Ksh_1). Judging from field occurrence, the zone corresponds almost to the entire distribution area of the hanging wall dacite (Kdc_2). This anticlinal zone forms a highly asymmerical fold as the half wave length of the synclined structure in northwestern wing is estimated to be more than 8 km, but half wave length of the southeastern wing is only 4 km. Accordingly, the cause of formation of this zone will not be a regional stress which formed an extensive folding structure but may be some other factor, for example, local elevation caused by the doming up of the foot wall dacite (Kdc_1). In this case, the up-heaved zone and its surrounding area attract attention as a place for exploring Kuroko type deposits because of the close relationship between this rock and Kuroko type deposits. No occurrence which suggests the existence of a caldera, which is attracting attention recently as a place of forming a Kuroko type deposit (for example, Ohomoto, 1978), was found in the survey area. As rocks which suggest the places of deposit formation indirectly, basaltic lava-pyroclastics (Kbs_1), ore horizon tuff (Koh), hanging wall dacite (Kdc_2), etc., which suggest the existence of paleo-basins at the time of ore deposition, are considered, and these rocks are rather more important.

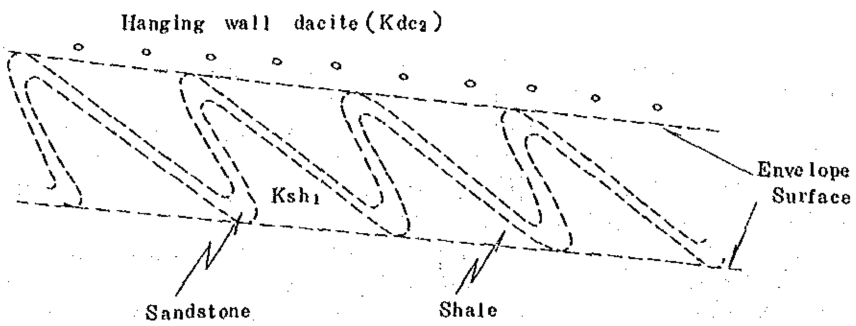


Fig.3−4 Idealized Structural Relation between Shale–Sandstone(Ksh1) and Hanging Wall Dacite(Kdc2)

(Tertiary System)

The Tertiary system in the survey area includes few severely folded parts like those observed in the Cretaceous system. In the northern part of the survey area, a fold structure of a wave length of 5 - 8 km running almost in the N-S direction is dominant, and sandstone (Tss_1), II - IV stage andesites (Tad_2 - Tad_4), and I - III stage dacites (Tdc_1 - Tdc_3) take part in this structure. In the southern part of the survey area on the other hand, an E-W strike also dominates in the sandstone (Tss_1) and the II - III stage andesites (Tad_2, Tad_3) which compose the Cacoma range in addition to the N-W series fold that stretches from the northern part.

The faults which have developed in the survey area can be classified in the order from older formation time into 1 N-S - NE-SW system, 2 E-W system and 3 NW-SE system. The N-S system faults have given dislocation to the limestone (Kls_1) and the III-stage andesites (Tad_3) near San Agustin at the southern end of the survey area. The NE-SW system faults dominate in the southeastern part of the survey area and have given block movement to the II-IV stage andesites (Tad_2 - Tad_4) in combination with NW-SE system faults. The E-W system faults have dislocated sandstone (Tss_1), I-stage dacite (Tdc_1) and III-IV stage andesites (Tad_3-Tad_4) to the east and the west in the area to the southeast of Talpa de Allende. The NW-SE system ones are the faults with the largest continuity, but their amount of dislocation is not so large.

The fault supposed along the Talpa River by Urabe (1982) exists near El Refugio in the southern part of the survey area, but is not supposed to continue to the northern part when judged from the state of distribution of rock formations.

The volcanic rocks of the Tertiary system show locally steep slopes, but usually show gentle slopes of 30^{o} or less.

In lower part of the sandstone formation (Tss_1) which has developed in the southern part of the La America - Descubridora area, black shales are intercaleted and can hardly be distinguished sometimes from the shale of the Cretaceous system, but when the result (Fig. 3-5) of stereo projections of bedding planes shown by the former is compared with those of the Cretaceous system (Fig. 3-3), clear difference can be noticed. The sandstone formation (Tss_1) is characterized by its stable strike and its degree of concentration of poles is far higher than that of the Cretaceous system.

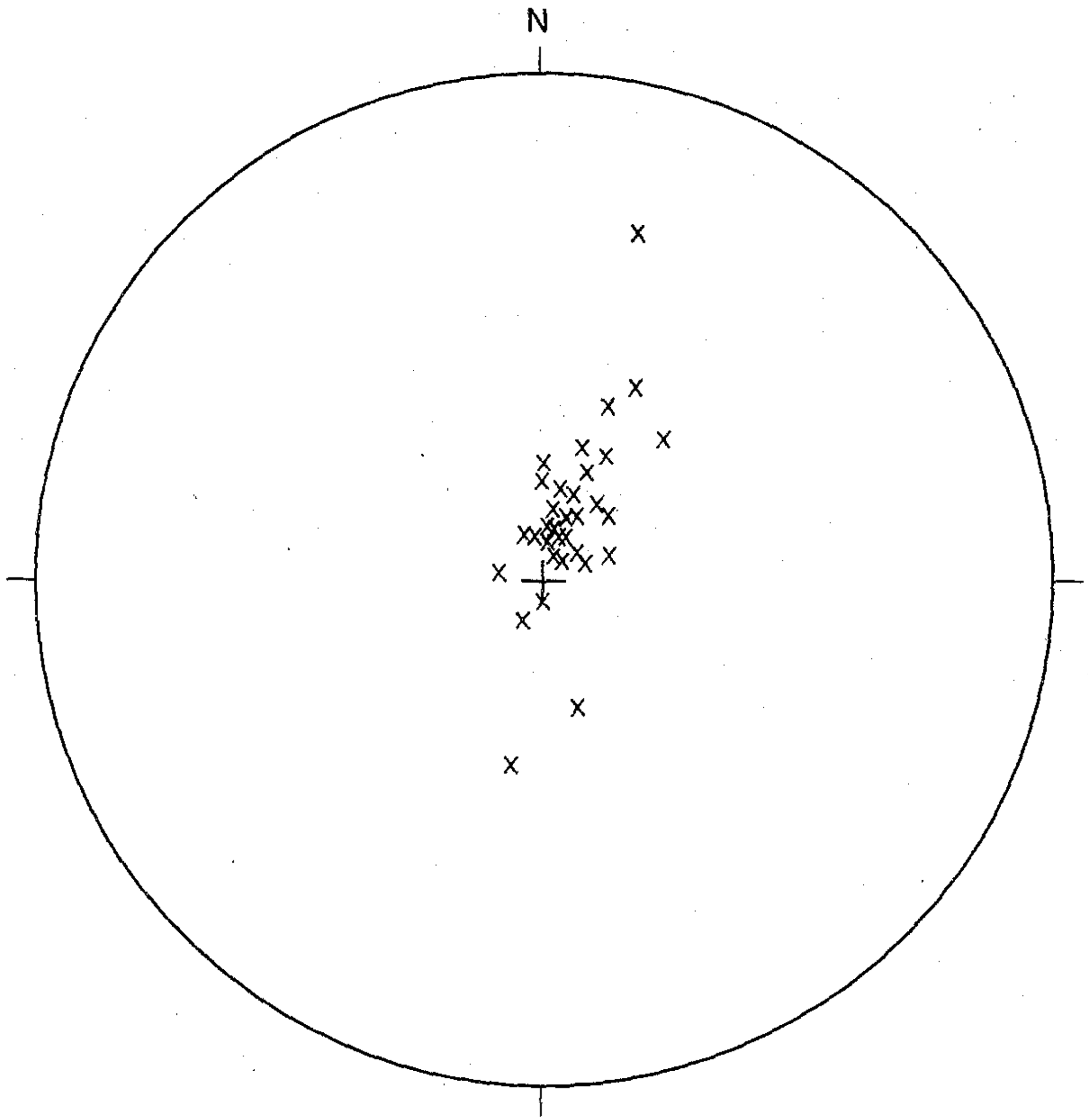


Fig. 3–5 Stereo Net Projections of Poles of Bedding Planes in Sandstone Formation (Tss_1)
(Projections on Lower Hemisphere)

3-4 Mineralized Zone

In the survey area, various mineralized zones such as gold-silver vein deposits, etc., in the hanging wall dacite (Kdc_2) were found in addition to Kuroko type deposits which exist with a close relationship to the dacites in the shale of the Cretaceous. However, those which have been regarded important are Kuroko type deposits, accordingly, emphasis was placed on diagnosing the possibility of existence of this type of deposit in this survey.

3-4-1 Details of Mineralized Zone

(1) La America (Altitude 1,410 m)

Location:

This zone is located in the central to westerly part of the survey area. The nearest village is Aranjuez. The distance from Talpa de Allende is about 10 km.

Occurrence:

The deposit exists with aphyric dacite (Kdc_1) as its foot wall and in the acidic fine tuff-lapilli tuff (Koh) of an ore horizon, which covers the dacite, conformably with these rocks with N60E 70 - 80 SE strike and dip. Covering the ore horizon, hanging wall dacite (Kdc_2), in which quartz phenocrysts are observed universally with the naked eye, is distributed. The pyroclastics (Koh) of the ore horizon have generally received alteration to chlorite and sericite and silicification. The degree of alteration of the hanging wall dacite (Kdc_2) is roughly same to that at the above alteration.

The deposit is stratiform or lens-shaped, and two main ore bodies exist. A kuroko bed (thickness: 1m) with a strike length of 40 - 50 m was confirmed in the upper horizon and a bed (thickness: 4m) consisting mainly of fine pyrite lies under the former bed. Although both beds are small in thickness, they show stable continuity (Fig. 3-6). The ore consists of the assembly of compact and fine sulphides (sphalerite, galena, pyrite, etc.), and shows a banded structure in some portions.

In the current state of tunnel development, siliceous ores are not observed in tunnels, but in the waste disposal, siliceous ores are also found, therefore, this deposit seems to be consisting of of black ore, yellow ore and siliceous ore. From the fact that the deposit exists near the foot wall dacite (Kdc_1), the deposit is supposed to be a Kuroko type deposit of the so-called proximal type, wich was formed near the source of flowing out ore solution.

According to the result of observing polished ore sections, the ore consists of the assembly of the crystals of sphalerite, galena, etc., and a reworked sedimentary texture consisting of crystal fragments is not found. According to the result of inspecting the thin sections of the gangue mineral, quartz is dominant. The analytical results of ore samples collected in this deposit are as follows.

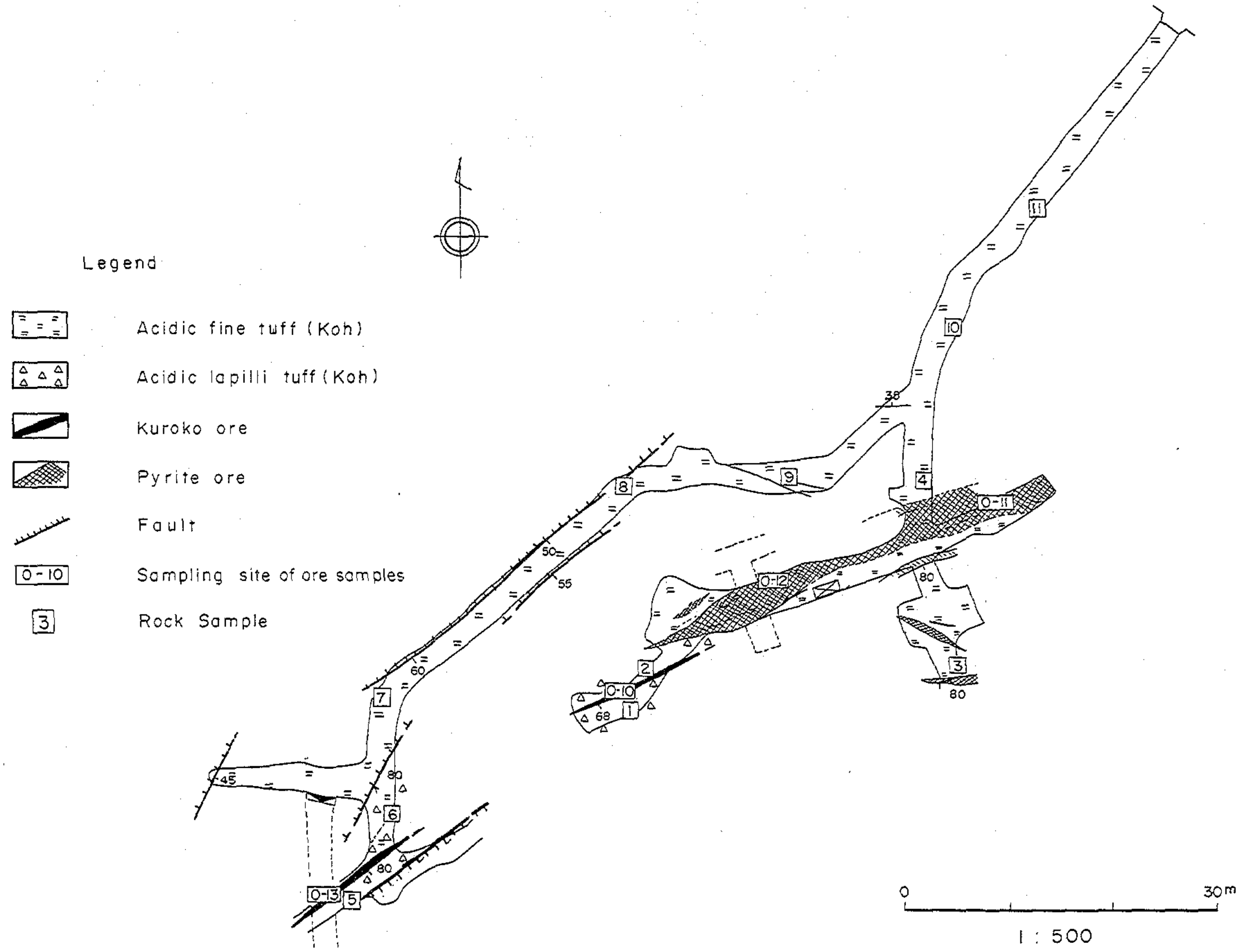


Fig.3-6 Geological Sketch Map of La America Deposit

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 10	0.7	1,014	0.32	3.95	23.89	Massive, compact fine Py-Sph ore
0 - 11	0.3	188	0.14	0.86	2.02	Massive, fine Py ore
0 - 12	0.7	244	0.20	1.47	10.77	"
0 - 13	12.8	3,799	1.20	24.39	34.08	Massive, compact Sph-Gn ore
0 - 14	2.1	230	0.17	0.58	2.64	Py-Sph dissemination in silicified rock
0 - 17	0.4	297	0.17	1.26	11.10	Fine Py ore

Both the black ore and the yellow ore attract attention that they will contain high percentage silver, but silver minerals were not found in microscopic observation.

This deposit is owned by Ing. Arnold Castaneda Martinez (living in Guadalajara) after many changes of owners. There are no data available about production in the past, but by supposing from the state of tunnel development and the scale of the deposit, the production scale of the deposit is estimated to be several tens of thousand tons.

(2) Descubridora (Altitude 1,440 m)

Location:

This zone is located about 1 km to the southwest of the La America tunnel and 1.6 km to the south of the Aranjuez village.

Occurrence:

A tunnel (Direction: N70E, Length: 360 m) has been developed 1,440 m above sea level. Most of the zone consists of the silicified acidic fine tuff (Koh) of the ore horizon, and the intercalation of shale seen on the surface is not found, so that the strike and dip of the ore horizon can hardly be determined. The deposit exists above the tunnel level, and it was unable to observe old working. An old working of a scale of 30 - 40 m x 10 m x 4.5 m was said to be found in this mine.

In this survey this time, only pyrite ore and the disseminated ore of pyrite was found in the waste disposal site, but in the past, black ore, yellow ore and silicified ore containing barite were said to be found in the same waste disposal site. In other words, although detailed occurrence of the deposit is unclear, this deposit is also supposed to be a proximal type kuroko deposit judging from produced ore species and the ore horizon of the deposit. From the scale of the old working, the amount of ore mined in the past is estimated to be 10,000 ton or less. The result of analyzing the ore samples collected in the waste disposal site are as follows:

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 9	0.1	71	0.07	0.20	0.65	Fine Py dissemination in silicified breccia
0 - 20	0.3	90	0.16	0.44	3.37	Fine Py-Sph dissemination in acidic fine tuff
0 - 22	1.2	322	0.16	0.20	0.26	Fine Py ore

(3) Atalaya (Altitude 1,600 m)

Location:

This zone is located 600 m to the east-northeast of the Decubridora tunnel.

Occurrence:

A tunnel directing almost eastward can be entered by about 50 m. About 15 m from the entrance, a reverse fault almost in the east-west direction exists, and the pyroclastics of ore horizon are distributed. Although clayey alteration is observed locally, silicification dominates generally. However, compared with the silicification, pyrite dissemination is weak. In the tunnel, several mined places were observed, but no mineralized zones were found. These mined places will probably be those for fine pyrite mainly and a certain amount of high silver content ore which accompanies sphalerite and galena.

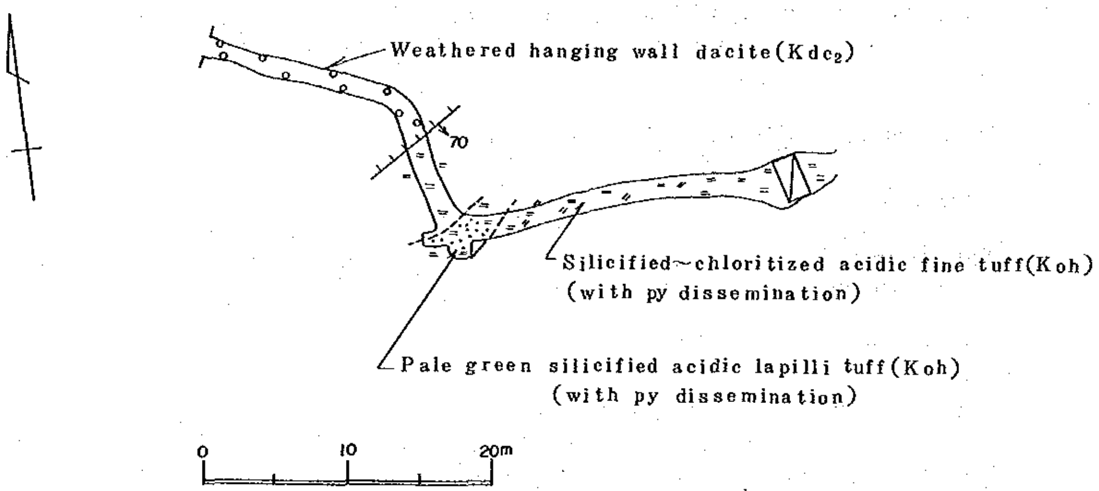


Fig.3-7 Geological Sketch of Atalaya Mine

(4) Atayarita (Altitude 1,560 m)

Location:

This zone is located 500 m to the south of the La America tunnel.

Occurrence:

There is a tunnel in the acidic fine tuff-lapilli tuff (Koh) of an ore horizon. Although weak pyrite dissemination and silicification are observed near the tunnel, silicification and dissemination both become weaker in the hanging wall dacite (Kdc_2) covering the tunnel. Although entry was impossible because of the collapse of the tunnel, the following results were obtained by analyzing a sample of ore (fine pyrite and sphalerite are disseminated in shale) heaped up near the tunnel.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 16	0.8	256	0.18	1.69	5.88	Fine Py-Sph dissemination in silicified shale

As is always the case in the ore produced in Kuroko type deposits in La America Descubridora area, silver content is high compared with lead and zinc contents.

(5) Hueso (Altitude 1,420 m)

Location:

This zone is located 450 m to the northeast of the descubridora tunnel.

Occurrence:

The occurrence of this deposit cannot be observed directly because of the collapse of the tunnel. As the tunnel is positioned just below the lower most face of the hanging wall dacite (Kdc_2), the object of mining seems to be the Kuroko type deposit in the fine tuff or in lapilli tuff (Koh) of ore horizon. The analytical results of a crushed pyrite sample collected from the waste disposal near the tunnel are as follows.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 15	0.8	276	0.36	0.73	2.06	Crushed Py ore

Although galena and sphalerite are not noticed macroscopically, they are thought to be filling the intergranulars between fine pyrite grains.

(6) Trinidad (Altitude 1,470 m)

Location:

This zone is located 350 m to the east-southeast of the Descubridora tunnel.

Occurrence:

There are irregular concentrations consisting mainly of pyrite in the ore horizon tuff (Koh) below the lower most face of the hanging wall dacite (Kdc_2). Fig. 3-8 shows a sketch of mineralized zone. Probably because of the attack of acid solution produced by the weathering of pyrite, the host rock is brittle and limonite stockwork-veinlets after pyrite cross the rock frequently. In the analytical results of a sample collected, silver grade is high compared with lead and zinc contents.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 3	0.7	87	0.12	0.39	1.11	Py dissemination in acidic fine tuff

Because of the fact that this mineralized zone also exists in an ore horizon and the ore grades are quite similar to those yielded in the Kuroko type in this area, this zone is supposed also to be a Kuroko type deposit of the same mineralization origin as that of La America and Descubridora.

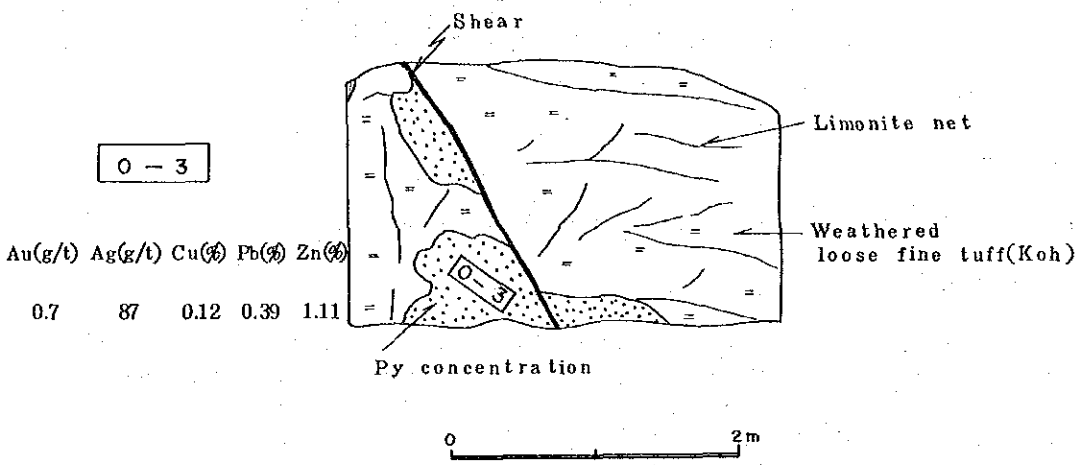


Fig.3-8 Geological Sketch of Trinidad Mineralized Zone

(7) La Eliza (Altitude: 1,440 m)

Location:

There are a collapsed tunnel and a waste disposal 100 m to the southeast of the Descubridora tunnel.

Occurrence:

The tunnel is in the fine tuff (Koh) of an ore horizon which intercalates black shale. The tunnel almost faces east and was developed probably for mining the Kuroko type deposit in the ore horizon. The analytical results of a pyrite disseminated siliceous ore sample collected in the waste disposal are as follows:

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 4	0.2	6	0.05	0.06	0.26	Py-disseminated siliceous ore

Compared with the samples collected in other deposits, the silver, lead and zinc contents are lower, so that this ore is judged to be that consisting solely of pyrite.

(8) Monte Cristo (Altitude 1,600 m)

Location:

This zone is located 350 m to the east-southeast of the Descubridora tunnel.

Occurrence:

An inclined shaft at an angle of 30 - 35° facing S35W has been developed for about 30 m and connected to a shaft. As mineralization, pyrite dissemination is noticed in the shale or lapilli tuff (thickness: 3 - 4 m) intercalated in hanging wall dacite (Kdc_2). Galena and sphalerite are accompanied in some parts. The analytical results of a pyrite sample contained in shale in the form of dissemination are as follows.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 8	0.4	102	0.17	0.38	0.85	Py-disseminated in shale

In common with Kuroko type ores near here, a feature of low copper, lead and zinc contents and a relatively high silver grade is noticed. Stratigraphically, this zone is regarded to be a mineralized sign in the uppermost part of the ore horizon.

(9) El Rubi (Altitude: 1,260 m)

Location:

This zone is located 10 km to the west of Talpa de Allende in the middle basin of the Toledo River.

Occurrence:

As the tunnel of the El Rubi deposit has nearly collapsed, it was unable to survey the underground geology, but the occurrence as shown in Fig. 3-9 was observed.

A Kuroko bed containing mainly galena and sphalerite dips gently towards southeast. In the upper part of this Kuroko bed, dolerite intrusive is noticed, and as it bends the bed, a dip which is not harmonic with the surrounding host rock (Ksh_1) is shown. In the deposit, two kinds of ores, an ore bed consisting of typical black ore and siliceous ore whose main component is pyrite and which lies in the lower part, are noticed macroscopically. The thickness of the black ore bed changes in a range of 2 m - 0.5 m. The siliceous ore can be confirmed to a thickness of about 1.5 m, but a thickness below this value is unclear. In the uppermost several ten centimeter thick part of the black ore bed, a clear banded structure of pyrite, galena and sphalerite has developed. Fine barite also takes part in the formation of this structure. Host rock of the siliceous ore seems to be slightly brecciated foot wall decite (Kdc_1), and pyrite is yielded in the form of dissemination, veinlets, stockwork or small scale ore nests. The analytical results of ore samples collected in this survey are as follows:

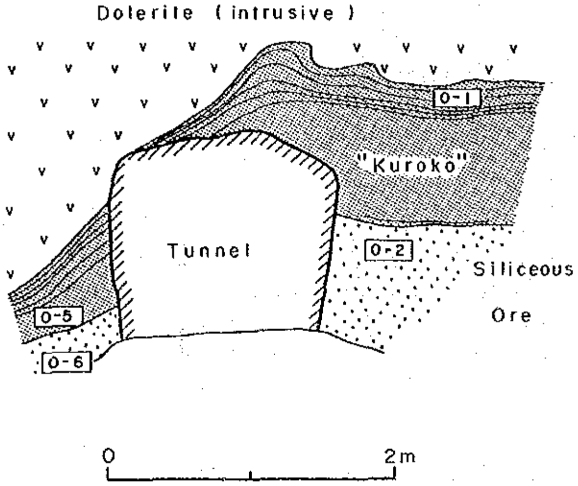


Fig.3-9 Geological Sketch of El Rubi Deposit

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 1	0.3	134	1.78	4.70	29.57	Kuroko
0 - 2	2.4	574	0.17	0.30	0.59	Siliceous ore
0 - 5	0.2	106	1.58	3.55	21.35	Kuroko
0 - 6	0.2	25	0.07	0.09	0.25	Siliceous ore

The high concentrations of gold and silver in the sample 0-2 collected in the upper part of the siliceous ore are noticeable.

The El Rubi deposit was mined for about seven years from 1967 to 1973 by Zimpan Company, a subsidiary of Fresnillo Company. The company constructed a dressing plant having a capacity of 200 t/d to process ore, but the quantity of ore mined in the past would not have reached 100,000 ton at the maximum estimation.

The foot wall dacite (Kdc_1) of the El Rubi deposit changes its strike of development to E-W direction in the eastern part of the deposit. A pyrite network zone (Ocotitlan tunnel) was found in the silicified rock in the horizon upper than that of El Rubi deposit. The analytical results of a sample collected in this part are as follows:

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 19	0.6	122	0.18	0.38	2.42	Py net in silicified rock

From the similarity of the grade, this mineralized zone is also regarded to belong to a Kuroko type deposit.

(10) Concha (Altitude: 1,550 m)

Location:

This zone is located 300 m to the northeast of the La America tunnel.

Occurrence:

A vein with a strike of N 15E, a dip of 80 - 90°W and a vein width of 20 - 30 cm exists in the hanging wall dacite (Kdc_2). Mineralization is noticed along an N 15E system shear zone for a length of about 15 m. Mining in the past was carried out above the level of 1,540 m. Although the development of the vein towards northeast can be confirmed as shown in Fig. 3-10, but its continuity towards southwest has been made unclear by the NW - SE fault.

The analytical results of a powdery ore sample which consists of pyrite and galena and was collected in this vein are as follows:

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 18	86.7	7,482	0.07	3.55	0.20	Py-Gn powdery ore Width: 20 cm

The existence of such a high grade vein near the Kuroko type deposit requires attention in exploring Kuroko type deposits in addition to the importance of such vein itself. In other words, the possibility of knowing the existence of a blind Kuroko type deposit, although indirectly, by catching the above showing by the geochemical exploration using stream sediments is remained.

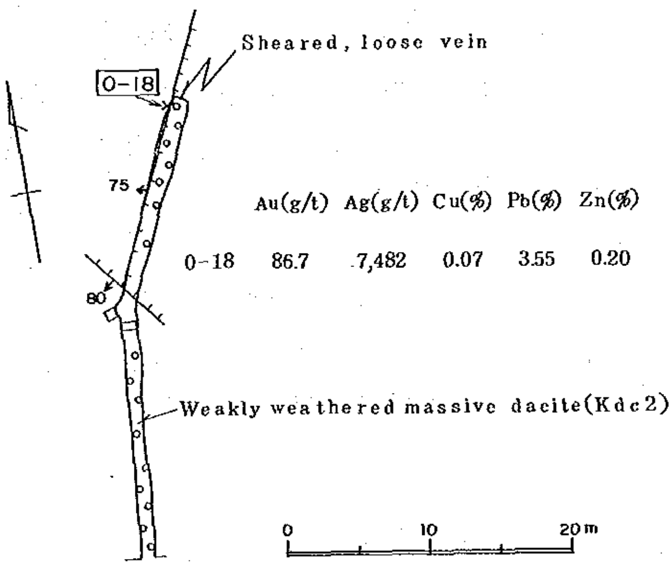


Fig.3-10 Geological Sketch of Concha Mine

(11) Plomosas (Altitude: 1,580 m)

Location:

This zone is located up the Los Tepozanes stream on the northwestern slope of a high peak, Cerro El Pintor (2,140 m above sea level) between the Toledo River and the Aranjuez River.

Occurrence:

A vein containing coarse grain sphalerite - chalcopyrite - galena in the form of ore nest or dissemination, was confirmed in light olive colored basic fine tuff with a vein width of 2 m. The vein has an N 60 W strike and a vertical dip. The existence of a flooded shaft in addition to the tunnel of the above level shows that the development of lower level was carried out, but production, development scale, etc., are not clear.

The vein has the features of a shear fracture more than a tensile fracture, because the boundary between the host rock and the vein is unclear and the constituents of the vein are the same as those of the host rock.

According to the X-ray diffractometrical study of an altered rock sample collected from this vein and that collected from the adjoining host rock, a considerably large amount of primary plagioclase still remains not decomposed in the latter, but primary plagioclase has been completely decomposed and disappeared in the former, representing a sudden change of alteration peculiar to a vein deposit. The chemical composition of the chlorite also shows that this chlorite can be classified into iron chlorite which is rich in iron and produced more generally in vein deposits (Fig. 3-14). According to the microscopic observation of a polished section of the ore sample produced in this vein, the exsolution of sphalerite "star" is noticed in chalcopyrite. In addition, as the paragenesis of primary marcasite and pyrite exists, this vein is not regarded to be a mere epithermal type vein but is regarded to be a xenothermal type vein. The possible existence of a concealed hypabyssal rock body near this vein is expected. The analytical results of an ore sample consisting of sphalerite and calcite are as follows:

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
W - 33	0.2	28	0.15	0.15	31.9	Coarse Sph and calcite

Compared with the ore produced in a Kuroko type deposit, this ore sample is characterized by its low silver grade.

(12) Virgencita de Fatima (Altitude: 1,800 m)

Location:

This zone is located 2.6 km to the west of the Descubridora tunnel. Although mined ore and the stake of a mining claim were found, the position of a tunnel was unable to be found.

Occurrence:

As far as judging from the mined ore, this is a pyrite - Sphalerite - galena - chalcopyrite vein in the I-stage andesites (Tad_1) distributed near here as its host rock. The sphalerite and the galena are of medium-coarse grain but become fine grains when they are disseminated into the host rock.

As epidote is also found in the host rock macroscopically, the host rock is supposed to have been subjected to propylitization.

The width, strike, dip, etc., of the vein are unclear.

The analytical results of an ore sample collected in the surface ore stockyard are as follows.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 7	0.1	272	1.65	9.83	5.94	Sph-Gn-Cp Vein in Andesite (Tad1)

Different from ore samples produced in Kuroko type deposits, the silver content of this sample is low compared with its high contents of galena, etc.

(13) Lorenzo (Altitude: 1,800 m)

Location:

This zone is located about 3 km to the west of the Monte Grande village up the stream of the same name.

Several old workings are scattered in an area of several hundred meters near here.

Occurrence:

The geology is composed of the andesite lava - lapilli tuff of the III-stage andesites (Tad_3) which assume a light green - light brown color. The Lorenzo vein is a quartz vein (vein width: 3 - 5 cm) with an N 50 W strike and a 65 W dip which runs in the lapilli tuff. The vein is constructed of quartz only which filled a tensile fracture. The boundary between the vein and the host rock is clear and no particular alteration is found even on the edge of the vein. The vein consists of milky white quartz and a very small amount of pyrite and black mineral (galena ?) accompanied by the quartz. The guide told us that there was a tunnel developed 50 - 60 years ago but it has collapsed at present, therefore, the length of development, the amount of production, etc., are unclear. The analytical results of this quartz part are as follows.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
0 - 21	2.6	189	0.06	0.02	0.04	Qz veinlet in acidic lapilli tuff (Tad_3)

The analytical results show that this zone represents the mineralization of a low Au/Ag ratio, and from the extremely low content of sulphide minerals in the ore, the silver is supposed to have come from some silver mineral directly.

There is Tajalin tunnel, now flooded, about 200 m to the south of the Lorenzo vein. This tunnel is said to have been developed for a length of about 20 m in the S 10 W direction in massive and compact andesite lava (Tad_3), and the quartz vein was mined 8 - 10 years ago. Only an intermittent veinlet of 1 - 2 cm width was found near the tunnel entrance. The signs of mineralization and alteration were rarely noticed in the host rock.

(14) Monte Grande (Altitude: 1,400 - 1,900 m)

Location:

A pyrite-disseminated zone was found near the Monte Grande village situated in the central part of the survey area.

Occurrence:

In this area, II-stage andesites (Tad_2), andesite intrusive (Ad_2) and III-stage andesites (Tad_3) are known to have been distributed. The mineralized signs are mainly those of fine pyrite dissemination but vary with the kinds of host rock. In other words, the signs are the pyrite dissemination accompanied by the wide propylitized zone seen in the II-stage andesites (Tad_2) and the andesite intrusive, and the signs subject to the fracture system observed in the III-stage andesites (Tad_3). While the former forms a wide disseminated zone, the latter is local. In the case of the former, only monotonous pyrite dissemination is found macroscopically, but sphalerite (0.02 - 0.01 mm in diameter) is sometimes found in pyrite in the microscopic observation of polished sections.

As gold mineralization (Lorenzo vein) has also been known near hear, the four samples mentioned below were analyzed expecting the accompaniment of noble metals. The results are as follows.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
G - 24	Tr	1	0.01	0.01	0.02	Py dissemination in andesite (Tad_2)
G - 37	Tr	2	0.02	0.01	0.04	" (Tad_3)
L - 1	0.1	2	0.03	Tr	Tr	Py dissemination in andesite intrusive (Ad_2)
L - 3	Tr	1	0.02	Tr	0.03	"

In spite of the different mineralization modes, the samples are similar in their grades.

(15) La Providencia (Altitude: 940 - 960 m)

Location:

This zone is located 4 km to the northeast of the La Cuest village in the southern part of the survey area, in the middle reaches of the Providencia stream.

Occurrence:

A quartz vein (N 20°W, 90°) is observed in the grey granodiorite. The vein has a width of about 50 cm and has been turned to light brown by oxidation. No particular alteration was found in the host rock except a certain amount of silicification. The boundary between the vein and the host rock is unclear in some places.

Although the tunnel has a length of only 3 m, another quartz vein with similar occurrence was found 50 m downstream this tunnel. According to the talk of the guide, exploration for gold seems to have been conducted in several places near here in addition to these two places. The analytical results of ore samples are as follows:

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
MR - 42	4.0	18	0.01	0.23	0.01	Qz vein
MR - 43	0.1	4	0.02	0.07	0.01	Qz vein

The zone represents the mineralization of gold only. Macroscopically, no sulphide minerals other than a small amount of pyrite were noticed.

(16) Cerro Cuesta de Heron (Altitude: 1,480 m)

Location:

This zone is located 6 km to the northeast of La Cuesta, up the La Providencia stream.

Occurrence:

Quartz veinlets are observed in the III-stage andesites (Tad_3) near its boundary with granodiorite. Small gossan consisting of brown limonite (partly hematite ?) after pyrite is noticed, and pyrite also remains in some parts. It is difficult to determine the dominated directions of quartz veinlet (width less than 1 cm). The analytical results of a mixture sample of limonite and quartz veinlet are as follows:

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
MR - 47	Tr	1	0.01	0.01	0.02	Limonite mixed Qz vein

As far as the analytical results are concerned, no sulphide minerals other than pyrite seem to be contained.

(17) Cerro Caplincillo (Altitude: 1,620 m)

Location:

This zone is located near Cerro Caplincillo at the eastern end of the central part of the survey area.

Occurrence:

Light grey altered rock accompanying pyrite dissemination is found in light grey glassy I-stage dacites (Tdc_1). No sulphide minerals other than pyrite are found. In some parts, the rock has changed to silicified rock. According to the X-ray diffractometrical study of altered rock with a little pyrite dissemination, plagioclase has leached and disappeared, and the formation of sericite and K-feldspar is noticed. This combination of minerals is that accompanied by gold-mineralization, but the analytical results of a sample showed low grades as follows.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
MLJ - 3	Tr	4	0.03	0.01	0.01	Py dissemination in in siliceous rock

In addition to the abovementioned deposits and mineralized zones, the signs of sphalerite and pyrite were found in some parts of the hanging wall dacite (Kdc_2) in the La America - Descubridora and E1 Rubi areas. Especially in the hanging wall dacite (Kdc_2) to the south of the La America deposit, a pyrite-disseminated zone accompanying a very small amount of sphalerite was found macroscopically. This zone requires attention about the grade of silver as

Table 3-1 List of Mineralized Zones (1)

No.	Mineralized Zones	Type of Ore Deposit	Occurrence	Remarks
1	La America	Kuroko type	Kuroko and Pyrite Stratiform Ore in acidic fine tuff and lapilli tuff (Koh)	Proximal type deposit
2	Descubridora	Kuroko type	Kuroko, Pyrite and siliceous ore in acidic fine tuff and lapilli tuff (Koh)	Proximal type deposit
3	Atalaya	Kuroko type	Pyrite mineralization in acidic fine tuff and lapilli tuff (?)	Urabe (1982) classified the deposit into as a distal type deposit
4	Atalayita	Kuroko type	Fine pyrite mineralization in acidic fine tuff (Koh)	
5	Hueso	Kuroko type	Pyrite mineralization in acidic fine tuff and lapilli tuff (Koh)	
6	Trinidad	Kuroko type	Pyrite concentration and dissemination in acidic fine tuff (Koh)	No stratiform mineralization
7	La Eliza	Kuroko type	Pyrite disseminated siliceous ore in acidic fine tuff (Koh)	
8	Monte Cristo	Kuroko type	Pyrite, sphalerite and galena dissemination in acidic fine tuff and shale (Koh)	Mineralization at the upper most portion of ore horizon
9	El Rubi	Kuroko type	Stratiform Kuroko and siliccous ore on foot wall dacite (Kdc 1)	Proximal type deposit
10	Concha	Au-Ag vein (Epithermal)	Au-Ag-Pb mineralization in shear zone of hanging wall dacite (Kdc 2)	High grade Au-Ag mineralization

Table 3-1 List of Mineralized Zones (2)

No.	Mineralized Zones	Type of Ore Deposit	Occurrence	Remarks
11	Plomosas	Zn-Cu-Pb vein (Xenothermal)	Zn-Cu-Pb mineralization in shear zone of basic fine tuff	Sphalerite exsolution "Star" in chalcopyrite
12	Virgencita de Fatima	Zn-Pb-Cu vein (Epithermal)	Zn-Pb-Cu mineralization in I-stage andesite: (Tad 1)	
13	Lorenzo	Au-Ag vein (Epithermal)	Au-Ag-Qz mineralization in tensile fracture of III-stage andesite: (Tad 3)	Very minor quantity of sulphide mineralization is accompanied
14	Monte Grande	Pyrite dissemination	Pyrite dissemination in II-stage andesite: (Tad 2) and andesite intrusive: (Ad 2) and pyrite: mineralization controlled by shear facture in III-stage andesite: (Tad 3)	No Pb-Zn mineralization is accompanied
15	La Providencia	Au vein (Epithermal?)	Au-Qz mineralization in granodiorite	Little sulphide mineralization is accompanied
16	Cerro Cuesta de Heron	Au-vein (?) (Epithermal?)	Au and limonite after pyrite in III-stage andesite: (Tad 3)	
17	Cerro Caplincillo	Pyrite dissemination	Pyrite dissemination in I-stage decite: (Tdc1)	Sericite and K-feldspar prevailing as alteration minerals

shown in the analytical result shown below. Although the genetical relationship with the above-mentioned meralization of Concha vein is unclear, if these mineralizations have a genetical relationship with the Kuroko type mineralization, a clue to find out the possibility of the existence of Kuroko type deposits will be obtained, although indirectly, by the geochemical exploration using stream sediments. Therefore, the above-mentioned disseminated zone is very important also from this viewpoint. The analytical results of ore samples are as follows.

Sample	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)	Remarks
FF-17 1)	0.8	374	0.22	0.80	2.64	Py-Sph vein in hanging wall dacite
M-9 2)	0.2	19	0.09	0.05	0.33	Py-Sph dissemination in hanging wall dacite

1) Kdc_2 in La America - Descubridora area

2) Kdc_2 in El Rubi area

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 deposits existing in the survey area. As microscopic observation was conducted for the ore samples collected during this survey, the Kuroko type deposits in the survey area were compared with Japanese Cenozoic 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:

Both in La America and E1 Rubi 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 shown in Figs. 4-8 and 4-9.

Near the areas where the Kuroko type deposits exist, 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 deposits 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 deposit 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 deposits exist (La America - Descubridora area and El Rubi area), the percentage of acidic fine tuff or basalts, which seem to suggest the shape of place of ore deposition, increases. If the Japanese Cenozoic Kuroko deposit, 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 deposits 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 deposits (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.

In addition, Kuroko type deposits 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 Deposits.

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 deposits, but this zonal texture has not been found in the sphalerite produced in the Kuroko type deposits in the survey area. This characteristic is common to sphalerite produced in the Taro deposit.

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 deposits 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 deposit (Yamaoka, 1983).

Existence of "Telescoped Ore":

Japanese Cenozoic Kuroko deposits 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 deposits also in this point and rather similar to the Taro deposit.

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 deposits in the survey area and the ore produced in the Taro deposit in the same Mesozoic era.

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

		I	II	III	Remarks
Number of Ore Mineral Species		I ~ II ≪ III	II ~ I ≪ III	III ≫ I, II	
FeS in Sphalerite		3-21 mole% (?)	3-21 mole%[1)]	Approx. 0.1 mole%[2)]	1) Yamaoka, 1983 2) Urabe, 1983
Banded Sphalerite		Not Observed	Not Observed	Common	
Chalcopyrite desease 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 : El Rubi and La America Deposits
II : Taro Deposit (Japanese Mesozoic Kuroko Type Deposit)
III : "Kuroko" Deposits in Hokuroku District, Akita, Japan (Japanese Cenozoic Kuroko Deposits)

3-5 Survey on Alteration Zone by X-ray Diffractometrical Study

It has been found that, accompanied by the formation of a Kuroko type deposit, a zonal distribution of altered minerals is found in the host rock around the deposit. This alteration of the host rock was caused by the reaction of the host rock with the hydrothermal solution (ore solution), which moved through the rock and formed the Kuroko type deposit. This zonal structure of altered minerals often reaches the hanging wall rocks of the deposit (for example, Utada et al., 1981, 1983). Therefore, there are cases in which the possibility of existence of concealed Kuroko type deposits can be supposed by finding the existence of this zonal distribution. This alteration phenomenon is not limited to Japanese Cenozoic Kuroko deposits but has been found also in Canadian Kuroko type deposits in middle Jurassic - Archean periods as shown by Urabe et al. (1983). Therefore, this phenomenon seems to be a universal mode of alteration in this type deposits. Accordingly, we surveyed the mode of alteration mainly of the pyroclastics (Koh) of ore horizon and the hanging wall dacite (Kdc_2) for the deposits in the survey area which are supposed to be the Kuroko type deposits in the upper Cretaceous era. Although the relationship with Kuroko type deposits is not clear, we also surveyed about acidic volcanic rocks (for example, I-stage and III-stage andesites) which form altered zones macroscopically to add a certain amount of investigation.

3-5-1 Measuring Conditions

Apparatus	:	Rigaku Denki Geiger Flex Type 2078
Target	:	Cu
Filter	:	Ni
Voltage	:	30 kV
Current	:	15 mA
Full Scale	:	800 cps
Time Constant	:	1 sec
Slit System	:	1 deg/0.3 mm
Scanning Speed	:	2^o/min
Chart Speed	:	20 mm/min

3-5-2 Method of Analysis

In the analysis, the quantity of a mineral existing in sample measured by an X-ray diffractometry was represented in a relative quantity ratio using a quartz index by the Hayashi's method (1979). In other words, the ratio represented with a percentage is the highest X-ray intensity Im (cps) of a mineral in the sample to the highest X-ray intensity Iq (cps) of pure quartz measured under the same experimental conditions.

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

When the first peak (3.33 Å) of quartz falls outside the range of the scale, the peak was estimated from the second peak (4.27 Å). The peaks used for a relative quantity determination of minerals are as follows.

Quartz	:	3.33 Å (101)
		4.27 Å (100)
Plagioclase	:	3.21 Å (002)
Albite	:	3.20 Å (002)
K-feldspar	:	3.24 Å (040, 002)
Sericite	:	9.93 Å (002)
Chlorite	:	7.19 Å (002)
Calcite	:	3.04 Å (220)
Dolomite	:	2.91 Å (104)
Pyrite	:	2.71 Å (200)
Galena	:	2.98 Å (200)
Sphalerite	:	3.13 Å (111)

3-5-3 Alteration Zone

Referring to the study by Utada et al. (1981) and that by Honda & Matsueda (1979), the zoning of the following mineral assemblage was adapted.

I	:	quartz + K-feldspar + sericite
II	:	quartz + chlorite + sericite
III	:	quartz + (plagioclase + albite) + (K-feldspar) + (chlorite + sericite)
IV	:	quartz + (plagioclase + albite) + (K-feldspar)
V	:	quartz + (plagioclase + albite)

After the Honda & Matsueda (1979) pointing-out, the K-feldspar in I-zone supposes a product by hydrothermal alteration, and that in III - IV zones suppose diagenetic formations. According to this zoning, the modes of alteration in La America-Descubridora area, El Rubi area and other areas were examined.

(La America-Descubridora Area)

In this area, the combinations of I - IV zones are found. The IV zone was detected only in one sample collected in the southern part of Descubridora deposit. Accordingly, the I-III zones are dominant, and this suggests that this area was subjected to hydrothermal alteration entirely. The quantities of chlorite and sericite, which are the products of hydrothermal alteration, are not so much, but these minerals are distributed universally. The alteration zoning shows directionality in the NE-SW direction as shown in Fig. 3-11. La America deposit, the representative deposit in this area, is located between the II and III zone of alteration. The I-zone, the most intensely altered zone, seems to show zonal distributions in the northwest and the southeast of this III-zone almost parallel to each other. As the number (27) of samples is limited, the modes of alteration cannot be clarified adequately, but the fact that a pervasive type alteration peculiar to Kuroko type deposits was found in the area of 1.5 km x 3 km attracts attention. In addition, the fact that the known deposits (La America, Descubridora deposits, etc.) do not correspond to the intensely altered zones may be suggesting the possibility of existence of unknown Kuroko type deposits which caused the intensely altered zones.

(El Rubi Area)

Compared with the La America-Descubridora area, the degree of alteration is less intensive X-ray diffractometrically. The most intensely altered zone in this area is the II-zone noticed in the foot wall dacite (Kdc_1) near the El Rubi tunnel. However, in the hanging wall dacite (Kdc_2), the IV-V zones dominate as shown in Fig. 3-12, and the sign of hydrothermal alteration is weak. As the number (15) of samples is small, the modes of alteration cannot be interpreted completely, but it is impossible to suppose the existence of unknown deposits in this area from these results as was pointed out about the La America-Descubridora area.

(Rincon Area)

In the field, the distribution of dacite clearly subjected to hydrothermal alteration was found near the Rincon valley. As the number of samples for the X-ray diffractometrical study was so small as four, it was unable to clarify the mode of alteration adequately. Near the middle-upper part of the dacite formation, an intensely altered zone, in which plagioclase has been leached and decomposed completely, has been formed, but the lower part of the formation gradually changes from weak alteration to non-alteration. The scale of the intensely altered zone is estimated to be about 400 m x 500 m in consideration of the alkali alteration index, etc., and this zone is regarded to be that of pervasive type alteration. In this point, this alteration is similar to the Kuroko type alteration, but the existence of the zonal distribution of alteration is unclear. Although no mineral showings are found near here, as the northern part of this altered zone has been intruded by granophyre which can be called "Tertiary granite," the possibility of hydrothermal alteration related with this intrusion can also be supposed.

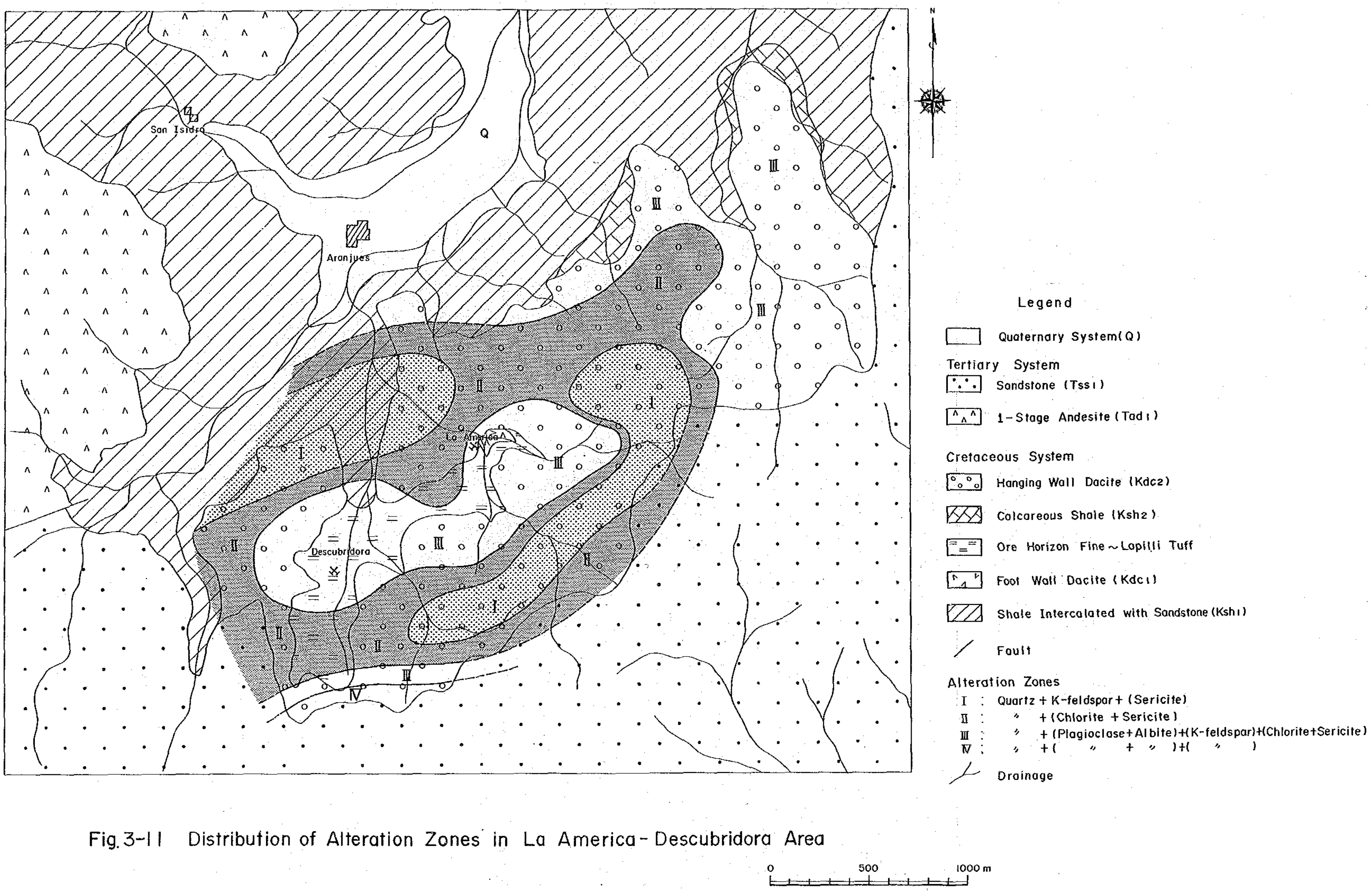


Fig. 3-11 Distribution of Alteration Zones in La America - Descubridora Area

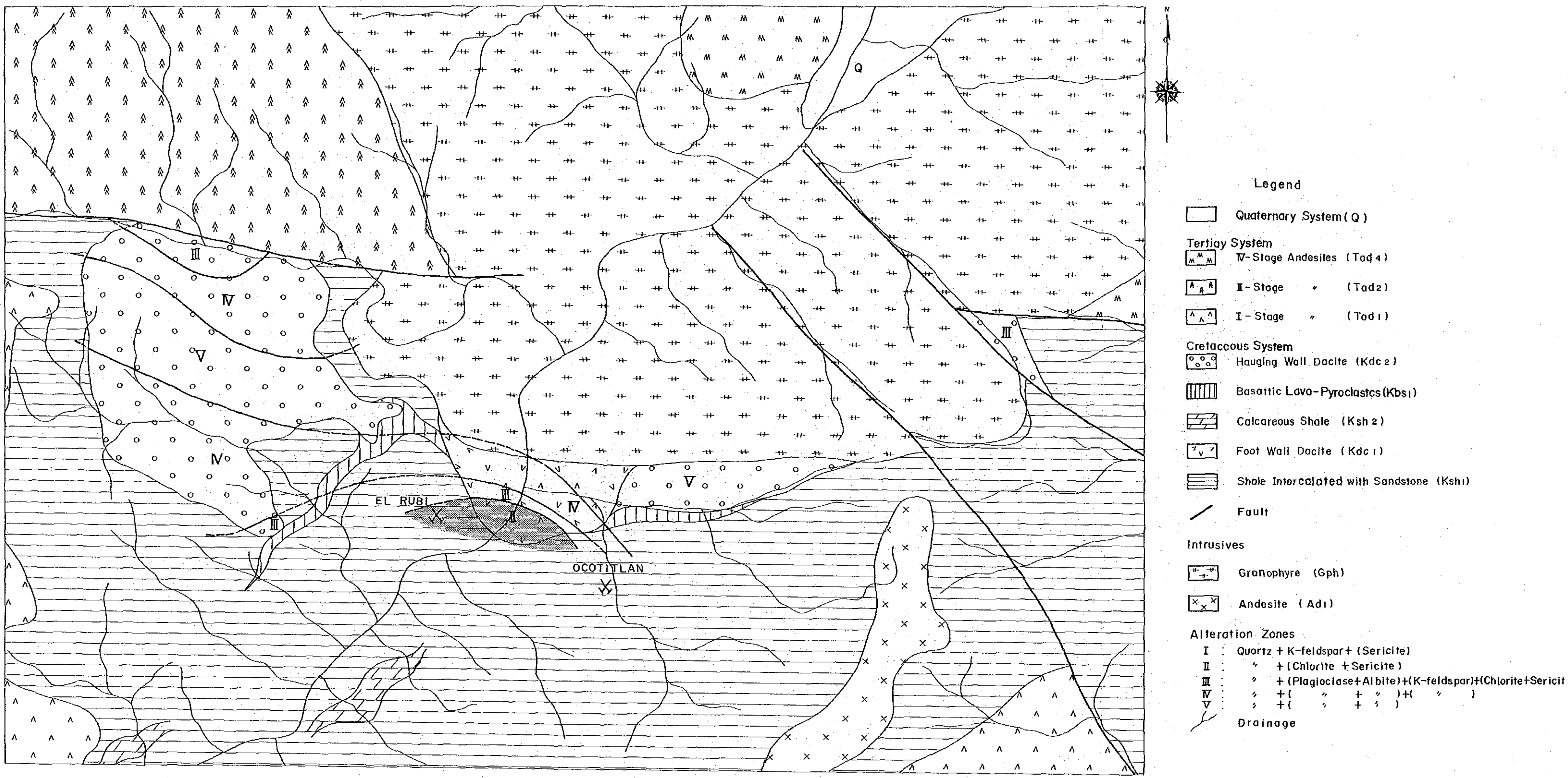


Fig. 3-12 Distribution of Alteration Zones in El Rubi Area

0 500 1000 m