EXPLANATORY NOTE
ON
THE GEOLOGY AND ORE DEPOSITS
OF
CERRO NEGRO
THE REPUBLIC OF CHILE

MARCH 1994

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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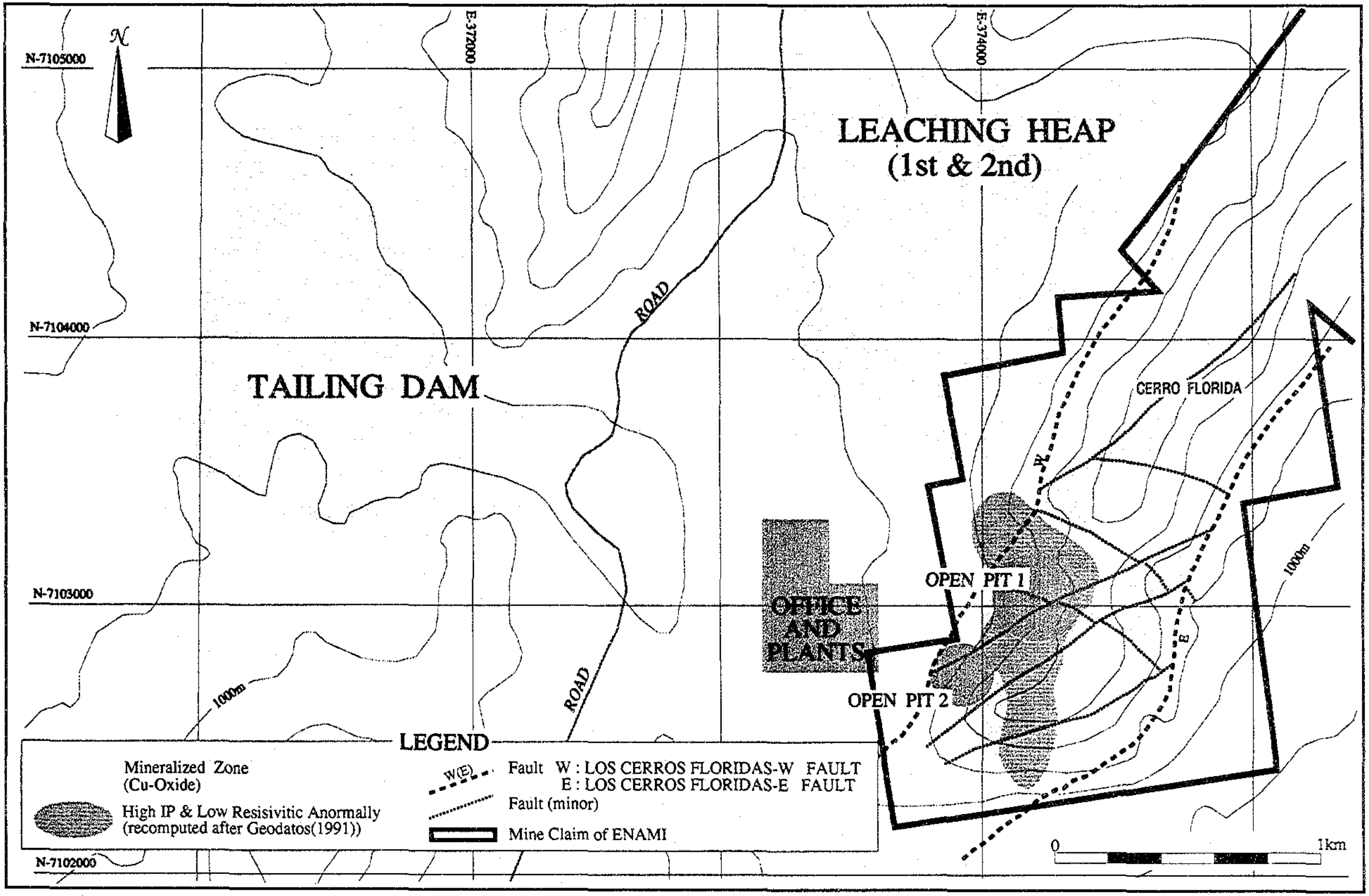

Summary figure

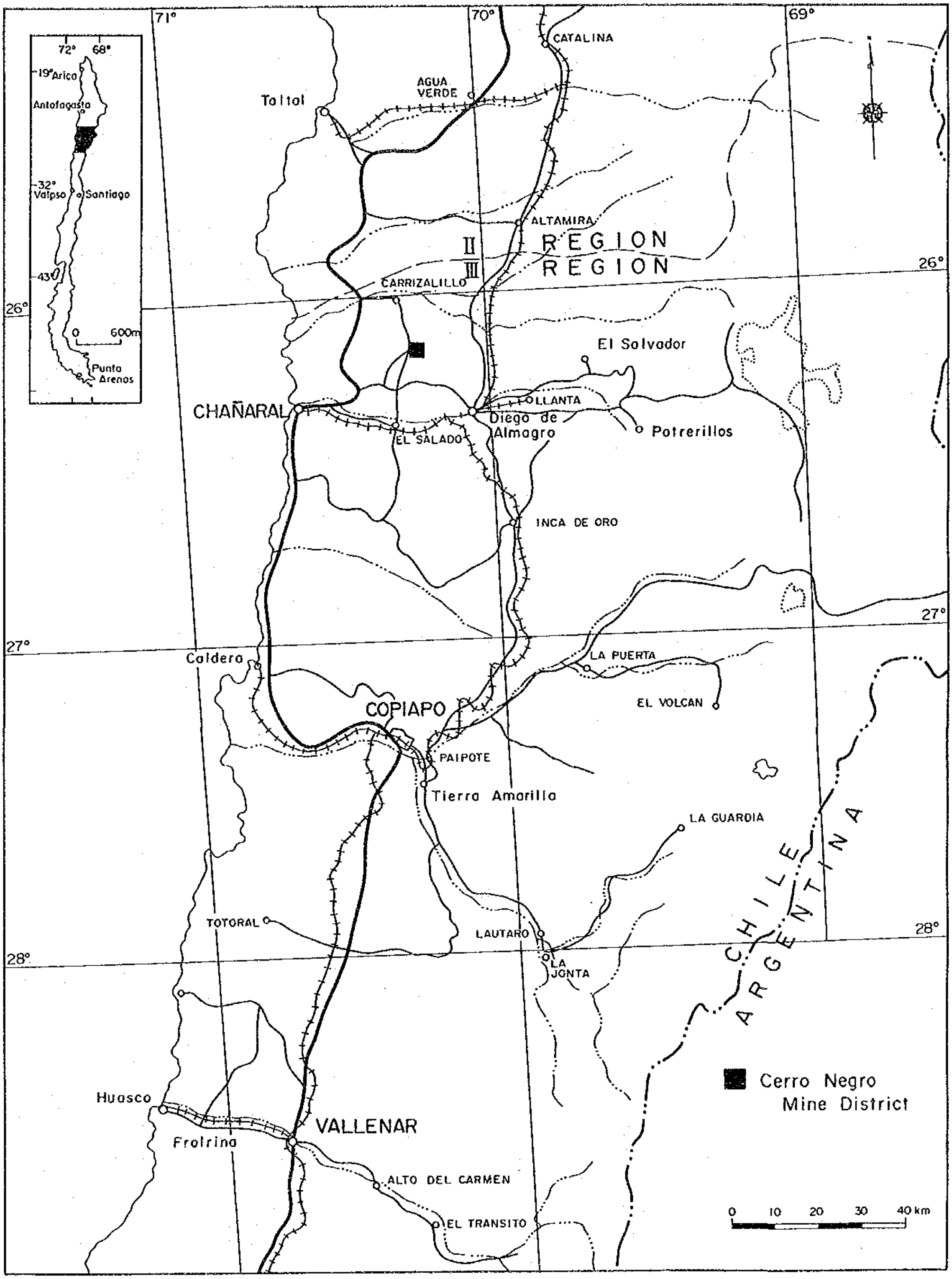

Fig. 1-1-1 Locality map of the survey area

[EXPLANATORY NOTE]

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EXPLANATORY NOTE

CHAPTER 1 OUTLINE OF SURVEY

1 — 1 Survey area and purpose of survey

This survey was carried out in order to confirm the existing ore deposit and to find out new ore reservers including estimation of the ore reserves.

This survey area is located in the III provice, the northern part of the Republic of Chile, and is located about 900km north from the Capital Santiago, about 90km in a straight line and 220km by road distance from Copiapo City which is the capital of this province.

1 — 2 Method, amount and term of survey

The outline of this survey is illustrated in Fig. I-2-1. 30 holes with total length of depth(160 ~500m/hole) of 6,424m drilling was carried out as the 1992 survey. IP logging in selected 12 drilling holes of above drilling, and IP and magnetic susceptibility measurement of 424 samples. Re-analysis of the existing surface IP and geomagnetic data were also carried out to refered the above geophysical data. The survey of the concerned organizations of Chile for entrust the ore dressing test which is scheduled in 1993. A term of this survey is as following;

Preparation in Japan	October 30, 1992~ November 6, 1992
Field survey(drilling)	November 7, 1992~ March 8, 1993
ditto (geophysical prospecting)	November 28, 1992 ~ January 27, 1993
ditto (analyses of the existing data and ore dressing)	January 5, 1993 ~ January 24, 1993
Reporting	January 25, 1993~ March 11, 1993
Total term of the survey	October 30, 1992~ March 11, 1993

23 holes and total length of depths of 3,604m drilling survey was carried out as the 1993 survey. During the drilling survey, dressing test in Chile and flotation test in Japan were carried out. In addition, collection of information for production on commercial basis in Chile was also carried out.

Calculation of ore reserves based on the drilling data and decision of flow sheet of optimum dressing were carried out. Pre-feasibility study for production on commercial basis based on the result of calculation of ore reserves and collected information in Chile was also carried out. Terms of the 1994 survey is as follows:

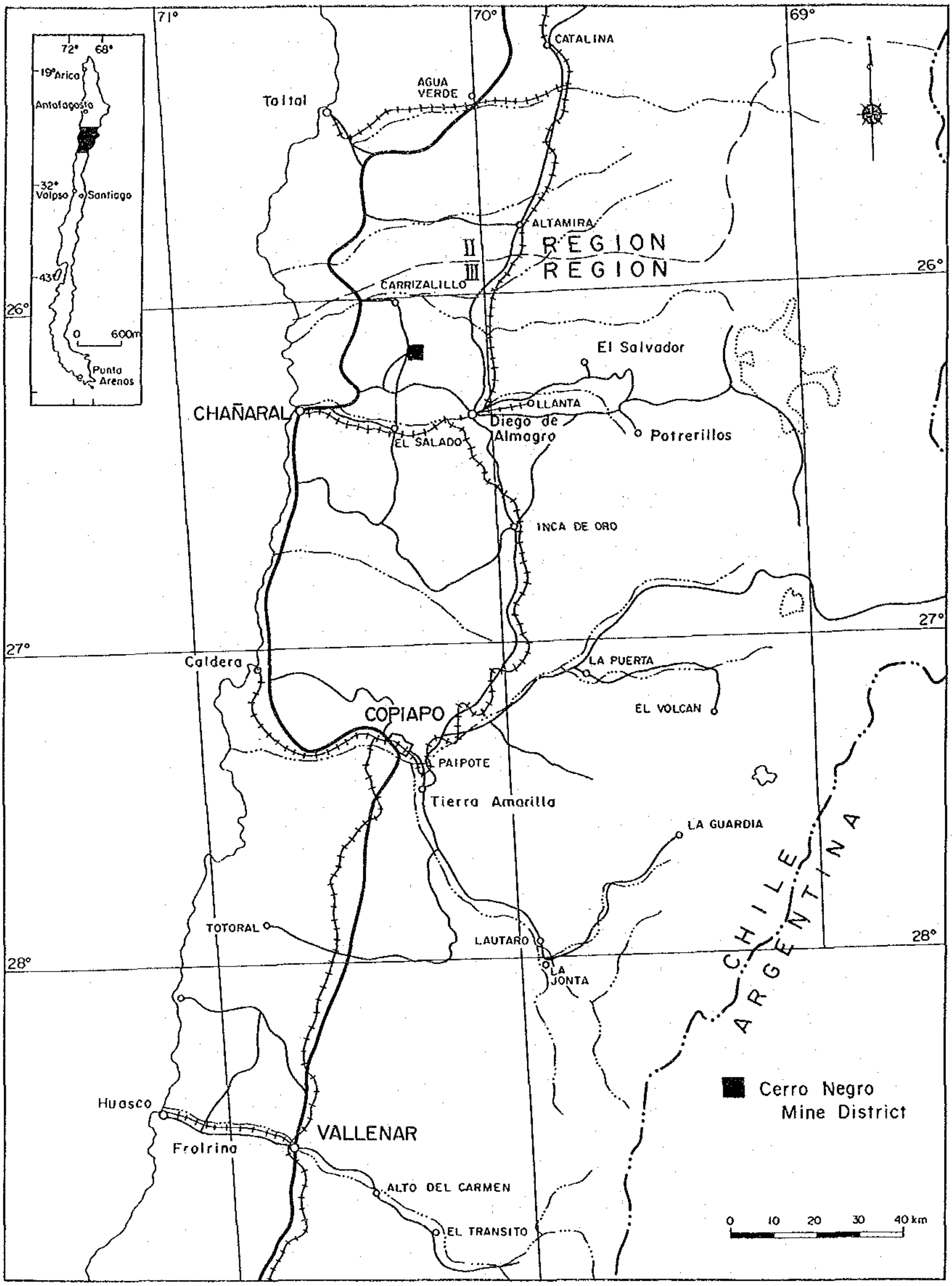

Fig. 1-1-1 Locality map of the survey area

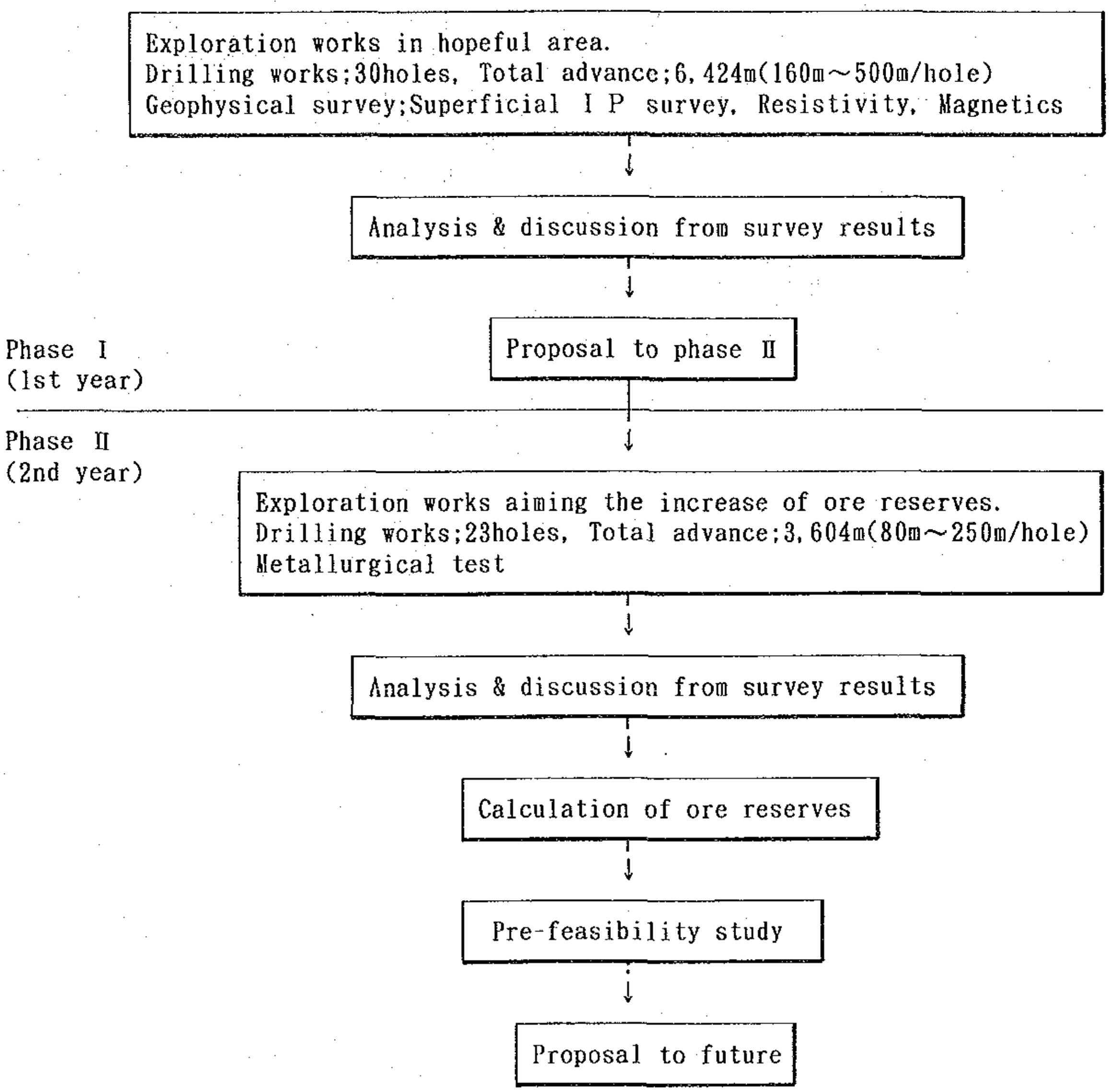

Fig. 1-2-1 Flowsheet of the survey

Preparation in Japan	August 20, 1993 ~ August 22, 1993
Field survey(dressing test)	August 23, 1993 ~ January 29, 1994
Dressing test in Japan	October 18, 1993 ~ January 15, 1994
Field survey(drilling)	October 1, 1993 ~ December 8, 1993
ditto (survc for commercia establishment)	November 15, 1993 ~ December 4, 1993
Calculation of ore reserves	November 1, 1993~ January 25, 1994
Reporting	December 18, 1993~ February 25, 1994
Total term of the survey	August 20, 1993 ~ February 25, 1994

CHAPTER 2 OUTLINE OF GEOLOGY AND ORE DEPOSITS

2—1 Outline of regional geology

This survey area is located in the Andes mountains in the wide sense. The Andes mountains in the wide sense is divided into following three zones which run parallel to each other from the Pacific coast to the west.

① Cordillera de la Costa
② Cordillera de los Andes
③ Precordillera

The Cerro Negro ore deposit of the surve area is located in above ③ Precordillera.

The Andes mountains is fold mountains which continues in the western margin of the South American continent, and the scale is approximately 9,500km from the north to the south and 300km to 500km of width. The mountains are considered to be formed by upheaval. The highest mountain Aconcagua is located in ② Cordillera de los Andes and the elevation of the summit is 7,021m.

The common view of the history of geological structure of the Andes is comparatively simple that the Andes mountains was formed by at least twice orogenic movements after the Palaeozonic era. Further detailed studies are energetically carried out and more detailed history of geological structure are clarified. For example, Mpodozis and Ramos(1989) try to explane the geologic history of the Andes using the recent theories such as plate tectonics, subduction zone, additional prizum zone, activity of magma and strike-slip fault.

The strata of the Palaeozoic to Quarternary are distributed in the Cerro Negro ore deposit area(refer Fig.2-1-1). The outline of geology is as follow;

① Alluvium(Quarternary) mud-flow deposits, talus deposits
② Atacama detritus(Neogene) talus deposits, terrace and gravel deposits
③ Los Cerros Floridas formation(Early Cretaceous)
andesites, pyroclastic rocks
④ La Negra formation(Late Jurassic)
andesites, continental sediments
⑤ Pan de Azucar strata(Early Jurassic)
limestone, conglomerate
⑥ Basement meta-sediments(Ordovician～Devonian)
quartzte, phyllite, meta-limestone

In addition to these strata, there are following three intrusive composite rock bodies as plutonic rocks.

① Serra Pastenos Batholith(Early Cretaceous)
intruded into Los Cerros Floridas strata with grano-dioritic, gabbroic,

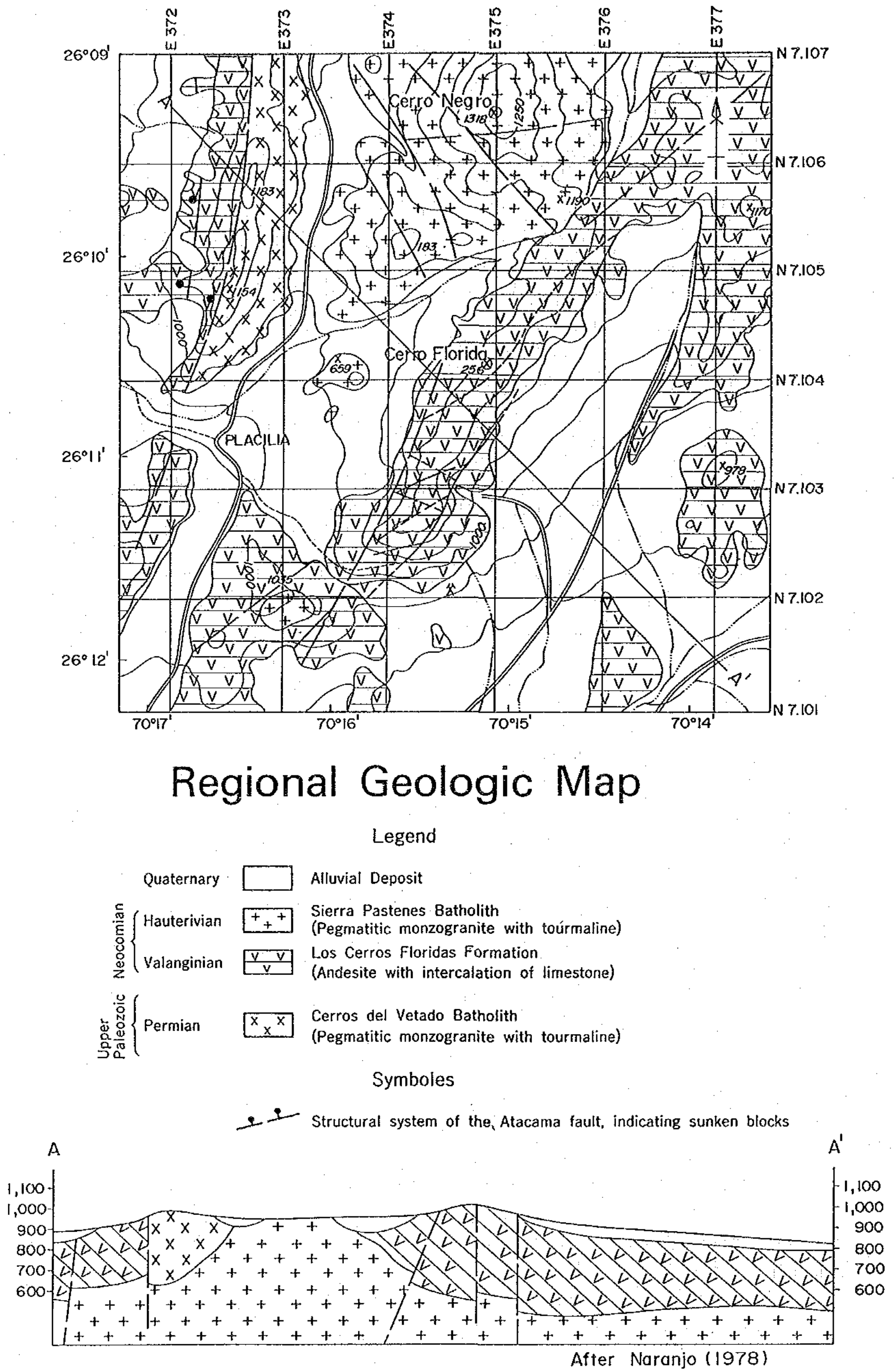

Fig. 2-1-1 Regional geological map

monzonite grano-dioritic and Tonalitic rock facies

② Sierra Minillas Batholith(Jurassic～Cretaceous)
intruded into La Negra strata with dioritic, grano-dioritic, and tonalitic rock facies

③ Cerros del Vetado Batholith(Permian)
intruded into basement metamorphic rocks with mainly granite with tonalitic, grano-dioritic and adamellitic rock facies.

Cordillera de la Costa is composed of the strata and rocks mentioned above, the igneous activity which is considered to have close relationship to the mineral ore deposits is observed within La Negra formation and Los Cerros Floridas formation. The outline of activity is as follows;

① La Negra formation has the strike of generally N-S direction and inclines to the east.
La Negra formation is composed of andesite and andesitic pyroclastic rocks and sandstone within former two rocks.
Andesite shows porphyritic and dark brownish to dark reddish color, their occrrence is massive, because they cannot be recognized as lava flow from the texture.
Plagioclase is generally argillizated and sericitizated, and mafic minerals altered to opaque minerals.
Sandstone shows brownish to reddish color. They are composed of layers of 5 to 20cm thick.
The thickness of the formation is considered to be 3,000m thick and covers Pan de Azucar concordantly.

② Los Cerros Floridas formation is the country rock of the Cerro Negro ore deposit.
The strike and dip are almost the same of lower strata which shows monoclinic structure of 20° E.
They are composed of greenish to grayish porphyritic andesite and brecciated andesite.
Limestone whose thickness is 5 to 10cm is distributed in the southeast of Los Cerros Floridas.
As regards general alteration, plagioclase is sericitized and mafic minerals altered to opaque mineral.
The thickness of the strata is considered to be 2,000m and coveres with unconformity La Negra formation.

One of the characterics of the area of Cerro Negro ore deposit is located within the fault zone of Falla Atacama. This Falla Atacama continues more than

700km from north to east, and is considered to be the great tectonic line which reachs the deep part of the crust. The line starts in Antofagasa(S24°) and continues via Copiapo area, and reachs Coquimbo(S30 °). The tectonic line generally shows left strike-slip, however, it also shows throw or right strike-slip in the secondary faults or in part. Although the width of the fault zone extrmely varies, the average width is 3km to 4km. The activity have begun in the early Cretaceos period and many faults have been made by the activity. The activity also affects to displace to La Negra formation, Los Cerros Floridas formation and batholith in the area of the Cerro Negro ore deposit. Many strike-slip faults and gliding planes are observed in this area. This great tectonic line is presumed to be deeply contributed to form the Cerro Negro ore deposit and related igneous rocks.

2—2 Outline of geology of Cerro Negro mine area

The rocks which are observed in drilling survey and field survey are fundamentally Quarternary deposits, Cretaceous Los Cerros Floridas formation (andesitic pyroclastic rocks partly with limestone),dykes, mineralized/alterated rocks and cataclasite by tectonic movement. Andesite of Los Cerros Floridas formation is divided into four different strata(Ad.4 to Ad.1)by their flow units *in descending order. Surface geology is shown in Fig.2-2-1.*

The general stratigraphy of this survey area by summarized rock facies are as follows;

Quarternary; Talus deposits

Cretaceous(Los Cerros Floridas formation);

Aphyric andesitic lava,

tuff breccia dominant(including "hydrothermal breccia)

corresponds to Ad.4 and Ad.3

Plagioclase porphyritic basaltic andesite dominant

(including smaa amount of "hydrothermal breccia")

corresponds to Ad.2 and Ad.1

Several fault systems were confirmed and presumed refering to existance of fracture zones and rapid change of rock facies by drilling survey and field survey. These fault systems are divided into several geological blocks, and they are one of the important factors to analyse the shape and grade of copper ore deposits.

On the other hand, so-called "hydrothermal breccia" is widely distributed in the drilling survey area, and it is the country rock of copper ore deposit. Therefore, the distribution features and mineral component is the important to analyse the shape and grade of copper ore deposits.

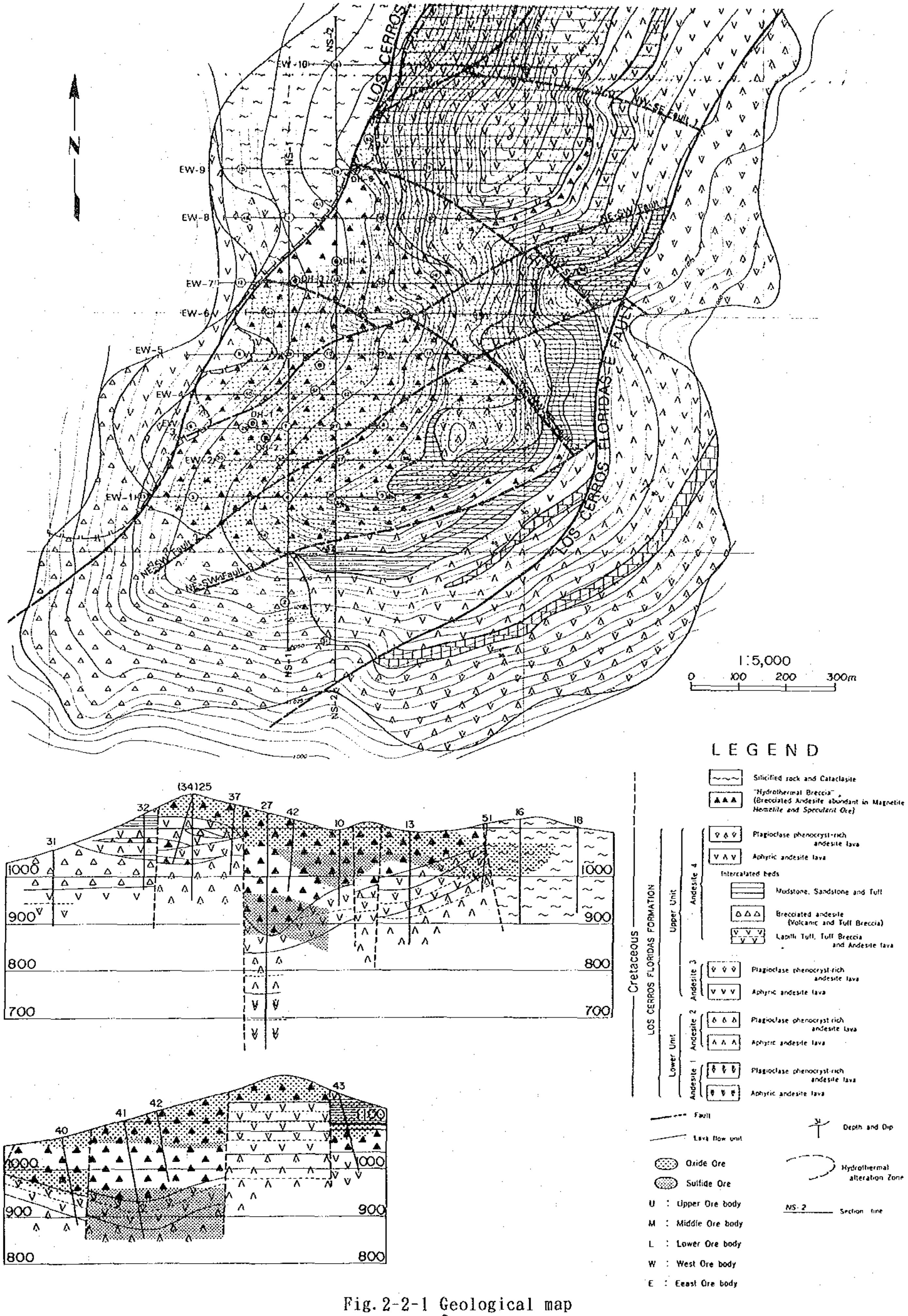

Fig. 2-2-1 Geological map

① General strike and dip

Inclination of 20 ~30° to the west as general dip is presumed by the shapes and content of plagioclase in andesitic lava, and its amygdaloidal structure. The moderate inclination of 20 ~30° to the north-west as general dip is presumed by the banded structure of tuffs which are distributed in small quantities near the summit of the mountain. On the other hand, almost vertical inclination is observed in the eastern and the southern part of the mountain.

② Faults and geological blocks

The following three kinds of fault systems were confirmed or presumed by drilling survey and field survey;

The fault with the direction of NNE-SSW (Fracture zone with Los Cerros Floridas-W fault and Los Cerros Floridas-E fault).

The fault system which runs parallel in the eastern and the western side of Mt. Los Cerros Floridas. The fault system forms the mountains topography, and is considered to be the secondary fault of the Atacama fault.

The fault with the direction of NE(NE-1 ~NE-4 faults). There are four faults. All the directions of strike are presumed to be N60° E with steep inclination. These faults are considered to be the secondary fault which located among the former three faults with the direction of NNE-SSW. Particularly, NE-2 fault and NE-3 fault lie crossing to the survey area, and controled "hydrothermal breccia" and the distribution of copper ore mineralization.

The fault with the direction of NW(NW-1 ~NW-3 faults).

There are two faults whose directions of the strike are considered to be N55°W and steep inclination. There are six valley topography which run parallel to the direction of NE between NE-2 fault and NW-3 fault. These six faults are considered to be the small fault systems or fracture zones with the same direction.

③ "Hydrothermal breccia"

The "hydrothermal breccia" which is observed at the deepest part was in 850mL of the MJCC-41 drilling hole. the rock is observed in the shallower part of 950mL in the surrounding area. The south-western part occurs generally deeper than that of other direction. However, the tendency is cut by the former fault of NE-3 and the occurrence in deep part is not observed in the southern part. The shape may be presumed to be like pipe in deeper part or funnel which widening upward, and spread with harmony to the strata in the shallower part whose center is MJCC-41 drilling hole.

2—3 Outline of ore deposits

Copper oxide mineralization zone and copper sulfide mineralization zone as copper ore deposits are located in this survey area. In addition to these two types of ore deposits, mixed zone(intermediate zone) is also located. The mineralization zones which is observed in each drilling hole is shown the list in TableI-4-2-1. The representative distribution of ore bodies is shown in Fig. I-4-2-1.

1) Copper oxide mineralization zone

Copper oxide mineralization zone are observed in almost all the drilling holes except the holes located in the western margin of the survey area. This mineralization zone is generally distributed the shallower underground of less than 50m～100m. The high Cu grade parts of more than 1%SCu repeats the intervals of about 10m～15m period. The high grade part of more than 10% SCu is partly observed(for example, under about 50m of MJCC-55 drilling hole), the continuity of the high grade part is not good. The main copper oxide minerals are atacamite and malachite with small quantities of chrysocolla, azurite and chalcanthite.

2) Mixed zone(Intermediate zone)

Copper sulfide minerals sometimes remind within copper oxide mineral zone, and particularly the part is called mixed zone(intermediate zone). The high grade part in the copper oxide mineral ore zone which described before is mostly composed of copper oxide minerals, however, many of the part of less than total Cu 1% within the high grade part is composed of almost the same quantities of copper oxide mineral and remnant copper sulfide minerals. The mixed zone as the transitional zone sometimes occurs between copper oxide mineral ore zone in the upper part and copper sulfide mineral zone of the lower part. But, the distribution features of above three zones are too complexed to define as individual zones.

3) Copper sulfide mineralization zone

Copper sulfide mineralized zone are observed in many drilling holes in this survey area, and high grade copper sulfide mineralization zone is observed in the drilling holes near the center of this survey area. Copper sulfide zone generally occurs in the underground of deeper than 50m～100m, and the parts of more than 20%ICu are observed in limited place(for example, 135m in the depth of the MJCC-29 drilling hole). The continuity of the above high grade part is not good. The main copper sulfide mineral is chalcopyrite with small quantities of chalcocite and covelline.

CHAPTER 3 OUTLINE OF SURVEY

3—1 Analyses of the existing data

Reference are listed in the end of the 1992 and the 1993 reports. Prticularly, regarding regional geology, Naranjo(1978) is refered. Regarding the geology of the ore deposit area, EGM Evaluacions Geologicos Mineras Ltda. (1991) is refered, and regarding geophysical prospevting data Geodatos(1991) is mainly refered. Particularly, regarding geophysical data, logging in drilling holes and measurement of physical properties of drilling cores were carried out as geophysical prospecting in 1992. After the prospecting, re-analysis of the data of Geodatos(1991) was carried out. The result is described in 3-3.

3—2 Geological survey

Early Cretaceous Los Cerros Floridas formation is widely distributed in this area. The formation is mainly composed of andesitic lava and andesitic "hydrothermal breccia", and small amounts of andesitic pyroclastic rocks and limestone also distributed in the upper horizon of the formation. The Atacama fault was formed soon after Los Cerros Floridas formation was formed, two faults of Los Cerros Floridas-W and -E(the NNE-SSW direction) was formed at the same time. The secondary fault systems with the direction of NE-SE and NW-SE were formed between the above two faults at the same time or after the formation. After the above activities, brecciation which was caused to form "hydrothermal breccia" and iron mineralization of specularite and magnetite occur controled by faults at almost the same time. After the iron mineralization, copper mineralization occurs under the porous conditions of faults, "hydrothermal breccia" and andesite with amygdaloidal structure. However, a part of the copper ore body shows slips by faults, the displacement by the faults is considered to intermittently continue comparatively for a long time.

These results are summarized in the Fig.2-2-1 and summary figur of the result.

3—3 Geophysical prospecting

The distributin of measurement result is shown as the ground plan of physical property in Fig.3-3-1 and the summary figure.

[Characteristics of physical properties of standard specimens]

IP and resistivity of specimens of drilling cores was measured.

① Chalcopyrite shows high IP and the lowest resistivity(3 Ωm). The magnetic susceptibility is the lowest as 27 x 10 -6cgs.

② Pyrite shows high IP, low resistibity and low magnetic susceptibility.

③ Hematite shows the lowest IP as 2.3 ~3.5%.

④ Specularite shows high IP as 47.3%. The resistivity widely varies as 1 98～ 6,533%.

⑤ Magnetite shows high IP as 21.0 ～48.0%. The resistivity widely varies as 171 ～8,777%. The magnetic susceptibility is remarkably low as 9,566～ 31,332 x 10 -6cgs.

[Comparison measurment of specimens with the surface IP anormaly in IP logging]

(IP distribution)

measured value of IP logging of specimens and the surface anormaly show the same tendency. The surrounding area of the MJCC-10 and MJCC-13 drilling holes shows the highest. In addition, the area of MJCC-7, 14 and 11 show high IP value. These developed high IP anomalies are well-matched to the presumed sources of anormalies by the surface anormaly survey. It proves the properity of the existing simulation result.

(Relative resistivity distribution)

Since both data of logging and measurement of specimens extremely vary, logalithmic mean value of each drilling hole was used for characteristics extraction. As the result, obvious low resistivity zone is not recognized by the logging data and the measurement data of specimen. The distribution shows comparatively lower values as 100 ～200 Ωm than those of the surrounding area. However, when the data are arranged in each depth of hole using the cross section, low resistivity zones(logging data) of 10～30Ωm are recognized in each depth corresponding high IP anomaly sources. The low resistivity zones are as follows:

MJCC-7	1 ～ 5	Ωm	at a depth of 120m～150m
MJCC-10	4 ～20	Ωm	at a depth of 50m～ 90m
MJCC-11	15 ～30	Ωm	at a depth of 80m～100m
MJCC-13	20 ～30	Ωm	at a depth of 55m～ 70m

The thickness of these low resistivity zones are comparatively thin as 15m ～40m. As electric current concentratedly flows in electric conductive layer by electric introduction into the earth, these low resistivity zones are considered to be detected as high IP/low resistivity zones by the surface IP measurement.

(Distribution of metal conduction factor)

High metal conduction factor from both data of IP logging and measurment of specimens shows the surrounding areas of the holes of MJCC-7, 10 and 13. The result(high IP/low resistivity) is well-matched to IP anomalous sources by the surface IP prospecting.

[Re-analysis of the surface IP anomalous data]

Re-analysis of IP anomaly data of past surface IP prospecting of ENAMI.

The IP prospecting data of the 1993 survey was used as the control data in this re-analysis. 2.5 dimensional Finite Element Analysis Method was used in the re-analysis. The targets of the re-analysis were four survey lines. Those are P-2 survey line (including MJCC-6, 7, 8 drilling holes), P-3 survey line (including MJCC-10, 11), P-4 survey line(including MJCC-12, 13, 14. however, refer to the physical property data of core in the MJCC-13) and P-7 survey line (the MJCC-18,20). The result of re-analysis is as follows;

(P-2 survey line)

Two models, high IP/low resistivity and high IP/high resistivity models, are considered for explane IP anomaly. The former model corresponds to pyrite mineralization zone within hydrothermal breccia at a depth of 120m～160m in the MJCC-7 drilling hole. It is presumed to spread 200m ～250m holizontally. Since magnetite shows high resistivity, the high IP/high resistivity model is considered to correspond to magnetite mineralization zone, which surrounds pyrite mineralization zone.

(P-3 survey line)

This survey line runs east to west about in the center of the surface IP anomalous area. High IP/low resistivity model is considered to reflect the succession of chalcopyrite mineralization zone, which occurs within hydrothermal breccia at a depth of 50m～100m in the MJCC-10 and occurs within phenocrystic andesite at a depth of 70m ～100m in the MJCC-11 hole. This mineralization zone inclined to the west. The distribution area is presumed to reach about 300m horizontally. This high IP/high resistivity model develops surrounding the high IP/low resistivity model. This high IP/high resistivity model is considered to correspond to magnetite mineralization zone like as P-2 survey line. The poverty of this high IP zone is proved in the eastern side of the MJCC-11 hole was confirmed by the calculation of model. Therefore, the merit of prospecting of this area is considered to be low.

(P-4 survey line)

Chalcopyrite mineralization zone, which continues east to west, was assumed as the model of the source of high IP/low resistivity by the surface IP prospect ing. The chalcopyrite mineralization zone is detected within hydrothermal breccia at a depth of 50m ～70m in the MJCC-13 hole. The continuity from east to west of the mineralization zone is considerd to be about 100m. This high IP/high resistivity zone is considered to develop in the upper and lower layer and the eastern part of this high IP/low resistivity model by the section analysis. This means magnetite mineralization zone is presumed to be widely distributed in this area.

(P-7 survey line)

Low resistivity with 30～50Ωm and dyke like shaped model is assumed by the section analysis in the middle of the MJCC-18 and MJCC-20. This model corresponds to fracture zone in the geological section. Weak IP/high resistivity and dyke like shaped model is assumed in the eastern part of the MJCC-20 hole. This model correspond to hydrothermal breccia with weak mineralization of magnetite by the geological section.

As overall analysis of the cross section, Anomaly source of high IP/low resistivity by the surface IP prospecting is considered to be copper sulfide mineralization zone within stockwork like hydrothermal breccia which develops from the MJCC-7 hole as the distribution center. The depth of upper part of the mineralization zone is considered to be controlled by the depth of oxide zone. And, this high IP/low resistivity zone is accompanied with high IP/high resistivity zone composed of magnetite in the surrounding area. Both anomaly zones is presumed to have close relationship in metallogeny.

In comparison with the result of the 1993 re-analysis and the existing result, the range of high IP/low resistivity zone is reduced to about one third of that of the existing zone, and the location of the MJCC-8 hole goes out of high IP/low resistivity zone and MJCC-11 comes inside of this zone(refer Fig.3-3-1).

As the result of section analysis, the continuation from east to west of high IP/low resistivity zone, which is the target of prospecting, is presumed to extend maximum 300m near the MJCC-10 hole. The continuity of high IP/low resistivity zone cannot be expected in the eastern part of the ridge of Mt.Cerro Negro. Therefore, the merit of prospecting must be low.

[The cause of the surface IP anormaly considered by physical prperty data]

① The high IP/low resistivity anomaly by model simulation of the surface IP anomaly is caused by the mineralization zone of magnetite and pyrite concentration.

② Since pyrite mineralization overlaps magnetite mineralization, the cause of high geomagnetic anomaly zone by geomagnetic survey is concluded by magnetite concentration.

③ Comparatively high IP anomaly by magnetite concentration sometimes detected outside of anomalous zone by the surface IP prospecting. The IP anomalous zone shows high resistivity. Therefore, The distinction of the anomalous zone by magnetite from that by sulfide mineralization zone (chalcopyrite and pyrite) is possible due to low resistivity anomalous zone by sulfide minerals.

[The re-analysis of geomagetic anomaly]

① More than 2 x 104(hereafter ommit 10-6cgs) of high magnetic susceptibility zone circularly spreads from the MJCC-10 and 13 holes as the center by the

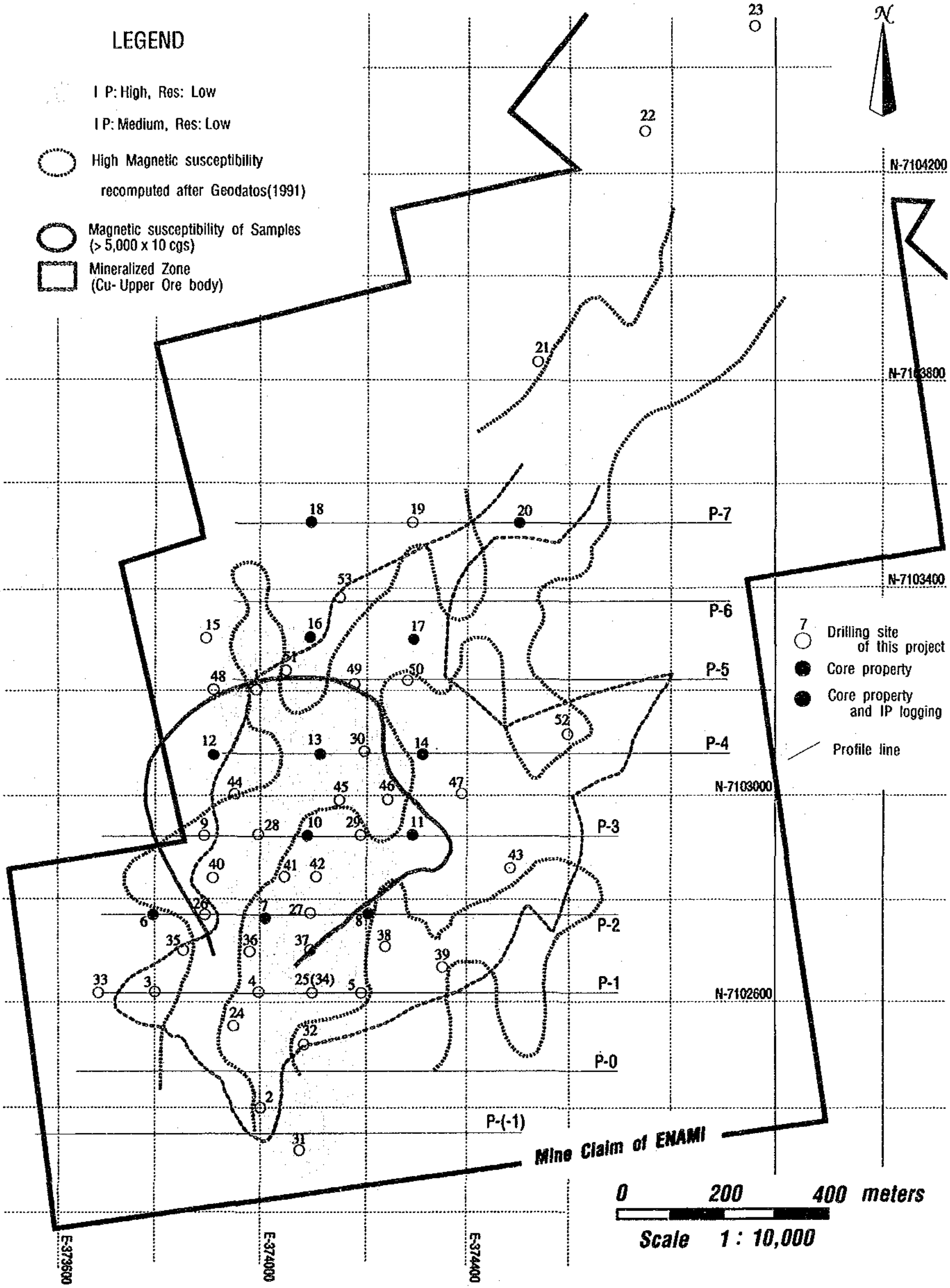

Fig. 3-3-1 Geophysical property map

result of re-analysis.

② The range of the high susceptibility zone is enlarged in comparison with the range by existing survey. The trend of the direction of NE-SW in the existing survey result disappears in the result of re-analysis. And, circular distribution of the high susceptibility zone is the characteristics.

③ The range of the high susceptibility overlaps the range of various high anomalies of physical properties shown in Fig. 3-3-1. It also shows good correrespondence to the high susceptibility of drilling core. Therefore, the high susceptibility is considered to be caused by magnetite concentration zone. Magnetite mineralization zone is considered to cause the high magnetic susceptibility.

④ This high susceptibility zone is particularly remarkable at a depth of more than 100m underground. However, susceptibility is high at the surface, it means that the shape of high susceptibility zone is pipe like shape. This shape like pipe is considered to be the possible center of magnetite mineralization.

3 — 4 Drilling survey

The target ore deposits are the copper deposits which was metasomatically precipitated within the andesite of Los Cerros Floridas formation and "hydro-thermal breccia" which is the same origin of the andesite of Los Cerros Floridas formation. The shape of the deposits is generally called manto shaped. Four unit of lavas of andesite(Ad. 1～Ad. 4 in descending order) was confirmed by their flow units. The country rocks of ore deposits are in the upper horizon of Ad. 2. Refer to the cross section in the appendix of this final report about the detailed relationship between the ore deposits and the country rocks.

The ore deposit is considered to be metasomatic deposit, and the deposits apparently occur in two or three horizons for the shape like mantle. The deposits are classified into five ore bodies(the upper, middle, lower, east and west ore bodies) by the distribution features. The upper ore body is mainly composed of copper oxide ore minerals. Sulfide ore body mainly composed of copper sulfide ore minerals, and mixed ore body composed of copper sulfide minerals and copper oxide minerals coexist are sometimes occur in the lower part of copper oxide ore body. The other ore bodies are mainly composed of sulfide minerals. However, the parts of them sometimes show the occurrence of oxide ore body or mixed ore body.

The juvenile copper mineral is considered to be chalcopyrite. It changes to chalcocite, atacamite, malachite and chalcanthite by oxidation in the shallow part and along the faults. Occurrence of chalcopyrite is dissemination～

reticulated, on the other hand, ordinary occurrence of copper oxide is menbrane. Copper minerals generally coexist with iron oxide minerals such as specularite and magnetite in this survey area because iron mineralization went ahead of copper mineralization. Division of oxide ore body and sulfide ore body is possible on the map. However, division of mixed ore body is difficult because of the complicated occurrence with other two ore bodies.

53 holes and total length of depth(at a depth of 80m～500m/hole) of 10,028 meters drilling survey was carried out in two years. Survey of the distribution of ore deposits and rough calculation of ore reserves was carried out by drilling with the drilling interval of 100m in detailed survey area. The accuracy of estimation of ore reserves must be difficult to remarkably improve, if the drilling density increases to one half of this survey.

Two of the drillings(MJCC-27 & 41) reached the lower ore body which was not the main target of this survey. As the parts of the west and the east ore bodies which are located in the eastern and the western side of the survey area were detected, further geophysical prospecting and drilling to both side and deeper horizon are hopeful to discover new ore deposits in spite of mining area.

Refer to the summary figure about the drilling points, the distribution of copper oxide ore bobies and relationship between copper oxide mineralization and the result of gyophysical prospecting.

3－5 Metallurgical tests

Metallurgical tests were entrusted to Centro de Investigacion Minera y Metalurgica (CINMM) of the Republic of Chile, succeeding the results of the previous year, for the development of the most suitable flowsheet in the productive operation, for the estimation of metallurgical results and for obtaining detailed data and information to be used in the plant design. In these tests flotation and leaching－SX/EW methods were applied to five kinds of ore samples, that is, one oxide ore from the upper ore body, two types of mixed (oxide and sulfide) ores from the upper and western ore bodies, and two types of sulfide ores from the upper and western ore bodies, all of which were taken from the boring cores carried out in the year of 1992. As a result of the tests, for the treatment of the oxide ore from the upper ore body and the mixed ore from the western ore body(the ratio, soluble Cu/total Cu is aout 50% in either ore) heap leaching－ SX/EW method proved suitable with about 76% of estimated extraction rate. On the other hand, for the mixed ore from the upper part (sol.Cu/total Cu is under 20%) and for all the sulfide ores, flotation is suitable with about 90% of recovery rate (around 77% in case of the mixed ore). As the results of analytical and other investigations on copper concentrates, tailings and also on cathode copper, any impurities that could cause troubles in commercial or environmental aspects were not detected.

As for the two types of mixed ores from the upper and western ore bodies, which are classified as geologically identical, treatment method shoulddepend up on the ratio, soluble Cu/total Cu. It was found that for ores, of which ratio is under 20%, flotation is suitable, while for those, of which ratiois above 50%, leaching— SX/EW method is suitable. Accordingy, from the point of mineral processing it is recommended that ores should be classified in terms of the ratio, soluble Cu/total Cu, simply into oxide or sulfide for the produc- tion program and discussion. Based on this idea, a flowsheet shown in Figs. 3-5-2 and 3-5-3 was developed after discussion of treatment methods for the Cerro Negro ores. In economical discussion, however, it should be noted that treatment of the mixed ores may bring somewhat lower metallurgical results as well as increased operation costs.

Flowsheet of the metallurgical tests is shown in Fig. 3-5-1. Principal metallurgical results and data obtained from the tests are summarized in Table 3-5-1

3—6 Calculation of ore reserves

The method of calculation of ore reserve is as follows;

① At first, ore deposits are divided into following five ore bodies, those are. The upper, lower, middle, east and west ore bodies, respectively. However, as three other ore bodies which are rich in sulfide minerals, there are totally eight bodies.

② Average Cu grades of each 10m in depth was calculated by the chemical analysis of each 1m in drilling cores, and the values were defined as the grade of each 10m of ore body. The values of chemical analysis of each 1m and each 10m on the section are shown in fig. II-3-1-2(1) & (2).

③ All the grades were assigned as a unit block which is 25m x 25m(plan) x 25m (depth) in all the ore bodies. The assigning method was distance inverse-square method, because variogram was impractical by geo-statistic method.

④ The actual range of data assignment was a sphere with 400m of radius. The reason was that the range of influence in the variogram of the NE-SW direction on the plane. However, it is necessary to further examination about the range of 400m.

⑤ Assigned grades are total Cu, soluble Cu and insoluble Cu. The example of assigned grades and ore body are shown in Fig. II-3-1-3(1) & (2), and average assignment in each block is shown in Fig. II-3-1-4. Specific gravity varies from 2.7 to 3.3, the value of 2.7 is adopted as specific gravity for safety.

Sample preparation

Chemical analysis &
Measurement of work index

(Oxide, Mixed ores)

Leaching-SX/EW tests
- Heap leaching tests
- Bacteria leaching tests
- Solvent extraction tests(SX)
- Electrowinning tests(EW)

(Sulfide, Mixed ores)

Flotation tests
- Rougher flotation tests
- Cleaner flotation tests
- Settling & dewatering tests on concentrate and tailing
- Analysis of recirculating water
- Design of flotation flowsheet

Development of complete flowsheet

Fig. 3—5—1 Flowsheet of the Metallurgical Tests

Table 3—5—1 Summary of the Metallurgical Tests

Sample	SC-1	SW-2	OX-1	MC-1	MW-2
Bond's Work Index (kWh/st)	13.62	17.65	14.45	13.90	16.90
Recovery by Flotation (%)	93.05	87.12	NA	76.60	55.53
Cu Grade of Cu Concentrates (%)	38.75	32.87	NA	33.40	26.63
Extraction by Leaching (%)	NA	NA	75.5	51.8	80.8
Consumption of Sulfuric Acid kg H2SO4/t ore) kg H2SO4/kg Cu)	NA NA	NA NA	30.3 5.10	51.9 10.8	124.2 14.0
Unit Area of Conc. Thickener (m^2/tpd)	0.177	0.202	NA	0.108	0.614
Unit Area of Tail. Thickener (m^2/tpd)	0.106	1.084	NA	0.541	1.490
Unit Area of Conc. Filter (m^2/tpd)	0.028	0.047	NA	0.032	0.099

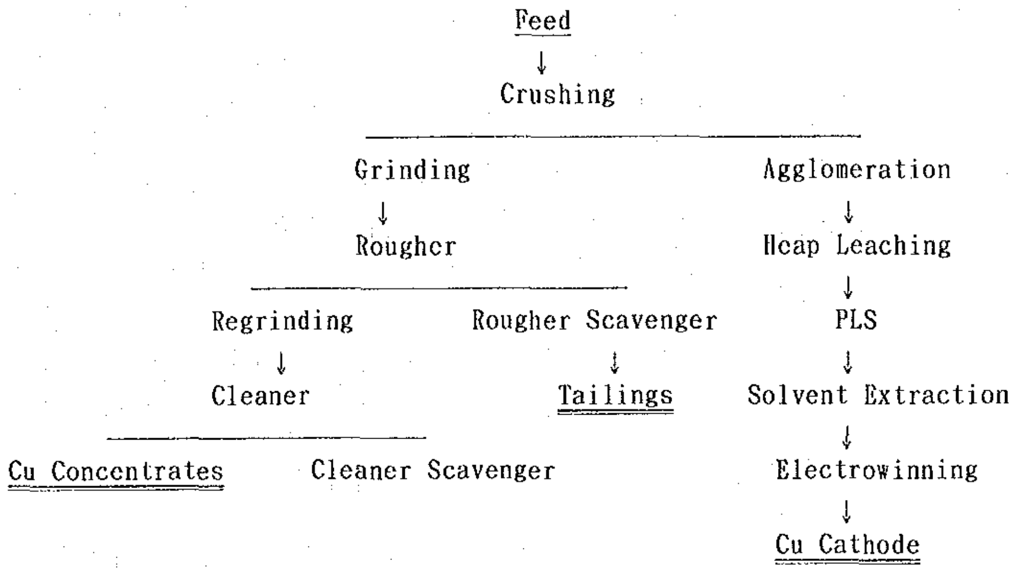

Fig. 3—5—2 Flowsheet of Ore Treatment

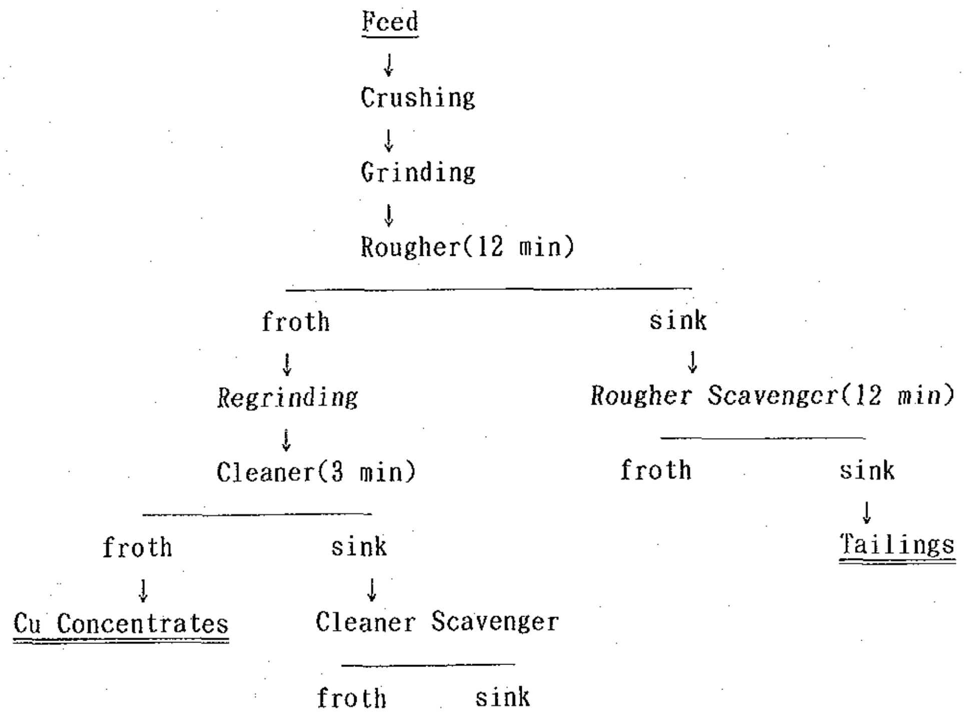

Fig. 3—5—3 Flowsheet of Flotation

As the result, 87,692,000tons of ore reserves and To-Cu 0.54%(Cut-off grade 0.4%) were estimated. The lowest level including ore reserves is 820mL above sea level. Please refer colored figure of grades of blocks on plan about assigned grades in all the blocks(attached document).

In addition to the calculation, design of open pit was carried out by Moving Cone Method under the following supposition;

① Cut-off grade is 0.4%(Total Cu).

② Total mining recovery is 80%.

③ Copper price is US$1.05/Pound. Though this price is fairly higher than actual price, it is considered to be better that setting up of open pit is fairly larger.

④ Total expences of mining, dressing, smelting, shipping and sales, etc are US$6.91/ton of ore.

⑤ Pit slope is 45°, road width within pit is 20m and road slope is 45° .

The result is shown in Fig. I-4-5-1.

The ore reserves within the open pit is estimated to be minable reserves of 33,787,120tons(To-Cu grade is 0.61%) is estimated. In this case, the lowest level is 960mL above sea level.

Summary of ore reserves and minable ore reserves are shown in Table 3-6-1.

3—7 Pre-feasibility study

The experts were dispatched to collect necessary information about production of commercial basis in order to examine the possibility of development of the mine in 1993. Design of open pit, calculation of minable ore reserves and flowsheet of ore treatment were recommended before this work. The examination about development by DCF method was carried out with these recommendations and informations.

Major presupposition is the following:

①Minable ore reserves; 33,787,000tons, To-Cu 0.613%(cut-off grade 0.4%)
breakdown;oxide ore 24,170,000tons, To-Cu 0.522%
sulfide ore 9,611,000tons, To-Cu 0.842%
(waste 41,280,000tons)

The ore is mined by open cut mining. Mining term is 10 years.

②Production

Oxide copper ore(recovery 72%)→cathode Cu 9,110tons/year(Cu 99.99%)
Cu amount 9,109tons

Sulfide copper ore(recovery 93%)→Cu concentrates 21,500tons/year(Cu 35.0%)
Cu amount 7,525tons

Table 3-6-1 Result of calculation of ore reserves

Ore Reserves

Cut-off grade (To-Cu %)	0.200	0.400	0.600	0.800	1.000
Ores (×1,000t)	175,572	87,258	18,588	5,298	3,578
Average grade (To-Cu %)	0.428	0.541	0.820	1.199	1.350

Minable Ore Reserves (Ore Reserves in the proposed open pits)

Cut-off grade (To-Cu %)	0.0000	0.2000	0.3000	0.4000	0.5000	0.6000	0.7000	0.8000
Ores (t)	75,062,304	56,607,024	45,413,876	33,787,120	19,763,740	9,438,694	5,479,144	4,556,588
Volume (cubic meters)	27,800,856	20,965,564	16,819,954	12,513,749	7,319,904	3,495,812	2,029,312	1,687,625
Average grade (To-Cu %)	0.374	0.487	0.545	0.613	0.729	0.932	1.145	1.228

Flowsheet of ore treatment is shown in Figs. 3-5-2 and 3-5-3. The SX-EW method is selected in treatment of oxide ore.

③Term of production

Since the longest term of special repayment as the tax privilage is eight years, a term of production actively is ten years. Besides the exploiting term, term of preparation is three years.

④Sales condition

The condition adjusts the standard sales condition in the refineries of Japan.

⑤Copper price

The standard is 90¢/lb, however, the cases of 110¢ and 130¢ are considered.

Under the above conditions, IRR was calculated by the DCF method. As a result, in case of 90¢, 110¢ and 130¢ of copper price, IRR(before interest) were 5.324%, 20.486% and 32.339%, respectively. The copper price which was calculated back to zero IRR(before interest) was 84.3¢. The IRR before interest of more than 15% is generally considered to be necessary. The copper price which was calculated back to IRR of 15% was 101.8¢.

Total Cu grade 0.57%(breakdown;oxide Cu ore grade 0.49%, sulfide Cu ore grade 0.78%) of crude ore grade is necessary in the copper price of 90¢ without any conditions change in order to zero IRR before interest. 15% of IRR in the same conditions is necessary the crude ore grade of total-Cu 0.89%(oxide Cu ore grade 0.76%, sulfide Cu ore grade 1.21%).

CHAPTER 4 DISCUSSION AND CONCLUSION

4 — 1 Discussion

Using the drilling data located with 100m intervals, it is difficult to calculate ore reserves with high accuracy, because most of copper ore minerals occurred complicatedly like as dissemination and networks. And increase of accuracy in caluculating ore reserves can not be expected in such kind of ore deposits as this mine, even if intervals between drilling sites.

In the upper ore body that is a main target of this survey, it was indicated that high variation in Cu grade is usual and ore reserve decreases highly with increse of Cu grade. Therefore oxide ore is suitable for small scale mining in high grade parts. Though sulfide ore body was not aimed mainly to explore in this survey, parts of lower, western and eastern ore bodies composed of sulfide ore were detected. Exploration for extension of these ore bodies is expected.

After metallurgical tests, it was concluded that oxide copper ore should be treated in leaching-SX-EW plant and sulfide copper ore should be treated in flotation plant. Mixed ore compprised of oxide ore and sulfide ore closely should be decided in accordance with ratio between soluble Cu and insoluble Cu, to which plant should be sent. Although the amount of mixed ore is not so big, decrese of recovery and increse of cost in treating it must be discussed.

As sulfide ore in lower ore body was not included in minable ore reserve, it is expected to be explored in future. The actual range of grade assignment in ore calculation is also needed to be discussed. Since ore reserves of sulfide ore does not decrese so much with increse of Cu grade, sulfide ore body should be explored mainly in future.

4 — 2 Conclusion

Calculation of ore reserves was carried out based on results of drilling works, on the steps as follows;

①At first ore reserves was calculated by distance inverse square-square method, and value of 87,692,000tons(To-Cu 0.54%) was obtained as whole ore reserves.
②Adding some other economical suppositions, open pit was designed.
③Ore reserves in the designed open pit was calculated as minable ore reserves, and its value was 33,787,120tons(To-Cu 0.61%).

IP logging, measuring physical properties of core samples, and reanalysis of surface IP data and surface geomagnetic data were performed as geophysical prospecting, consequently it was revealed that high manetic zone corresponds well to distribution of "hydrothermal breccia" (main country rock of oxide ore), and high IP and low resistant zone corresponds well to lower ore body composed of sulfide ore.

Three kinds of ores(that is, oxide, mixed and sulfide ores) were collected from upper and western ore bodies, then totally 5 samples(western ore body has too small amount of oxide ore to perform metallurgical tests) were tested metallurgically. Afterwads suitable flowsheet of ore treatment in this mine was recommended as shown in Fig. II-4-3-2.

Internal rate of return(=IRR) was calculated by DCF method, based on the results of ore reserves calculation and metallurgical tests as economical evaluation. In cases of copper price 90¢, 110¢ and 130¢, IRR before interest were caluculated as 5.324%, 20.486% and 32.339% respectively. Usually IRR before interest is said to be necessary more than 15% in order to start enterprise. Then copper prices were calculated to be 84.3¢ and 101.8¢ so as that IRR(before interest) would be zero and 15%. Low copper grade was the reason why unusually high copper price must be waited to start development in this mine. Then copper grades were reckoned backwards to be 0.57% total Cu(breakdown;oxide Cu ore grade 0.49%, sulfide Cu ore grade 0.78) and 0.89% total Cu(breakdown;oxide Cu ore grade 0.78%, sulfide Cu ore grade 1.21%) so as that IRR before interest become zero and 15%.

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