CHAPTER 6 GEOPHYSICAL SURVEY

6-1 Outline of Survey

The CSAMT (Controlled-Source Audio Frequency Magnetotellurics) survey determines the underground resistivity distribution by transmitting audio frequency current through the grounded dipole, and measures the electric field (E), parallel to the transmitter dipole, and the magnetic field (H), perpendicular to the electric field.

Transmitted current frequencies were 2048, 1024, 512, 256, 128, 64, 32, 16, 8 and 4 H_2.

Signals from both electric and magnetic field are processed by a GDP-12 receiver, which outputs the following:

(1) Apparent resistivity

(2) Phase difference between electric and magnetic fields

6-2 Survey Results

From the view point of Kuroko exploration, general discussion on the survey results is described below with our special attention to low resistivity zones (LRZs).

(1) The LRZs in the east of the survey area are widely distributed in the shallow depth but shifted to high resistivity zones (HRZs) in a depth of 100 m, and they are distributed in topographically lower places. This is, therefore, considered to be LRZs derived from Quarternary (Q). The thickness is estimated to be 100 to several ten m. It is anticipated that shale (Ksh_1) exists in the northeast and sandstone (Tss_1) exists in the southeast under Quarternary (Q).

(2) In the south of the survey area, Aranjuez LRZ from the east of the east of the La America deposit to Aranjuez, Aranjuez East LRZ to its east and Descubridora West LRZ to the east of the Descubridora deposit were extracted.

- These are found in the north edge of volcanic rocks (hanging wall dacite (Kdc_2) and fine tuff (Koh)) which are closely related to Kuroko type deposit, and are roughly arranged from the northeast to southwest. Considering geological structure, they are located in the north wing of an anticlinal structure on the axis of the La America deposit area and its location correspond to the places where the existence of ore horizon tuff (Koh), foot wall dacite (Tdc_1), and so on is expected. These LRZs are also located around medium resistivity zone (MRZ)/HRZ roughly corresponding to the distribution area of the above mentioned volcanic rocks.

- There is a strong possibility in terms of its depth and distribution that Aranjuez LRZ corresponds to the extension of ore horizon tuff (Koh) which has received mineralization or alteration for resistivity structure.

LEGEND

Station Point, No

Transmitter Bipole

Contour of Resistivity (Ω-m)

H High Resistivity Zone

L Low Resistivity Zone

● Drilling Site

Fig. II-15 Plan of Resistivity Structure (200 m below the surface)

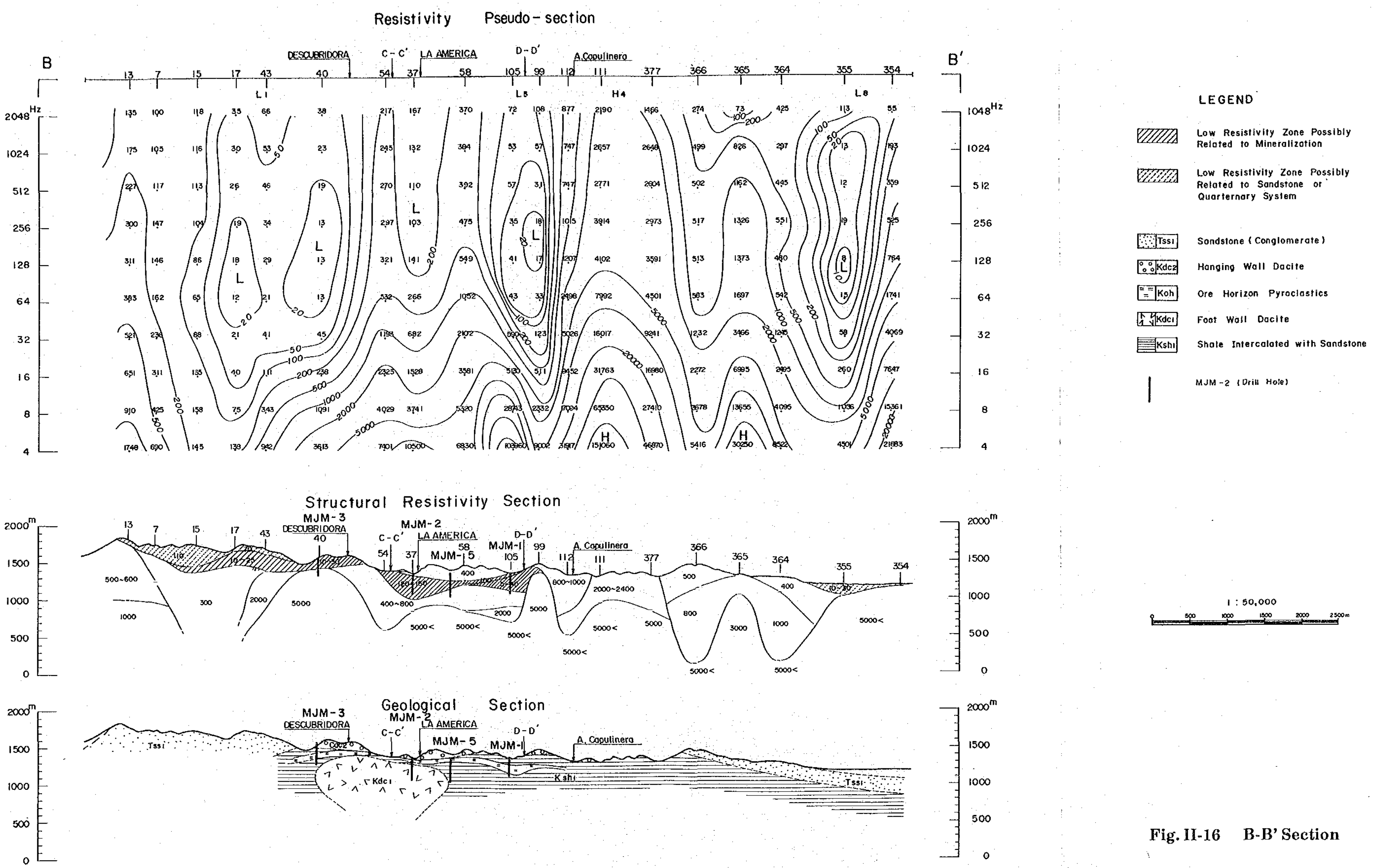


Fig. II-16 B-B' Section

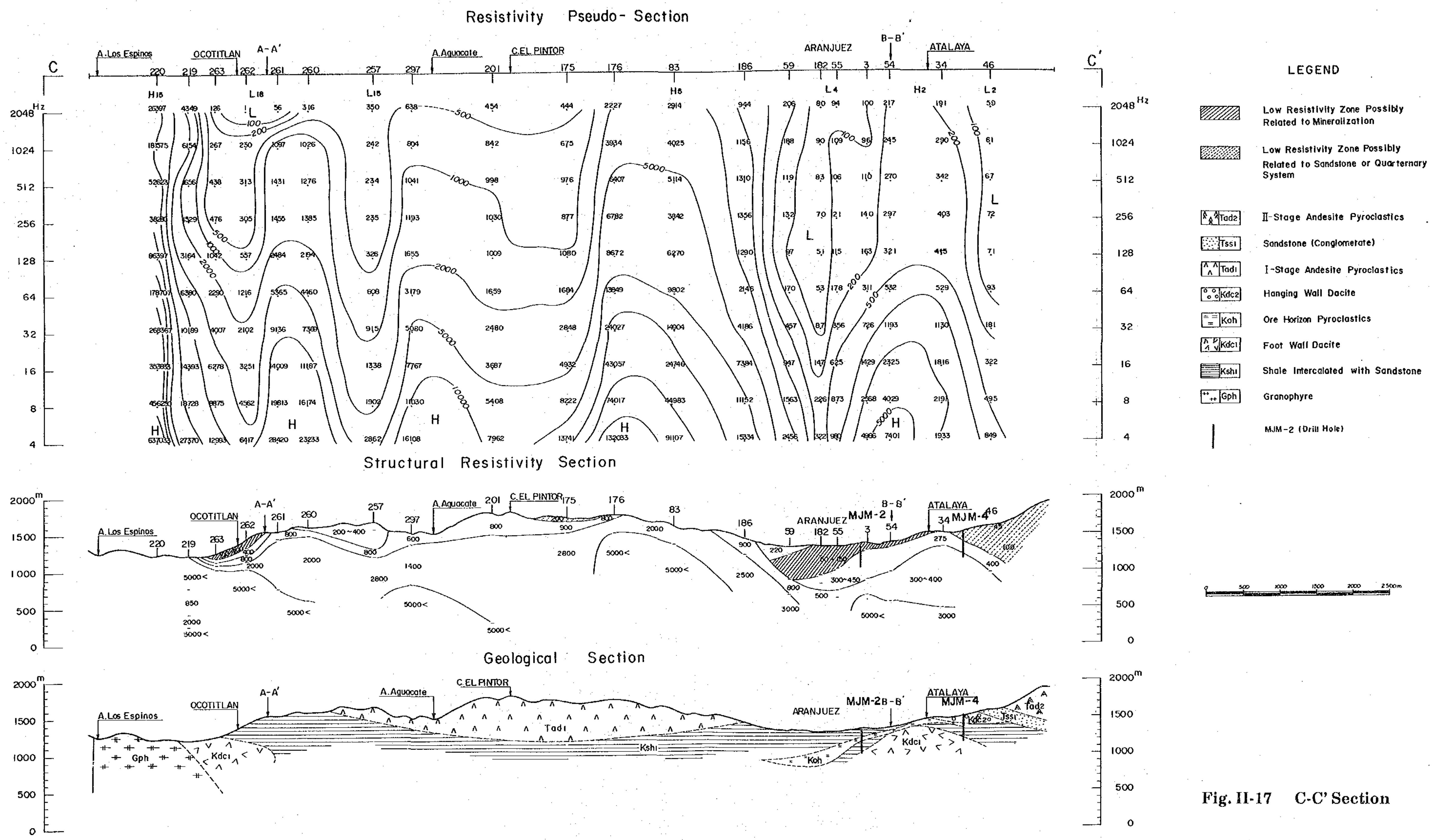


Fig. II-17 C-C' Section

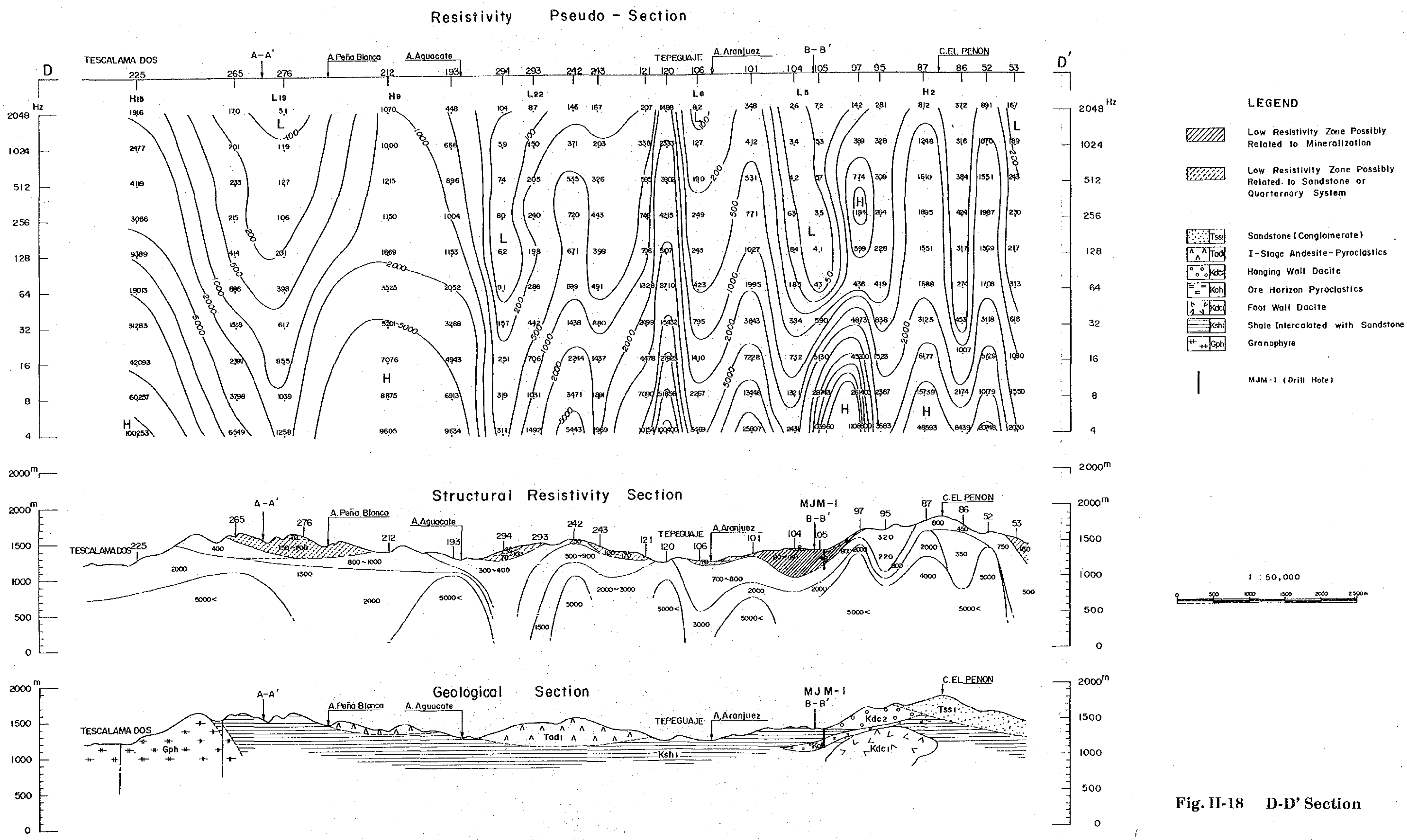


Fig. II-18 D-D' Section

- Aranjuez East LRZ is also found in the geological and structural position similar to the above LRZ, and is also similar to Aranjuez LRZ for resistivity structure. Thus, there is a possibility that this LRZ is also derived from the same kind of ore horizon tuff (Koh). Both the above two LRZs roughly correspond to multi-elements showing type which may suggest Kuroko type deposit caught as a result of the geochemical exploration using stream sediments.

- Descubridora West LRZ seems to be connected to the LRZ that may be derived from Tertiary sandstone (Tss_1), in terms of comparison with geology. However, the survey of alteration zone and study of alkaline alteration index show that this LRZ corresponds to the southwest extension of intensely altered zone. Furthermore, also in terms of geological section, this LRZ is located on the extension of ore horizon tuff (Koh) from the Descubridora deposit, and can be considered to be promising from the viewpoint of Kuroko type deposit exploration.

(3) Small-scale LRZs are dotted with in the central part of the survey area. They may suggest the weathered zones extending into I-stage andesite (Tad_1), because they shift rapidly to HRZ in the depth.

(4) In the north part of the survey area, a LRZ, which seems to reflect pyrite dissemination in silicified rock nearby the Ocotitlan tunnel, is found.

This is of small-scale and limited in the shallow depth, and may not correspond to the ore horizon depth. Therefore, it is not considered to be promising low anomaly zone for Kuroko exploration.

CHAPTER 7 DRILLING SURVEY

7-1 Outline of Survey

7-1-1 Purpose and Location of Drilling Survey

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 survey. Five drills aiming at exploration of Kuroko type deposits were conducted there. Location of drill holes is shown in Fig. II-19.

7-1-2 Period and Volume of Survey

Outline of the survey are shown in Table II-11. Total drilling depth was 2,369.70 meters (planned total depth: 1,350.00 meters).

Table II-11 Outline of Each Hole

Hole No.	Location			Proposed Depth	Drilled Depth	Period
	X	Y	Above the sea			
MJM-1	9,360	21,410	+1,350 m	250 m	253.3 m	15.10.1985 -31.10.1985
MJM-2	8,250	20,720	+1,320 m	250 m	262.6 m	1.11.1985 -3.12.1985
MJM-3	7,840	19,190	+1,560 m	250 m	250.6 m	4.12.1985 -7.1.1986
MJM-4	8,440	19,320	+1,520 m	300 m	301.6 m	8.1.1986 -28.1.1986
MJM-5	8,540	21,050	+1,320 m	300 m	301.6 m	29.1.1986 -15.2.1986

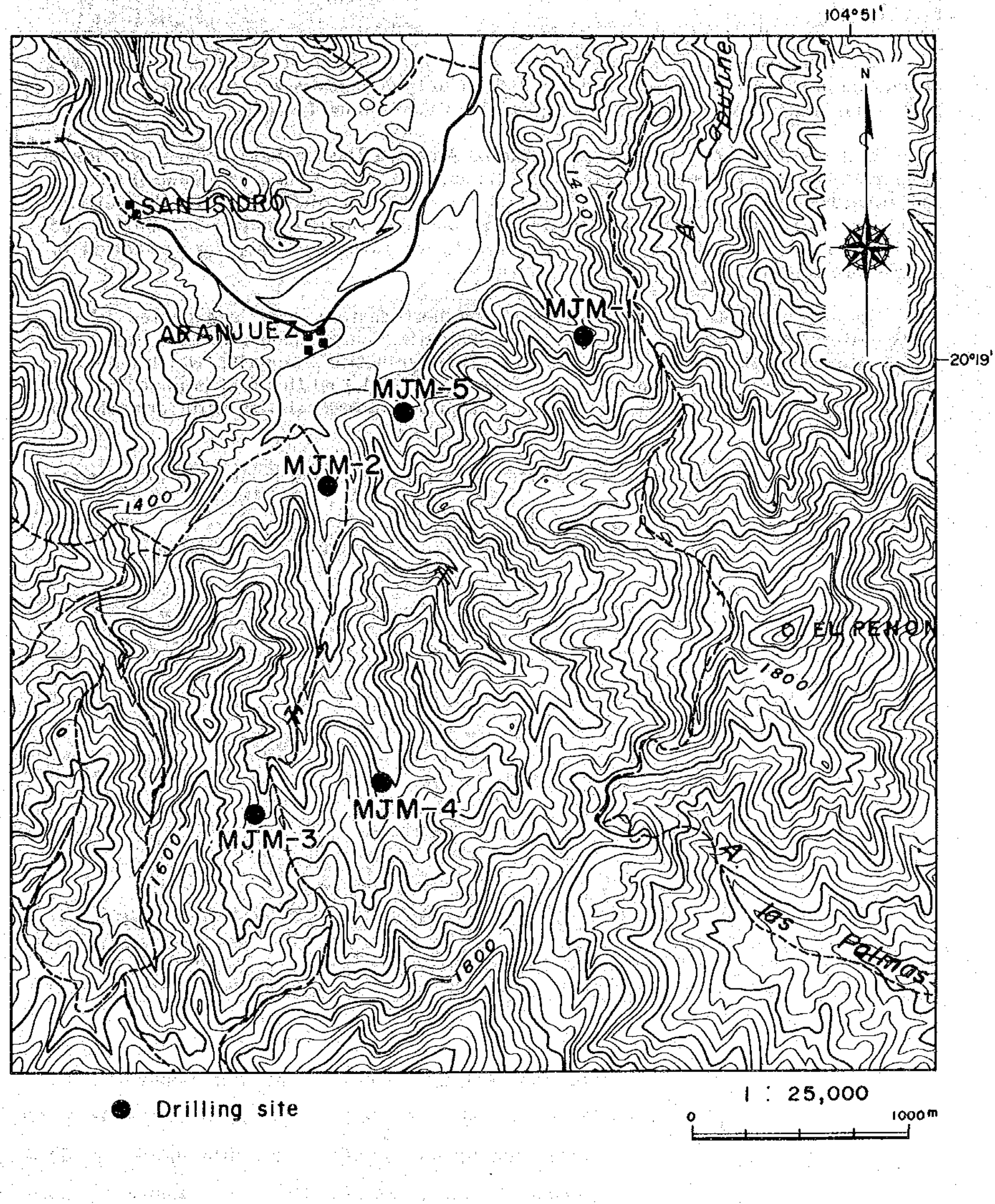


Fig. II-19 Location Map of Drill Holes

7-2 Geology

A drilling survey, consisting of five holes, total depth of 1,369.70 meters, was conducted in this year. Even no significant Kuroko type deposits were encountered some new valuable information for Kuroko exploration was obtained from it.

As a result of the drilling survey in the La America-Descubridora area, it was made clear that two areas, the northeastern area (includes MJM-1, MJM-2 and MJM-5) and the southwestern area (includes MJM-3 and MJM-4), are in different volcanic activity environments. MJM-1 is situated far from a volcanic eruption center, but MJM-2 and MJM-5 are in paleo-basin of submarine, which are favourable site for formation of Kuroko ore deposits.

No extension of the volcanics from the northeastern area is expected in the southwestern area, and no other evidence indicating paleo-basin structure was seen there. However, black shale disseminated by fine pyrrhotite and pyrite, which indicates reduction environment in submarine, was found in MJM-4, and this fact is important for sulphide precipitation, in regard to volcanic eruption centers relating with formation of Kuroko ores.

No dacite lava was found in this zone, therefore this zone is situated in a remote area from such centers.

Geological map and sections are shown in Fig. II-20 ~ Fig. II-26.

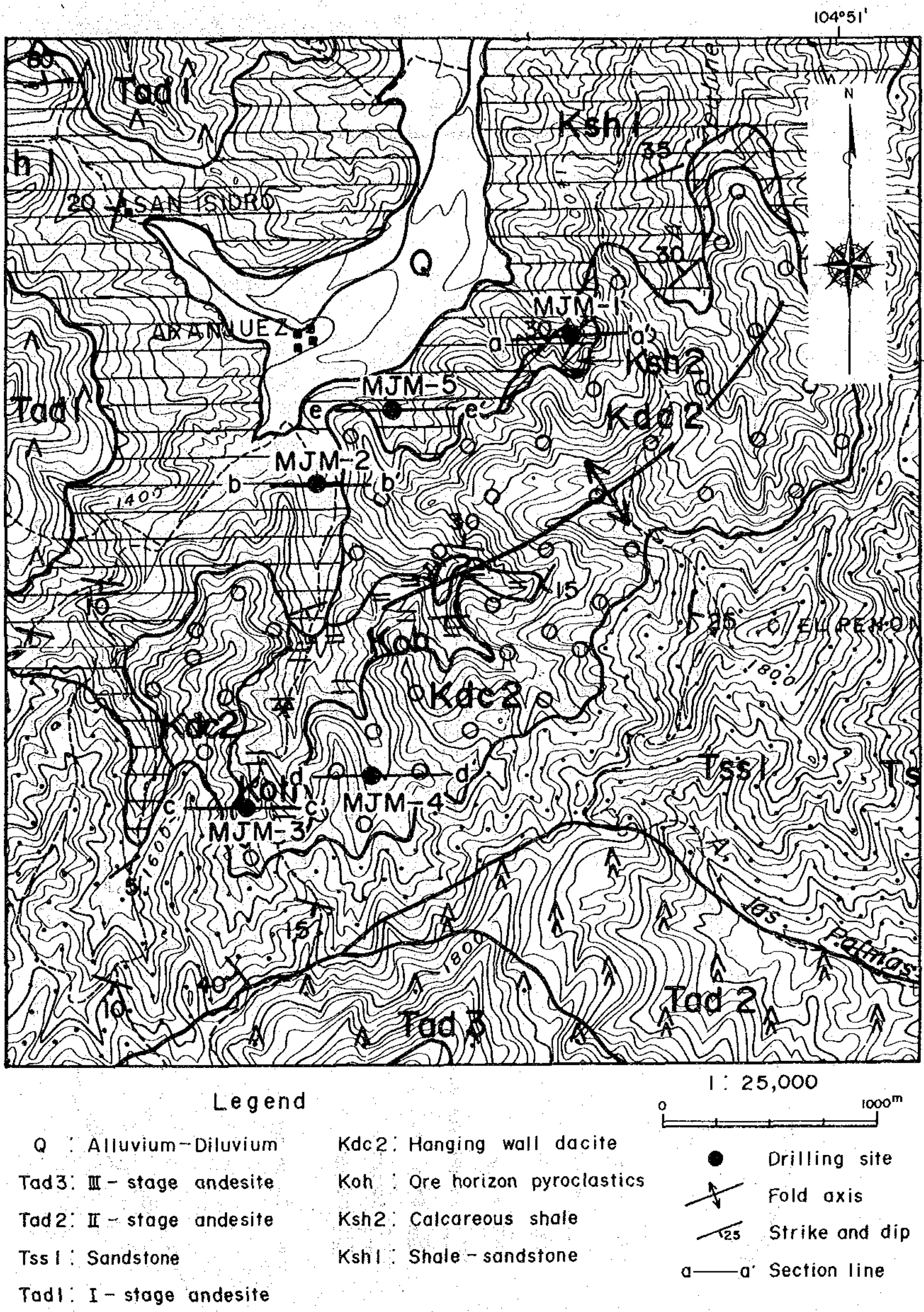


Fig. II-20 Geological Map around Drilling Sites

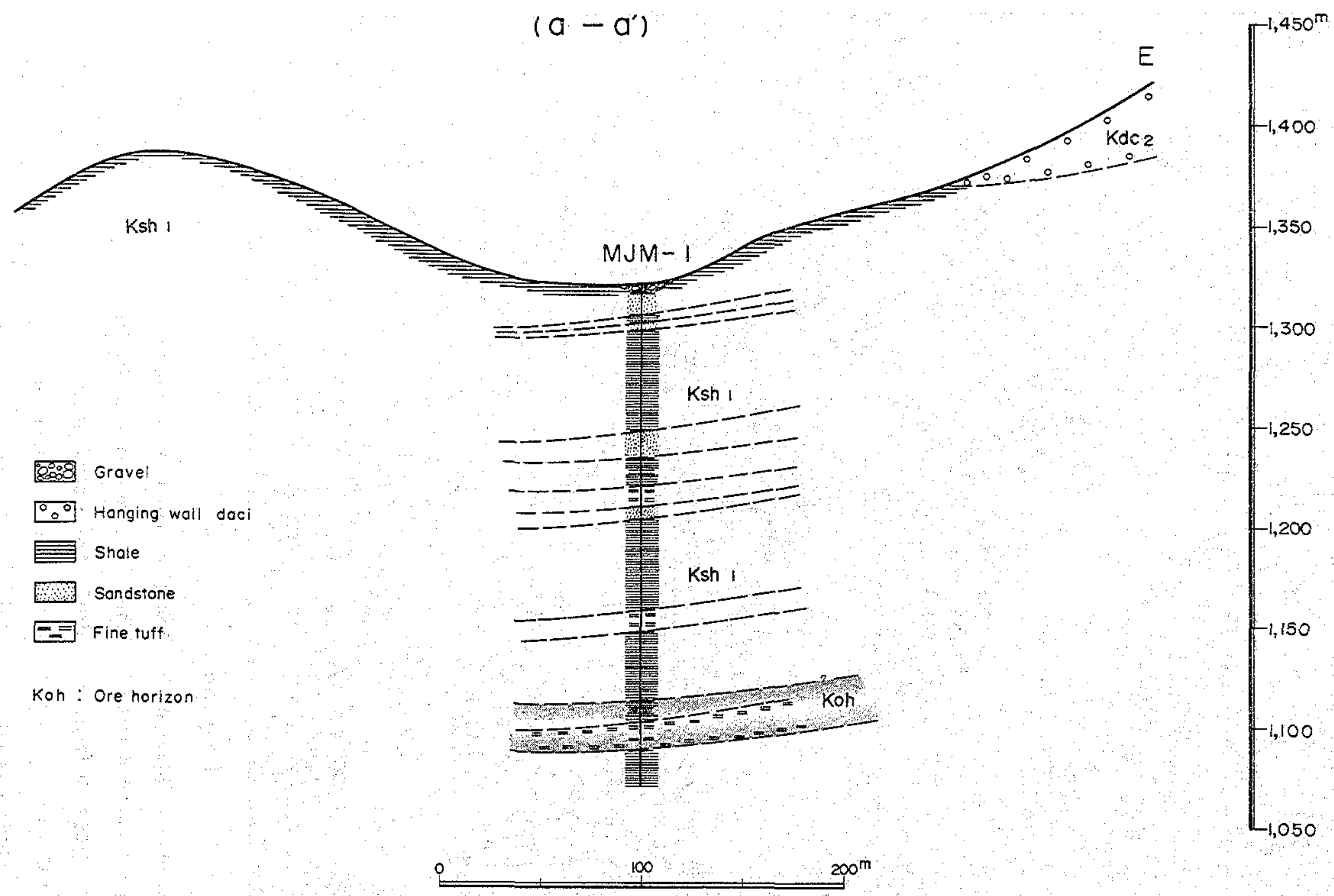


Fig. II-21 Geological Section of Drill Hole (MJM-1)

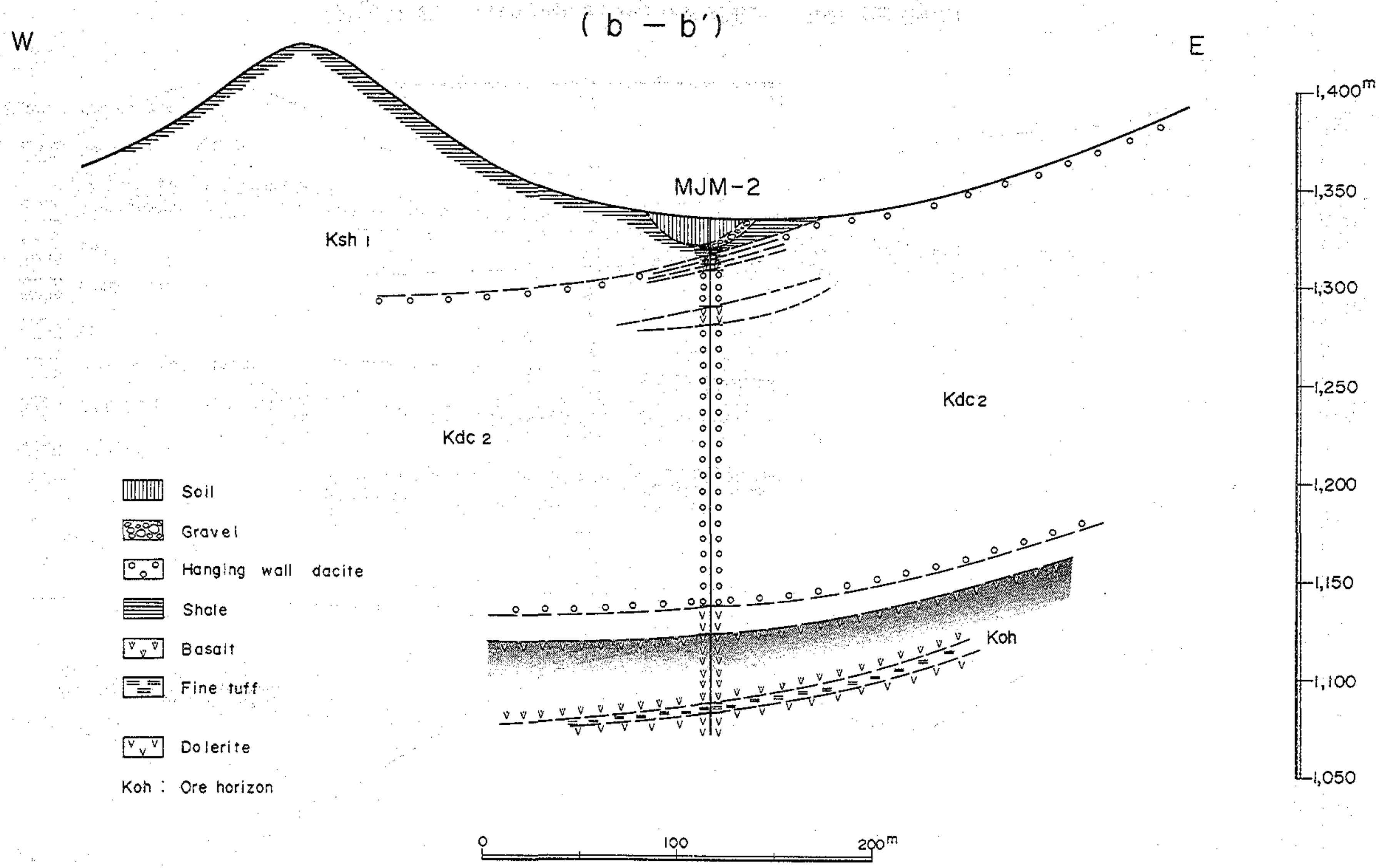


Fig. II-22 Geological Section of Drill Hole (MJM-2)

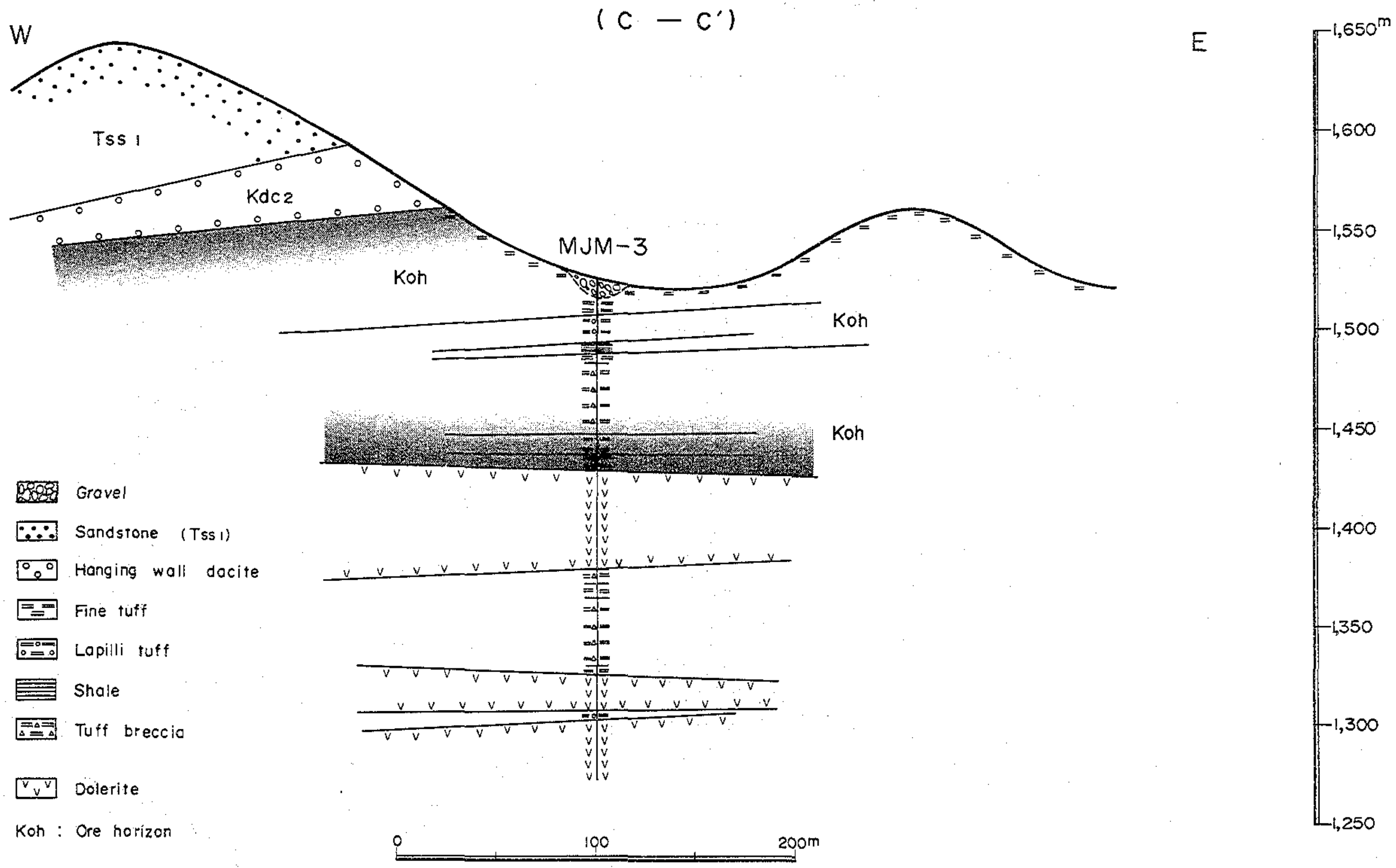


Fig. II-23 Geological Section of Drill Hole (MJM-3)

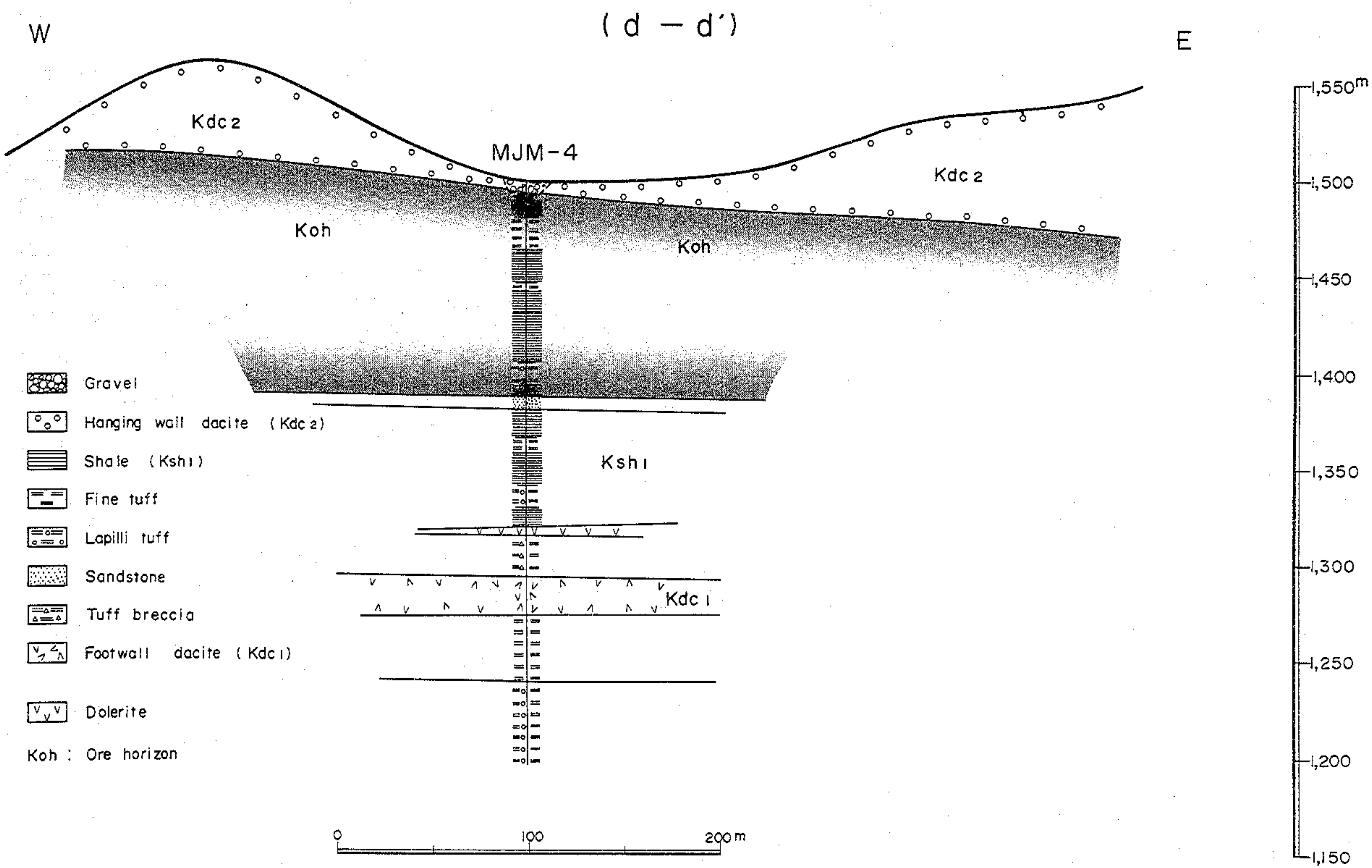


Fig. II-24 Geological Section of Drill Hole (MJM-4)

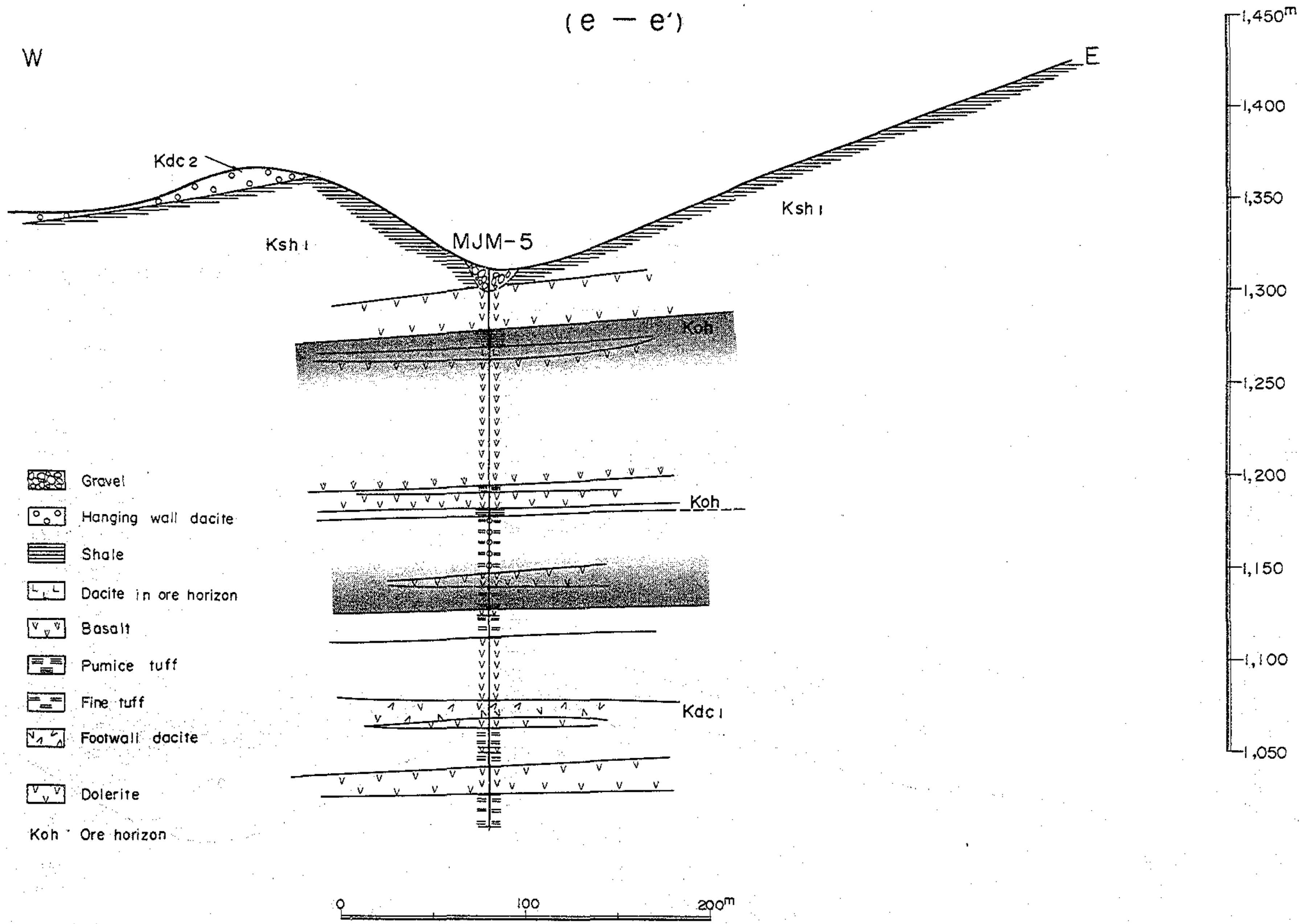


Fig. II-25 Geological Section of Drill Hole (MJM-5)

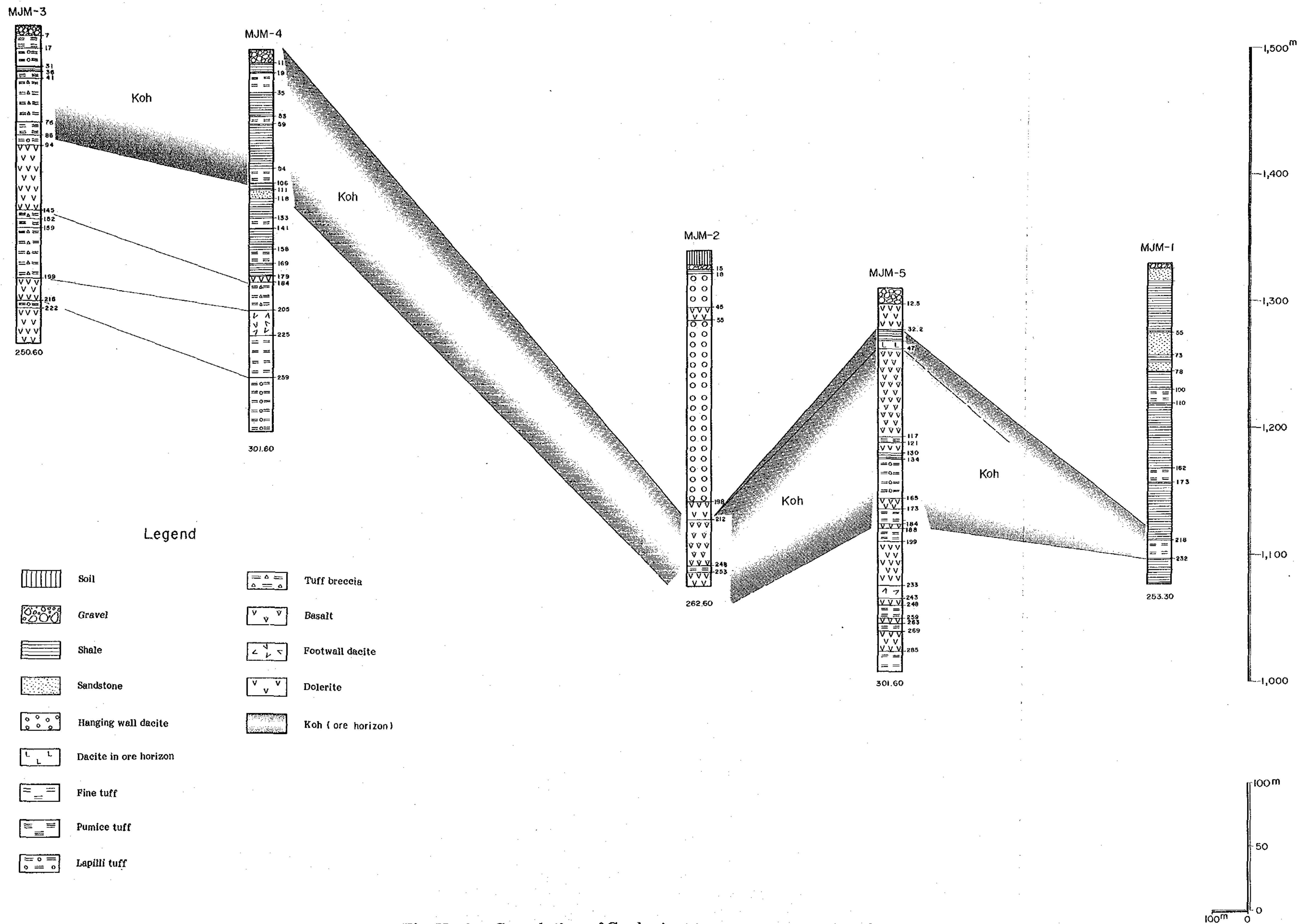


Fig. II-26 Correlation of Geological Succession of Each Hole

7-3 Mineralized Zone

As a result of the drilling survey in the La America-Descubridora area, no significant Kuroko mineralization was encountered. From the geological point of view, it is considered that MJM-2 and MJM-5 are situated in paleo-basin of submarine, which are favourable site for formation of Kuroko ores.

As the ore horizon strongly disseminated by fine pyrite are found in MJM-2 and MJM-5, it is judged that extension zones of the ore horizon of these holes are favorable for Kuroko ores.

Clay minerals (chlorite, sericite, etc.) as products of hydrothermal alteration are observed in the all holes, fluctuating their amounts. It suggests that the whole area is subjected to "pervasive" type alteration. No significant alteration zone was found in the holes.

As a conclusion, area around MJM-2 and MJM-5 are favourable for further exploration activity.

7-4 Comparison Between Drilling Survey and Geophysical Survey Results

Three holes, MJM-1,. MJM-2 and MJM-3, out of five holes drilled in La America-Descubridora area were selected based on the result of the geophysical survey (CSAMT method). Fig. II-27 shows correlation between results of drilling and geophysical survey.

Followings are the summary of the results.

- Black shale dominant parts show about 300 Ω·m, unless accompanied by sheared or clay zone. In case accompanied by them, they show lower than 100 Ω·m.
- Volcanic rocks mainly composed by pyroclastics show 700 to 800 Ω·m, unless accompanied by sheared or clay zones.
- These values of resistivity are generally lower than those determined in laboratory test. This fact is noticeable in CSAMT surveys.

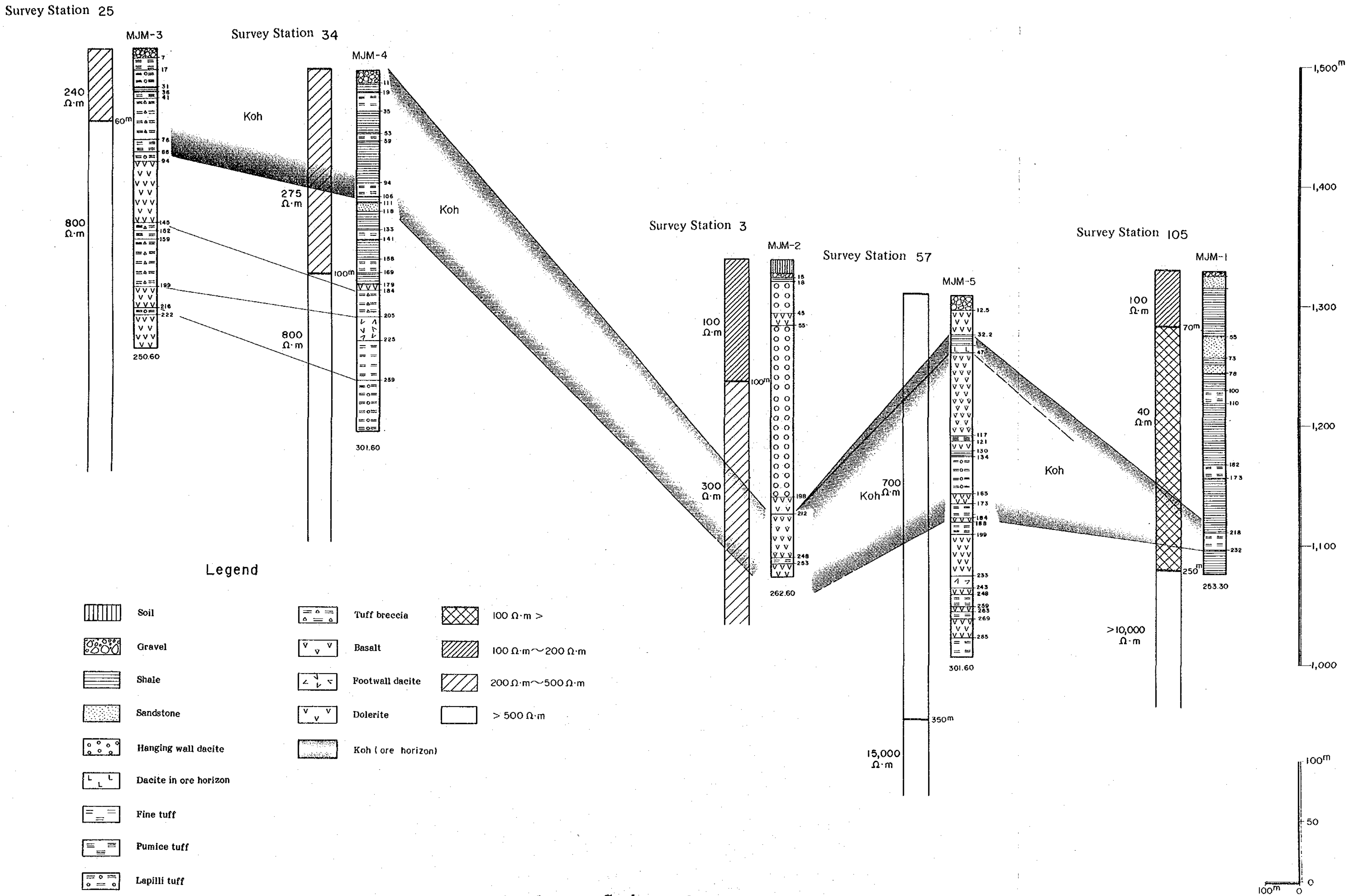


Fig. II-27 Comparison between Geology and Resistivity Distribution of Each Hole

PART III WESTERN AREA

CHAPTER 1 GEOLOGY

1-1 Outline of Gelogy

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

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

The Cretaceous System is distributed in areas around the Cuale mine in the northwestern area and the Amaltea mine in the central east area, and El Bramador to La Concha. The main constituents are dacitic lavas (Kdc1-a, -b) and pyroclastics (Koh-a, -b, Kdc-sh), and black shale (Kshl). The dacite lava (Kdc1-a, -b) shows pale brown to pale green, suffered slightly alteration, and seated as foot walls of the Kuroko ore deposits. The ore deposits of the Cuale, Amaltea, and El Bramador mines in the area are hosted in the ore horizon (Koh-b). The hanging wall dacitic pyroclastics (Kdc-sh) also overlie the Cuale and El Bramador deposits, therefore it is suggested that Kuroko type ores are very closely associated with such felsic volcanic activities.

The black shale (Kshl) shows locally slaty cleavages, but generally are of several centimeters-thick massive beds. Thin layers of basalt lavas and pyroclastics (Kbs1-a) are intercalated in the black shale overlying Kuroko ores (La Crucecita, the eastern survey area). No significant depositional intermission has been noted in the Cretaceous System. The system unconformably overlies the basement metamorphic rocks.

The Tertiary System is extensively distributed in the eastern area. The main constitutents are andesites (Tad1-4) with minor sedimentary rocks (Tss1) and dacites (Tdc1). Ages of these volcanic activities are not clear, because no volcano-stratigraphic and age determination data are available. Even the activities were frequently intermitted, no big sign has been noted. The Tertiary System unconformably overlies the Cretaceous System.

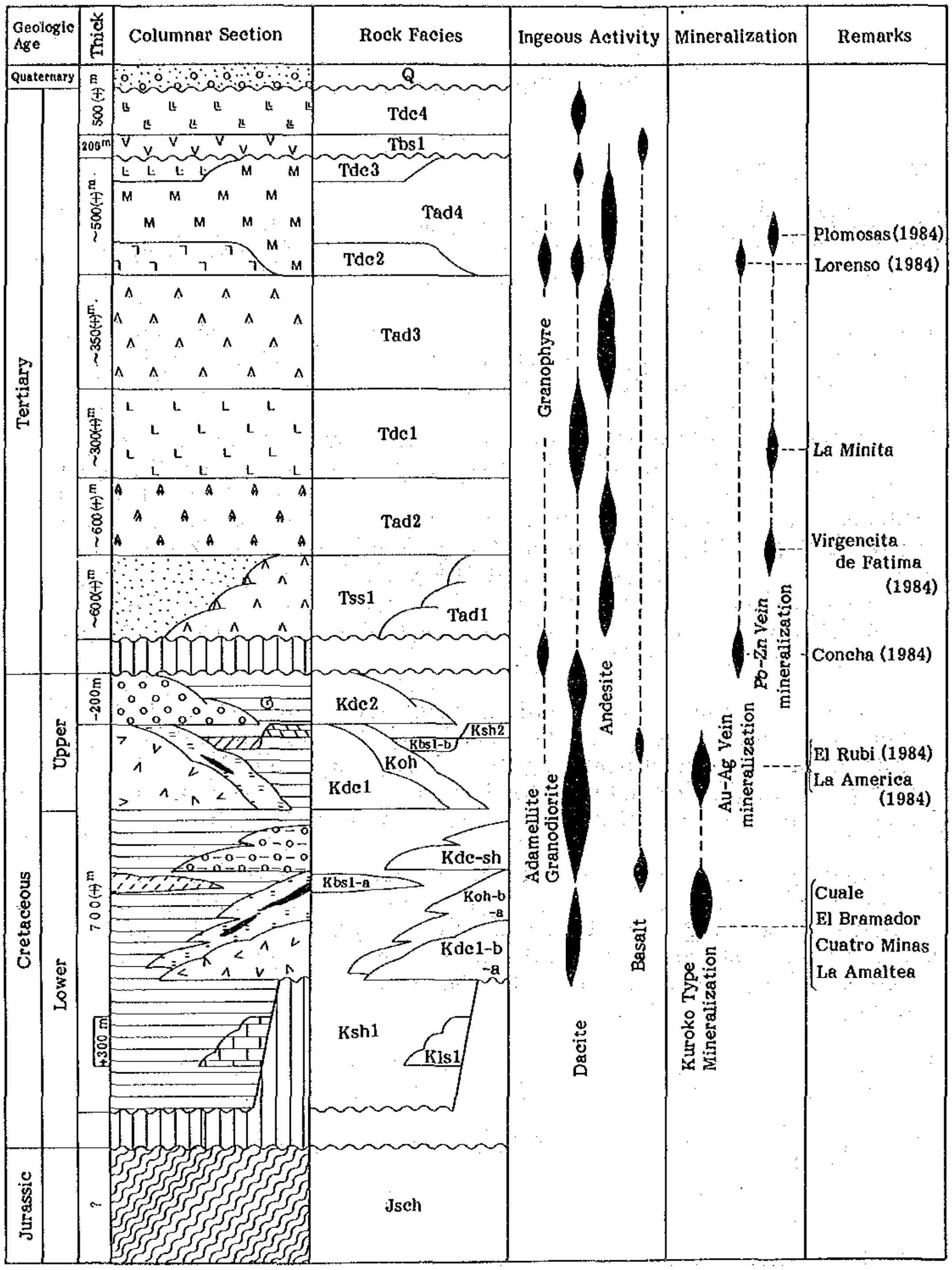
The Quaternary System is distributed in flat area along the Cuale River etc. Unconsolidated gravel layer are main constituents of the system.

The intrusives are granodiorite (Gd), granophyre (Gph), andesite (Ad), and dacite (Dc).

1-2 Stratigraphy

1-2-1 Jurassic System

No stratigraphic succession has been confirmed yet on the metamorphic rocks in the area. However they are similar to rocks defined as Jurassic (Berrocal & Mendoza, 1985). Fig. III-1 and Fig. III-2 show generalized geological columnar section of the survey area.



Abbreviation

(Jurassic)
- Jsch: Metamorphic rocks

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

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

(Quaternary)
- Q: Alluvium-Diluvium

- Ġ: Nannoplankton

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

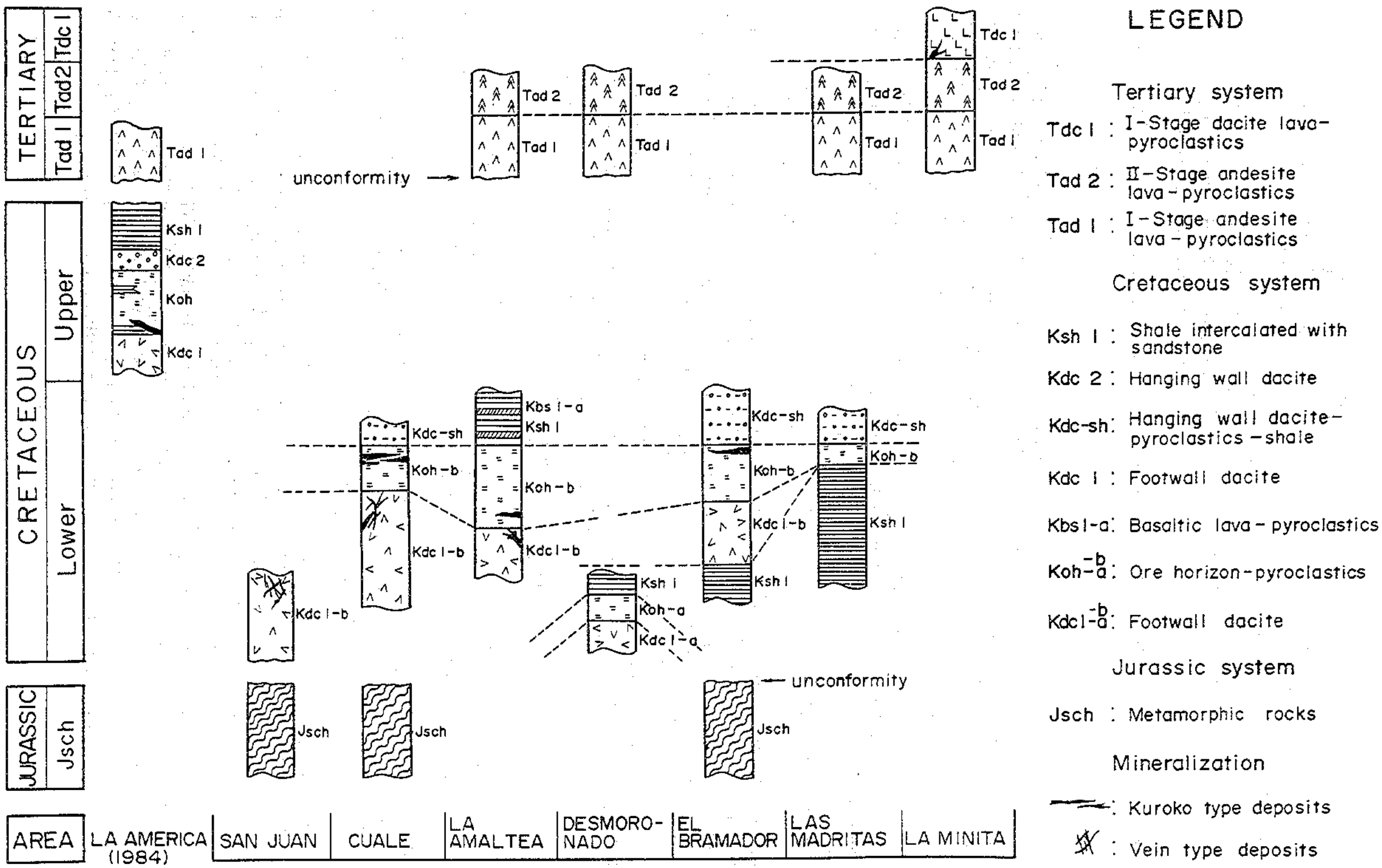


Fig. III-2 Correlation of Geological Columns of Each Area

(1) Metamorphic Rocks (Jsch)

The metamorphic rocks are of oldest in the area.

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

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

The system mainly consists of pelitic schist, partly with intercalations of psammitic, sericite, and chlorite schists. Pelitic and psammitic schists are generally black, containinng segregating quartz and quartz veinlets, and commonly show microfolding texture. Under the microscope, quartz, sericite, feldspar, and chlorite are observed. Degrees of recrystallization are generally low. However, sericite and chlorite schist commonly show well developed schistosity.

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

1-2-2 Cretaceous System

Judging from the nannoplankton determination study, it is possible to say that the Cretaceous System in the Eastern Area is of Campanian to Maastrichtian stages (Later Cretaceous Period, 78 to 65 m.y.), on the other hand as mentioned later the Cretaceous System in Western Area are is of Early Cretaceous Period.

Rocks of the system are shale-sandstone (Kshl), footwall dacite lava (Kdcl-a, -b), dacitic pyroclastics of the ore horizon (Koh-a, -b), hanging wall dacite lava and pyroclastics (Kdc-sh), and basalt lava and pyroclastics (Kbsl-a, -b).

(1) Shale-Sandstone Formation (Kshl)

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

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

The formation was folded showing general dips of 30° to 60°, but locally disturbed by multi-stage micro-foldings and some shearings. It is assumed that the true thickness of the formation is significantly thinner than its aparent one as seen in examples of other Mesozoic formations, might be 700 meters thick.

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

Fossils are poor in the formation, but some radiolarias are observed in the sample from El Bramador. This species is common one in Early Cretaceous Period.

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

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

The activity is separated into two stages, older one (Kdc1-a) located in an area from the El Coyulito village to the Trementina valley, and younger one (Kdc1-b) located in areas around the La Concha village, the La Amaltea Mine, the Cuale Mine, and the Blanco valley in the northwestern area.

Even the rocks are intercalated in the shale-sandstone formation (Ksh1), the ore horizon pyroclastics (Koh-a, -b) overlie the rocks as a succeeding volcanic activity. The shale-sandstone formation underlie the rocks, and unconformably overlie the basement Jurassic System (Jsch) in the Cuale and La Concha area.

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

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

The lavas are generally light gray to pale green, aphyric, compact and hard, but in some parts weakly brecciated or semi-massive. Under the microscope, phenocrysts of quartz and plagioclase are occasionally observed, and the groundmass which used to be glassy are strongly silicified resulting unclear texture.

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

The rocks are very important for exploration purposes because of hosting Kuroko ores. The rocks are closely related to the above mentioned footwall dacite lavas, and overlies them. The rocks accompanied by Kdc1-a and Kdc1-b are named as Koh-a and Koh-b respectively, but both are of similar lithology and rock facies.

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

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

The rocks are pale green to gray, and mainly consist of fine tuff and lapilli tuff, showing several meters thick alternation with shale beds. Under the microscope, various alteration minerals such as quartz, carbonate minerals (calcite), chlorite, epidote, sericite, etc. are observed.

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

The rocks are distributed in the area closely relating to the location of the Kuroko type ores around El Rubi deposits in the Eastern Area. In the Western Area, they are distributed around La Crucecita where the La Amaltea deposit is in the ore horizon dacitic pyroclastics (Kooh-b).

The rocks are lenticularly intercalated in the shale-sandstone formation (Ksh1), and their maximum thickness is about 50 meters.

The rocks mainly cosnsit of dark green to green basaltic lavas and pyroclastics such as fine tuff, generally showing fine grained and compact. The lavas are generally brecciated, but in some parts transforming to massive facies and to doleritic ones.

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

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

The rocks distributed closely related to Kuroko ores. Therefore it is very important to clarify their distribution for exploration purpose.

The rocks are distributed in the Cuale and El Bramador area in the survey area, where Kuroko ores underlie. Also these are distributed only in the La America - Descubridora and the El Rubi area in the Eastern Area, where Kuroko ores underlie.

The rocks are intercalated in the shale-sandstone formation (Ksh1), and their maximum thickness is estimated as 500 meters.

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

Fossils are generally poor in the shale, but nannoplankton is found in the sample from the El Bramador area, and radiolarias in the sample from the La Concha area.

These species are common in Early Cretaceous.

1-2-3 Tertiary System

In the Eastern Area, it is clarified that the shale-sandstone formation (Kshl) contains nannonplanktons which belong to species of Late Cretaceous Period, and is unconformably overlain by the I-stage andesites (Tad1) and the sandstone formation (Tss1), together with the hanging wall dacite and dacitic pyroclastics (Kdc-sh). Therefore it is presumed that the I-stage andesite (Tad1) and the sandstone formation (Tss1) are probably of Tertiary Period. This assumption consistents with the general volcanic activity history of the Sierra Madre Occidental and Eje Neovolcanico. The Tertiary System mainly consits of volcanic piles of andesites and dacites. The succession of the piles from the bottom to the top is as follows:; I-stage andesites (Tad1), sandstone formmation (Tss1), II-stage andesites (Tad2), I-stage dacites (Tdc1), III-stage andesites (Tad3), and IV-stage andesites (Tad4).

(1) I-Stage Andesites (Tad1)

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

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

The rocks mainly consist of lavas and pyroclastics such as lapilli tuff. The lavas are the most dominant constituent of the rocks, showing dark green to green, brecciated or compact. Under the microscope, porphyritic texture is distinctly observed, and large idiomorphic plagioclase (shorter than 7 mm) and idiomorphic to hypidiomorphic augite (shorter than 5 mm) are observed as well as hypidiomorphic iron minerals (magnetite?) and minor amount of hypersthene (altered to chlorite). The groundmass shows felty texture, mainly consisting of brown glass and very fine grained plagioclase with minor amount of pyroxene and iron minerals (magnetite?)

The lapilli tuff is green, intercalated in the lavas, containing dark green to brown andesite fragments, and subjected to alteration stronger than lavas.

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

(2) Sandstone-Conglomerate Formation (Tss1)

The formation is the only one of sedimentary in the Tertiary System.

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

Thickness of the formation is about 200 meters in the Western Area, on the contrary the maximum about 700 meters in the Eastern Area.

The formation mainly consists of sandstone and conglomerate,, with thin black shale beds and andesite lava flows. The sandstone is gray and massive to layered wacke-like appearent, and well sorted. The conglomerate is gray to brown, and its fragments consist of angular to subangular andesite, dacite, mudstone, basalt, and other silicified rocks.

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

(3) II-Stage Adnesites (Tad2)

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

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

The rocks mainly consist of lavas and pyroclastics such as lapilli tuff and tuff breccia. The lavas are dark green to dark gray, compact and hard, mainly of medium grained andesite. The lapilli tuff and tuff breccia are dark green to reddish purple, containing mainly andesitic fragments as essential one with minor amount of dacitic fragments as accidental one, appearing subangular.

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

(4) I-Stage Dacites (Tdc1)

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

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

The rocks mainly consist of lavas and pyroclastics such as fine tuff and lapilli tuff. The lavas are pale gray to pale brown, showing non-porphyritic and porphyritic textures, and generally massive. They generally do not show clear auto-brecciated texture, presumably because of strong alteration. Lapilli tuff and tuff breccia are pale brown to pale gray, and their fragments are of dacite, rhyolite, quartz porphyry, etc.

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

(5) III-Stage Andesites (Tad3)

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

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

Thickness of the rocks is about 350 meters in the area, but it was estimated as the maximum about 850 meters in the Eastern Area.

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

The rocks directly overlie the basement granodiorite (Gd) and I-stage andesite (Tad1).

(6) IV-Stage Andesite (Tad4)

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

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

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

The lapilli tuff and tuff breccia are not welded, showing brown to reddish purple, and their fragments consist of andesitic pebbles and poorly vesculated pumices.

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

1-2-4 Quaternary System

The Quaternary System is distributed in flat areas along the Cuale river and the San Jose river. Unconsolidated gravel is main constituents of the system, and they are usually stratiformed.

1-2-5 Intrusives

The intrusivew rocks are granodiorite (Gd), granophyre (Gph), andesite (Ad), and dacite (Dc).

(1) Granodiorite (Gd)

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

The rock is gray, compact, hard, and coarse to fine grained granodiorite. Main parts of the rock show equigranular texture. Its principal constituent minerals are quartz, plagioclase, potash-feldspar, biotite, amphibole, and iron minerals (magnetite).

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

(2) Granophyre (Gph)

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

The rock is generally pale brown to gray, compact and hard, appearing 5 to 6 millimeters long columnar plagioclase phenocrysts.

The rock intruded in the II-stage andesites (Tad2) in the areas around the Derramado hill and the Camacho river, but no clear evidence for the relation between the rock and the later stage rocks than the I-stage dacites (Tdc1) is availabe. It is suggested that the rock is of shallow intrusion because facies change is very common.

(3) Andesites (Ad)

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

The rocks are dark green to dark brown, and hard, having giantic plagioclase phenocrysts resembling to the I-stage andesites (Tad1).

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

(4) Dacite (Dc)

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

The rock is generally gray, compact and massive, containing two to three millimeters long quartz crystals, showing porphyritic texture.

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

CHAPTER 2 GEOLOGICAL STRUCTURE

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

Jurassic System

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

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

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

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

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

Cretaceous System

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

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

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

Synclinal and anticlinal axes having an about 600 meters half wave length is in the San Jeronimo valley, plunging to the southeast. Ore horizons in the El Bramador and Cuale-Amaltea area are possibly correlated with a same stratigraphic position, locating in both wings of a anticlinal structure, being underlain by the dacites (Kdc1-a).

Teritary

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

Folding structure is gentle, and folding axes found in the Eastern Area tend to disappear in the area.

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

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

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

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

CHAPTER 3 MINERALIZED ZONE

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

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

(a) Cuale area

(b) El Bramador area

(c) Amaltea area

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

List of mineralized zones in the Western Area is shown in Table III-1.

Table III-1 List of Mineralized Zones

(1)

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

(2)

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

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

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

No investigation on ore minerals has been made for the Kuroko type ore existing in the Western Area. As microscopic observation was conducted for the ore samples collected during this survey, the Kuroko type ore in the survey area were compared with Japanese Cenozic Kuroko deposits or Mesozoic Kuroko type deposits in combination with other geological modes of occurrence and in relation to the genesis of the deposits in the survey area (Table III-2)

Related Igneous Rock:

In Cuale, El Bramador and Amaltea deposits, galena and sphalerite are principal component minerals. As is usual with the related volcanic rocks of this kind of Kuroko type deposits, acidic calc-alkaline rock series are anticipated (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.

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

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

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

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

Near the areas where the Kuroko type ores exists, granophyre, which is supposed to be the product of the volcanoplutonic activity, exists, and this fact resembles the existence of Ohtaki granodiorite (9.0 m.y., 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 ores exist, seems to be noticed in this survey area.

Environment of Ore Formation

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

Kind of Ore Minerals

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

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

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 more % (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 referacted color reflects the amount of solid-soluted iron in sphalerite, the sphalerite in this area is supposed to include the amount of FeS similar to that of sphalerite produced in the Taro deposit, which was estimated by Yamaoka (1983) to be 3 - 21 mole %.

Zonal Texture of Sphalerite

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

"Chalcopyrite Disease" in Sphalerite

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

Existence of "Telescoped Ore"

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

CHAPTER 4 SURVEY ON ALTERATION ZONE BY X-RAY DIFFRACTOMETRICAL STUDY

It is well known that some alteration mineral zoning exists in country rocks of Kuroko type ore deposits, associating with their genesis. Zoning of alteration minerals, some cases, extends beyond hanging wall rocks (Utada et al., 1981, 1983), therefore, it is sometimes possible to evaluate potential for Kuroko type ore deposits applying such fact. In this survey, the dacite lavas and dacite pyroclastics (Kdc1-a, Kdc1-b, etc.) which are closely related to the Kuroko type mineralization in the area are investigated from the alterational point of the view.

4-1 Alteration Zone

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

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

Note: Minerals in blankets are of small amount.

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

Alteration patterns in El Bramador area, La Amaltea-La Crucecita area and Cuale area were investigated applying the above mentioned zoning.

El Bramador Area

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

La Amaltea - La Crucecita Area

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

Cuale Area

Most of the ore deposits in Cuale area are located in Zone I and II, therefore, it is suggested that Kuroko ores are closely related to intensity of alteration.

4-2 Residual Content of Plagioclase

Plagioclase is the most soluble mineral in due courses of hydrothermal alteration, therefore to determine residual content of plagioclase is a useful tool for alteration survey. Fig III-4 shows the result of such survey in the El Bramador area. Samples detected some remained plagioclase by a X-ray determination survey are correlated with the V zone of the alteration zoning.

Ore deposits in the El Bramador are located in a zone, where plagioclase entirely disappeared, and no ore deposit is located in a zone of remained plagioclase. It is indicated that areas involved ore deposits in the La Concha and El Bramador area are subjected to strong alteration. This fact is similar to Japanese Cenozoic Kuroko situation. Therefore it is said that perfect decomposition zones of plagioclase are potential areas for Kuroko ores. However some remained plagioclase is noted in outskirts zone of Kuroko ores in some cases. In any cases further detailed survey for that is required.

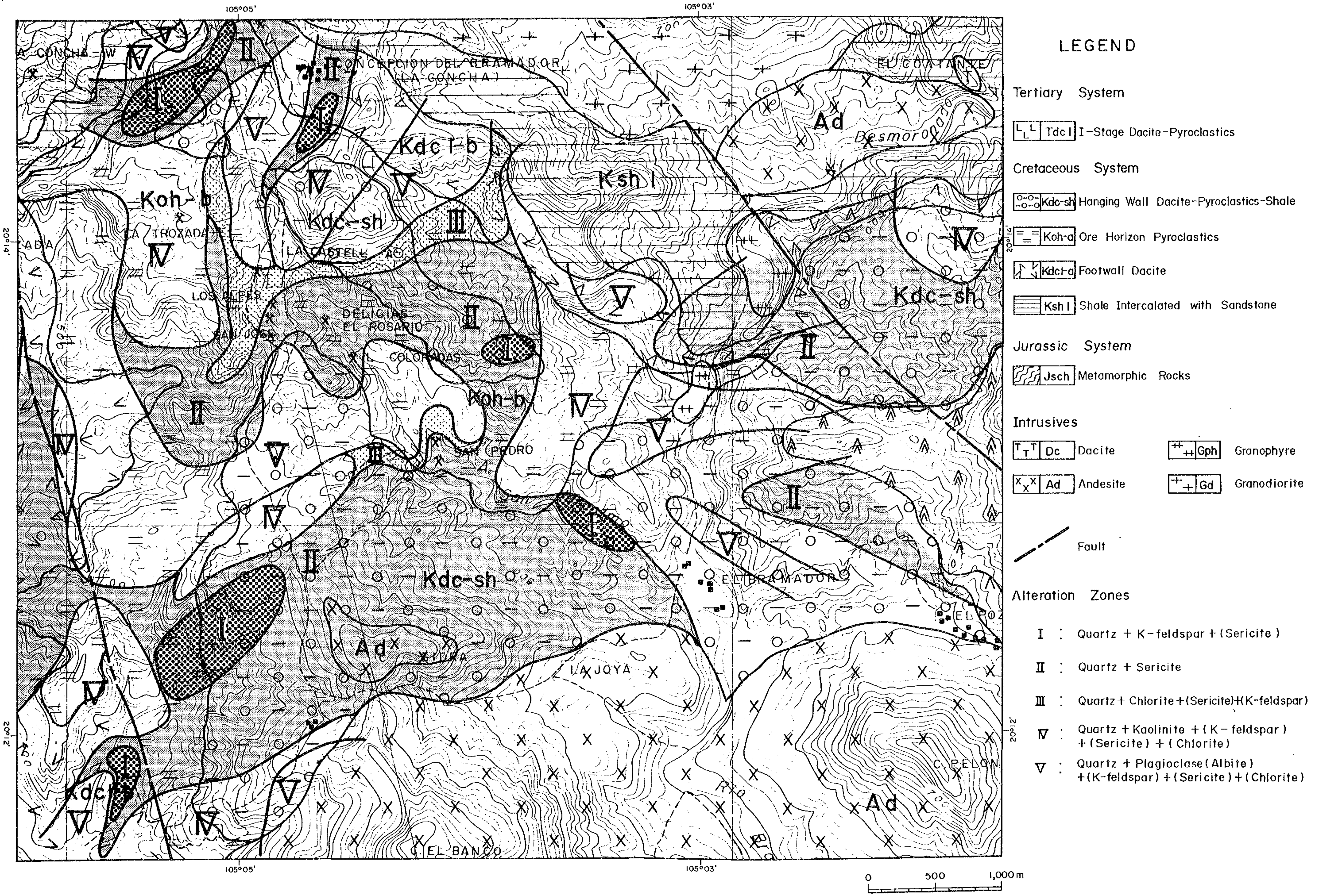


Fig. III-3 Distribution of Alteration Zones in El Bramador Area

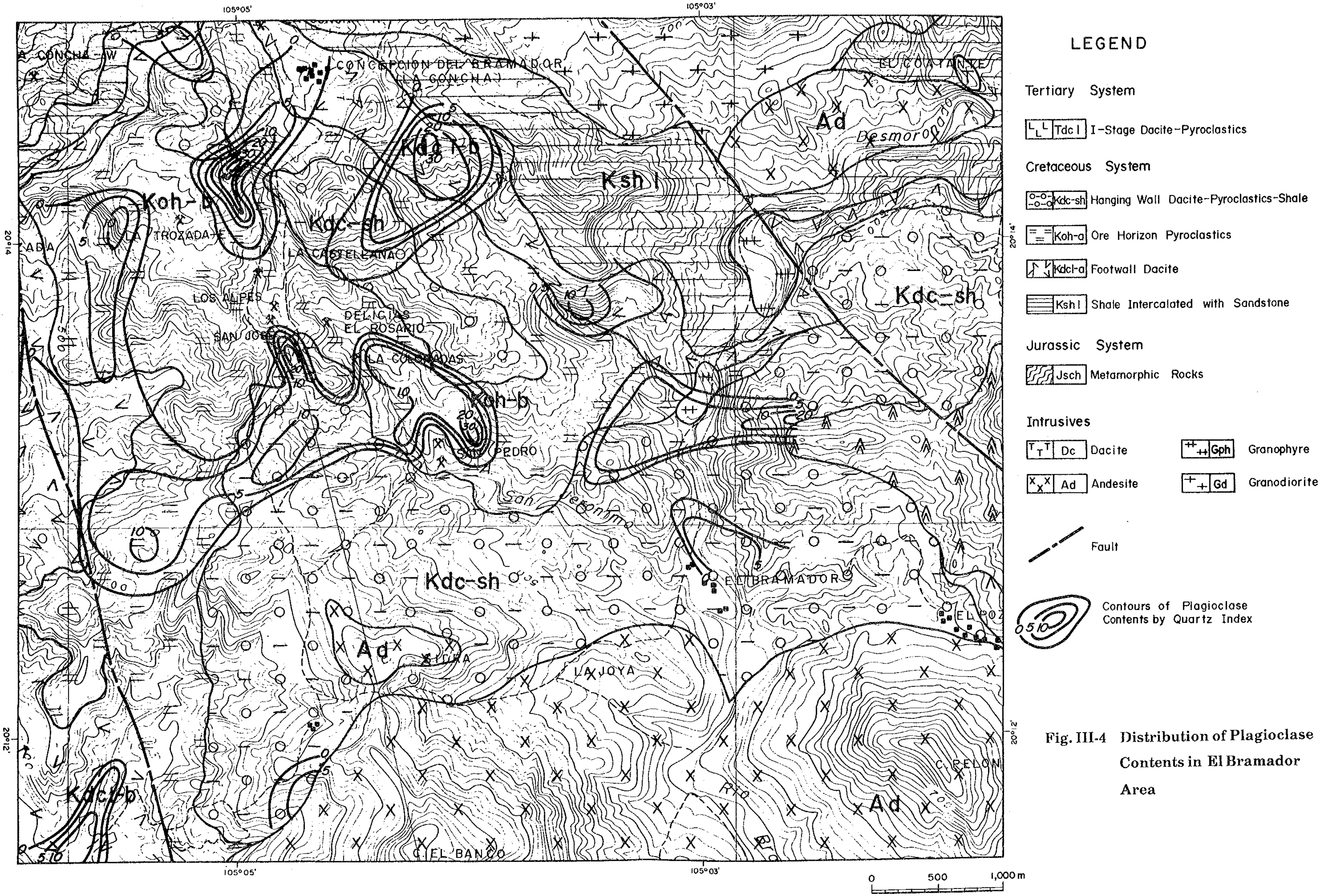


Fig. III-4 Distribution of Plagioclase Contents in El Bramador Area

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, 1,012 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.

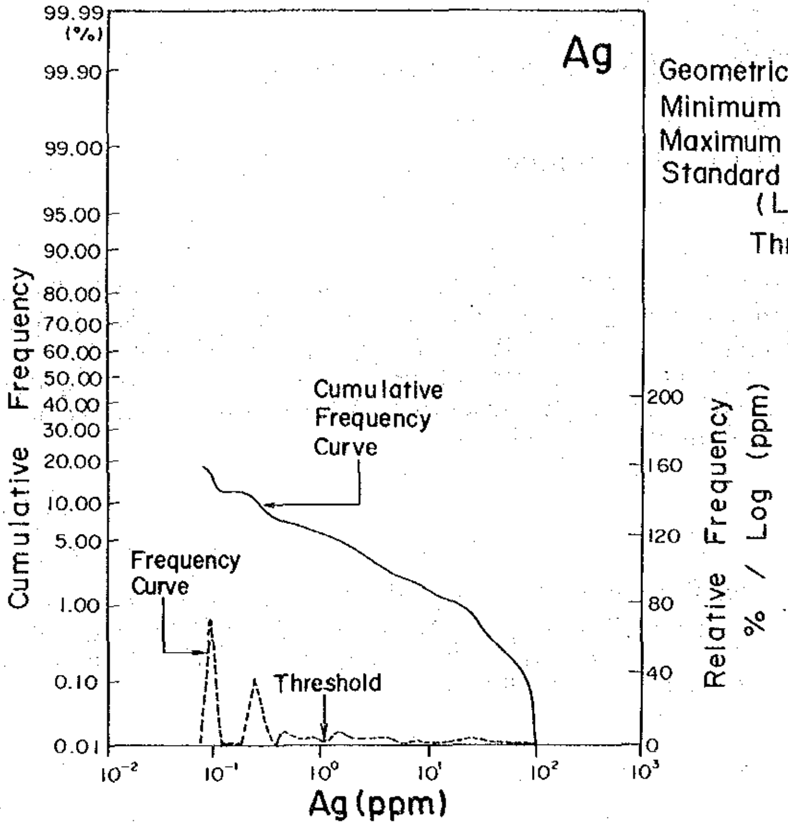
5-1-2 Indicators

Four elements (Ag, Cu, Pb, 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 (80%) for Ag, statistical treatment was carried out by assuming the values below the detection limit as 0.01 ppm.

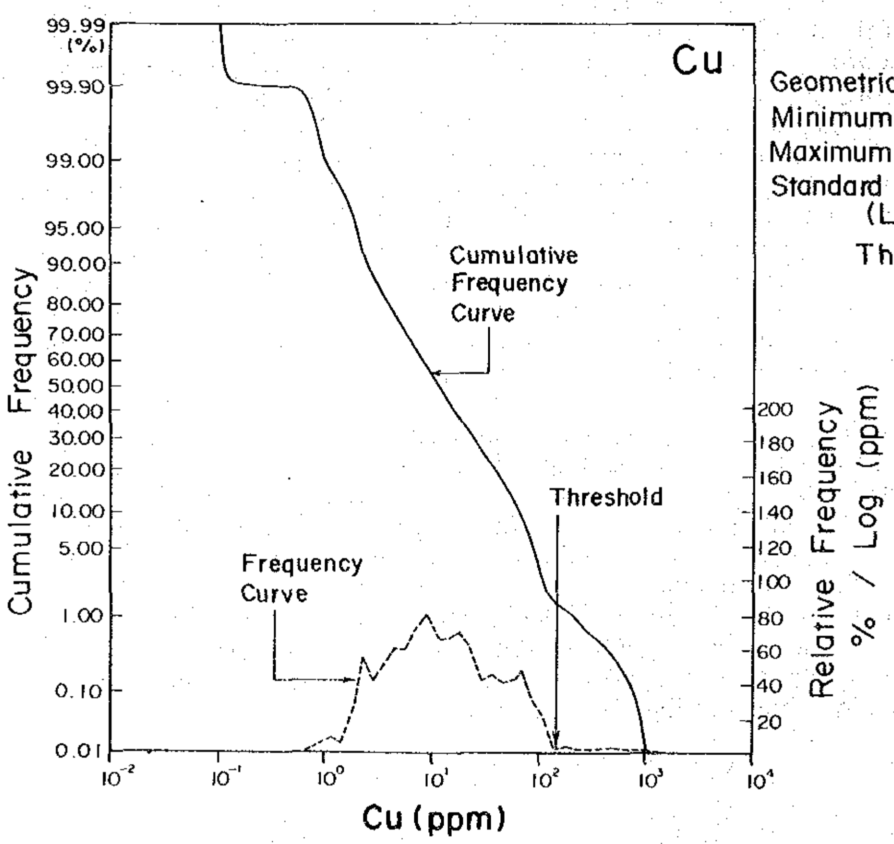
5-1-3 Statistical Treatment of Analytical Values

Single variable and multivariable analyses were carried out for the four elements (Ag, Cu, Pb and Zn) of 1,012 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. (1983), to solve the above problem, we used this method for determining the threshold values of single variables.

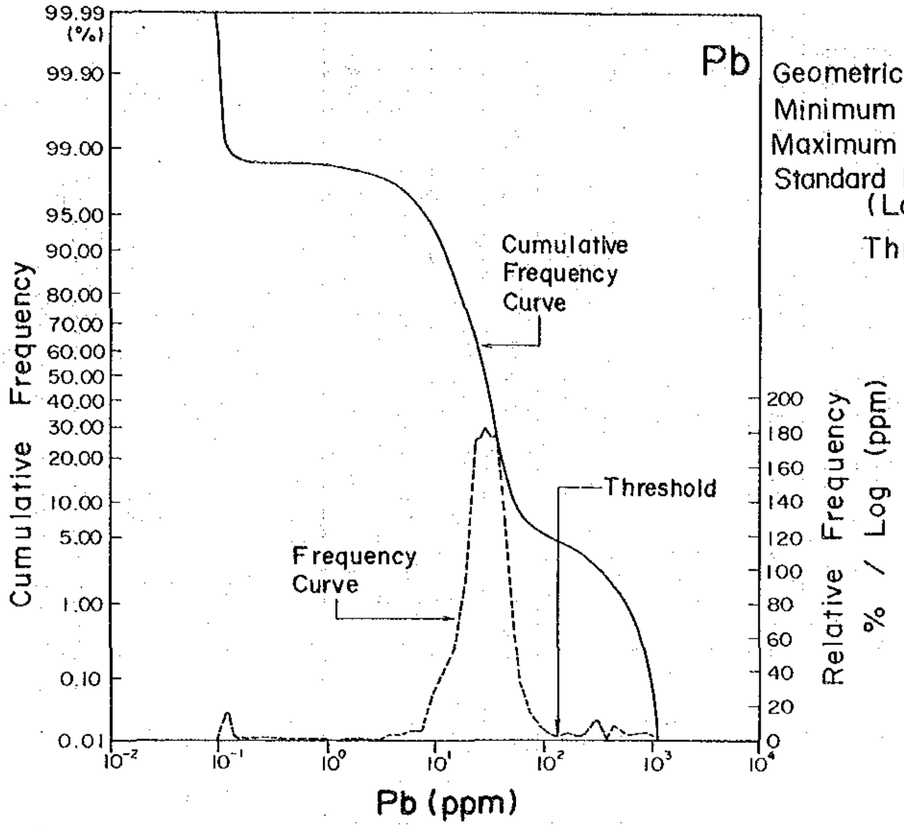


N	:	1012
Geometric Mean	:	0.02ppm
Minimum Value	:	<0.1 ppm
Maximum Value	:	86.2ppm
Standard Deviation (Log)	:	0.74
Threshold	:	1.2ppm

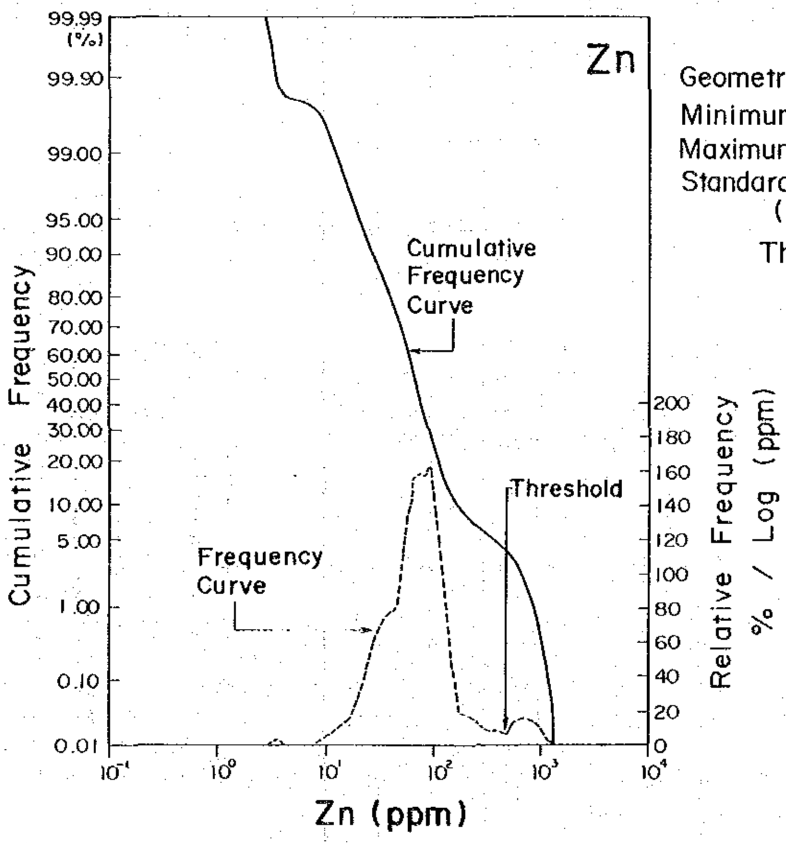


N	:	1012
Geometric Mean	:	12.3 ppm
Minimum Value	:	<0.1 ppm
Maximum Value	:	861.0ppm
Standard Deviation (Log)	:	0.52
Threshold	:	136ppm

Fig. III-5 Frequency and Cumulative Frequency Curve



N : 1012
Geometric Mean : 25.8ppm
Minimum Value : <0.1 ppm
Maximum Value : 936.0ppm
Standard Deviation (Log) : 0.53
Threshold : 147ppm



N : 1012
Geometric Mean : 68.9ppm
Minimum Value : 3.0ppm
Maximum Value : 979.2ppm
Standard Deviation (Log) : 0.35
Threshold : 440ppm

Table III-3 Statistical Parameters of Geochemical Indicators

Rock Code	Number of Samples	Geometric Mean(ppm)				Threshold(ppm)				Minium Value(ppm)				Maximum Value(ppm)				Standard Deviation(Log)			
		Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn	Ag	Cu	Pb	Zn
Whole Rocks	1,012	0.02	12.3	25.8	68.9	1.2	136	147	440	<0.1	<0.1	<0.1	3.0	86.2	861.0	936.0	979.2	0.74	0.53	0.53	0.35
0	197	0.02	16.4	27.7	87.0	—	—	—	—	<0.1	1.5	<0.1	9.9	53.8	419.2	747.8	941.0	0.77	0.32	0.37	0.37
1	142	0.07	20.8	46.2	111.9	—	—	—	—	<0.1	0.7	0.1	6.4	86.2	516.8	936.0	979.2	0.11	0.51	0.46	0.42
2	69	0.01	43.8	33.5	76.5	—	—	—	—	<0.1	4.6	13.3	24.9	0.3	121.1	68.2	122.4	0.31	0.34	0.15	0.13
3	4	0.02	40.0	31.6	62.4	—	—	—	—	<0.1	28.3	27.5	48.9	0.2	69.9	40.1	87.8	0.65	0.17	0.08	0.11
4	123	0.02	17.4	31.5	68.5	—	—	—	—	<0.1	1.6	<0.1	15.5	23.8	244.6	535.3	303.9	0.52	0.48	0.41	0.21
5	61	0.01	8.8	17.8	54.4	—	—	—	—	<0.1	<0.1	<0.1	15.5	0.2	77.4	61.2	107.8	0.38	0.57	0.87	0.20
6	1	—	—	—	—	—	—	—	—	—	—	—	—	1.6	31.2	309.8	293.7	—	—	—	—
7	367	0.02	6.1	17.9	50.5	—	—	—	—	<0.1	0.7	<0.1	3.0	71.8	861.0	754.0	948.0	0.61	0.44	0.60	0.35
8	48	0.02	15.3	34.0	79.3	—	—	—	—	<0.1	0.9	11.2	33.5	7.7	115.4	677.0	894.0	0.70	0.69	0.28	0.23
11	109	0.09	19.3	50.8	121.4	—	—	—	—	<0.1	2.3	9.5	6.4	86.2	516.8	936.0	979.2	0.12	0.52	0.49	0.44
12	33	0.03	26.8	33.7	85.5	—	—	—	—	<0.1	0.7	9.9	11.7	22.4	159.5	274.0	367.0	0.80	0.47	0.29	0.33

Rock Code

0 : Metamorphic Rocks (Jsch)
1 : Cretaceous System (=Rock Code 11+12)
2 : I−Stage Andesites (Tad_1)
3 : Sandstone (Tss_1)
4 : II−Stage Andesites (Tad_2)
5 : III〜IV−Stage Andesites (Tad_3, Tad_4)
6 : I−Stage Dacites (Tdc_1)
7 : Intrusives (Gd, Gph)
8 : Others (Q, Dc, etc.)
11 : Dacites in Cretaceous System ($Kdc_1{}^{-b}_{-a}$, Kdc−sh, Koh^{-b}_{-a})
12 : Shale (Sandstone) in Cretaceous System (Ksh_1)

The results are shown in Fig. III-5, and statistical parameters of geochemical indicators is shown in Table III-3.

5-1-4 Principal Component Analysis

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

Table III-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	2.38	0.60	0.49	0.47	0.47	0.57	0.75	0.72	0.73	0.87	6.41	-4.33
Z_2	0.67	0.16	-0.66	0.75	-0.02	-0.04	-0.54	0.62	-0.02	-0.03	1.89	-5.23
Z_3	0.61	0.16	-0.34	-0.28	0.88	-0.21	-0.26	-0.22	0.68	-0.16	1.03	-6.39

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

As shown in this table, the contribution ratio for the first principal component to all the principal components is about 60%, occupying more than a half of all. The total to the ratio of the third principal component amounts to 92% approximately, so that a greater part of the fluctuation of all the components can be explained with them. However, the contribution ratio of the second and the third principal component markedly drop to 16%.

Factor loading is composed of correlation coefficients between principal components and variables (indicator contents). For the first principal component, all indicators show a high value 0.72-0.87. Therefore, the first principal component is characterized by high correlation with all indicators, especially Zn (0.87).

The second principal component is characterized by the high correlation (0.62) with Cu and the negative correlation (-0.54) with Ag. The third principal component has the high correlation with Pb and the low negative correlation with Ag, Cu, and Zn. However, there are few geochemical anomalies with a structure characterized by the third principal component.

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

The anomalous zone in the survey area is classified into the single element showing type and the multi-element showing type by a combination of indicators showing the anomaly. In the former case, a comparison and study based upon the contrast of the content of the indicators forming each anomalous zone and the background value of the governing geological unit of the sample, or a comparison and study based upon the first to third factor loading are necessary. Furthermore, the anomalous zone can be classified into several specific zones. The latter multi-element showing type can be classified into two element types among Ag-Pb-Zn and three or more element type among Ag-Cu-Pb-Zn. The explanation and evaluation of each anomaly are as follows:

(1) Single Element Showing Type - Age

The evaluation list of the anomalous zone is shown in Table III-5.

This type of anomalous zone has a close relation with the geological unit and is found in intrusive rocks (Gd, Gph), Cretaceous System dacite (Kdc1-a, -b, Koh-a -b, etc.), metamorphic rocks and granodiorite, etc. The type found in metamorphic rocks is found in the El Caracol and La Concha areas. The type found in intrusive rocks (GD, Gph) is found in the San Francisco and Aguacate areas. And the type found in dacites (Kdc1-a, -b), etc., is found in the Amaltea and Grandeza areas.

By comparing and studying the first to third principal component scores ($Z_1 \sim Z_3$) presented by these anomalous zone groups, the geochemical characteristics of each anomalous zone becomes clear. In other words, the structures of the principal component scores presented by the anomalous zones at two places in San Francisco resemble each other closely and can be assumed to have the same kind of mineralization. A similar tendency can be found at three places in the El Caracol area. The anomalous zone in Los Alacranes has a special score structure in the Ag anomalous zone group. In this case, Z_1 shows a positive score near zero and is characterized by a low or somewhat low negative score of $Z_2 \sim Z_3$. From these figures, it can be seen that this anomalous zone has a small content of elements (Cu, Pb, Zn) other than Ag, that is, it can be assumed to have a mineralization of only Ag.

(2) Single Element Showing Type - Cu

The anomalous zone of this type is found in the La Minita area only. The geological unit governing the anomalous zone is II-stage andesites (Tad_2), but as the anomalous zone is located to the west of the La Minita deposit and is considered with the extended direction in La Minita deposit, it can be considered as an anomaly in a series of Cu mineralization. This anomalous zone features has a slightly high Z_2 value in the principal component score structure that shows mineralization of only Cu.

(3) Single Element Showing Type - Pb

This type of anomalous zone is found in a part of La Minita and Bramador areas only. The type in the La Minita area is considered to accompany the mineralization of Cu and Zn to some extent. And the type in the Bramador area resembles the multi-element showing type appearing around the Kuroko type deposit.

Table III-5 Evaluation of Anomalous Zones (Single Element Showing Type)

Elements	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	
Ag	San Francisco	1738	7	3.9 (229)	9.5 (2)	83.2 (5)	414.1 (8)	3.10	-2.28	-0.59	Ag-Zn
		1746	7	2.7 (159)	13.6 (2)	54.3 (3)	232.5 (3)	2.57	-1.88	-0.76	
	El Caracol	1821	0	1.4 (64)	46.2 (3)	62.3 (2)	147.0 (2)	2.59	-0.84	-0.70	Ag
		1822	0	1.3 (59)	37.3 (2)	58.1 (2)	131.0 (2)	2.37	-0.94	-0.65	
		1824	0	1.8 (82)	66.2 (4)	84.1 (3)	88.0 (1)	2.55	-0.69	-0.48	
	El Aguacate	1828	7	1.7 (100)	33.0 (5)	33.4 (2)	38.0 (1)	1.32	-1.05	-0.76	Ag-(Cu)
	Grandeza	1981	11	1.5 (21)	18.4 (1)	96.4 (2)	167.8 (1)	2.51	-1.46	-0.22	Ag
	La Amaltea	2014	11	5.8 (81)	5.0 (0)	13.0 (0)	127.0 (1)	1.42	-2.34	-1.55	Ag
	Los Alacranes	2138	11	2.8 (39)	6.5 (0)	23.7 (1)	33.4 (0)	0.61	-2.24	-0.69	Ag
	La Concha	2213	0	9.2 (418)	21.0 (1)	35.0 (1)	135.9 (2)	2.54	-2.04	-1.28	Ag
Cu	La Minita	2296	4	<0.1 (0)	162.1 (9)	40.0 (1)	67.8 (1)	0.94	1.89	-0.13	Cu
Pb	El Bramador	2247	11	1.1 (15)	18.7 (1)	271.1 (6)	324.7 (3)	3.29	-1.38	0.41	Pb-(Ag)
	La Minita	2302	4	0.4 (25)	48.1 (3)	175.0 (6)	204.2 (3)	-1.41	-0.12	-0.05	Pb-(Ag)
Zn	El Aguacate	1688	0	0.6 (27)	29.8 (2)	54.1 (2)	590.0 (7)	3.09	-0.85	-0.89	Zn-(Ag)
		1690	0	0.6 (27)	32.2 (2)	52.4 (2)	450.0 (5)	2.92	-0.79	-0.86	
		1692	0	0.1 (5)	23.0 (1)	25.1 (1)	458.9 (5)	2.01	-0.30	-0.96	
		1817	0	0.1 (5)	25.4 (2)	30.7 (1)	723.7 (8)	2.45	-0.26	-0.95	
	El Caracol	1823	0	0.9 (41)	32.0 (2)	53.6 (2)	745.0 (9)	3.40	-0.98	-1.05	Zn-(Ag)
	Grandeza	1965	0	<0.1 (0)	27.2 (2)	89.4 (3)	667.0 (8)	2.17	0.65	0.27	Zn
	La Amaltea	2017	12	0.9 (13)	29.9 (1)	113.8 (2)	637.0 (6)	3.55	-1.03	-0.45	Zn-(Ag)
	Desmoronado	2037	7	0.4 (24)	48.7 (8)	138.6 (8)	631.7 (13)	3.58	-0.41	-0.26	Zn-(Cu)-(Pb)
		2042	7	<0.1 (0)	21.8 (4)	54.7 (3)	497.4 (10)	1.69	0.54	0.05	
	El Encino-N	2092	0	0.7 (32)	18.5 (1)	71.4 (3)	476.6 (5)	2.91	-1.21	-0.55	Zn-(Ag)
	El Portezuero	2259	12	0.2 (3)	28.5 (1)	51.5 (1)	448.4 (4)	2.55	-0.45	-0.62	Zn

Rock Code Numbers are shown in Table Ⅲ — 3

Figures in blankets = $\frac{\text{Contents in the specimen}}{\text{Geometric mean of the background rock}}$

(4) Single Element Showing Type - Zn

This type of anomalous zone is found in several places as shown in Table III-5.

In metamorphic rocks (Jsch), this type is found in the El Aguacate, El Caracol, Grandeza, and El Encino-N areas. In the Cretaceous System shale (sandstone) layer, it is found in the La Amaltea and Camacho areas. In granodiorite (Gd), it is found in the Desmoronado area. The type found in metamorphic rocks (Jsch) is a slightly higher in the contrast of Ag, but the contrast of Cu and Pb is somewhat low and is considered to show the Ag - Zn mineralization. These are presented clearly in the principal component score structure. In addition, the anomalous zone found in granodiorite (Gd) is large in the contrast of Cu and Pb compared with the others and is considered as the showing type accompanying the Cu - Pb mineralization.

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

The evaluation list of the anomalous zone by multi-elements is shown in Table III-6. The zones are classified into multi-element showing types by combination of three elements Ag, Pb, Zn and by the type of combination of Ag-Pb including Cu and Zn. The anomalous zone of Ag-Pb is found in a part of the Grandeza, Tintilahua, El Bramador and La Minita areas. Various kinds of geology (Table III-5) are found in the background areas of these anomalous zone groups, but the principal component score structure closely resemble each other. In one place in the Tintilahua area and the Grandeza area, Z_3 shows a negative score and a Pb anomaly in both places is considered to be less strong.

The principal component score structure shown by the anomalous zone group in the prevailing area of the Kuroko type deposit and the structure in other places closely resemble each other. The anomalous zones due to Ag-Zn are fond in the El Aguacate, El Caracol, Mina Cuale and El Corazon areas. Each of them is found in metamorphic rocks (Jsch) and granodiorite (Gd) and seems to have a relation to Ag-Zn vein type mineralization.
Taking the geology in the background area into consideration, it seems there is nothing produced by the Kuroko type mineralization in the anomalous zone.

However, in the principal component score, the structure of Mina Cuale (Table III-6) slightly resembles the principal component score structure presented in the prevailing area of the Kuroko type deposit.

The anomalous zone by Pb-Zn is found in the La Amaltea area only and seems to have a close connection with the Kuroko type deposit from the point of view of the geology of the background area and the principal component score structure. In the anomalous zones classified by indicators of more than three elements, the Ag-Cu-Pb, Ag-Pb-Zn and Ag-Cu-Pb-Zn types are found. The Ag-Cu-Pb anomalous zone is found in the Grandeza, Mina Cuale, La Amaltea, El Portezuelo and El Banco areas. Judging from the geology and other factors in the background area, the anomalous zones in the Mine Cuale and La Amaltea areas seem to have a relation to the Kuroko type mineralization, but the anomalous zones in the other areas seem to suggest an anomaly due to vein type mineralization.

Table III-6 Evaluation of Anomalous Zones (Multi-Element Showing Type) (1)

Elements	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	
Ag-Pb	Grandeza	1846	8	7.7 (321)	115.4 (8)	677.0 (20)	62.0 (1)	3.74	-0.93	0.68	Kuroko
		1881	7	10.6 (624)	122.2 (20)	295.5 (17)	216.0 (4)	4.41	-1.06	-0.31	
	Tintilahua	2225	7	1.5 (88)	37.2 (6)	146.2 (8)	147.3 (3)	2.85	-1.02	-0.05	Ag-Cu-Pb vein
	El Bramador	2238	11	13.0 (181)	99.2 (5)	858.6 (19)	152.0 (1)	4.55	-1.27	0.55	Kuroko
		2351	11	3.7 (51)	58.1 (3)	435.1 (9)	144.0 (1)	3.69	-1.11	0.45	
	La Minita	2298	6	1.6 (1)	31.2 (1)	309.8 (1)	293.7 (1)	3.57	-1.20	0.34	Ag-(Cu)-Pb vein
		2299	4	1.3 (81)	33.6 (2)	379.3 (12)	303.9 (4)	3.65	-1.08	0.50	
Ag-Zn	El Aguacate	1815	7	1.4 (82)	23.2 (4)	39.4 (2)	823.0 (16)	3.35	-1.35	-1.31	Ag-Zn vein
		1816	0	5.0 (227)	48.0 (3)	101.6 (4)	560.0 (6)	4.09	-1.38	-0.95	
		1819	0	1.5 (68)	44.3 (3)	44.9 (2)	941.0 (11)	3.77	-0.98	-1.41	
		1829	7	3.9 (229)	74.2 (12)	84.9 (5)	948.0 (19)	4.49	-1.04	-1.27	
	El Caracol	1827	0	2.1 (95)	73.8 (5)	86.0 (3)	669.0 (8)	4.07	-0.79	-1.04	Ag-Zn vein
	Mina Cuale	1856	7	1.4 (82)	39.6 (6)	163.0 (9)	578.4 (11)	3.86	-1.02	-0.33	Ag-Zn vein
	El Corazon	1959	0	10.0 (455)	75.4 (5)	118.0 (4)	498.0 (6)	4.44	-1.37	-1.06	Ag-Zn vein
Pb-Zn	La Amaltea	2013	11	0.5 (7)	48.0 (2)	401.1 (9)	534.6 (5)	3.93	-0.52	0.50	Kuroko
		2015	11	0.5 (7)	34.3 (2)	169.4 (4)	795.1 (7)	3.75	-0.73	-0.14	
Ag-Cu-Pb	Grandeza	1848	11	42.1 (585)	472.7 (23)	607.0 (13)	201.0 (2)	5.56	-0.76	-0.36	Kuroko
	Mina Cuale	1854	7	71.8 (4224)	861.0 (141)	671.0 (37)	212.0 (4)	6.02	-0.60	-0.55	Ag-Cu-Pb vein
	La Amaltea	2003	7	3.4 (200)	329.9 (54)	696.6 (39)	213.0 (4)	4.79	-0.02	0.31	Kuroko
	El Portezuelo	2256	12	22.4 (311)	159.5 (8)	274.0 (6)	77.0 (1)	3.98	-1.13	-0.31	Ag-Cu-Pb vein
	El Banco	2364	4	23.8 (1488)	244.6 (14)	535.3 (17)	69.0 (1)	4.34	-0.90	0.09	Ag-Cu-Pb vein
Ag-Pb-Zn	Mina Cuale	1845	11	1.9 (26)	26.7 (1)	191.3 (4)	583.6 (5)	3.86	-1.39	-0.18	Kuroko
		1847	11	7.0 (97)	54.1 (3)	425.6 (9)	976.0 (9)	5.18	-1.49	-0.16	

Rock Code Numbers are shown in Table Ⅲ−3

Figures in blankets = $\frac{\text{Contents in the specimen}}{\text{Geometric mean of the background rock}}$

Elements	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	
Ag-Pb-Zn	Grandeza	1878	11	2.0 (28)	91.8 (4)	251.3 (5)	571.0 (5)	4.44	-0.64	-0.27	Kuroko
		1879	7	2.6 (153)	120.6 (20)	291.0 (16)	704.0 (14)	4.83	-0.59	-0.34	
		1880	11	21.8 (303)	109.1 (5)	476.4 (10)	740.1 (7)	5.62	-1.48	-0.40	
		1885	11	18.3 (254)	52.4 (3)	453.8 (10)	756.4 (7)	5.28	-1.87	-0.24	
		1977	0	25.3 (1150)	124.4 (8)	490.9 (18)	677.0 (8)	5.67	-1.45	-0.41	
		1978	11	1.6 (22)	58.5 (3)	228.3 (5)	543.4 (5)	4.13	-0.83	-0.19	
	El Corazon	1953	8	4.0 (167)	70.2 (5)	301.8 (9)	894.0 (11)	4.92	-1.10	-0.34	Ag-Pb-Zn vein
		1958	0	3.7 (168)	62.5 (4)	268.6 (10)	761.4 (9)	4.70	-1.14	-0.34	
	La Trozada	2220	0	3.2 (145)	43.8 (3)	211.6 (8)	825.5 (9)	4.48	-1.30	-0.42	Ag-Pb-Zn vein
		2221	0	2.1 (95)	39.6 (2)	193.3 (7)	557.0 (6)	4.01	-1.18	-0.27	
	El Bramador	2223	11	4.3 (60)	49.9 (4)	260.7 (6)	979.2 (9)	4.82	-1.35	-0.40	Kuroko
		2239	11	12.2 (169)	66.4 (3)	461.8 (10)	626.9 (6)	5.14	-1.56	-0.15	
		2240	11	6.9 (96)	114.2 (5)	419.2 (9)	819.6 (7)	5.33	-1.01	-0.30	
		2244	11	1.9 (26)	80.1 (4)	256.4 (6)	660.0 (6)	4.49	-0.72	-0.26	
		2245	11	4.8 (67)	63.9 (3)	936.0 (20)	760.4 (7)	5.26	-1.25	0.50	
		2246	11	3.1 (43)	29.7 (1)	576.3 (12)	960.2 (9)	4.82	-1.56	0.36	
Ag-Cu-Pb-Zn	Mina Cuale	1844	11	17.5 (243)	265.1 (13)	290.0 (6)	655.0 (6)	5.63	-0.83	-0.88	Kuroko
		1855	7	32.3 (1900)	696.2 (114)	754.0 (42)	622.0 (12)	6.51	-0.48	-0.53	
	Grandeza	1876	11	25.6 (356)	179.2 (9)	647.2 (14)	558.1 (5)	5.78	-1.23	-0.25	Kuroko
		1877	7	2.4 (141)	278.2 (46)	475.2 (27)	848.0 (17)	5.45	-0.06	-0.21	
	La Amaltea	2005	11	86.2 (1197)	516.8 (25)	210.0 (5)	865.0 (8)	6.41	-1.03	-1.66	Kuroko
		2011	11	30.0 (417)	169.1 (8)	859.3 (19)	924.0 (8)	6.27	-1.35	-0.20	
	El Encino-S	2202	0	53.8 (2445)	419.2 (26)	747.8 (27)	523.0 (6)	6.33	-0.98	-0.48	Ag-Cu-Pb-Zn vein

However, the principal component score structure in the Amaltea anomalous zone is different from the others. This is due to the fact that the Pb content is relatively high in the sample, and the Cu content is relatively low. The number of Ag-Pb-Zn anomalous zones is the largest among all anomalous zones. They are found in the Mina Cuale, Grandeza, El Bramador, El Corazon, and La Trozada areas. Such anomalous zones have a relation to the geology in the background area, and most of them belong to the dacites and metamorphic rock groups. The anomalous zones in the Mina Cuale and El Bramador areas and most of them in the Grandeza area belong to the Cretaceous System dacites and seem to have a relation to the Kuroko type mineralization. The anomalous zones in the El Corazon and La Trozada areas are found in metamorphic rocks and are considered to have a relation to the vein type mineralization. The Ag-Cu-Pb-Zn anomalous zones are found in the Mina Cuale, Grandeza, La Amaltea and El Encino zones. Among the above anomalous zones, the one in the El Encino-S area exists in metamorphic rocks and seems to have a relation to the vein type mineralization. The anomalous zones in the other areas can be considered to be anomalies related to the Kuroko type mineralization judging from the locational relation to the known Kuroko type deposit and the geology in the background area. From the stand point of the principal component score structure, a clear difference cannot be found between the structure of an anomalous zone which is considered to be the origin of the Kuroko type mineralization and the score structure of the vein type mineralization.

5-2 Geochenical Exploration by Whole Rock Analysis

From the lithogeochemical point of view, trials to classify rocks into two categories, Kuroko relating and non-Kuroko relating, were done by several investigators (Sopuck, et al., 1980; Dudas, 1983; Hashimoto, 1983). However, no versatile method for Kuroko exploration has been established yet, whether it is of principal or minor elements of rocks. It seems that specific areas need to develop their own specific exploration methods, utilizing their own specific characters.

In this survey, a study on this matter was conducted for the footwall dacite (Kdc_1), hanging wall dacite (Kdc-sh), and intrusive dacite (Dc).

5-2-1 Alkali Alteration Index*

Alkali alteration index (AAI) is a device to quantitatively evaluate intensity of alteration from the view point of mobility of alkali and alkaline-earth metals during hydrothermal alteration, devised by Ishikawa, et al. (1980).

It significantly contributed to the discovery of a Cenozoic Kuroko ores, Ezuri deposit, in Japan.

In this survey, no map showing such alteration intensity was made because the number of samples is too small.

According to the results of the calculation for each sample, strong alteration zones (AAI higher than 90) are shown in the Chivos de Abajo and Naricere deposits in the Cuale Mine, (CC-11, DA-73, WCUM-12).

However, strong alteration zones are shown in the footwall rocks in the El Bramador deposits, and weak alteration zones (AAI lower than 50) are shown near the San Pedro adit (D-68). No other samples were taken around there, therefore details are not clear yet.

AAI is a very sensitive device to detect strong alteration zones, therefore it is useful for detailed surveys rather than regional one. (Hashiguchi, et al., 1981).

5-2-2 Principal Component Analysis

After standerizing all assay values, a principal component analysis was conducted. Table III-7 shows the result.

The maximum eigenvalue is 3.67, a square sum of the first factor loadings, being able to explain about 28 percent of the total.

The second, third, and fourth factors are 17, 14, and 11 percent respectively. Accordingly about 70 percent of the all original data is explained by factors up to fourth.

Factor loadings (correlation coefficients between each factor and variate) is the most important element for the analysis, therefore characters of each factor loading were investigated.

Z_1 is characterized by significant negative correlations between SiO_2 and other components, meaning increasing SiO_2 versus decreasing other components. It means that addition of SiO2 by silicification is commonly dominant in the area. Results of the field survey support this fact too.

Z_2 is characterized by negative correlations between acidic components (SiO_2, Al_2O_3, Na_2O, K_2O, BaO, etc.) and basic components (FeO, MgO, etc.). Accordingly it is said that Z_2 is a representative factor loading for lighogeochemical characters of rocks itself.

Z_3 is characterized by negative correlations between K_2O, and Na_2O and CaO, which are most sensitive components for Kuroko type alteration, it means that they take mutually complementary behaviours, and represent characters of movement of components by hydrothermal alteration.

Fe_2O_3 showing the highest factor loading in Z_3 is a good indication for oxidation-reduction environment, but it is difficult to find concrete lithogeochemical relations to other factor loadings.

It appears that Z_4 reflects states of alkali and alkaline-earth metals, which are of high mobility in Kuroko type alteration, meaning negative correlations between Na_2O and CaO (decreasing components), and K_2O and MgO (increasing components).

Geologic domains and sampling points are as follows:

A. Hanging wall dacite (Kdc_2, La America-Descubridora area)
B. Hanging wall dacite (Kdc_2, El Rubi area)
C. I-stage dacite (Tdc_1)

Table III-7 Analytical Results of Principal Component Analysis

N = 136

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	3.67	0.28	-0.66	0.61	0.71	0.02	0.47	0.60	0.48	0.63	0.66	0.40	0.55	0.33	0.37	4.41	-8.75
Z_2	2.15	0.45	-0.05	0.14	-0.40	0.34	0.55	0.10	0.51	0.08	-0.41	-0.68	0.29	0.45	-0.59	5.38	-2.57
Z_3	1.86	0.59	0.41	-0.42	-0.10	-0.65	0.40	0.20	0.38	0.50	0.37	-0.27	-0.47	-0.24	0.00	3.34	-3.16
Z_4	1.40	0.70	0.42	0.38	-0.42	0.21	-0.23	0.48	-0.43	0.40	0.15	-0.23	0.28	-0.26	0.11	3.49	-3.18
Z_5	1.12	0.79	0.14	-0.34	-0.07	0.32	-0.10	0.42	0.04	0.06	-0.20	0.11	-0.34	0.57	0.45	2.49	-3.44
Z_6	0.81	0.85	0.21	0.13	-0.25	-0.20	0.35	0.04	0.17	-0.25	-0.33	0.32	0.25	-0.16	0.37	2.32	-3.90

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

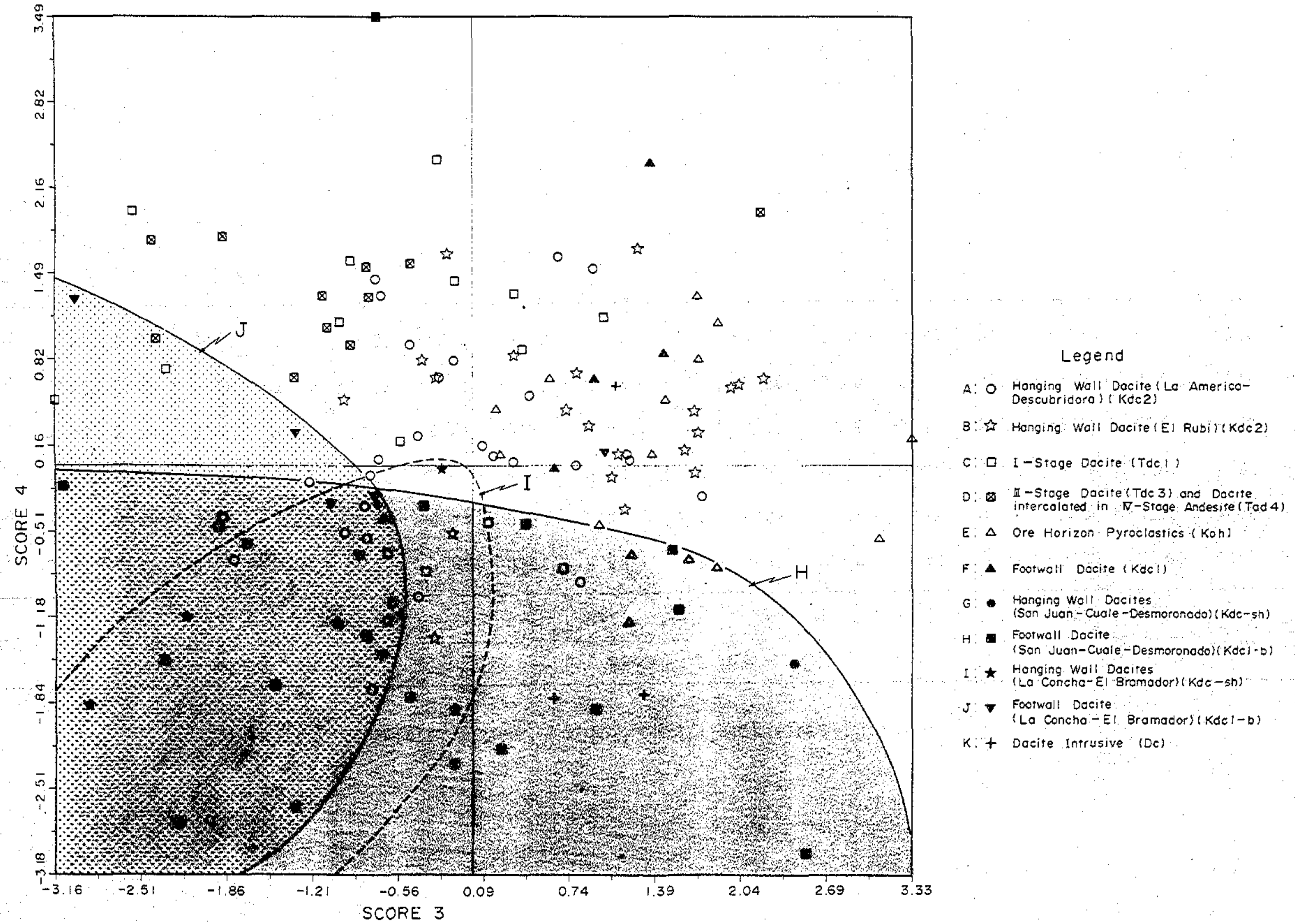


Fig. III-6 Relation between Factor 3 and Factor 4

D. III-stage dacite (Tdc3), etc.
E. Ore horizon pyroclastics (Koh)
F. Footwall dacite (Kdc1, La America-Descubridora area)
G. Hanging wall dacite (Kdc-sh, San Juan-Cuale-Desmoronado area)
H. Footwall dacite (Kdc-b, San Juan-Cuale-Desmoronado area)
I. Hanging wall dacite (Kdc-sh, La Concha-El Bramador area)
J. Footwall dacite (Kdc1-b, La Concha-El Bramador area)
K. Intrusive dacite (Dc, various points)

According to this diagram, the footwall dacite (H group) from the San Juan-Cuale-Desmoronado area is mostly distributed in the third and fourth quadrants, and is characterized by mostly negative scores in the fourth factor scores.

The footwall dacites (J group) in the La Concha-El Bramador area is in the second and third quadrants, mostly of negative scores in the third factor scores. J group and H group overlap with each other in the third quadrant, therefore, they have similar geochemical characters.

On the other hand, the scores of the hanging wall dacite (I group) in the La Concha-El Bramador area tend to be distributed in the middle of the previously mentioned two groups.

The H and I groups are extensively distributed, and have no other characteristics than the above mentioned factor scores.

It is due to that even a same rock group shows different factor scores in cases it has different grade of alteration. The hanging wall dacites (G group) in the Cuale area and the intrusive dacite (K group) are lacking in the number of samples and distribute sparsely on the diagram, therefore details of their lighogeochemical characteristics are not clear.

5-2-3 Cluster Analysis

For the purpose of distinguishing rocks related with Kuroko type ores 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. The results of cluster analysis are shown in Fig. III-7 in a dendrogram. By this diagram, the relationship between each sample and a cluster can be found. The alphabet before a number shows the geological unit (see previous section) from which the sample originated.

Samples classified into ten categories (A to J) based on their geological domains and sampled points were investigated in view of distribution in each cluster classified in 12 clusters for 136 samples. As a result of the investigation, some characteristics were found in some clusters. Important conclusions from the result are as follows:

As a result of the cluster analysis, it is clarified that each cluster is subjected to alteration, overlapping to their genuine lithogeochemical characters.

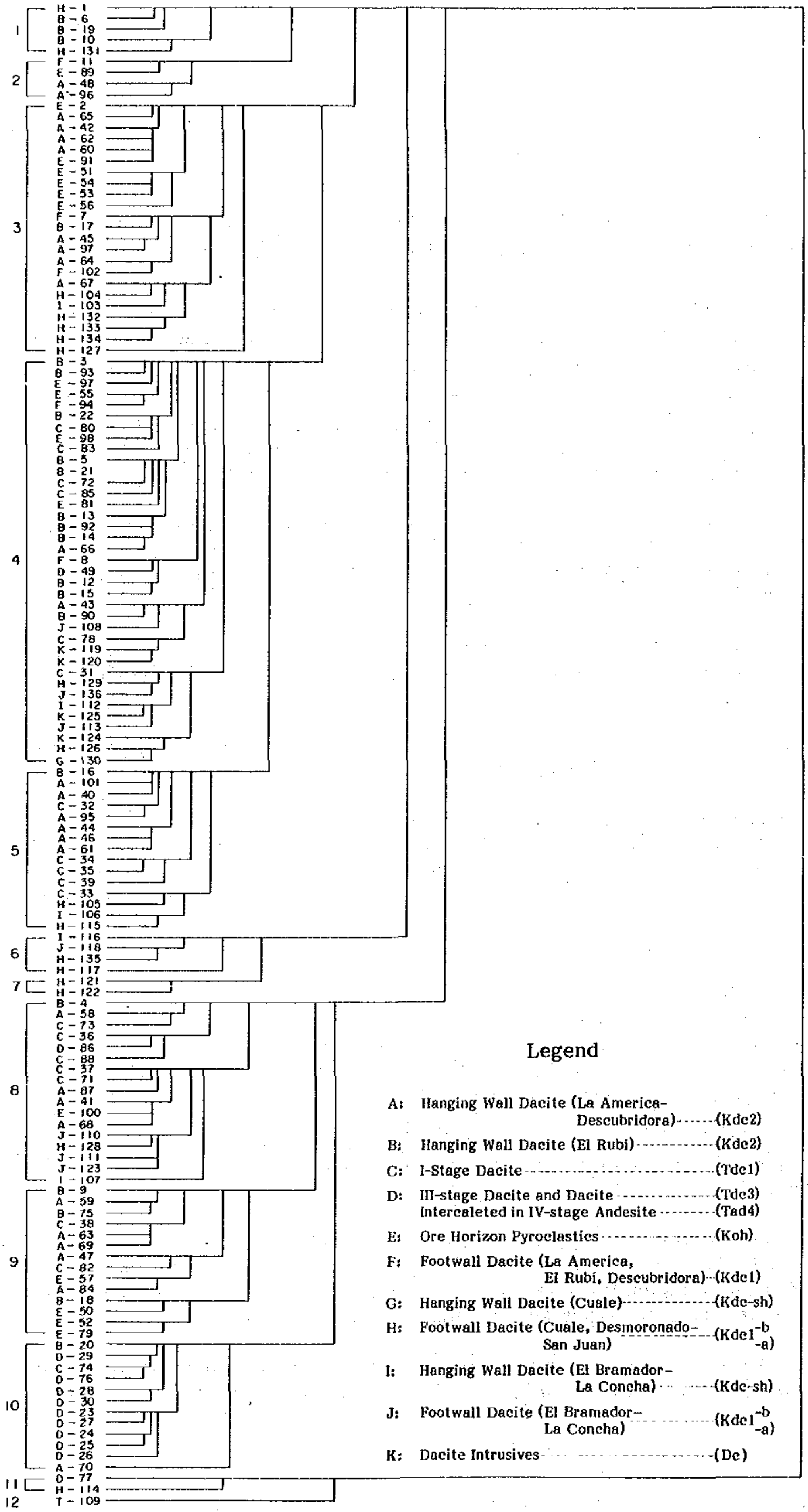


Fig. III-7 Cluster Dendrogram of Rock Samples

In other words, it is possible to classify types of alteration for rocks by cluster analysis.

In summary, it is concluded that cluster 5 is of relating to Kuroko type mineralization, consisting of expected components in Kuroko mineralization-alteration zone.

CHAPTER 6 GEOPHYSICAL SURVEY

6-1 Outline of Survey

The CSAMT (Controlled-Source Audio Frequency Magnetotellurics) survey determines the underground resistivity distribution by transmitting audio frequency current through the grounded dipole, and measures the electric field (E), parallel to the transmitter dipole, and the magnetic field (H), perpendicular to the electric field.

The transmitted current frequencies were 2048, 1024, 512, 256, 128, 64, 32, 16, 8 and 4 Hz (ten in total).

Signals from both electric and magnetic fields are processed by a GDP-12 receiver, which outputs the following:

(1) Apparent resistivity

(2) Phase difference between electric and magnetic fields

6-2 Survey Results

An integrated interpretation of the geological, geochemical and geophysical survey results was done, and its result is as follows (Fig. III-8, Fig. III-9, Fig. III-10, Fig. III-11):

(1) L-5 in an area southeast of La Concha shows a complicated pattern, trending two directions, northwest to southeast and northeast to southwest.

A small Low Resistivity Zone nearby the Survey Station 5 is located in an area north of the San Pedro ore deposit. Therefore this zone should be paid attention. The zone is in a distribution area of the shale-sandstone formation (Ksh_1), footwall dacite (Kdc1-b), ore horizon dacitic pyroclastics (Koh-b), and hanging wall dacite and pyroclastics-shale alternation (Kdc-sh), being subjected to argillization (kaolinization). The main body of the zone is in the lower formations than the ore horizon, therefore it seems that it is not favourable for further exploration activity. However as a result of the interpretation, following facts were made clear; a moderate resistivity zone is in the shallow part (down to 100 meters depth), and a thick low resistivity zone (100 Ω·m) underlies below it. This low resistivity one corresponds to a distribution area of the footwall dacite (Kdc1-b) and ore horizon pyroclastics (Koh-b), it is not negligible from the list of favourable anomaly zones.

(2) L-6 in an area east to northeast of El Bramador shows 4 to 150 Ω·m from the shallow part to the depth, widely extending. The zone extends to two directions, northeast to southwest and northwest to southeast, especially to the northeast, and tends to connect with L-6 and L-7. The low resistivity zone group is in a distribution area of the hanging wall dacite and pyroclastics-shale alteration (Kdc-sh), being subjected to argillization (sericite, chlorite). A low resistivity zone in an area east of El Bramador is located in a southeastern extension zone of the San Jeronimo valley being old workings and it is expected that the ore horizon extends to this area.

(3) L-10 in San Jose shows 140 to 200 Ω·m in the shallow part, 250 Ω·m in the middle, and 100 Ω·m in the depth, forming three layers resistivity structure. The zone is of small scale, but coincides with a part of an electromagnetic anomaly zone. It is in a distribution area of the ore horizon dacite pyroclastics (Koh-b), and hanging wall dacite and pyroclastics-shale alteration (Kdc-sh), being subjected to argillization (sericite, chlorite), and coincides with a multi-element geochemical anomaly zone of Ag-Cu-Pb-Zn. Therefore it should be paid attention for Kuroko exploration. It is possible that the zone is caused by a postulated mineralization-alteration zone extending from the La Castellana, Los Alpes, and San Jose ore deposits.

(4) L-12 in Santa Edwiges shows 40 to 1200 Ω·m from the shallow part to the depth. It is of small scale, but extends to the south. It is in a distribution area of the hanging wall dacite and pyroclastics-shale alteration (Kdc-sh), being subjected to argillization (sericite, chlorite), and coincides with a multi-element geochemical anomaly zone of Ag-Pb. In addition an extension of mineralization zones from the Santa Edwiges ore deposit is expected there, therefore this zone is one of the most promising area for Kuroko exploration.

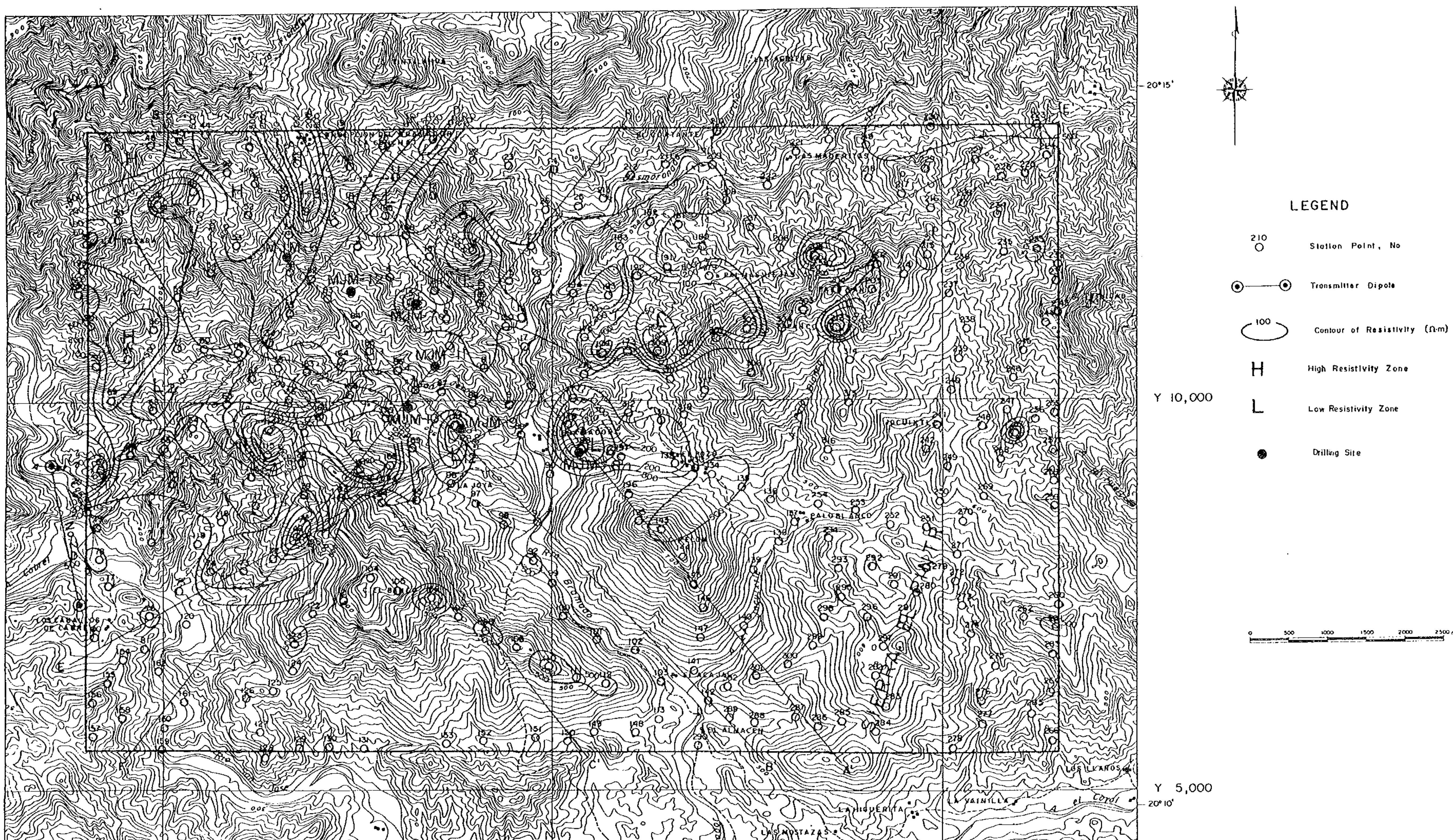


Fig. III-8

Plan of Resistivity Structure (200 m below the surface)

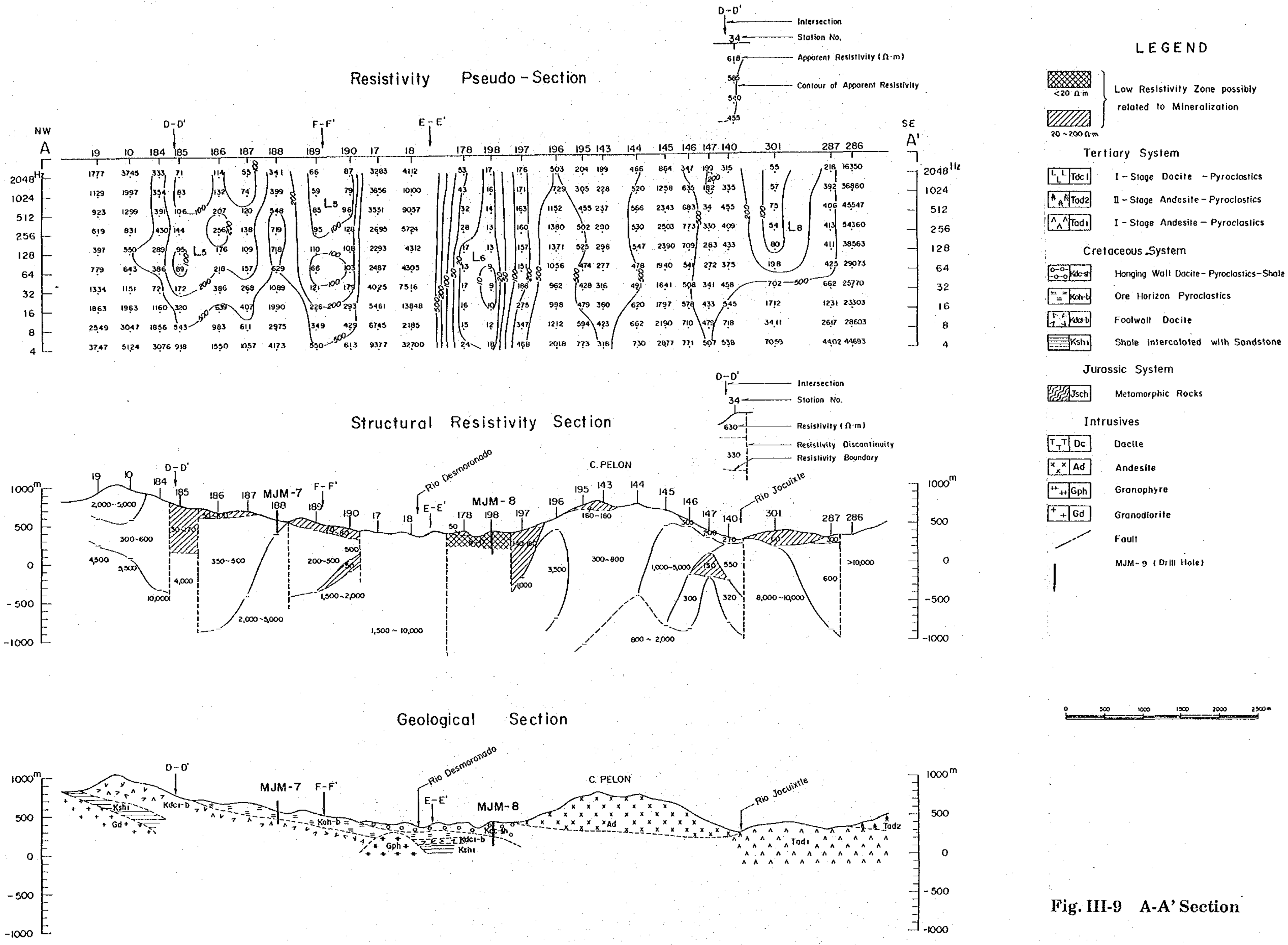


Fig. III-9 A-A' Section

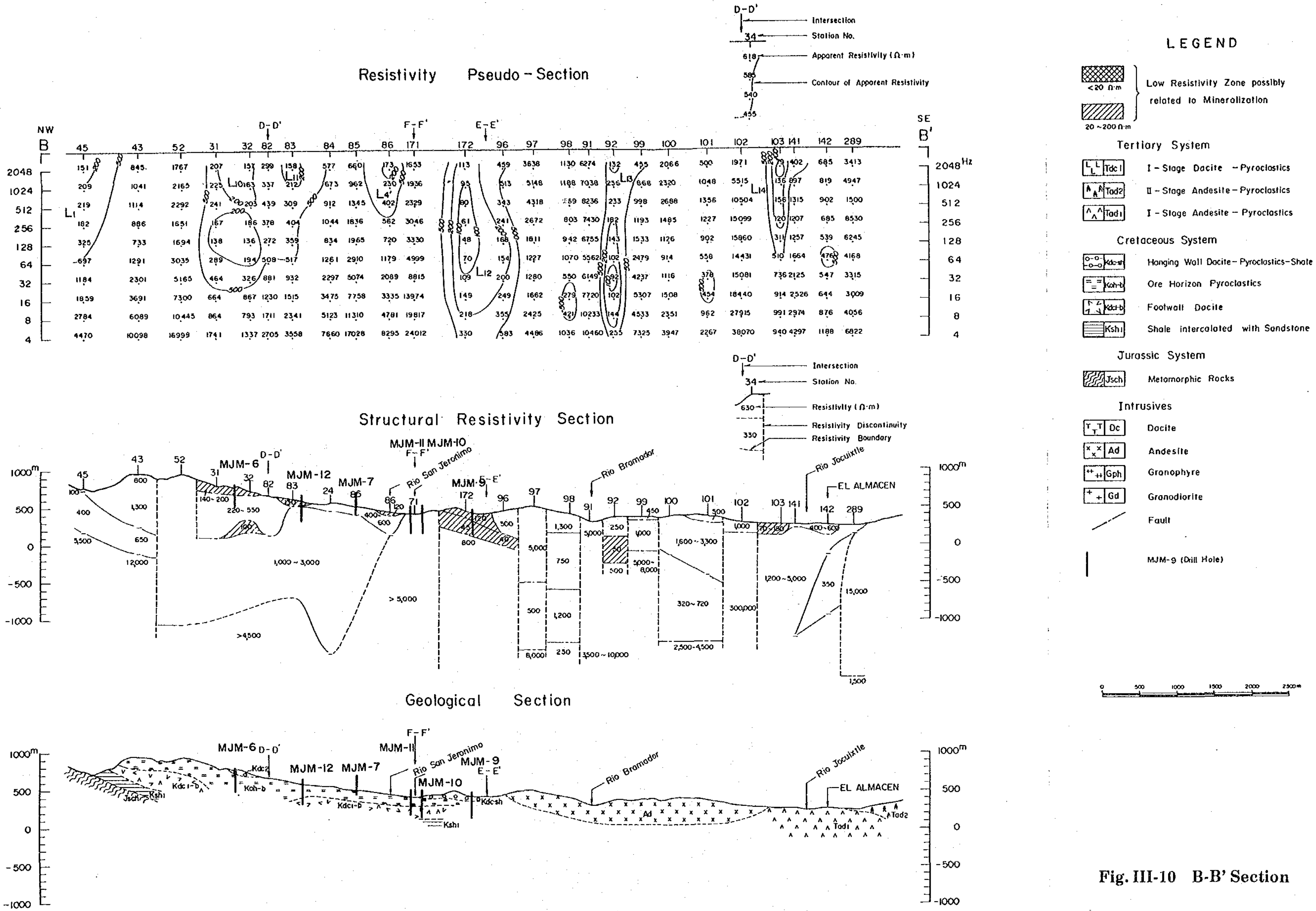


Fig. III-10 B-B' Section

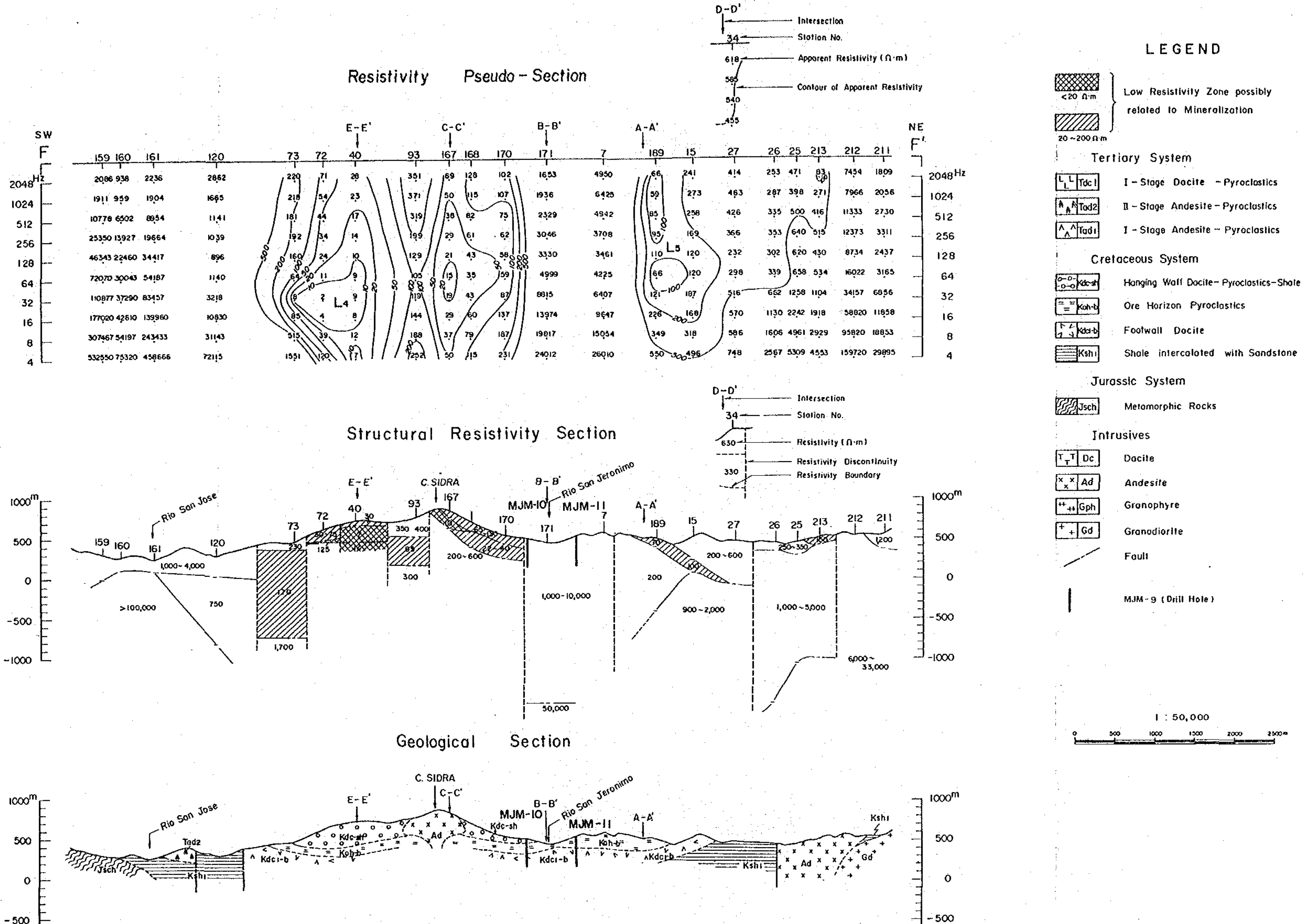


Fig. III-11 F-F' Section