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

SUMMARY

FEBRUARY 1987

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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 area 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 execution of this survey, because the contents of this survey, which are the survey of geology and mineral resources, belong to a specialized field. This survey continued for three years from 1984 to 1986.

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

This report is summary of the survey results for those three years.

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.

February, 1987

Keisuke Arita
President
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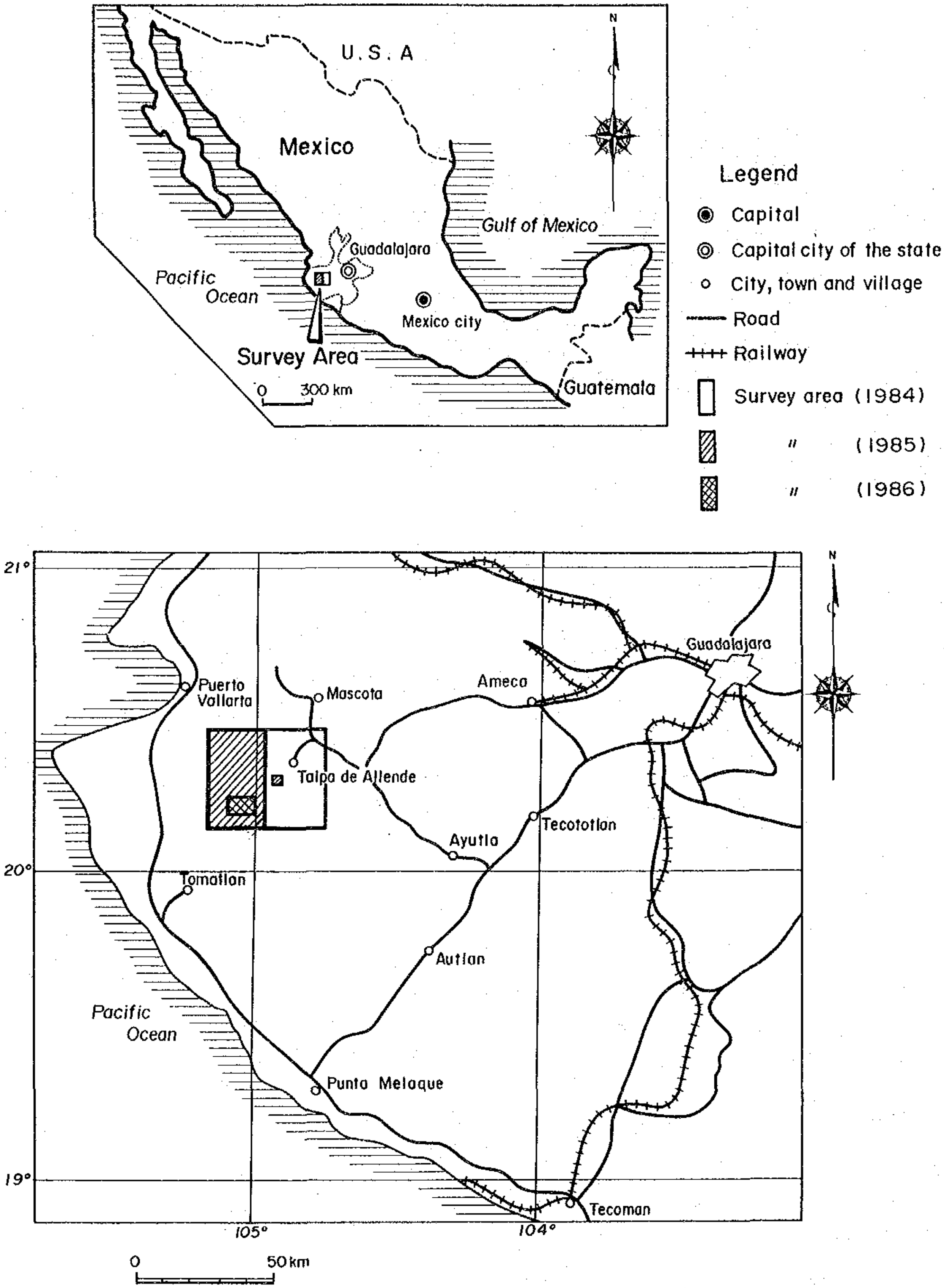

Fig. G-1 Location Map of Survey Area (A)

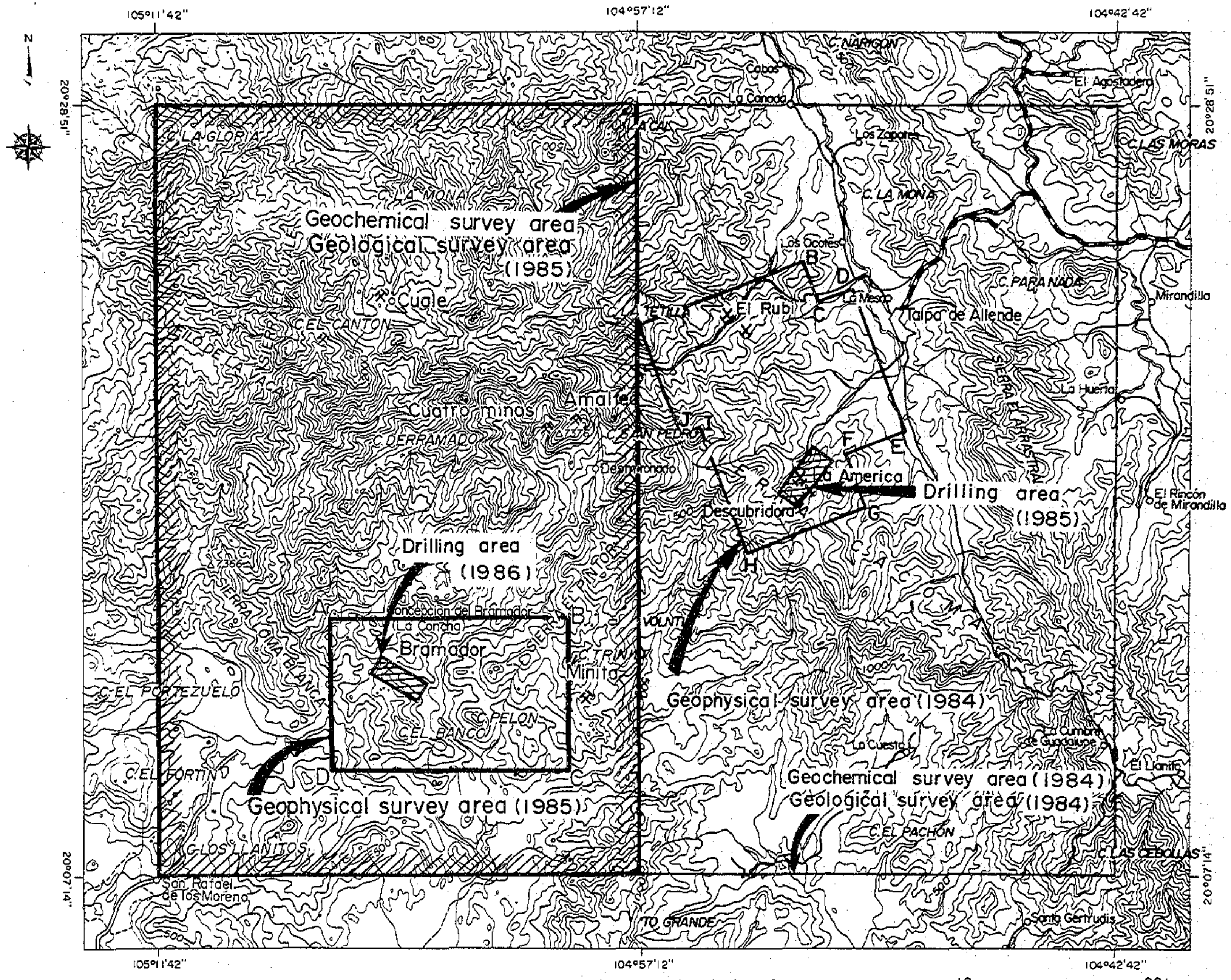

Fig. G-2 Location Map of Survey Area (B)

SUMMARY

The survey aims at exploration of Kuroko type deposits in Talpa de Allende area, Jalisco State with the cooperation of the Consejo de Recursos Minerales (C.R.M.) of the United Mexican States.

This survey basically continue for three years from 1984 to 1986.

The first year (1984), geological survey and geochemical survey of the stream sediments were carried out in the Eastern Area (1,000 km^2). In addition, based on results of geological survey, an area 122 km^2 was selected as a high potential area for existence of Kuroko type deposits and then a geophysical survey (CSAMT method) was conducted there.

On the basis of an integrated investigation on all survey results in the first year, La America-Descubridora area was selected as a target area for drilling exploration.

The second year (1985), also geological survey, geochemical survey of the stream sediments and geophysical survey (CSAMT method, 100 km^2) were carried out in the Western Area (1,000 km^2) aiming at exploration of Kuroko type deposits.

On the basis of the integrated interpretation of all survey results, La Concha-El Bramador area was selected as a high potential area for existence of Kuroko type deposits.

In addition, a drilling survey, consisting of five holes (total depth of 1,369.70 meters), was conducted in La America-Descubridora area in the Eastern Area. Even no significant Kuroko ores were encountered, some new valuable information for Kuroko exploration was obtained from it. Especially, MJM-2 and MJM-5 are in paleo-basin of submarine, which are favourable site for formation of Kuroko ores. As the ore horizon rocks disseminated by sulphides are found in MJM-2 and MJM-5, it is judged that extension zones of ore horizon of these holes are favourable for Kuroko exploration.

The third year (1986), a drilling survey, consisting of seven holes (total depth of 2,296.20 m) was conducted in La Concha-El Bramador area in the Western Area. As a result from the survey, Kuroko type mineralization has been catched up in MJM-6, MJM-7 and MJM-9. Especially, a high grade Kuroko ore (15 centimeters thick; Au: 7.8 g/t, Ag: 1,108 g/t, Cu: 1.15%, Pb: 16.2%, Zn: 32.2%) and a gold mineralized zone (8 meters thick; average Au grade: 4.2 g/t) has been encountered in the Kuroko ore horizon of MJM-9.

On the other hand, disseminated zone of fine pyrite, which are one of characteristics of Kuroko type mineralization have been observed in acidic pyroclastics of the Kuroko ore horizon in MJM-6 and MJM-7.

These disseminated zones partly include silver mineralized zone (MJM-6; 8 meters thick; average Ag grade: 145 g/t, MJM-7; 5 meters thick; average Ag grade: 100 g/t). These facts implicate that the Kuroko mineralization in this area may also be accompanied by mineralization of precious metals.

We, therefore, consider ourselves to have found a clue for the future full-scale exploration in this area.

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PART I INTRODUCTION

CHAPTER 1 OUTLINE OF SURVEY

1-1 Survey Area and Purpose of Survey

The survey area is located in the Talpa de Allende of the State of Jalisco in the central part of the United Mexican States and has an area of 2,000 Km2 enclosed by lines connecting the following four point (Fig. G-1, Fig. G-2).

Northwest point: lat. 20°28'51"N and long. 105°11'42"W
Northeast point: lat. 20°28'51"N and long. 104°42'42"W
Southwest point: lat. 20°7'14"N and long. 105°11'42"W
Southeast point: lat. 20°7'14"N and long. 104°42'42"W

The survey area is situated in the intersection of the Sierra Madre Occidental with the Eje Neovolcanico, which are two major Volcanic belt in the United Mexican States and is widely covered with Tertiary volcanics.

This survey aims at conducting the exploration of the Kuroko type deposit in this area in cooperation with the Consejo de Recursos Minerales (C.R.M.) in the United Mexican States.

1-2 Method and Volume of the Survey

The method and volume of the survey are as follows:

Table I-1 Outline of Surveys

Method of Survey	Year	Area	Volume of Survey
Geological survey Geochemical survey Geophysical survey	Phase I (1984)	1,000 km^2 1,000 km^2 122 km2	Survey route: 500 km 1,505 samples 377 survey stations
Geological survey Geochemical survey Geophysical survey Drilling survey	Phase II (1985)	1,000 km^2 1,000 km^2 100 km^2	Survey route: 500 km 1,012 samples 318 survey stations 1,369.70 m (5 drill holes)
Drilling survey	Phase III (1986)		2,296.20 m (7 drill holes)

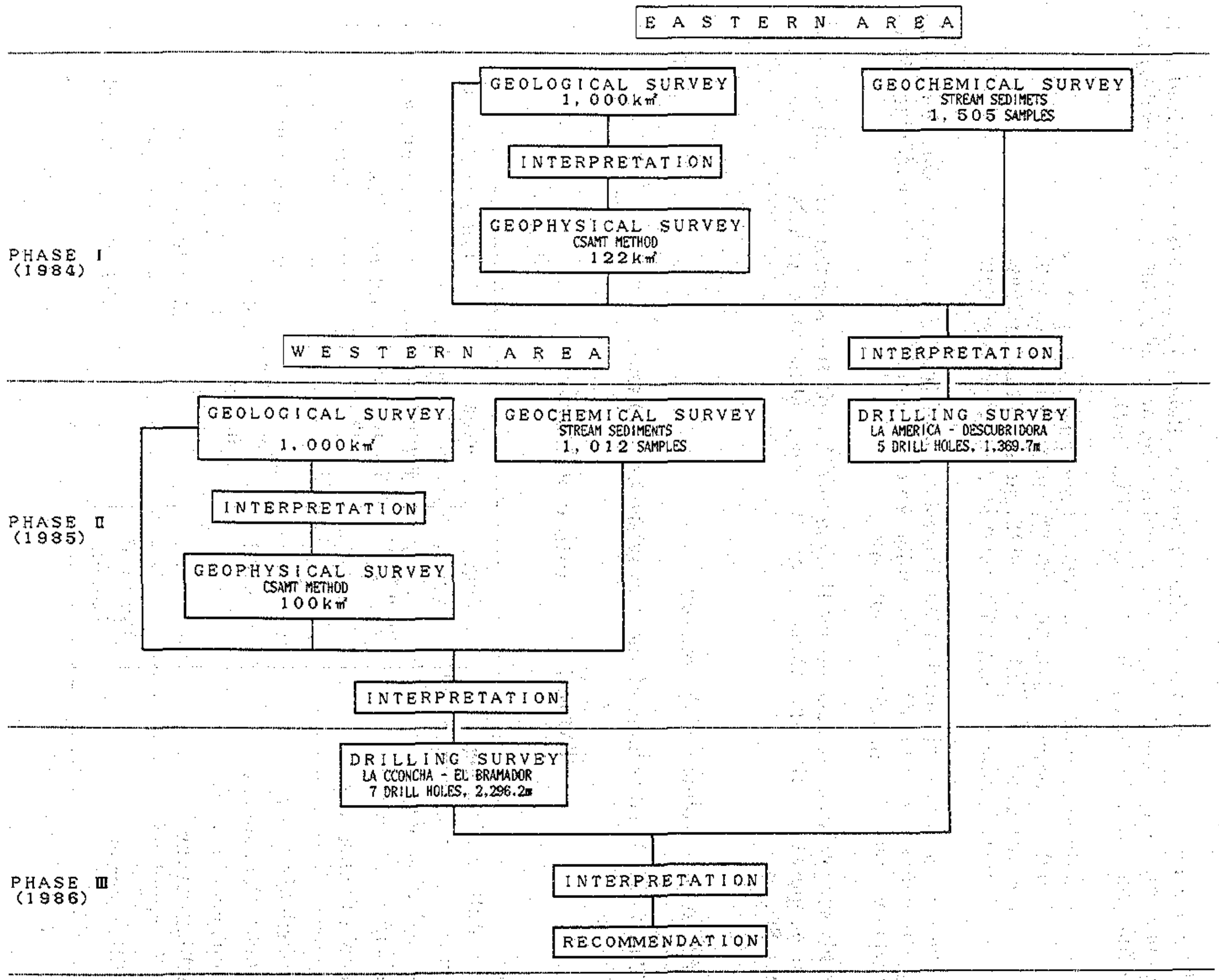


Fig. I-1 Mineral Exploration Flow Chart in Jalisco Area

1-3 Period and Members of Mission

The field survey was carried out as follows:

Phase I	(First year)	: from August 28, 1984 to January 25, 1985
Phase II	(Second year)	: from July 8, 1985 to February 27, 1986
Phase III	(Third year)	: from May 21, 1986 to January 15, 1987

Members of the mission who participated in preparation of the survey program, negotiations in Mexico, and the field survey are as follows:

Duties	First year (1984)	Second year (1985)	Third year (1986)
Survey Planning and Cooperation (Japan Side)	Toru Miura Makoto Ishida Takeshi Ogitsu Ken Nakayama Yoshiyuki Kita Yasuo Endo Masatake Kitajima Masaaki Kato Komao Hosaka	Toshio Sakasegawa Kohei Arakawa Takeshi Ogitsu Akio Hoshino Tadaaki Ezawa Takashi Kamiki	Toru Miura Kohei Arakawa Akio Hoshino Hideyuki Ueda
Survey Planning and Cooperation (Mexican Side)	Jorge Leipen Garay Gustavo Camacho Ortega Raúl Cruz Rios Akira Hirayama	Ramon Farias Garcia Jorge Leipen Garay Luis Brizuela Venega Gustavo Camacho Ortega Cesar J. Villegas Garcia Raúl Cruz Rios	Ramon Farias Garcia Luis Brizuela Venega Hector Rodriguez Medina Gustavo Camacho Ortega Cesar J. Villegas Garcia Raúl Cruz Rios
Field Survey (Japan Side)	Fumio Wada Kazuyoshi Masubuchi Makoto Takeda Minoru Yoshikawa Akira Fukunaga Masaru Fujita	Fumio Wada Kazuyoshi Masubuchi Makoto Takeda Yasuo Endo Kurae Iwaki Masaru Fujita Masayuki Oshima Tatsuhiro Aoyama Hisato Kai	Fumio Wada Fumio Nakajima Tatsuhiro Aoyama Hisato Kai
Field Survey (Mexican Side)	Panfilo Sanchez Alvarado Ladislao Segura Garcia Antonio Gonzalez Ramos Roberto Ortega Guerrero David Gutierrez López Apolinar Zumaran Gastor David Ventura López Jesus Garcia Pineda	Panfilo Sanchez Alvardo Ladislao Segura Garcia Antonio Gonzalez Ramos Hugo A. Omaña Pulido Roberto Ortega Guerrero David Gutierrez López	Panfilo Sanchez Alvardo Hugo A. Omaña Pulido

CHAPTER 2 FORMER SURVEY

In the survey area, no systematic geological survey and regional mineral exploration have been conducted. The geological map (scale 1: 50,000) of the area is only published chiefly based on the interpretation of photogeology by CETENAL (the governmental geological survey agency). However, the map does not seem to have a little sufficient accuracy, because no sufficient field geological survey has been followed and this area is covered with dense vegetation. Therefore, stratigraphical succession of the area have not been fully interpreted.

The Kuroko type deposits distributed in the area have also been surveyed by many governmental survey agencies and private companies, but these surveys have covered only the deposits themselves or their neighboring parts. No survey seems to have been carried out with regard to mutual stratigraphical position of Kuroko type deposits and geological structure in the area.

CHAPTER 3 GEOLOGICAL OUTLINE OF SURVEY AREA

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

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

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

The Cretaceous System is distributed in various places in the survey area. Especially, La America-Descubridora area and La Concha-El Bramador area, which are known as distributed area of the Kuroko type deposit, are typical in distribution of the System. This System chiefly consists of the dacite lava (Kdc, Kdc1-a, -b), acidic pyroclastics (Koh, Koh-a, -b, Kdc-sh), and black shale (Ksh_1). The distributed area of the Cretaceous System is much smaller than that of the Tertiary System, but it is important, because it is the strata containing Kuroko type deposits.

The Tertiary System is widely distributed over the entire survey area, and is chiefly composed of andesites and dacites. The time of activity of these volcanics is unclear, because there is no study of volcanostratigraphical survey and the measurement of absolute age. The I-stage andesites (Tad_1) cover the Cretaceous System in unconformity.

The Quaternary System is distributed in the flat part of the basin of the Talpa River, etc. This System comprises mainly a gravel layer of a poor degree of consolidation.

The intrusives include granodiorite (Gd), adamellite (Adm), granophre (Gph), andesite (Ad_1, Ad_2) and dacite (Dc). Especially, we can consider that the former two *kinds of rock intruded in the same period.* They are widely distributed from the southern part to the southwestern part of the survey area. The result of the K-Ar age determination of the samples taken from the western part of Desmoronado Village which is considered to stand on the same rock suggests that the rock intruded in the Late Cretaceous Period (71.8 ± 6 m.y ~ 71.1 ± 6 m.y). It is considered that other intrusives were formed in the Tertiary Period.

According to the determination of nannophlankton contained in the black shale (Ksh_1) distributed in the Easter Area, it is concluded that the shale was formed in the Late Cretaceous Period (the Campanian ~ Maastrichtian period, 78 ~ 65 m.y.). On the other hand, according to the determination of nannoplankton and radiolaria found in the black shale (Ksh_1) in the Western Area, the shale was probably formed in the Early Cretaceous Period.

CHAPTER 4 CONDITIONS OF SURVEY AREA

4-1 Transportation

Transportation from Mexico, the capital city, to Talpa de Allende Town via Guadalajara City is as follows:

(1) Air Route:

Transportation between Mexico and Guadalajara cities is very convenient with many flights operated by the Aero Mexico and Mexicana de Aviación. The distance between the two cities is about 450 km in a straight line and it takes 50 minutes by jet liner.

(2) Land Route:

Between the above two cities, it is the most convenient to use the Pan-American Highway (Route 15), which has been completely paved. The distance is 540 km and it takes eight hours. Talpa de Allende Town, which was the base for the survey, is 220 km distant from Guadalajara City, and it takes four hours. The road between Guadalajara City and Ameca Town, which is 100 km long, has been completely paved. However, the remaining section of 120 km to Talpa de Allende Town is consists of simple pavement (100 km) and non-pavement (20 km). The non-pavement section between the spot 20 km before Talpa de Allende Town is in bad conditions whether in rainy season or in dry season. There is one gas station in the Town.

4-2 Conditions of Survey Area

Geographical features of the survey area are generally steep, and we often find cliffs with height from around several ten meters to about 100 meters near ridges. Talpa de Allende Town is located within the basin formed along the Talpa River, which flows through the survey area north to south. The Town is 1,200 m above sea level. Mountain ranges in the northern and middle parts of the area is generally around 2,000 m above the sea, and the height decreases up to 140 m in the southern and south-western parts of the area. And then, the mountain ranges gradually descend to the coastal plain, which extends along the Pacific coast.

Climates can be classified into the following three types depending on the height above sea level in the area:

(1) Mountain district:

The vegatation is chiefly composed of conifer, and the climate is cool all the year round.

(2) Talpa de Allende Basin:

The vegatation is overall composed of citrus fruits and palm trees. The average temperature all the year round is 18° to 20°C, and the annual rainfall reaches as much as more than 1,200 mm. It is rainy season in June to October, and the maximum monthly rainfall amounts to 340 to 350 mm. It is the coldest in January with the average temperature of 15° to 16°C and the hottest in May to June with that of 20° to 21°C.

(3) Southern and south-western parts of the survey area:

The vegatation is the same as that of Talpa de Allende Basin in many aspects. The annual rainfall is around 1,200 mm. The average temperature in June to August, when it is the hottest, reaches 28° to 29°C, and it is warm even in February, the coldest month with the temperature of 23° to 24°C.

CHAPTER 5 K-Ar AGE DATING

For the granodiorite widely distributed in the survey area, the absolute age dating has not been performed, so the time of its intrusion has remained unknown.

In the survey, K-Ar dating has been carried out to deepen the understanding of igneous activities in the area for granodiorite.

Samples for dating was collected in the western part of Desmoronado (AE-1-DESM) (Fig. I-1). With regard to kuroko type deposits, from the biostratigraphical point of view, those distributed in the Eastern Area were possibly formed in the Late Cretaceous Period and those in the Western Area seem to be formed in the Early Cretaceous Period. This fact implies that times of formation of the Kuroko type deposits in the two areas seem to be different. In order to verify this problem, the K-Ar age dating on samples has been carried out. All samples were collected from typical Kuroko type deposits in the two area (Eastern Area: La America deposit; AE-2-AMEC, Western Area: Los Alpes; AE-3-MIRA) and strongly affected by hydrothermal alteration of the Kuroko type mineralization.

As a result of the dating, it is concluded that the rock intruded in the Late Cretaceous Period as shown in Table 1-2. Therefore, the formation time of the Kuroko type deposits in both areas is concluded to be the Late Cretaceous Period. However, the deposits formed in the Western Area are a little older. The reason for this may be elucidated, at present, by the theory that Kuroko type deposits were formed by volcanic activities closely related to the global tectonics (Cathles, et al., 1983) and the theory that the tendency of the volcanic front in that period to move nearly from the west to east can be recognized (Damon, et al., 1981).

Table I-2 K-Ar Ages of Dated Rock

Sample NO.	Rock Name	Coordinates		Analyzed Sample	K(%)	$^{40}Ar^{R}/^{40}K$	Air Contamination (%)	Age (m.y.)
		X	Y					
AE-1-DESM	Granodiorite	-3,440	20,450	Hornblend	0.42	0.00422	86.7	71.1 ± 6
				Biotite	6.07	0.00426	27.0	71.8 ± 6
AE-2-AMEC	Sandy Tuff	8,750	20,350	whole rock	2.64	0.00426	23.8	71.9 ± 6
AE-3-MIRA	Pumice Tuff	-13,450	11,650	whole rock	3.61	0.00511	66.4	86.0 ± 7
				Sericite	4.63	0.00529	10.4	89.0 ± 7

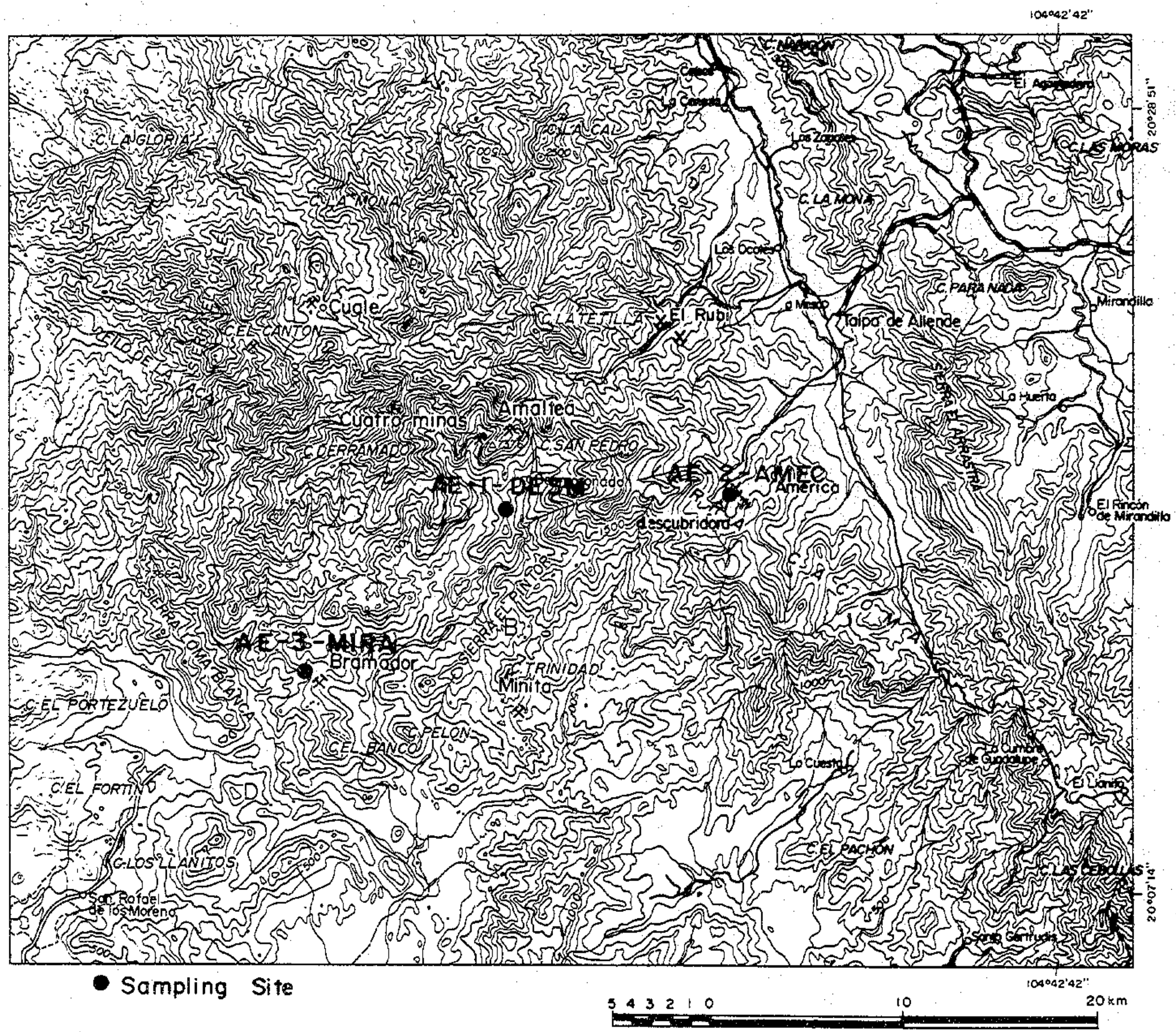


Fig. I-2 Sampling Localities of Dated Rocks

PART II EASTERN AREA

CHAPTER 1 GEOLOGY

1-1 Outline of Geology

In the survey area, the Cretaceous, Tertiary, and Quaternary System, and intrusives are distributed.

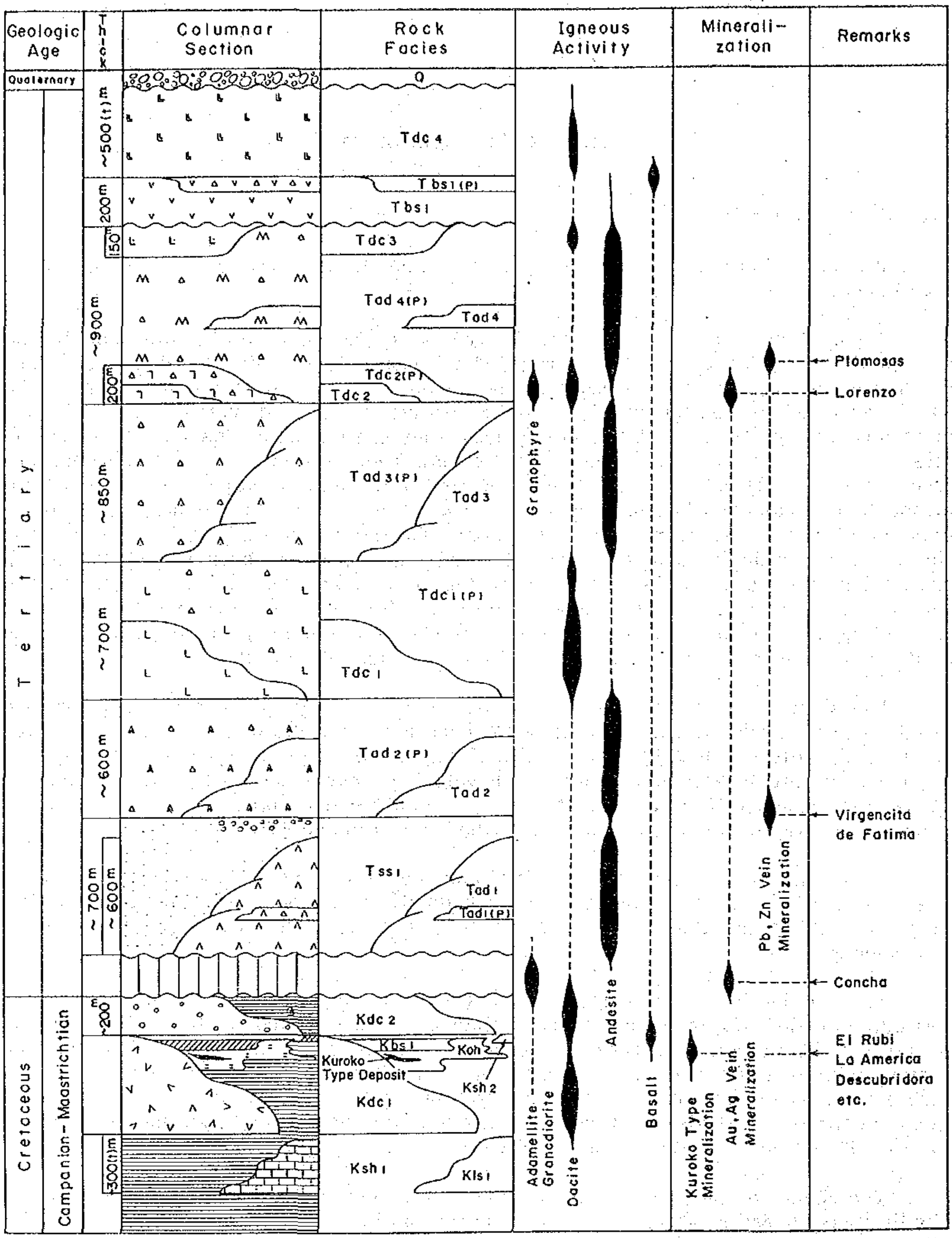
The Cretaceous system in the survey area, which are covered unconformably by the I-stage andesites (Tad_1) and the sandstone formation (Tss_1) of the Tertiary Period, are *distributed in the form of Fenster along the Toledo River in the northwestern part of the* survey area and the Aranjuez River in 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. 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 (Fig. II-1, Fig. II-2).

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 m.y.) 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 study 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 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).



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 intercolated 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

- 6 : Nonnoplankton

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

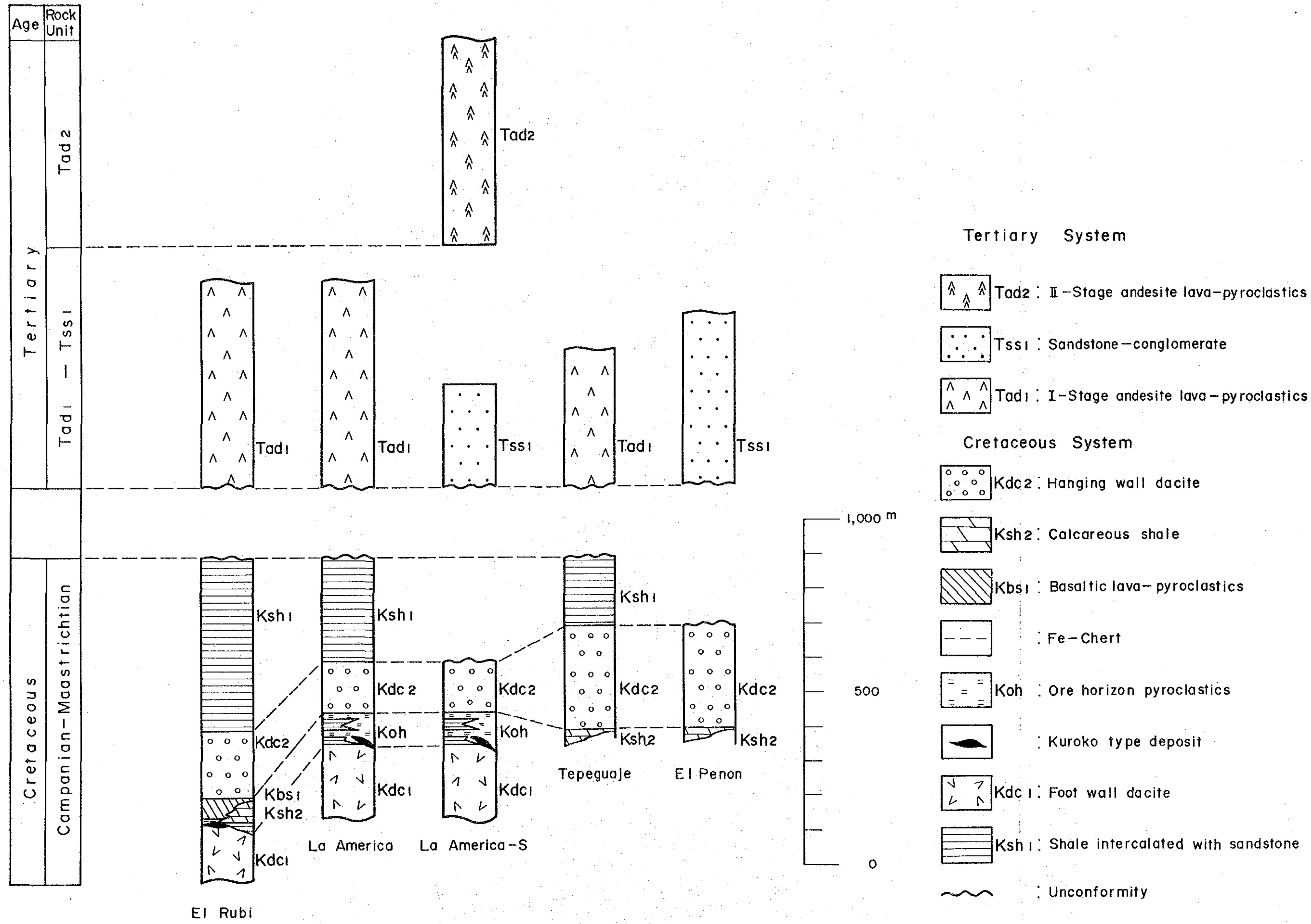


Fig. II-2 Geological Column of La America and El Rubi Area

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 Coronadero 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.

The Quaternary system is chiefly distributed in the flat part of the basin and the mountain foot of the survey area. This system comprises mainly poorly consolidated gravel layer.

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

1-2 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.

1-2-1 Cretaceous System

As a result of inspecting the nannoplanktons 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 m.y.).

(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).

The limestone is distributed in small scale near San Agustin in the southwestern part of the survey area.

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.

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 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.

This has received folding and often shows dips of $30° \sim 60°$, and higher order folds or disturbed zones are also found. 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. The total thickness of exposed parts becomes about 700 m when the above-mentioned two-storied structure is taken into account.

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. 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.

This layer contains few fossils, and very little nannoplanktons were observed in the shale collected in north of La Yerba Buena and north of Toledo.

The stage of this layer is estimated to range from Campanian to Maastrichtian stage (Upper Cretaceous Period: 78 ~ 65 m.y.).

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).

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.

The thickness of this dacite cannot be measured as its bottom has not been confirmed.

The rocks 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.

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.

(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.

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.

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.

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. 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.

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

(5) Basaltic Tuff-Lava (Kbs_1)

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.

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.

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.

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 deposit, which has developed from the foot wall dacite (Kdc_1).

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.

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.

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.

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.

1-2-2 Tertiary System

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 southwestern part of the survey area.

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.

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.

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.

These rocks cover the shale (sandstone) layer (Ksh_1) of the Cretaceous System with dip-unconformity in the Peña 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.

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.

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.

This layer comprises mainly wacke sandstone, 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.

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.

(3) II-stage Andesites (Tad_2)

These rocks are distributed independently in the Coronadero 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.

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.

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 Coronadero 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.

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

These rocks in the Coronadero 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 Coronadero stream basin, but the lapilli tuff includes fine grains more.

Although the depositional relation of these rocks with lower layers cannot be observed in the Coronadero 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.

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.

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.

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 strong 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.

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

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.

(5) III-stage Andesites (Tad_3)

These rocks are distributed over an area from the Agua Fria stream basin in the southern part of 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.

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.

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.

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 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.

(6) II-stage Dacites (Tdc_2)

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

These thickness are estimated to be about 200 m.

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.

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

(7) IV-stage Andesites (Tad_4)

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

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.

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

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 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.

These rocks are in a conformable relation with the I-stage dacites (Tdc_1) and the III-stage andesites ($Tadc_3$).

(8) III-stage Dacite (Tdc_3)

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.

A thickness of about 150 m was measured.

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.

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.

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.

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.

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.

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.

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.

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 at Cerro Para Nada amounts to 500 m approximately.

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

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.

1-2-3 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.

1-2-4 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)

This is distributed in granodiorite (Gd) in a range of 2.5 km × 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.

Macroscopically, this rock is a compact, hard, and medium grain holocrystalline rock in which pink K-feldspar is conspicuous.

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)

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.

Macroscopically, this rock is grey, compact and hard meidum-fine grain granodiorite.

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.

(3) Granophyre (Gph)

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.

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.

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)

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)

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).

CHAPTER 2 GEOLOGICAL STRUCTURE

Various elements about the geological structure observed in the survey area are different between the Cretaceous System and the Tertiary 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. II-3.

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).

The type of anticlinal form shows 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.

(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 ~

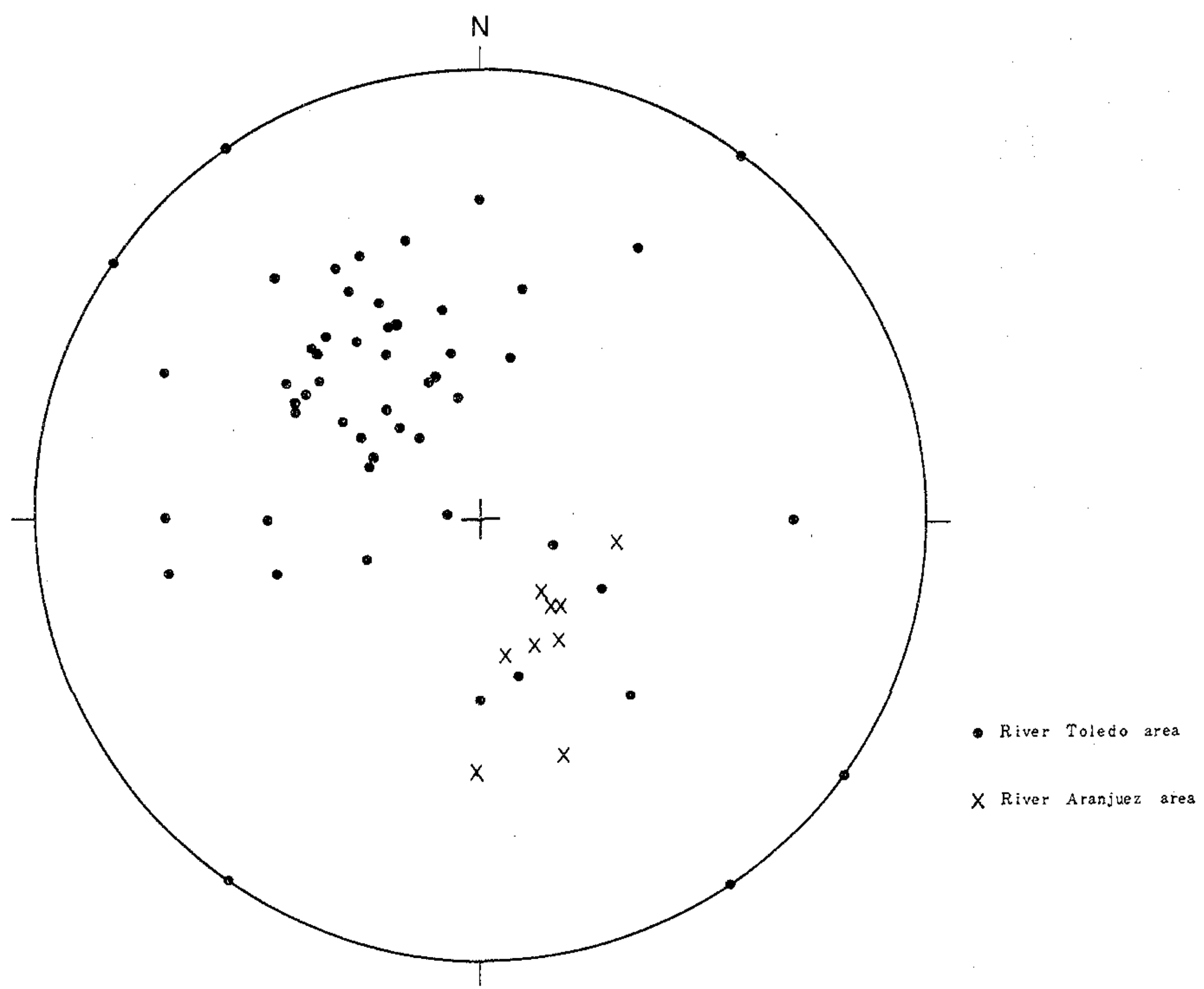


Fig. II-3 Stereo Net Projections of Poles of Bedding Planes in Shale-Sandstone (Ksh_1)

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.

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. II-4) of stereo projections of bedding planes shown by the former is compared with those of the Cretaceous System (Fig. II-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.

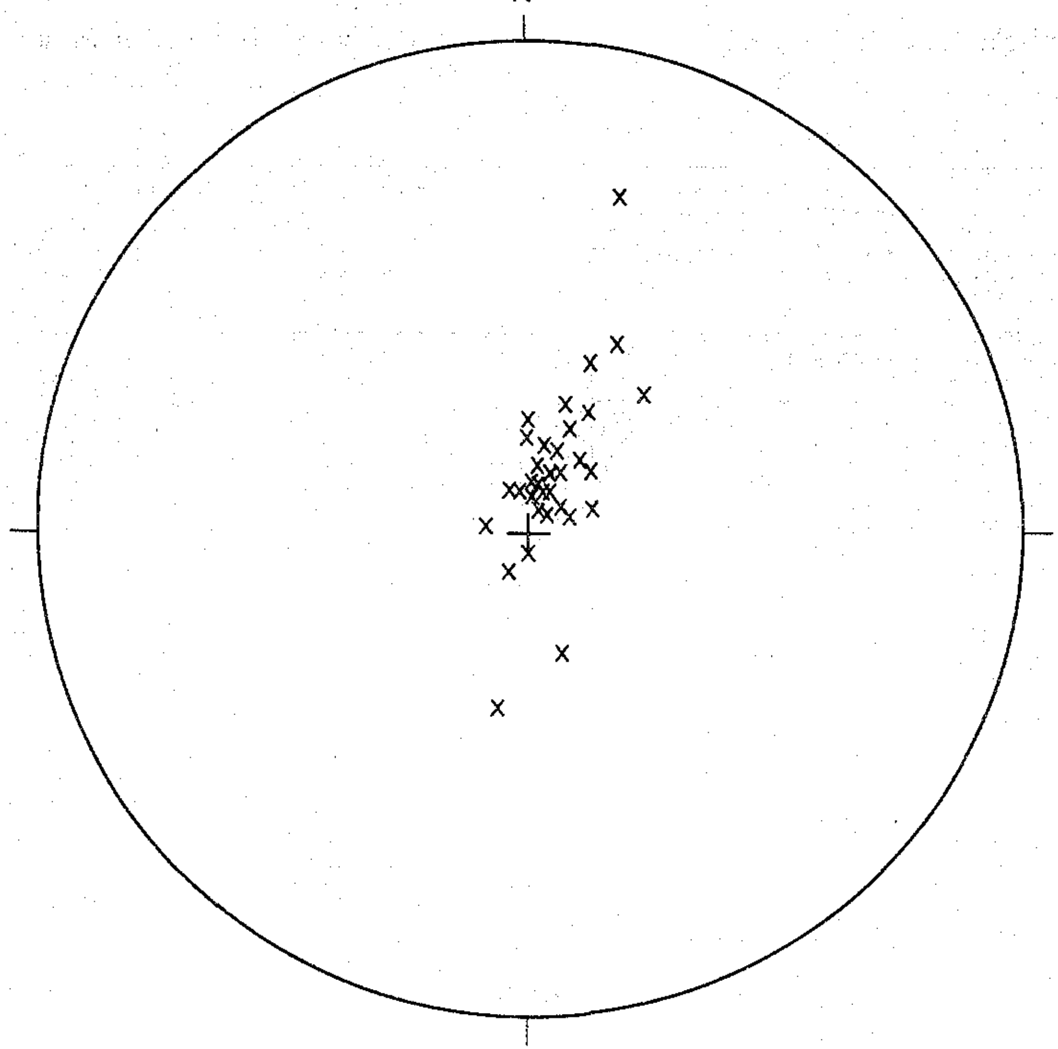


Fig. II-4 Stereo Net Projections of Poles of Bedding Planes in Sandstone Formation (Tss_1)

CHAPTER 3 MINERALIZED ZONE

In the survey area, various mineralized zones such as gold-silver vein deposits, etc., in the hanging wall dacite (Kdc2) 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.

List of Mineralized Zones in the survey are is shown in Table II-1.

Table II-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 siliceous 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 II-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

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 El 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 (Hutchinson, 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.

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., Takahashi & Tanimura, 1980), whose activity was later than the Kuroko formation (15 ~ 13 m.y., 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.

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 if 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.

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 mineral 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 II-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 same Mesozoic Taro deposit.

Table II-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 disease in Sphalerite		Not Observed	Not Observed	Common	
Colloform and framboidal texture		Common	Common	Common	
Telescoped ore		Not Observed	Not Observed	Observed	
Gangue Minerals	Barite	Common	Not Observed	Abundant	
	Calcite	Minor	Common	minor	
	Sericite	Common	Common	Common	

I : 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)

CHAPTER 4 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 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 (Kdc2) for the deposits in the survey area which are supposed to be the Kuroko type deposits in the Upper Cretaceous Period.

4-1 Alteration Zone

Referring to the study by Utada, et a., (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 II ~ 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. 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 × 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. (Fig. II-5).

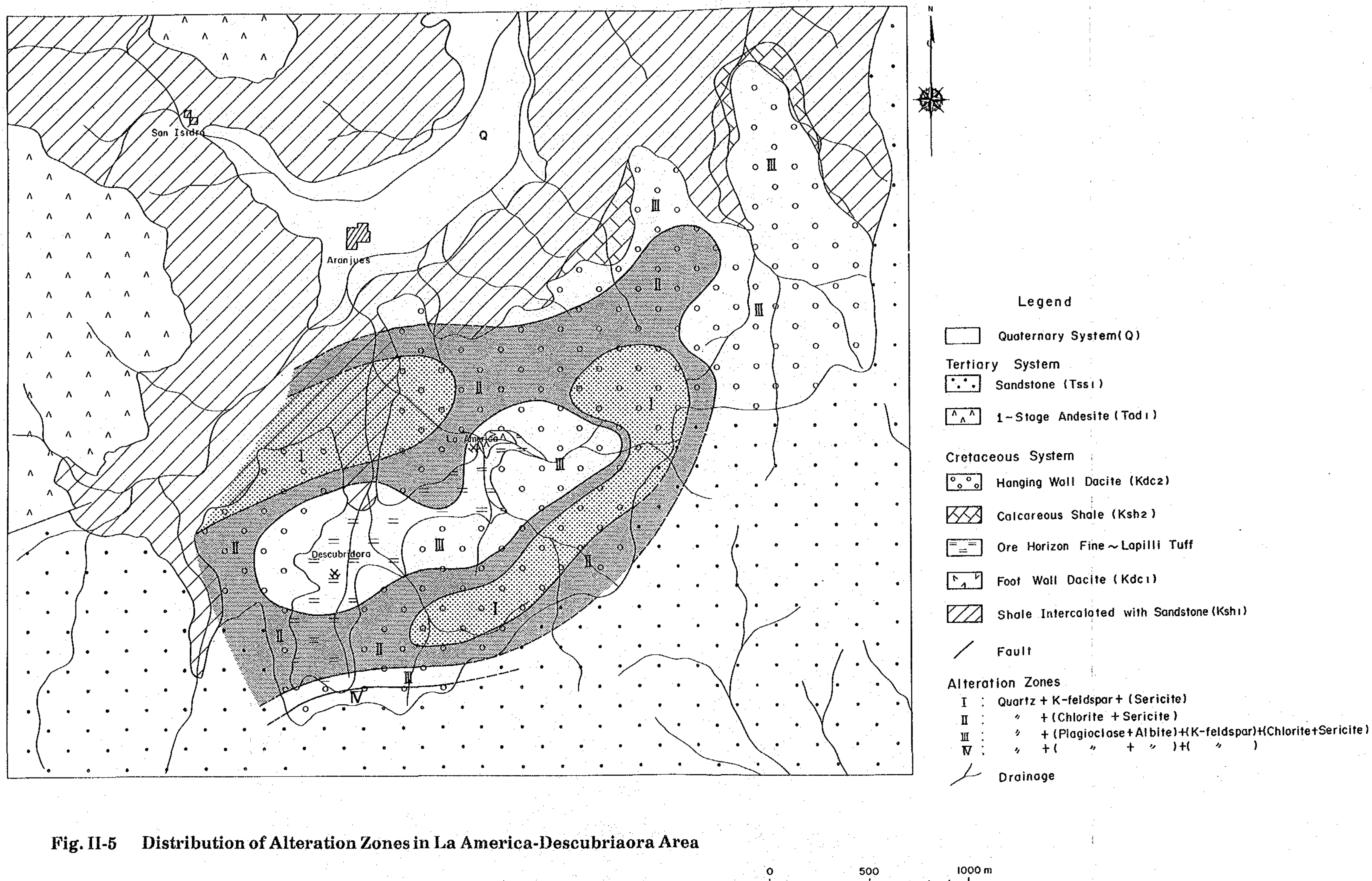


Fig. II-5 Distribution of Alteration Zones in La America-Descubriaora Area

(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 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.

4-2 On Residual Content of Plagioclase

The residual content of plagioclase, the mineral which is decomposed most easily by hydrothermal alteration, was investigated. The place where the residual plagioclase can be noticed by X-ray diffractometrical study corresponds to the III-zone in the alteration zoning. Around the residual zone, plagioclase has been decomposed completely as shown in Fig. II-6 in contrast with the distribution shown in Fig. II-5.

The La America deposit is located between perfect decomposition zone and residual zone, but the Descubridora deposit is in a residual zone of plagioclase. As pointed out in the section of alteration zoning, the fact that the zones of high alteration degrees seem to exist rather in other places than known deposits requires attention in Kuroko exploration.

Chlorite is comparatively a popular mineral in Kuroko type deposits, and its appearance frequency is high also in this area. About the chemical composition of chlorite which appears in the altered zone around a Kuroko type deposit, it has been known that the chemical composition of chlorite near the deposit differs from that in the peripheral part (Izawa, et al., 1978; Urabe & Scott, 1982-A).

Chlorite in this area has chemical compositions almost equivalent to those of chlorite appearing in places 0.7 ~ 4 km apart from the deposit around Fukazawa deposit, but chlorite like that, which is produced in Fukazawa deposit and is extremely rich in magnesium to an extent of $y = 0.5$, has not been found. These characteristics of chlorite can be interpreted that the chlorite in this survey area is different from that of the Kuroko deposit and relatively richer in iron, or that, as pointed out in the section of alteration zoning mentioned before, the center of alteration may be concealed in other places than known Kuroko type deposits (Fig. II-7).

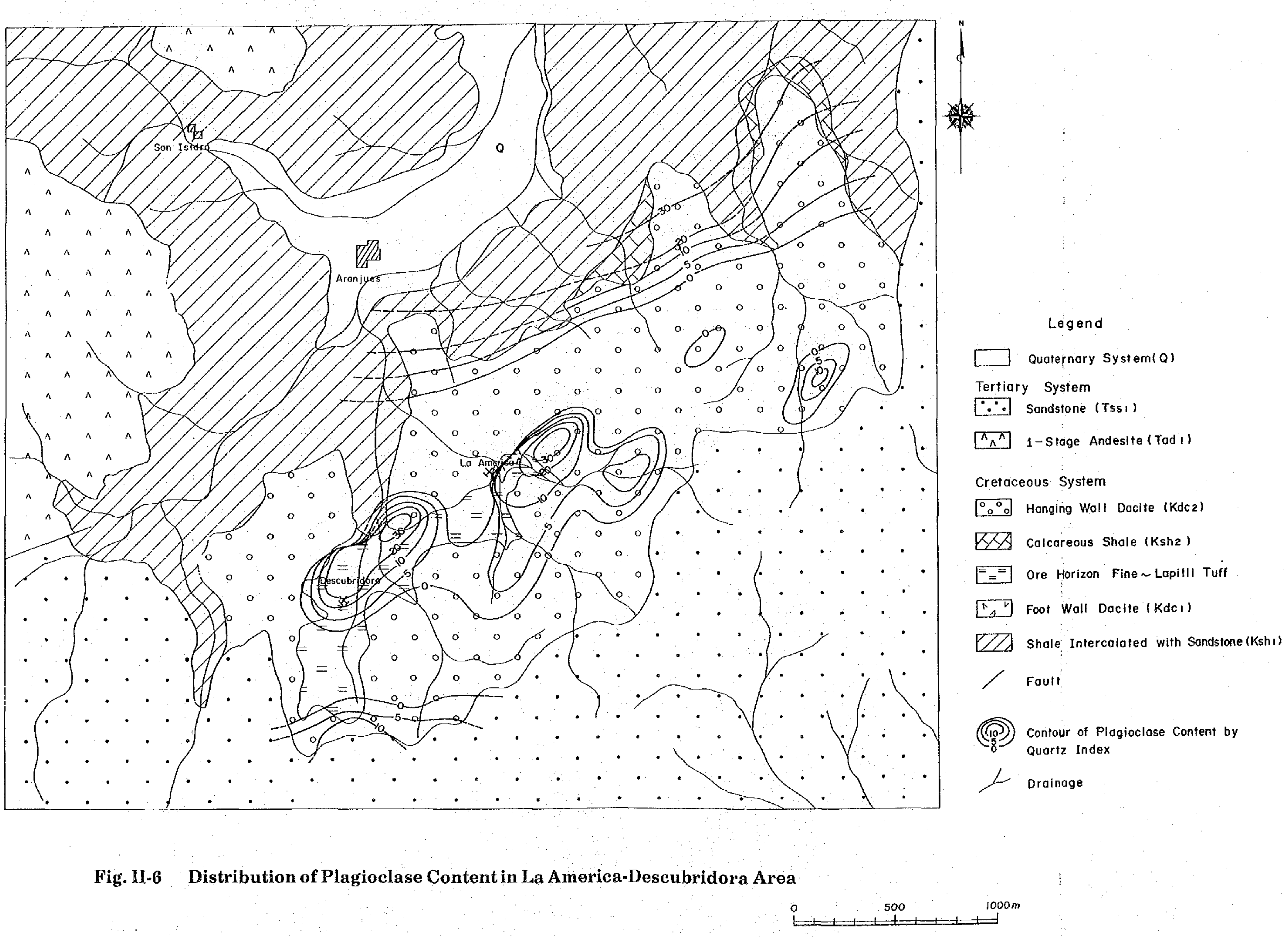


Fig. II-6 Distribution of Plagioclase Content in La America-Descubridora Area

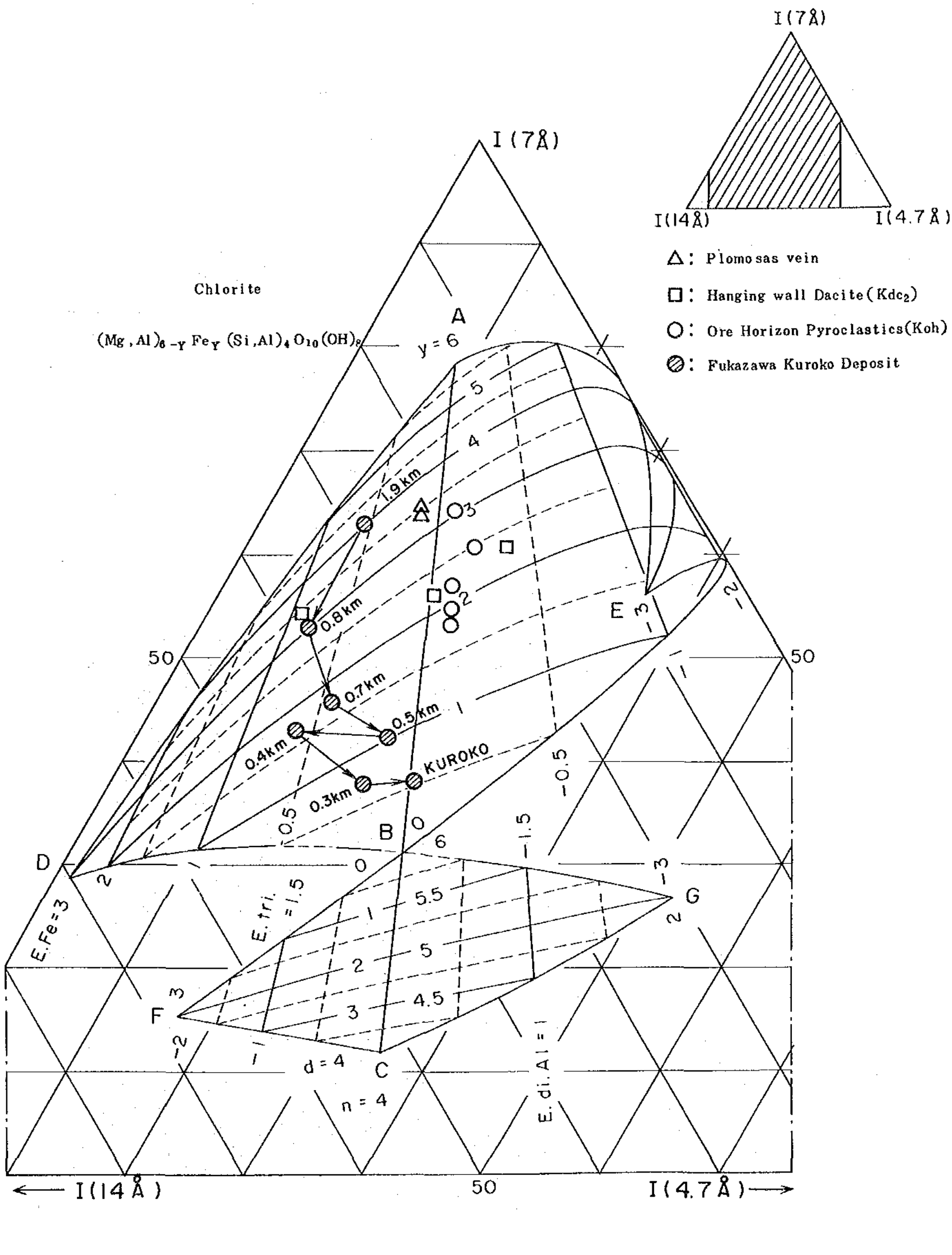


Fig. II-7 Diagram on Chemical Composition of Chlorite

CHAPTER 5 GEOCHEMICAL EXPLORATION

5-1 Geochemical Exploration using Stream Sediments

5-1-1 Sample Collection

In the geochemical exploration using stream sediments, samples were collected checking sample collecting points, which were established previously so as to cover the entire survey area, on topographical maps and with barometers. In a survey area of 1,000 km^2, 1,505 samples were collected. Sample collecting places were on the bank of a stream, the sandbank in a stream or in the underneath of a rock, etc., and a sample of about 30 g of -80 mesh size was collected in each place.

5-1-2 Indicators

Four elements (Ag, Cu, Pb and Zn) were chosen as indicators. Analytical detection limits were all 0.1 ppm for Ag, Cu, Pb and Zn. As the frequency of appearance of values below the detection limit was high (66%) for Ag, statistical treatment was carried out by assuming the values below the detection limit as 0.01 ppm.

5-1-3 Statistical Treatment of Analytical Values

Single variable and multivariable analyses were carried out for the four elements (Ag, Cu, Pb and Zn) of 1,505 samples collected during this survey. In geochemical data analyses, it has been known empirically that the frequency distribution of the contents of minor elements contained in geochemical samples assumes log normal distribution (Lepeltier, 1969). Accordingly, it has been the general method of determining anomalous values to pay attention to the deviation (anomalous population) from the log normal distribution (background population) shown by the most part of a certain indicator. The population handled in geochemical exploration is usually the composite population of the background population and the anomalous population, and it becomes an important subject how to divide these two in conformity with actual conditions. Apart from the case where the object composite population assumes log normal distribution, when the population assumes a distribution deviated from the log normal distribution, particular consideration is required. In the past, a method to determine background values and threshold values using a cumulative frequency distribution curve by Lepeltier (1969) and Sinclair (1976) has been used as a method to solve this problem.

However, a composite population shown by actual geochemical data is usually an assembly of several kinds of populations each having different geochemical characteristics. Therefore, there is a problem in the manner to divide a composite population into each element population at the bending points on the cumulative frequency distribution curve or at the middle points of curves which appear near the boundaries of plural different populations. As we thought is rational to use the method to determine a frequency curve by determining a spline function approximate to the cumulative frequency curve and its derivative of the first order, which was recently devised by Otsu, et al., (1883), to solve the above problem, we used this method for determining the threshold values of single variables.

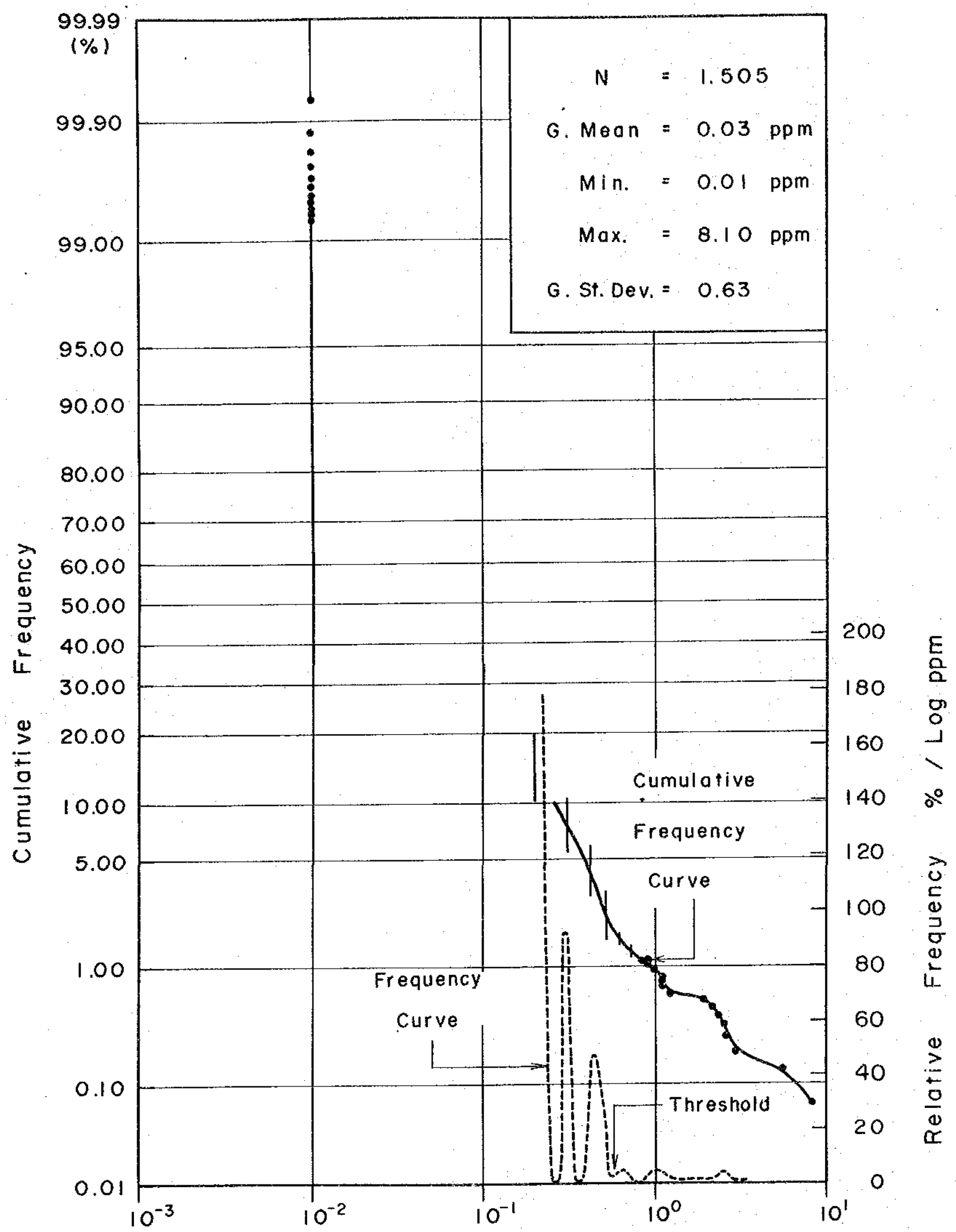


Fig. II-8 Frequency and Cumulative Frequency Curve (Ag)

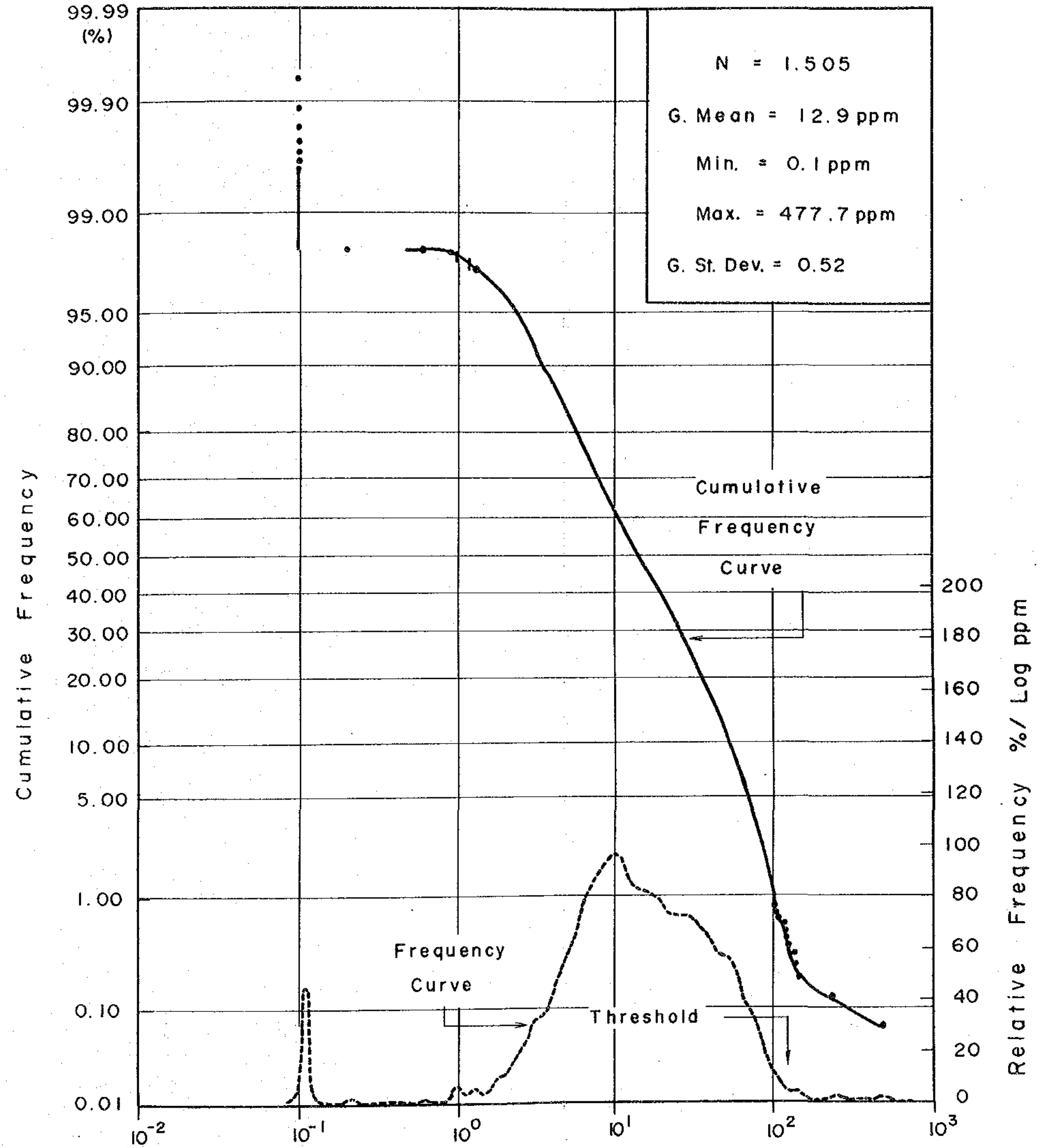


Fig. II-9 Frequency and Comulative Frequency Curve (Cu)

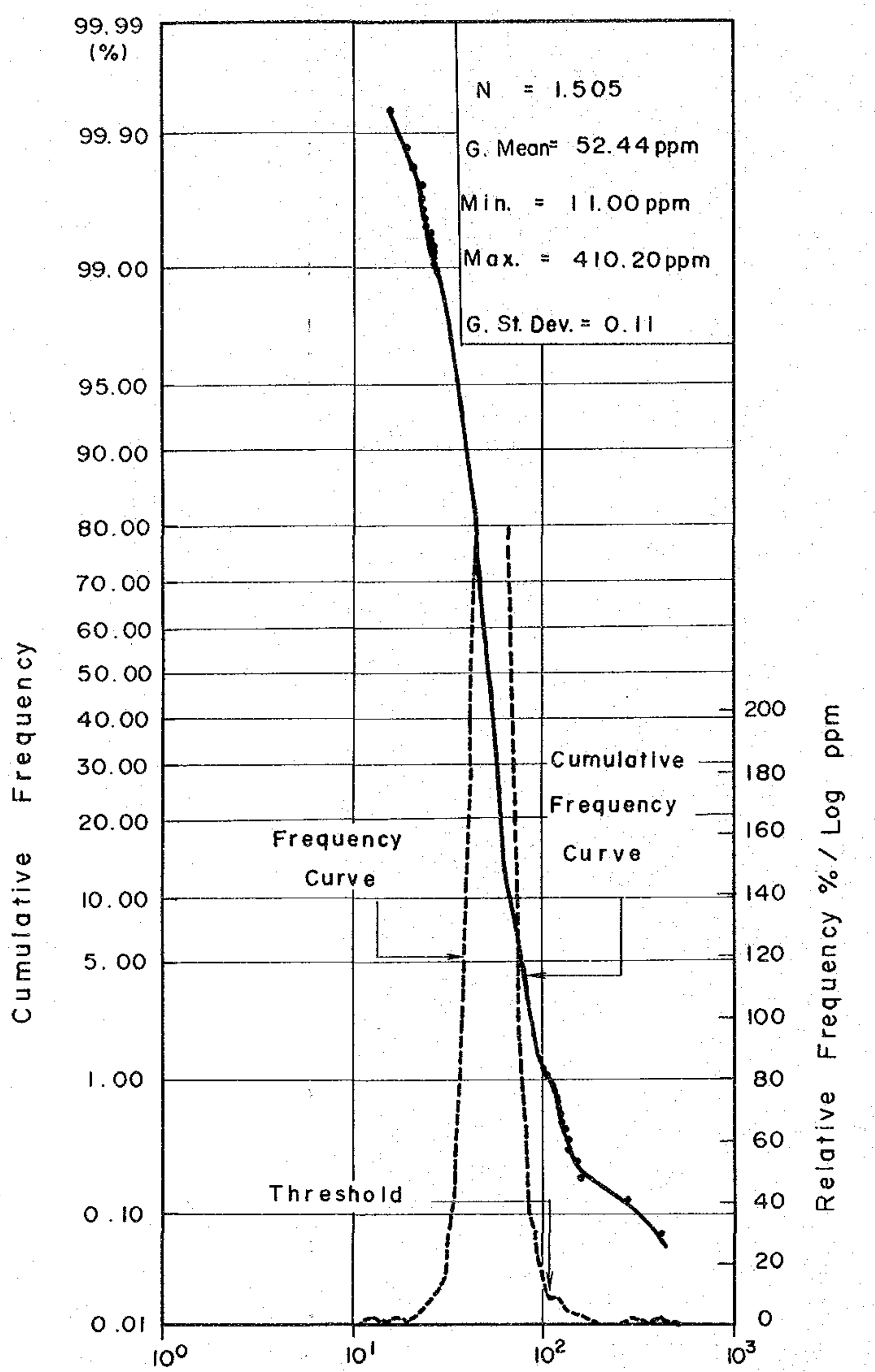


Fig. II-10 Frequency and Cumulative Frequency Curve (Pb)

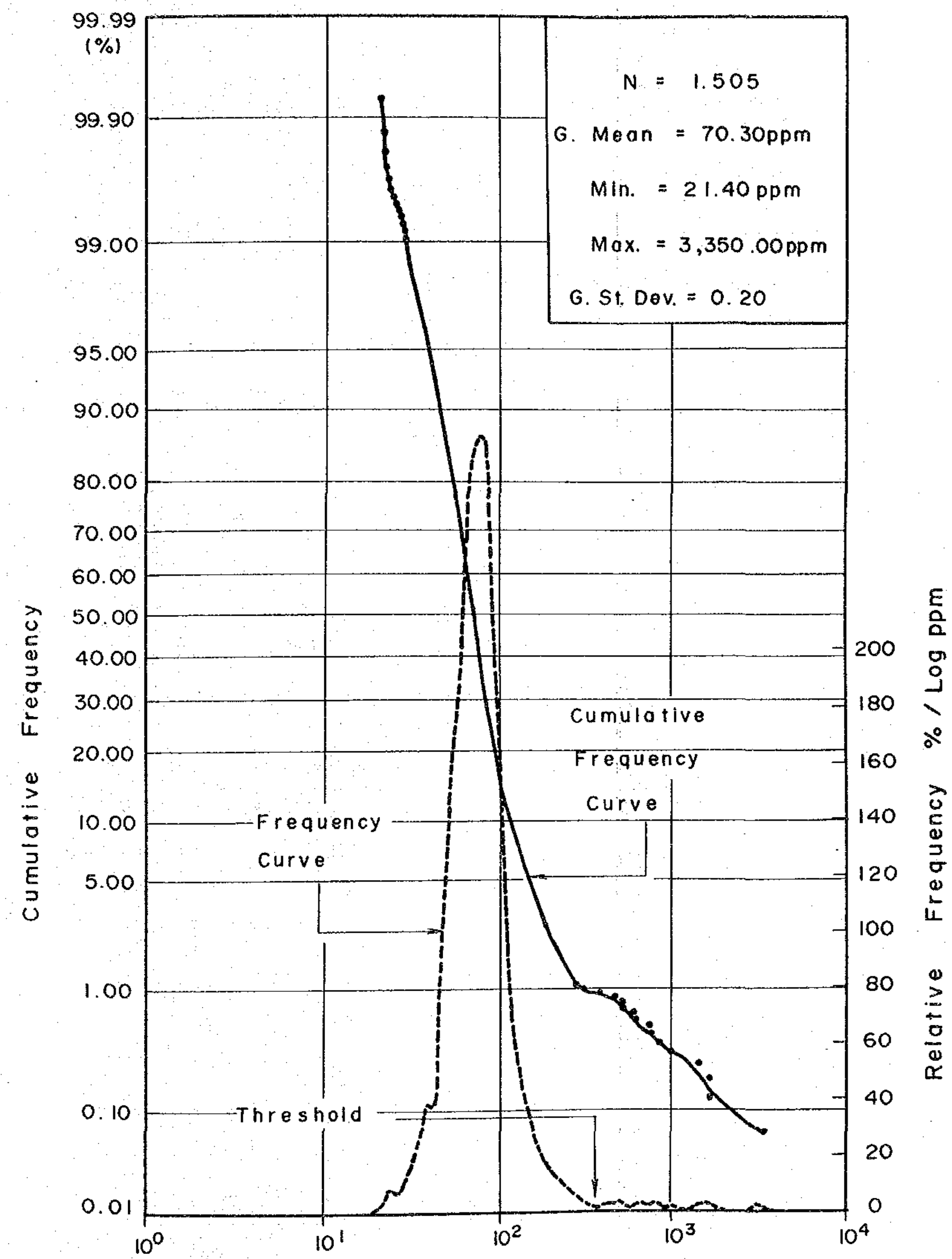


Fig. II-11 Frequency and Cumulative Frequency Curve (Zn)

Table II-3 Statistical Parameters of Geochemical Indicators

Rock code	Number of Sample	Geometric Mean (ppm)				Threshold (ppm)				Minimum Value (ppm)				Maximum Value (ppm)				Geometric Standard Deviation				Distribution Type			
		Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn
Whole Rocks	1505	0.03	12.9	52.4	74.3	0.54	130	114	356	0.01	0.10	11.0	21.4	8.10	477.7	410.2	3,345.0	0.63	0.52	0.11	0.20	-	N-N	N-P	N-P
1 Cretaceos System	124	0.03	28.0	58.5	116.1	-	-	-	-	0.01	0.10	27.4	39.6	8.10	477.7	410.2	3,345.0	0.76	0.61	0.15	0.36	-	N-N	N-P	N-P
2 I-Stage Andesites(Tad 1)	153	0.014	47.6	54.9	72.3	-	-	-	-	0.01	0.60	23.8	26.0	0.70	231.5	117.9	264.1	0.44	0.29	0.08	0.17	-	N-N	N-O	N-P
3 Sandstone(Tss 1)	105	0.018	19.9	53.9	71.7	-	-	-	-	0.01	1.90	32.2	28.3	0.30	65.1	161.0	525.5	0.49	0.29	0.08	0.16	-	N-N	N-P	N-P
4 II-Stage Andesites(Tad 2)	251	0.021	12.0	51.6	74.9	-	-	-	-	0.01	0.10	24.8	31.8	0.50	99.9	139.4	315.8	0.54	0.41	0.12	0.15	-	N-O	N-P	N-P
5 III-, IV-Stage Andesites (Tad 3, Tad 4)	487	0.032	8.4	51.1	73.0	-	-	-	-	0.01	0.10	11.0	24.2	1.90	101.6	149.8	258.4	0.64	0.49	0.11	0.16	-	N-O	N-O	N-O
6 I-Stage Dacites(Tad 1)	85	0.077	6.4	51.7	66.3	-	-	-	-	0.01	0.10	33.5	31.0	0.35	46.7	77.5	182.9	0.64	0.48	0.08	0.15	-	N-O	N-O	N-O
7 Intrusives(Gd, Adm, Gph)	134	0.017	9.7	51.9	63.2	-	-	-	-	0.01	0.10	16.3	21.4	0.70	138.0	102.5	391.0	0.49	0.46	0.12	0.19	-	N-O	N-O	N-O
8 Others(Tsb 1, etc.)	166	0.061	12.1	50.6	69.9	-	-	-	-	0.01	0.10	27.0	22.4	2.50	77.9	86.4	189.1	0.67	0.47	0.09	0.18	-	N-N	N-O	N-O

Abbreviation

N-O : Log normal distribution without skewness
N-P : Log normal distribution with positive skewness
N-N : Log normal distribution with negative skewness

The results are shown in Fig. II-8, Fig. II-9, Fig. II-10 and Fig. II-11. And statistical parameters of geochemical indicators is shown in Table II-3.

5-1-4 Principal Component Analysis

By determining the correlation coefficients between indicators, which cannot be extracted by single variable analyses, from multidimensional distribution characteristics, they were applied to the determination of character and the evaluation of geochemical anomalies (Table II-4).

Table II-4 Results of Principal Component Analysis

P.C.	Eigen-values	C.R.	Eigenvectors				Factor Loading				Max. Score	Min. Score
			Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn		
Z_1	1.71	0.43	0.14	0.37	0.65	0.64	0.19	0.49	0.85	0.84	12.53	-4.45
Z_2	1.20	0.30	0.78	-0.60	-0.03	0.20	0.85	-0.66	-0.03	0.22	4.32	-2.38
Z_3	0.66	0.17	0.59	0.71	-0.33	-0.21	0.48	0.58	-0.27	-0.17	2.92	-5.30

Abbreviation
P.C. : Principal Component
C.R. : Contribution Ratio

As shown in this table, the contribution ratio of the first principal component to all the principal components is about 43%, occupying nearly a half of all. The total to the ratio of the third principal component amounts to 90% approximately, so that a greater part of the fluctuation of all the components can be explained with them. However, compared with the contribution ratio of the second principal component, 30%, that of the third principal component markedly drops to 17%.

Factor loading is composed of correlation coefficients between principal components and variables (indicator contents). For the first principal component, Pb-Zn shows a high value 0.85-0.84, but Cu shows 0.49 reduced to nearly a half. Therefore, the first principal component is characterized by high correlation with Pb and Zn and medium degree of correlation with Cu.

The second principal component is characterized by the high correlation (0.85) with Ag and the negative correlation (-0.66) with Cu. The third principal component has medium degrees of correlation with Ag and Cu and must show high scores in samples with indicator contents not correlated with Pb and Zn. However, there are few geochemical anomalies with a structure characterized by the third principal component.

5-1-5 Evaluation of Geochemical Anomaly using Stream Sediments

Anomalous zones in the survey area can be classified into single element showing type ones and multi-element showing type ones according to the combinations of indicators which show anomaly.

Table II-5 Evaluation of Anomalous Zones (Ag)

Anomalous Zones	Sample No.	R·C	Contents of Indicators (ppm)				P.C. A'S Score			Type of Inferred Mineralization
			Ag	Cu	Pb	Zn	Z1	Z2	Z3	
Tierra Coloradas-N	172	6	0.9 (11)	46.7 (7.3)	71.3 (1.4)	118.1 (1.8)	2.211	1.381	1.538	Ag-(Cu) mineralization
El Crucero	214	8	0.6 (10)	13.7 (1.1)	44.8 (0.9)	189.1 (2.7)	1.229	2.032	1.062	Ag-(Zn) mineralization
Tierra Coloradas	390	6	0.6 (7.5)	40.6 (6.3)	77.5 (1.5)	93.5 (1.4)	2.016	1.123	1.285	Ag-(Cu) mineralization
San Carlos	427	5	1.1 (37)	46.9 (5.6)	67.9 (1.3)	93.8 (1.3)	1.776	1.389	1.792	Ag-(Cu) mineralization
	706	5	1.2 (40)	50.9 (6.1)	75.8 (1.5)	97.0 (1.3)	2.148	1.398	1.712	
Para Nada	457	8	2.5 (42)	12.5 (1.0)	68.1 (1.3)	98.5 (1.4)	1.522	2.506	1.318	Ag mineralization
La Yerba Buena-W	509	2	0.7 (50)	40.8 (0.9)	81.5 (1.5)	250.5 (3.5)	3.565	1.634	0.835	Ag-(Zn) mineralization
Puerto del Colomo	695	8	0.6 (10)	4.7 (0.4)	49.0 (1.0)	46.7 (0.7)	0.853	1.936	0.947	Ag mineralization
La America-S	820	1	0.7 (23)	15.4 (0.6)	70.3 (1.2)	244.7 (2.1)	2.838	2.124	0.470	Ag-(Zn) mineralization
Chambueres	877	5	1.1 (37)	6.2 (0.7)	50.9 (1.0)	96.2 (1.3)	0.419	2.437	0.975	Ag mineralization
San Agustin	1364	5	1.9 (63)	2.6 (0.3)	88.7 (1.7)	52.8 (0.7)	0.819	2.839	0.210	Ag mineralization
San Agustin-N	1389	5	1.1 (37)	3.2 (0.4)	67.1 (1.3)	49.8 (0.7)	0.009	2.447	0.513	Ag mineralization

(7.3): Contrast (Ratio of background value of geological unit to threshold)

R·C: Rock code (R·Cnumber shown in Table II-3)

P.C.A'S: Principal Component Analysis's

(1) Single Element Showing Type-Age

This type seems to be divided again into three types, a type which shows the mineralization of Ag only (the mineralization of Cu, Pb and Zn is not accompanied or is weak) and the score of the first principal component near zero, and types which accompany the mineralization of Cu or Zn although to a low degree.

The characteristics of each anomalous zone are as shown in Table II-5.

These anomalous zones are usually found in Tertiary volcanic rocks (III-IV stage andesites, I-stage dacites, etc.), and in this case, they are characterized by the mineralization of Ag only or that of Ag-(Cu). On the other hand, those found in or near the Cretaceos System are characterized by the mineralization of Ag-(Zn).

(2) Single Element Showing Type-Cu

This type anomalous zone is found only around Cerro San Pedro and shows the mineralization of Cu only. The geology dominating the anomalous zone is composed of I-stage andesites (Tad_1) and granodiorite (Gd), but it is difficult to suppose the origin of the mineralization.

The characteristics of each anomalous zone are as shown in Table II-6. They are characterized by the low scores (low Ag, high Cu) of the second factor.

Table II-6 Evaluation of Anomalous Zones (Cu)

Anomalous Zones	Sample No.	Rock Code	Contents of Indicaters (ppm)				P.C.A' Scores			Type of Inferred Mineralization
			Ag	Cu	Pb	Zn	Z_1	Z_2	Z_3	
San Pedro	739	2	0.01 (0.7)	145.5 (3.0)	49.5 (0.9)	53.3 (0.7)	0.028	-1.897	1.005	Cu-mineralization
	744	7	0.01 (0.6)	138.0 (14)	56.6 (1.1)	76.8 (1.2)	0.884	-1.723	0.862	
	787	2	0.01 (0.7)	135.7 (2.9)	52.6 (.10)	58.0 (0.8)	0.287	-1.831	1.079	
	788	2	0.01 (0.7)	231.5 (4.9)	41.2 (0.8)	28.9 (0.4)	-1.182	-2.381	2.039	

(3) Single Element Showing Type-Pb

With this type anomalous zones, San Pedro-NW area and Arroyo El Naranjo area form geochemically similar anomalous zones regardless of geological difference. The mineralization inferred by them will be of a type accompanying that of a certain degree of Cu and Zn. In the case of the latter, the anomalous zone is shown by plural geochemically similar samples but is different from the multi-element showing type found around a Kuroko type deposit in the structure of principal component scores.

Table II-7 shows the characteristics of anomalous zones.

Table II-7 Evaluation of Anomalous Zones (Pb)

Anomalous Zones	Sample No.	Rock Code	Contents of Indicaters (ppm)				P.C.A' Scores			Type of Inferred Mineralization
			Ag	Cu	Pb	Zn	Z_1	Z_2	Z_3	
San Pedro-NW	726	1	0.01 (0.3)	48.3 (1.7)	114.9 (2.0)	202.8 (1.7)	3.808	-0.842	-1.150	Pb-(Cu)-(Zn) mineralization
	727	2	0.01 (0.7)	51.5 (1.1)	117.9 (2.2)	199.5 (2.7)	3.873	-0.883	-1.139	
Arroye las Palmas	990	3	0.1 (5.6)	14.9 (0.7)	161.0 (3.0)	152.4 (2.1)	4.155	0.810	-1.235	Pb-(Pb?)-(Zn) mineralization
	1437	4	0.01 (0.5)	74.4 (6.2)	139.4 (2.7)	289.6 (3.9)	4.960	-0.919	-1.317	
	1438	4	0.10 (5.0)	29.6 (2.5)	123.0 (2.4)	140.0 (1.9)	3.536	0.458	-0.430	
Arroyo el Naranjo	1439	4	0.01 (0.5)	45.7 (3.8)	120.6 (2.3)	170.8 (2.3)	3.675	-0.895	-1.169	Pb-(Cu)-(Zn) mineralization
	1478	4	0.01 (0.5)	27.5 (2.3)	136.9 (2.6)	168.7 (2.3)	3.835	-0.660	-1.633	
	1483	4	0.01 (0.5)	24.2 (2.0)	127.6 (2.5)	167.8 (2.2)	3.601	-0.592	-1.612	
Cruz Gorda-W	1495	5	0.10 (3.3)	19.9 (2.4)	149.8 (2.9)	97.4 (1.3)	3.418	0.475	0.764	Pb-(Ag?)-(Cu)-(Zn) mineralization

(4) Single Element Showing Type-Zn

These anomalous zones found in and around the La America-Descubridora area are classified into the single element showing type group, but all show high Ag contrast which is judged to be the sign accompanying Ag mineralization (Table II-8).

Table II-8 Evaluation of Anomalous Zones (Zn)

Anomalous Zones	Sample No.	Rock Code	Contents of Indicaters (ppm)				P.C.A' Scores			Type of Inferred Mineralization
			Ag	Cu	Pb	Zn	Z_1	Z_2	Z_3	
Descubridore	821	1	0.2 (6.7)	37.0 (1.3)	75.9 (1.3)	467.3 (4.0)	4.109	1.299	0.083	Zn-(Ag)
Arroyo las Palmas-N	961	3	0.2 (11)	25.3 (1.3)	91.7 (1.7)	525.5 (7.3)	4.657	1.521	-0.449	Zn-(Ag) mineralization

(5) Multi-Element Showing Type (Composite Type) - Ag, Cu, Pb, Zn

This type anomalous zones appear characteristically in most cases in or around areas containing Kuroko type deposits. The showing indicator is basically the combination of Ag-Zn, and Cu and Pb add to it. This type is characterized by the high scores of the first principal component and the medium degree scores of the second principal component.

Table II-19 shows the geochemical characteristics of this type anomalous zones.

The anomalous zone in the Espinos de Pina area is different from other anomalous zones in the factor scores and cannot be regarded as Kuroko type mineralization.

As discussed above, the geochemical anomalies found in an area containing Kuroko type deposits are multi-element showing type based on the combination of indicators, principally Ag-Zn, and can be clearly distinguished from the single element showing type dominant in other areas. These anomalies may not be directly originating from the Kuroko type mineralization but are highly possible to be showing, so to speak, subsequent Kuroko mineralization which succeeds the principal mineralization of the kuroko type, and are important in the point it shows the existence of Kuroko mineralization although indirectly.

Tablee II-9 Evaluation of Anomalous Zones (Composite Type)

Anomalous Zones	Sample No.	R.C	Contents of Indicators(ppm)				P.C. A'S Score			Type of Inferred Mineralization
			Ag	Cu	Pb	Zn	Z1	Z2	Z3	
Espinos de Pina	349	7	0.7 (41)	46.6 (4.8)	44.7 (0.9)	391.0 (6.2)	2.651	1.827	1.519	Ag-Zn-(Cu) minerali za-tion
El Rubi-E	490	1	8.1 (270)	477.7 (17)	410.2 (7.0)	3,345 (29)	12.526	2.697	-0.077	Ag-Cu-Pb-Zn minerali za-tion
La America	765	1	0.2 (6.7)	0.2 (0.01)	276.5 (4.7)	1,627 (14)	7.673	4.320	-5.299	Pb-Zn-(Ag) minerali za-tion
Descubridora-N	812	1	2.9 (97)	62.8 (2.2)	117.3 (2.0)	1,666 (14)	7.493	2.979	0.313	Ag-Pb-Zn-(Cu) minerali-zation
Aranjuez-NE	797	1	5.3 (177)	40.0 (1.4)	131.8 (2.3)	1,441 (12)	7.514	3.449	0.200	Ag-Pb-Zn mineralization
Aranjuez-E	808	1	2.1 (70)	29.4 (1.1)	112.7 (1.9)	833.4 (7.2)	6.135	2.882	0.104	
	813	1	1.0 (33)	19.9 (0.7)	79.5 (1.4)	610.6 (5.3)	4.576	2.579	0.184	Ag-Zn-(Pb) mineralization
	814	1	2.5 (83)	72.7 (2.6)	96.4 (1.6)	633.9 (5.5)	5.633	2.419	1.042	
La Queseria-S	823	1	0.8 (27)	39.8 (1.4)	76.5 (1.3)	990.1 (8.5)	5.355	2.333	0.335	
	824	1	0.9 (30)	34.3 (1.2)	95.0 (1.6)	526.7 (4.5)	4.997	2.168	0.290	Ag-Zn mineralization
	1139	1	0.6 (20)	23.5 (0.8)	64.7 (1.1)	773.4 (6.7)	4.369	2.350	0.245	
Descubridora-S	957	1	2.3 (77)	25.6 (0.9)	91.3 (1.6)	753.6 (6.5)	5.402	2.977	0.388	

5-2 Geochemical Exploration by Whole Rock Analysis

Various attempts (for example, Dudas, 1983; Hashimoto, 1983) have been made to distinguish volcanic rock related with Kuroko type deposits in their origin from those not related from a lithogeochemical standpoint, but perfect solution has not been given to this problem in results regardless of the principal elements or the minor elements of rocks. In this survey, this problem was studied taking the foot wall dacite (Kdc_1), the pyroclastics of ore horizon (Koh), the hanging wall dacite (Kdc_2) and other dacites (Tdc_1, Tdc_3) with alteration signs, which are distributed around known Kuroko type deposits, and the dacite intercalated in the IV-stage andesites (Tad_4).

5-2-1 Alkali Alteration Index*

The alkali alteration index is an index devised for the quantitative representation of the degree of alteration paying attention to the high responsiveness of alkali and alkaline earth elements to hydrothermal alteration and greatly contributed to the discovery of Ezuri deposit, a Japanese Cenozoic Kuroko deposit, by Ishikawa, et al. (1980).

For the movement of elements by Kuroko type alteration, commonness is noticed apart from the formation time and the distribution of deposits. Especially, the addition and leach of alkali and alkaline earth elements are characteristics.

As the La America and Descubridora deposit is are also regarded to be Kuroko type deposits, the mode of alteration accompanied by these deposits were was investigated from the viewpoint of alkaline alteration index.

(La America-Descubridora Area)

Two inensely altered zones (alkali alteration index above 90%) stretching in the NE-SW direction are noticed in the distribution areas of hanging wall dacite (Kdc_2) and the pyroclastics (Koh) of ore horizon, and these two zones are bounded by a weak alteration zone of the alteration index of 50 ~ 60%. La America deposit is included in the intense alteration zone, but Descubridora deposit corresponds rather to the weak alteration zone. The development of the two intensely altered zones towards southwest has not been interrupted in both cases and the development can be expected (Fig. II-12).

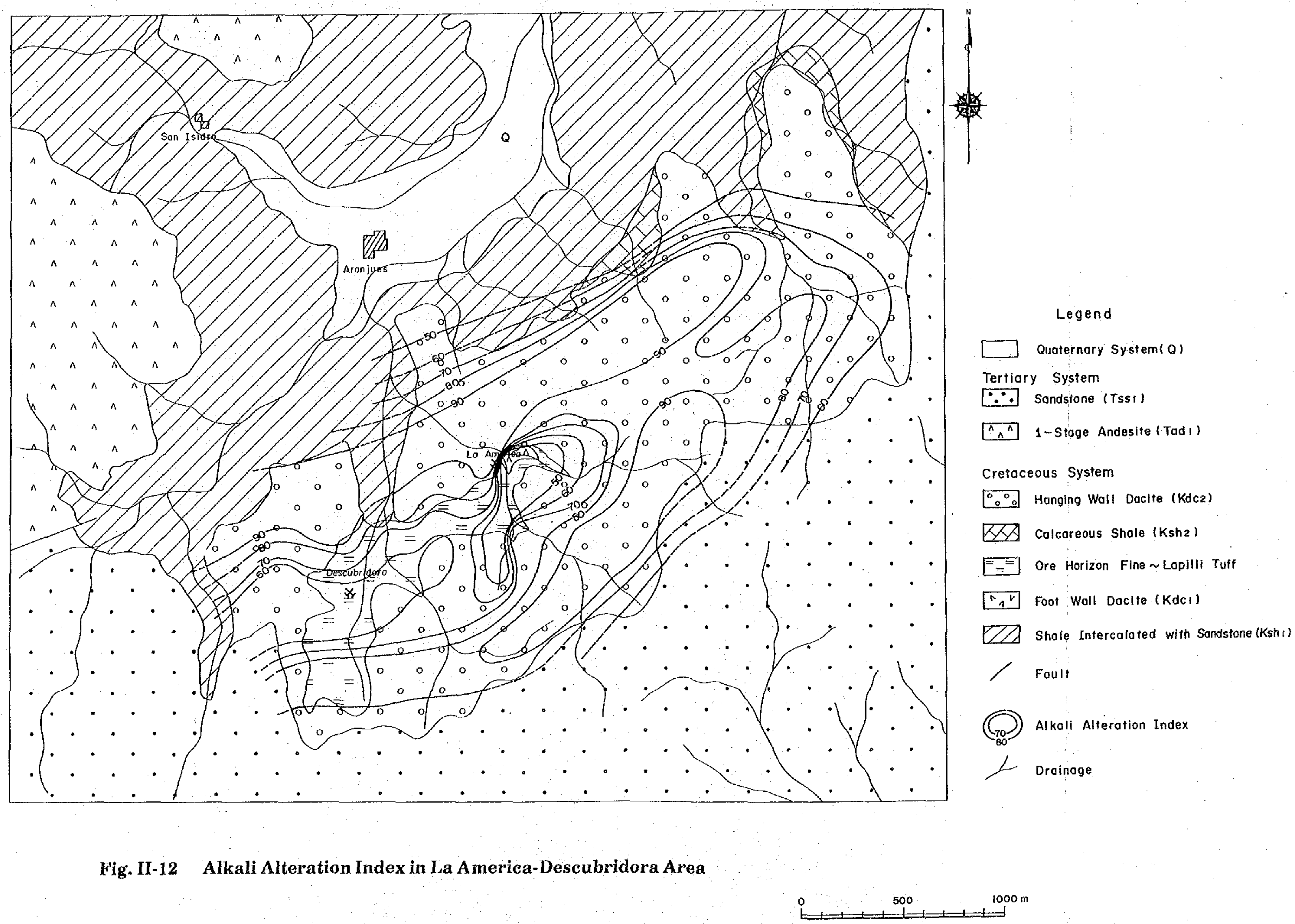


Fig. II-12 Alkali Alteration Index in La America-Descubridora Area

5-2-2 Principal Component Analysis

For the main 13 components in 102 rock samples collected in the survey area, principal component analyses were carried out to clarify the relationship with the Kuroko type mineralization.

After standardizing the value of each component, principal component analyses were carried out. The results are shown in Table II-10.

According to this table, the maximum eigenvalue is 3.66, which is the square sum of the first factor loading, so a 28% of the whole can be explained with this first factor. When calculated in the same way for the second and the third factors, 19% and 12% are determined and 11%, for the fourth eigenvalue. Therefore, a 71% of the original data used for this analysis can be explained with the first to fourth eigenvalues.

When the factor loading, which is regarded most important in this analysis, is observed, Z_1 is characterized by negative correlation of SiO_2 with other components. It shows that when SiO_2 is increased by silicification, other components have strong tendency to decrease relatively.

Generally, silicification includes two types, one is to add silica and the other is that relative increase in silica occurs as a result of leaching of components other than silica. In the survey area, the former case is supported from the results of principal component analysis and the field occurrence.

Z_2 is characterized by the non-correlation of the petrological basic elements such as FeO, MgO and CaO with K_2O, Al_2O_3 and BaO.

K_2O, which is most highly correlated with Z_2, shows, in the case of Kuroko type alteration, a tendency of remarkable increase with the progress of the alteration, and has character to assume a opposite behavior with Na_2O. Therefore, negative correlation can be expected, but this principal component analysis showed non-correlation merely between Na_2O and K_2O.

About Z_3, the high correlation (0.75) with Na_2O is noticeable. It can be ranked as the principal component for explaining the behaviors of Na_2O which reacts most sensitively for hydrothermal alteration.

About the principal components from Z_4 and lower, positive correlation of medium order of Z_4 with TiO_2 and P_2O_5, about Z_5, negative correlation of medium order with LOI, about Z_6, positive correlation of medium order with Fe_2O_3 are only noticed, and it is difficult to give petrological meaning.

For alteration, the distribution of each sample in the two-dimensional space due to the second and the third factor scores, to which alkali and alkaline earth elements most sensitive to alteration seem to contribute greatly, was investigated (Fig. II-13).

Especially, attention was paid to the mutual distribution relation resulting from difference in the geological units of sampling sites. The geological units are as follows:

A : Hanging wall dacite (Kdc_2, La America-Descubridora Area)
B : Hanging wall dacite (Kdc_2, El Rubi Area)

Table II-10 Analytical Results of Principal Component Analysis

P·C	E·V	C·R	Factor Loading													Max. Score	Min. Score
			SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	BaO		
Z_1	3.66	0.28	-0.78	0.64	0.59	0.25	0.52	0.72	0.54	0.54	0.54	0.04	0.63	0.37	0.12	5.15	-6.88
Z_2	2.52	0.48	0.42	0.20	0.53	0.35	0.59	0.17	0.59	0.49	0.06	0.79	0.12	0.03	-0.53	4.11	-3.22
Z_3	1.56	0.60	-0.12	0.12	0.31	0.16	0.30	0.09	0.33	0.41	0.75	0.11	0.22	0.59	-0.28	3.99	-2.85
Z_4	1.47	0.71	0.15	0.62	0.20	0.40	0.28	0.18	0.21	0.12	0.05	0.32	0.54	0.12	-0.54	3.01	-3.30
Z_5	0.98	0.78	0.29	0.05	0.34	0.14	0.17	0.35	0.10	0.15	0.01	0.28	0.23	0.56	0.35	2.15	-4.02
Z_6	0.88	0.85	0.08	0.21	0.11	0.71	0.16	0.14	0.02	0.13	0.17	0.25	0.27	0.22	0.18	2.06	-3.86

P·C : Principal components
E·V : Eigenvalue
C·R : Contribution ratio
LOI : Loss on ignition

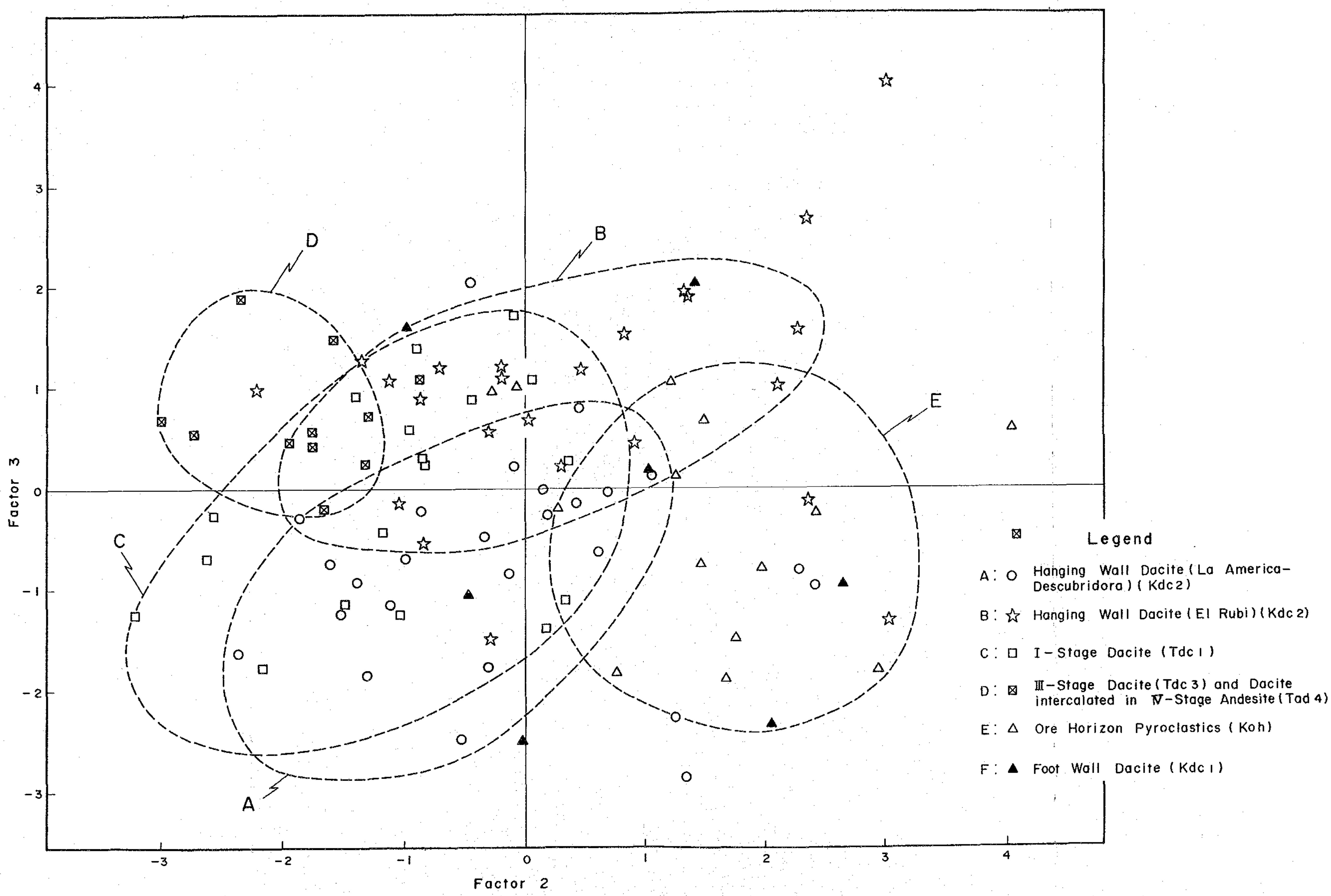


Fig. II-13 Relation Between Factor 2 and Factor 3

C : I-stage dacite (Tdc_1)
D : III-stage dacites (Tdc_3), etc.
E : Ore horizon pyroclastics (Koh)
F : Foot wall dacite (Kdc_1)

According to these unit, the distribution areas of D group and E group are separated not overlapping with each other. With the second principal component, while the former is characterized with a negative value, a greater part of the latter have positive scores, so that the two can be distinguished clearly from each other.

A, B, and C groups are distributed in the zone between D and E groups overlapping with each other, and it is difficult to distinguish them clearly based on the scores of respective factor scores. Especially, A and C groups overlap with each other greatly and they can be said to have similar character in the distribution of two scores.

The foot wall dacite (Kdc_1) is distributed over a wide area in the figure and its characteristics cannot be specified.

As mentioned above, the behaviors of D group differ too greatly to regard it as a rock related with a Kuroko deposit positively. As C group shows behaviors similar to those of A and B groups, which are regarded as Kuroko deposit related rocks in this method, it is difficult to conclude the kind of rock of D group.

5-2-3 Cluster Analysis

For the purpose of distinguishing rocks related with Kuroko type deposits from those not related or checking for the possibility of dividing each rock group into finer groups, the cluster analysis was carried out using the results of the principal component analysis (Fig. II-14).

At first, 102 samples were classified into ten clusters and it was checked how the samples divided into six groups according to their collection sites were classified into the ten clusters.

Similarly to the principal component analysis, it was unable to define a cluster to which the foot wall dacite (Kdc_1) belongs.

Although it is difficult to make clear distinction among four main clusters from their chemical components, the following evaluations can be given.

(1) Although a few samples from the hanging wall dacite (Kdc_2) of La America-Descubridora area are distributed into each cluster, the characteristics in components of the cluster 5 which includes the greatest number of samples from the dacite are closest to the behaviors of the chemical components shown by Kuroko type alteration among these four clusters. Also about the state of formation of altered minerals in this hanging wall dacite (Kdc_2), the formation of sericite and chlorite over the widest area compared with other areas in this survey area was confirmed by X-ray diffractometrical study, therefore, the characteristics are closest to be Kuroko type alteration also in this point. Therefore, it can be concluded that this area is that of the strongest Kuroko type alteration.

Legend

A : Hanging Wall Dacite (La America-Descubridora) (Kdc2)

B : Hanging Wall Dacite (El Rubi) (Kdc2)

C : I - Stage Dacite (Tdc1)

D : III - Stage Dacite (Tdc3) and Dacite intercalated in IV-Stage Andesite (Tad4)

E : Ore Horizon Pyroclastics (Koh)

F : Foot Wall Dacite (Kdc1)

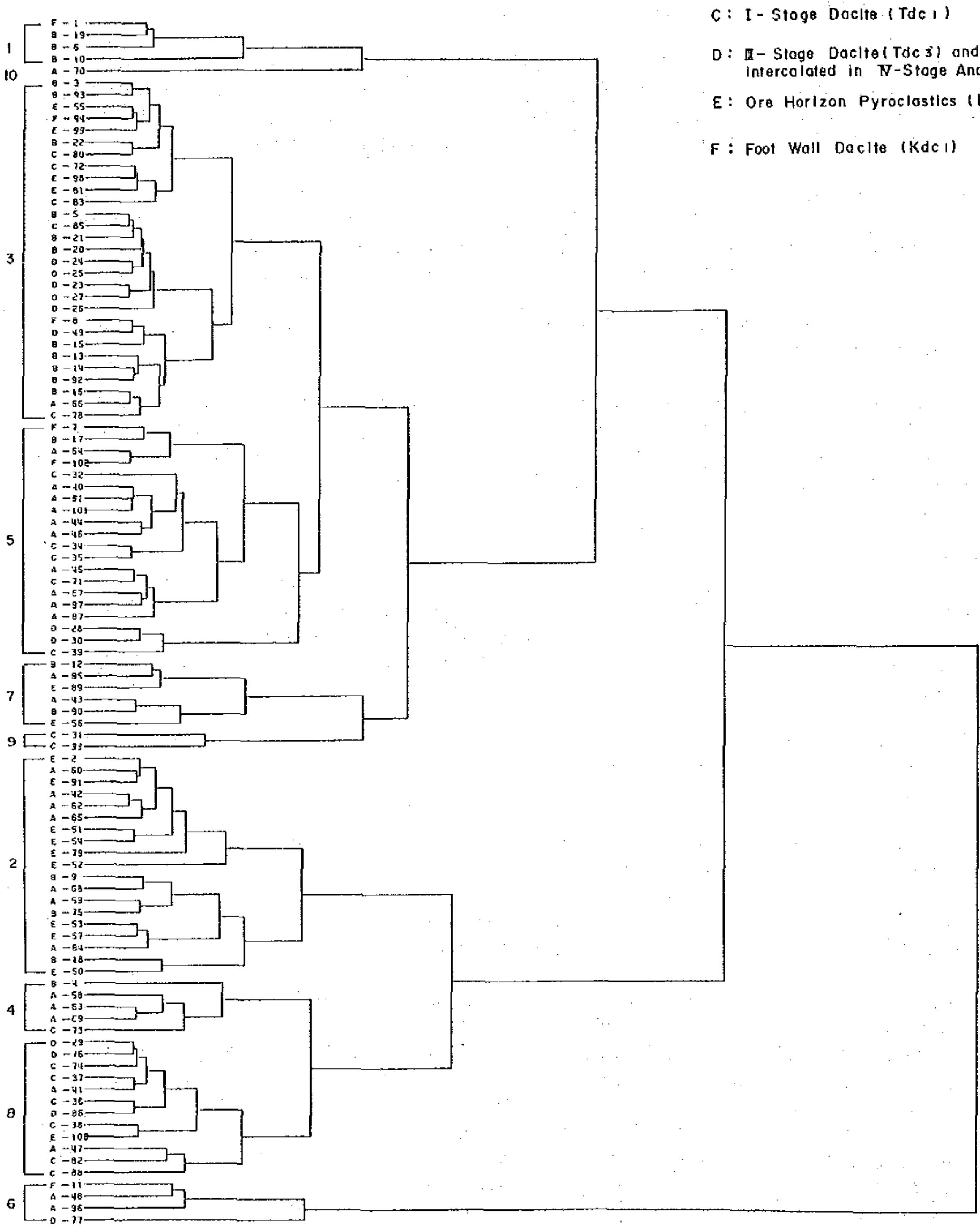


Fig. II-14 Cluster Dendrogram of Rock Samples

(2) The samples from the hanging wall dacite (Kdc_2) of El Rubi deposit are also distributed to each cluster, but in the characteristics of the chemical composition of cluster 3, to which these samples concentrate most, relative decrease in Na_2O, was not noticed as mentioned above, therefore, this cluster shows different features from those of Kuroko type alteration. It can be concluded that the alteration suffered by this cluster was generally weak.

(3) Most of the ore horizon pyroclastics (Koh) of La America-Descubridora area are supposed to have received the Kuroko type alteration from their positional relation with known deposits, but the chemical component behaviors of cluster 2, to which the samples from these rocks concentrate most, seem to be considerably different in alteration type from the hanging wall dacite (Kdc_2) which covers these pyroclastics.

(4) About the samples from the areas which have no clear relation with Kuroko type deposits, there are few of these samples distributed to cluster 5 whose characteristics are most similar to those of the Kuroko type alteration. On the contrary, these samples tend to concentrate into cluster 3, which is thought to be of different type. Therefore, these dacites (Tdc_1 and Tdc_3) do not have sufficient positive evidence to judge them as rocks related with Kuroko type deposits.