REPORT ON THE SURVEY

FOR

MINERAL RESOURCES DEVELOPEMENT

IN

THE REPUBLIC OF CHILE

MARCH 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

Preface

In response to the request of the Government of the Republic of Chile, the Government of Japan with the Japan International Cooperation Agency as the implementing arm has carried out the survey for the mineral resources development for 30 days from January 28 to February 26, 1980, in the Republic of Chile.

The development of mineral resources is a priority project of the republic of Chile in promoting the local economic development.

The Japan International Cooperation Agency (JICA) formed a mineral resources survey team consisting of five experts headed by Mr. Minoru Sumita of Dowa Engineering Co., Ltd.

The team, in close collaboration with the Government of the Republic of Chile and its various instrumentalities, was able to complete the survey work on schedule during the given period of stay.

The team reviewed, collected and interpreted the investigated data and collected samples. Presented herewith is the report of the team. I sincerely hope that the report will be of further help in the mineral resources development and will advance further the frontiers of science and friendship between two countries.

Finally I wish to express my heartful gratitude to the team members for their efforts, the officials of the Government of the Republic of Chile, the officials of the Japanese Embassy in Chile for their kind cooperation, and the Ministries of Foreign Affairs and of International Trade and Industry for their unsparing supports in dispatching the survey team.

March 1980

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency

Letter of Transmittal

Mr. Keisuke Arita
President
Japan International Cooperation Agency

Dear Sir,

Submitted herewith is a report on the Mineral Resources Development in the Republic of Chile.

The survey was carried out by the Japan International Cooperation Agency as the technical cooperation of the Government of Japan. The survey was conducted for 30 days from January 28 to February 26, 1980 with five experts dispatched from the Japan International Cooperation Agency, Dowa Engineering Co., Ltd., Overseas Mineral Resources Development Co., Ltd., and Mesco, Inc. on the western region of Santiago, Chile.

The team made a field investigation and also a collection of data or informations on the mineral resources and those in general as possible.

After returning to Japan, the team examined and analyzed the investigated results samples, collected data to select a area for future exploration and to plan the adequate exploration method on the area concerned through the discussion within the team members. As the results of these works, the final report was prepared here.

Nearly eighty ore deposits exist in the investigated area and a few deposits are merely operating in large scale. However most of these deposits are short of prospecting work. Consequently depending on the future exploration or prospect these deposits have a possibility to expand moreover and it is possible to discover a new ore deposit in the unexplored area. I earnestly hope that the report will be of further help in the development of mineral resources in the area.

Finally I wish to express my heartful gratitude to those who are concerned to the Oficina de Planificación Nacional and Universidad Técnica del Estado of the Republic of Chile. Also heartful appreciations are given to the Japanese Embassy of Chile, the Japan International Cooperation Agency and the Metal Mining Agency of Japan.

Sincerest best wishes and highest esteem.

March 1980

Respectfully yours,

Minoru Sumita
Leader
Japanese Survey Team
for
Mineral Resources Development
in the Republic of Chile

Conclusion and Guide to Future Exploration

The interpretation analysis of field observation, study of collected data, and laboratory works are carried out on the geology and ore deposits in the western region of Sangiago, which was requested by the Government of Chile as a target area to study.

Especially, field investigation to select the future exploration area was carried out paying attention to ① relevancy of the ore deposits and geology ② extent of explanation target area, and ③ mining concession.

1-1 Conclusion

① Many volcanogenic-syngenetic copper ore deposits exist in the lower and upper Cretaceous formations in this area. Any systematic and detailed exploration work on these deposits has been scarcely done, except two or three mines.

② It is considered that the most copper-sulphide mineralization took place at the final stage of the unit of volcanic activity beginning with basic or intermediate volcanic activity and ending with acidic one under submarine environment sedimented muddy materials.

③ The occurrence of the ore deposits is generally in stratiform or disseminated form and is embedded conformably or quasiconformably to stratification of volcanic or sedimentary rocks.

④ On the basis of the above results, selected exploration target area covers about 1,100 km^2 of northern part and 370 km^2 of southern part totaling to 1,470 km^2.

1-2 Guide to Future Exploration

① It is necessary to apply the systematic exploration method as same as that of "Kuroko" deposits in Japan to study (a) relevancy of the ore deposits and volcanic activity and (b) ore horizon, since ore deposits in the target area is genetically similar to "Kuroko" deposits.

② In consideration of the relation between the ore deposits and the geology, and of the geographical condition, it is desired to select the most considerable priority area for future exploration by means of photogeology, detailed geological survey at first and to decide a drilling site by the geochemical and aeroelectromagnetic method, and finally to carry out the diamond drilling.

REPORT ON THE SURVEY FOR MINERAL RESOURCES DEVELOPMENT
IN THE REPUBLIC OF CHILE

CONTENTS

PART II

PART III

Figure List.

Table List:

Plate List:

Appendices:

PART I

Chapter 1. Introduction

1−1 Object and Background of Survey

So-called bedded cupriferous deposits in Chile exist widely in many formations from the upper Jurassic through the Cretaceous to the Paleogene. Particularly it is considered to be important that "manto type" and irregularly disseminated ore deposits develop in the lower Cretaceous formation related to the vigorous submarine volcanic activity being represented mainly by andesitic rocks. Majority of these ore deposits have genetically many similarities to the Black ore deposit in Japan. It is known that these kind of ore deposits are distributed concentratedly in the central Chile.

In November, 1978, Universidad Tecnica del Estado (U.T.E.), the counterpart in the present survey required officially to the Government of Japan through the Chilean Government the technical and financial cooperation to promote the study and survey on the genetic relationship between the mineralization and the Cretaceous volcanic and sedimentary rocks in the central Chile.

In August, 1979, the Government of Chile offered to the Government of Japan the area of western region of Santiago to execute a detailed joint study by a verbal note. In response to this proposal Japan International Cooperation Agency (JICA) sent the field survey team of five geologists headed by Mr. M. Sumita for about one month from 28, January to 26, February in 1980 in order to select a target area for mineral resources exploration on a full scale and to plan the most suitable exploration method in the area.

Although the offered area is in favourable situation within a hundred kilometers of Santiago city and the port of Valparaiso, the systematic exploration work on the area has been done scarcely except in a few mine areas. It is possible that the excellent copper ore deposits in medium scale have been expected to be discovered in the area and that the area has the advantages of locality condition to carry out exploration and exploitation.

1−2 Scope of Survey

1−2−1 Outline of Investigated Area

(1) Extent of the Investigated Area

The area offered by the Government of Chile covers 5,500 km^2 being located beyond 20 km west of Santiago. La Ligua Valley and Leguna de Aculeo are respectively north and south border of the area. East to west width is 40 km in the northern part and 25 km in the southern part. North to south length is 160 km (see Fig. 1).

(2) Geographical Feature and Access

The area occupies mainly the eastern half part of costal mountains ranging north to south between the Pacific coast and Santiago. The plain at eastern side of the mountains is 500 to 700 m above the sea level and mountain tops are about 2,000 m high. Generally the

topography of the area corresponds to a stage of youth in erosion cycle with 1,000 m to 1,500 m high.

The four principal roads cross the area from east to west and north-south roads run at the eastern and western foot of the mountains. As Santiago and the port of Valparaiso are located near the project area and then there are many towns in the plain part of the area, transportation and materials and labor supply for field work is considered to be good condition.

(3) Climate and Vegetation

The area belongs to semi-dry zone. Precipitation varies by seasons and generally it is much in the western side of the mountains as compared with the eastern side. The rainy season begins in May and ends in August. Rainfall is negligible amount in the dry season. Precipitation and temperature of the western and eastern sides of the mountains are as follows.

Area	Temperature (°C)			Precipitation (mm)
	Mean Tem. of Summer	Mean Tem. of Winter	Annual Mean Tem.	Annual Mean
Eastern Side. Santiago	22.0	10.0	14.0	362
Western Side: Valparaiso	17.7	12.1	14.8	461

A fog often covers Quillota, El Melon and Catapilo Valleys in the morning of spring and summer.

Vegetation consists of scattered trees and thorny bush, and it is dense in the coast area generally.

(4) Mining Industry in the Investigated Area

Mines in the investigated area are almost copper one except a few gold mines. The total number of copper mines amount to 77 mines in the area and the team investigated 24 mines out of them. Remaining 53 mines are on the basis of existing data and informations (see Table 1, 2 and Plate 1). The operating condition of those mines is as follows, one foreign mining company, Exxon Minerals International Inc., operates El Soldado mine (ore reserve 20 million tons, Cu 1.8%), 38 mines are under operation by Chilean private company such as Lo Aguirre mine (Cia Minera Pudahuel, ore reserve 9.4 million tons, Cu 2.1%) and others are the abandoned mines or operating ones by "Pirquinero" (a private miner).

Dressing plants in the area exist at Catemu (ENAMI), El Soldado (Exxon), La Africana (Pudahuel), El Luro (Private enterprise at Tiltil) and El Sauce (Cia Minera El Sauce). The active refinery is only Chagres plant and another Nultagua plant (Cia. Minera Nultagua) has been closed.

1-2-2 Field Investigation

After the discussion with Chilean geologists at U.T.E. about an examination of published

reports on geology and ore deposits in the area, and about the selection of the investigation routes and routine works, field investigation was made. It was carried out in consideration of following points.

(1) Understanding general geological environment by the investigation along main routes in the area.

(2) Observations on several types, occurrences and geological features of the ore deposits, and on petrological specialities at the ore horizons, altered zones, and rock sampling.

(3) Making some tables and figures indicating the results of (2) with the geological data and references.

(4) Selecting hopeful areas for further explorations.

(5) Planning of exploration system for the areas (4).

1-2-3 Laboratory and analytical works in Japan

Twenty six rock thin sections were microscopically observed as a laboratory work. In view of the purpose of the investigation, following rocks are selected.

(1) Typical rocks in each formation.

(2) Country rocks in ore horizons

Photomicrographs and microscopic descriptions are shown in appendix 2. Making geological map and profiles, stratigraphical columnar section and so on based on the geological investigation in Chile were done as the analytical work in Japan

1-3 Members of Survey Team

The member of the team are as follows.

Team leader	Mr. Minoru Sumita Dowa Engineering Co., Ltd.
Coordinator	Mr. Hisamitsu Moriwaki Japan International Cooperation Agency.
Member	Mr. Yoichi Takeshita Dowa Engineering Co., Ltd.
"	Mr. Naoaki Tomizawa Overseas Mineral Resources Development Co., Ltd.
"	Mr. Shin'ichi Doi Mesco, Inc.
Counterpart	Mr. Andrés Dávila Diaz Universidad Técnica del Estado
"	Mr. Ricardo Galatzan Albala Universidad Técnica del Estado

Counterpart	Mr. Tsuyoshi Nishimura Universidad de Chile
"	Miss. Sol Rivano G. Universidad de Chile
"	Miss. Myriam Brockway A. Universidad de Chile

1–4 Period and Process of Investigation

The field investigation was carried out according to the following process for 30 days from January 28 to February 26.

Date order	Month/ date	Day of the week	Station	Contents of Works
1	Jan./28	Mon.	(Via New York)	Lv. Tokyo
2	Jan./29	Tues	Santiago	Visit to Embassy of Japan
3	Jan./30	Wed.	"	Visit to U.T.E. and ODEPLAN Collection of data and informations. Discussion on itinerary of the investigation with U.T.E
4	Jan./31	Thurs.	"	Preparation for the investigation (providing jeeps and laborers, and purchase of topographic maps)
5	Feb./1	Fri.	"	Geological excursion in Southern area (Melipilla)
6	Feb./2	Sat.	"	Geological excursion in Northern area (La Calera)
7	Feb./3	Sun.	"	Geological excursion in Central area (Tiltil)
8	Feb./4	Mon.	La Calera	Moving and investigation in Central and Northern areas (Tiltil ~ LlaLlay)
9	Feb./5	Tues.	"	Investigation in Northern area (La Ligua, Cabildo, El Soldado)
10	Feb./6	Wed.	"	"
11	Feb./7	Thurs.	"	"
12	Feb./8	Fri.	Santiago	Moving and investigation in Northern area (La Carmeca)

Date order	Month/ date	Day of the week	Station	Contents of Works
13	Feb./9	Sat.	Santiago	Investigation in Northern area (Caqui, Rio Aconcagua, Santa Teresita)
14	Feb./10	Sun.	〃	Data arrangement
15	Feb./11	Mon.	〃	Investigation in Central area (Cervo Negro, Desengaño)
16	Feb /12	Tues.	〃	
17	Feb /13	Wed.	〃	Investigation in Central area (Lo Aguirre, Portezuelo)
18	Feb./14	Thurs.	〃	
19	Feb./15	Fri.	〃	Investigation in Southern area (Consuelo, Andacollo, Las Guias)
20	Feb./16	Sat.	〃	〃
21	Feb./17	Sun	〃	〃
22	Feb./18	Mon.	〃	〃
23	Feb./19	Tues.	〃	〃
24	Feb./20	Wed	〃	Data arrangement
25	Feb./21	Thurs.	〃	Visit to ODEPLAN and Embassy of Japan. An outline of the results of the geological investigation was reported verbally.
26	Feb./22	Fri.	〃	Data arrangement
27	Feb./23	Sat.	〃	Preparation for departure.
28	Feb./24	Sun.	(Via Los Angeles)	Lv. Santiago
29	Feb./25	Mon.	(Travelling by airplane)	
30	Feb./26	Tues.	Tokyo	Ar. Tokyo

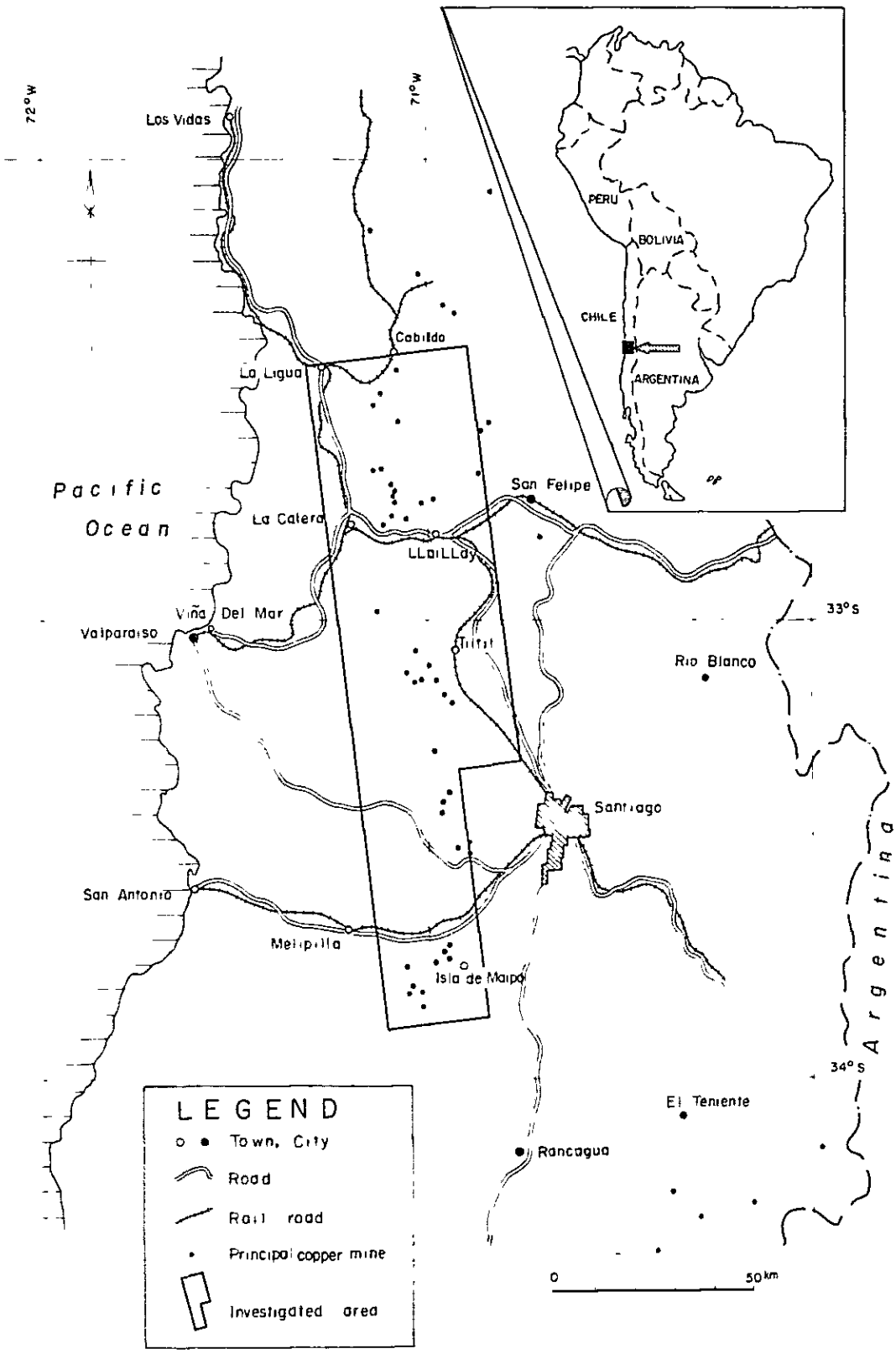


Fig 1 Location Map of Investigated Area

Chapter 2. Recent Political and Economical Situation of the Republic of Chile

2–1 Outline of Policy and Economy

2–1–1 Policy

Present President Pinochet's political power, which is six years old after the revolution, has been reliable for the people and generously kept up the political stability through the steady policy in economical business and the like.

2–1–2 Fundamental Economic Policy

Ceasing inflation

Improvement of international income and expenditure

Magnification of economic activity

The industrial policy has been concentrated on an intensification of international competition power through emerging from the control of import and protection for national industry.

The considerable good results are obtained as follows.

① The inflation ratio dropped remarkably from 375% in 1974 and 174% in 1976 to 30% in 1978, and the ratio in 1979 is an order of 30% in spite of tremendous raising oil price, owing to transferring from national enterprises to private one, promotion of free trade, reducing the customs tariff, deflation and so on.

② As the result of reducing the number of national enterprises from 464 to 60 in 1978, the red at more than 500 million dollars in the national enterprises has been converted to put in the black at 25 million dollars.

③ A growth ratio of gross national product is going to be stable on a level of 8% annually.

2–2 Mining Policy

The present political power has taken over the policy of national control for five major copper mines, which had been established by previous government. While, the developing another mines has been widely opened for foreign companies according to the law of foreign capital, which was promulgated in April, 1974.

Fundamental policy of the government for the foreign investment, which has been expanded steadily, is as follows.

① Guarantee for carrying out a contract is given to foreign investors.

② Procedures for the investment are simplicified.

③ Recoveries of the several foreign investments such as capital, benefit, and interest are free completely.

④ Right and obligation of foreign investors are same as those of national investors.

2–3 Introduction of Foreign Capital

① The number of the foreign investment in Chile sums into 346 cases and its amount into 4.17 million U.S. dollars since 1974, and that it has been increased year by year. It is notable

that 70% of total foreign capital invests in mining industry during the time January, 1978 to June, 1979.

② Although the number of foreign investment in the mining industry, especially in copper mine, is only 14 cases, the amount takes more than 90% of total one. Countries investing in the mining reaches more than 10 nations, of which 91%, 5.4%, and 3% are of U.S.A., Canada and Panama respectively, and the rest are of countries in Europe, Asia and Latin America.

③ Foreign enterprises investing in copper mine development in Chile are as follows,

Foreign Enterprise	Mine	Total Amount of Investment (million U.S.$)
Exxon	Disputada de Los Condes	1,200
Falconbridge Super Oil Mc. Intyre Mines	Quebrada Blanca	500
Noranda Mine	Andacollo	350
ANACONDA	Los Perambres	1,500
St. Joe Minerals	El Indio	100
Total		3,600

(The source: Data of foreign investment committee, 1978)

2–4 Mining Products

Mining products such as copper, niter, iron, iodine and molybdenum and so on have been supporting Chilean economy and that the export was copper monoculture some years ago. However, the ratio of the copper export amount to the total has been decreased from 74% in 1973 to 50% at present owing to diversification of export items.

2–4–1 Financial Income

The financial income was 2,885 million U.S. dollars in 1978, of which 277 million U.S. dollars (9.6%) was derived from copper product.

2–4–2 Export Amount

The total export amount was 2,473 million U.S. dollars, of which 1,420 million U.S. dollars (57%) was occupied by mining output in 1978. The ratio of mining output to the gross domestic product leached 11.8%.

2–4–3 Major Mining Products

Year	Copper	Iron Ore	Molybdenum	Iodine
1976	1,005	10,055	10,899	1,259
1977	1,056	7,890	10,938	1,856
1978	1,041	9,666	13,197	1,922

(Copper and iron ore: 1,000 tons,
Molybdenum and iodine: tons)

2–4–4 Export Amount of Major Mining Products

Year	Copper	Iron Ore	Molybdenum	Iodine
1976	1,247	86	46	41
1977	1,187	82	54	40
1978	1,201	80	47	47

(million U.S. dollars)

2–4–5 Production cost of Copper Mine

The copper production cost in Chile has been lower than those in the free world. The production cost of four Major copper mines being operated by CODELCO was 47.6 cents per pound on the average and the selling price was 55.5 cents per pound in 1977. (ARC report "Chile", 1980).

PART II

Chapter 1. Outline of Geology and Ore Deposits

1-1 Geology

Andean geosyncline in Chile developed from Jurassic to Paleogene time characterizing by widespread volcanic activity of andesite accompanied by marine or continental sedimentary rocks. The distribution area of the geosyncline extends over 1,700 km in the direction of north to south from Tocopilla, Antofagasta to Los Angeles, Biobio with about 100 km width. It is remarkable that many "manto type" and irregularly disseminated copper ore deposits are often embedded in the Cretaceous system relating to the development of the Cretaceous geosyncline with vigorous volcanic activity (see Fig. 2).

In the investigated area, four formations ranging from lower to upper Cretaceous time are closely related to occurrence of copper ore deposits, which are Lo Prado, Veta Negra, Cerro Morado and Las Chilcas formations in ascending order.

These formations are composed mainly of intermediate to acidic volcanic rocks, pyroclastic ones and marine and continental sedimentary ones striking north-south and dipping 30 to 60° east of monoclinal structure. Granitic rocks is distributed widely in the central to southern part of the investigated area.

1-2 Ore Deposits

① Copper ore deposits are embedded in a part of above mentioned four formations and are mostly considered to be volcanogenic-syngenetic copper ore deposit being genetically similar to "Kuroko" deposit (Black ore) in Japan.

② Such ore deposits are widely distributed in the investigated area. Assemblages of ore minerals bornite or bornite-chalcopyrite in the upper Lo Prado formation, Cerro Morado formation and/or Las Chilcas formation and are chalcopyrite-pyrite and/or chalcopyrite-bornite in Lo Prado formation and Cerro Morado formation.

③ Volcanic activity changing its component from intermediate (occasionaly basic) to acidic is closely related to the copper mineralization. A part of formations above mentioned correspond to such ones.

④ Minimum geological sequence relating to copper mineralization is, in ascending order: 1) basic to intermediate volcanic activity, 2) submarine intermediate to acidic volcanic activity and 3) sedimentation of marine (occasionally continental) muddy materials. The uppermost part of acidic volcanic rocks shows so-called "peperite"-like rock or autobrecciated structure in which copper mineralization is recognized characteristically, and is overlain by muddy sedimentary rocks.

The sequence such as, (volcanic rocks)-(mineralized zone)-(sedimentary rocks) is often recognized repeatedly more than two times in an ore body and this phenomenon is megascopically observed in all of above-mentioned four formations.

⑤ No remarkable hydrothermal alteration is observed in and near mineralized zone.

⑥ Details of investigated 24 mines and 53 mines in reference are shown in Plate 1, 2-1 and 2-2. A description covers ore horizon, country rocks, type of ore deposit, ore minerals, gangue minerals, dimensions, ore grade, and present condition of operation.

⑦ William D. Carter classified so-called "manto type" ore deposit into following three types;

type I : contact metasomatic ore deposit in marine limestone. Ore minerals are chalcopyrite. Skarn minerals consists mainly grosularite.

type II . bornite mineralization in vesicles and fissures at uppermost part of amygdaloidal structure bearing porphyritic andesite lava.

type III : mineralization of chalcopyrite, bornite and chalcocite in calcareous matrix of tuff breccia, overlain by thin layer of fossil-bearing limestone and calcareous limolite.

As Carter's classification is not always suitable to identify the ore deposits in the investigated area, they are mainly classified on the basis of their forms in this report.

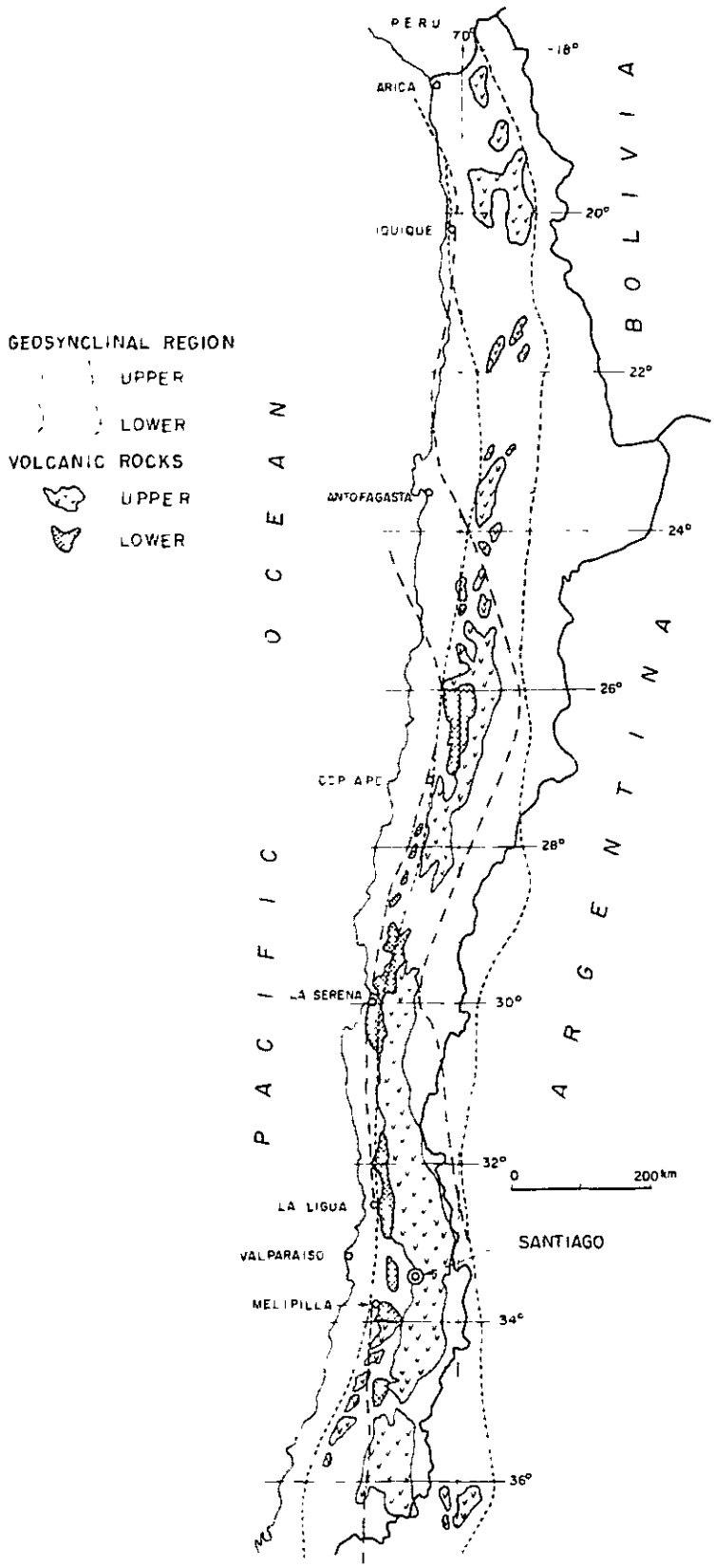


Fig 2 Distribution of Upper and Lower Cretaceous Palaeogeography

Chapter 2. Geology and Ore Deposits

2–1 Geology and Ore Deposits

General geology and main ore deposits in the investigated area are shown in Fig. 3 and Table 3 Jurrasic El Melón Formation is generally exposed in the western region of the coastal mountains, and crops out mostly in the northern part of the Aconcagua River of the investigated area.

Cretaceous formations and the ore deposits are described in detail in ascending order as follows. The geological map and profiles are shown in PL. 2 and PL. 3.

2–1–1 Lo Prado Formation

The Lo Prado Formation is exposed in the whole investigated area, especially in the north-west part of Tiltil and the south-west part of Talagante, and is cut by granite batholith in the central area.

This formation is composed of marine sedimentary rocks (limestone, sandstone, shale), volcanic rocks (basalt, andesite, dacite), pyroclastic rocks and ignimbrite.

The formation strikes NS to N10°E and dips 38° to 45°E.

The characteristic features of ore deposits and country rocks are as follows;

① Ore minerals: assemblages of chalcopyrite-pyrite, bornite-chalcopyrite and bornite.

② Sequence of the country rocks in ascending order: andesite lava, dacitic or rhyolitic lava partly autobrecciated, partly peperite, and shale or calcareous shale.

③ Veinlets contained ore minerals is absent.

④ Occurence of the ore deposits is so-called "manto type", or conformable to the strata, occasionaly exist some irregular-shaped ore body disseminated, and also banded ore in the sedimentary rocks (shale).

⑤ Hydrothermal alteration is hardly observed with the naked eye.

The Lo Prado formation is considered as Neocomian by H. Thomas (1958) and the Veta Negra formation is overlain above.

2–1–2 Veta Negra Formation

The Veta Negra formation is exposed in the whole investigated area and intruded by granite in the northern part of Talagante. The formation is mainly composed of fine-grained marine and continental andesite, coarse-grained porphyritic andesite and continental sedimentary rocks.

This formation is divided into Purehue (lower) and Ocoa (upper) members.

The Prehue member consists of continental sandstone, tuff, tuff breccia and andesite lava. The Ocoa member is characterized by marine andesite lava containing large phenocryst of plagioclase, named "Ociotas" by H. Thomas (1958).

The mineralization is performed in the last stage of one cycle of the volcanic activity

by intermediate or acidic rocks. These volcanic activity and mineralization are the same as those of the Lo Prado formation.

The characteristics of the mineralization are as follows.

① Ore minerals are mainly composed of assemblages of bornite, bornite-chalcopyrite and bornite-chalcocite.

② Acidic or intermediate rocks are overlain by the porphyritic andesite lava or/and fine-grained andesite lava, and are observable a fluidal texture frequently in the mineralized portion.

③ The occurrence of mineralization is of disseminated, massive-form or pseudo-stratiform.

④ Hydrothermal alteration is scarcely observed.

The Veta Negra formation is overlain unconformably by the Las Chilcas Formation (H. Thomas, 1958) or Cerro Morado Formation (W. Carter and N. Aliste, 1962). The Veta Negra formation was correlated with Aptian-Albian by H. Thomas.

2–1–3 Cerro Morado Formation

The Cerro Morado formation is distributed only in the northern part of the Aconcagua River, and the southern end of the formation pinched out in wedge-shape between Veta Negra formation (lower) and Las Chilcas Formation (upper). The Cerro Morado Formation has a maximum thickness of 3,000 m in the northern part of Catemu town. The formation is composed of continental sedimentary rocks, andesite, dacite and pyroclastic rocks. Although the study on the formation has been scarcely carried out, the ore exploration in this formation is important, because some ore deposits of Las Animas and Blanqueado are included in the formation.

The characteristics of the ore deposits are as follows.

① The mineralized peperite occurs on the top of the acidic volcanic rocks.

② Ore minerals are chalcopyrite-pyrite, partly chalcopyrite-bornite.

③ Ore deposits show generally "manto type" or disseminated massive type and partially psudo-stratiform type.

The Cerro Morado formation is unconformably overlain by the Las Chilcas formation (Cartar and Aliste, 1962) and is constituted the base of the upper Cretaceous systems

2–1–4 Las Chilcas Formation

The Las Chilcas formation is restricted around Tiltil town and to the eastern hills in the town. The bedrock of the Las Chilcas formation is mostly composed of continental red sandstone, and the upper part is composed of continental volcanic breccia, andesite lava, andesitic tuff and basalt. This formation is correlated with the upper Cretaceous by H. Thomas (1958). There are some disseminated ore deposits related to the rhyolitic or dacitic rocks, but they are not so important.

2–2 Consideration on Environment of Ore Mineralization

2–2–1 Geology of Ore Deposits

Some important ore deposits which are investigated during this time are described as follows (cf. Fig. 4–1, 4–2, Table 1, 2).

(1) Venus Mine (Lo Prado formation)

A unit of rock sequence composed in ascending order of andesite lava-decite lava (mineralized)-reperite (mineralized)-shale appears repeatedly several times at an interval of 20 to 30 m. Recognizable ore deposits are three units of them. Even though one mineralized unit is small and thin, it is important to prospect lateral or down-dip continuity.

(2) Consuelo Mine (Lo Prado formation)

The rock sequence composed of andesite to dacite lava-dacite lava or volcanic breccia (mineralized)-peperite (mineralized)-shale-limestone (containing fossils) is a sedimentary unit which contains mineral ore deposits.

(3) Las Animas Mine (Cerro Morado formation)

The rock sequence is composed of andesite lava-andesite lava (mineralized)-shale (calcareous)-andesite lava (brecciated and mineralized)-shale. The mineralization is observed in the lower and upper andesite lava interbedded between shale.

(4) Blanqueado Mine (Cerro Morado formation)

The mineralized horizon is considered to be continuation of the Las Animas ore deposits, also peperite is exposed in this area. Both of lower andesite and peperite are mineralized and the network of chalcopyrite mineralization in peperite is characteristic.

(5) El Salado Mine (Veta Negra formation)

Geology of the ore deposit is the same as that of the ore deposits mentioned above. There are two distinct mineralized formations.

The lower mineralized formation is composed of andesite lava, dacite lava (massive at lower part, amygdaloidal at upper part) and tuffaceous shale. The mineralization had been formed at the dacite part during a unit of sedimentation from andesite to tuffaceous shale. Then, andesite lave was overlain by a thin layer of tuffaceous shale. The upper mineralized formation is also composed of andesite lava, dacite, and tuffaceous shale. The mineralization in dacite part changes gradually to volcanic breccia showing graded structure.

(6) La Verde Mine (Lo Prado formation)

The stratigraphical sequence of volcanic rocks of 300 m in thickness, under part of La Verde ore horizon is observed as continuous outcrop.

The geological unit of the lowest part is composed of andesite lava-peperite-tuffaceous sandstone-andesite lava. No mineralization is observed in peperite. These rocks are overlain by the acidic volcanic rocks of 200 meters in thickness, composed of ignimbrite, a thin layer of andesitic tuff breccia and dacitic pumice tuff in ascending order. And then, these acidic rocks are overlain by andesite lava of 100 meters in thickness. The mineralized zone at La Verde mine is recognized on the top of the andesite.

The mineralized horizon is divided into two layers i.e. lower and upper. The lower part is dacite lava and the upper is dacitic peperite. The both of them are covered with thin

muddy and sandy layers. Furthermore, these thin sedimentary layers overlain by another andesite lave (cf. Fig. –5).

2–2–2 Environment of Ore Deposition

The important geologic characters on the volcanogenic-syngenetic copper ore deposits have been mentioned already in chapter 1–2, 2–1, and 2–2 of Part II. The following discussion about the environment of ore deposition leads to the great importance for the selection of exploration area and the prospecting plan.

① The mineralization had been performed under the submarine or lacustrine environment where muddy sediments were deposited during the late stage of one cycle of volcanic activity which took place continuously from basic or intermediate to acidic one.

These continuous volcanic activities and mineralizations took place only once or repeatedly in short time and performed ore deposit, and then, similar mineralizations in each formation is observed.

② Ore minerals are mostly composed of chalcopyrite, bornite and chalcocite, and they generally show fine-disseminated form (or compact massive in the same case).

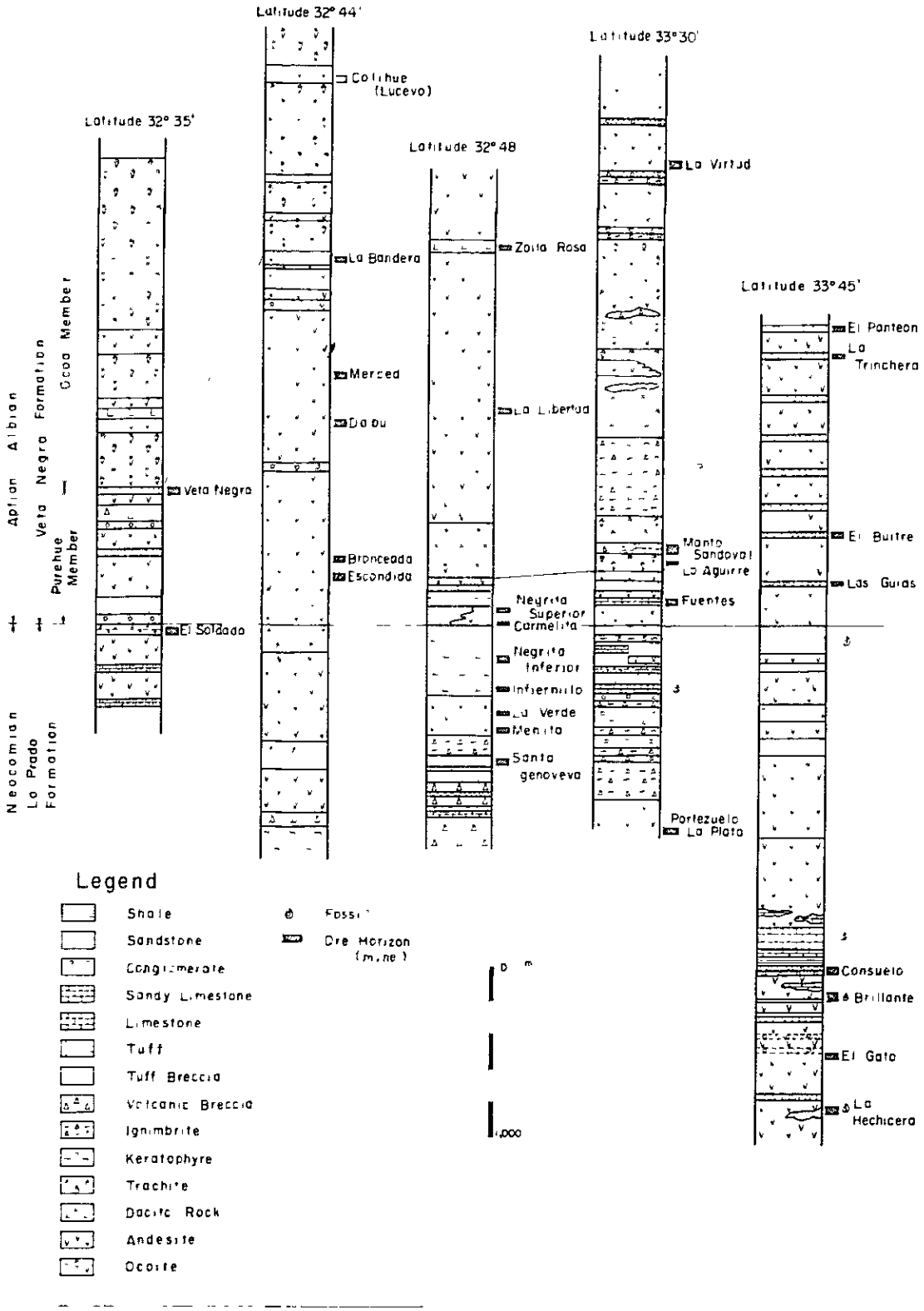
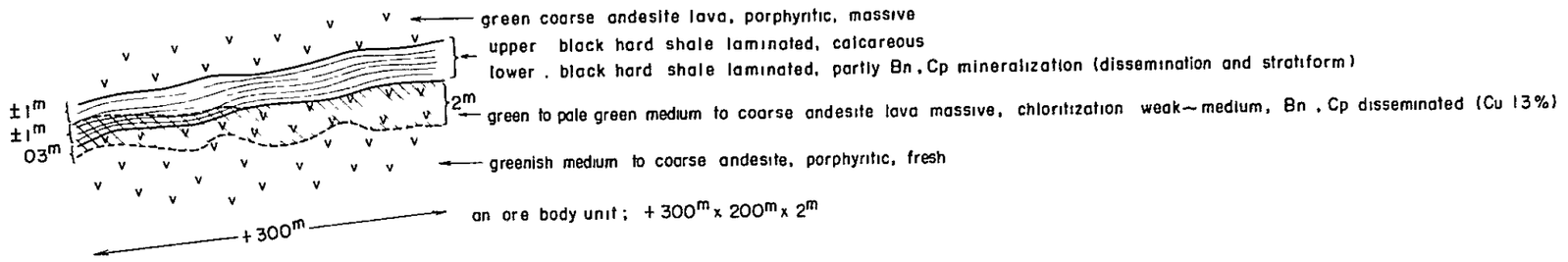
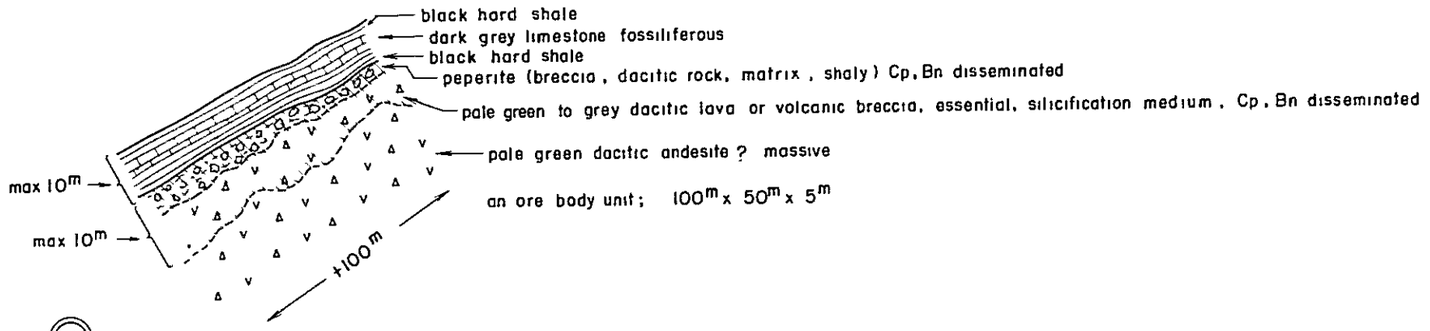


Fig 3 Stratigraphic Correlation of Western Region of Santiago, Chile

⑥ Guayacan Mine (modified section) (Lo Prado Formation)



⑤1 Consuelo Mine (Lo Prado Formation)



⑤2 Venus Mine (Lo Prado Formation)

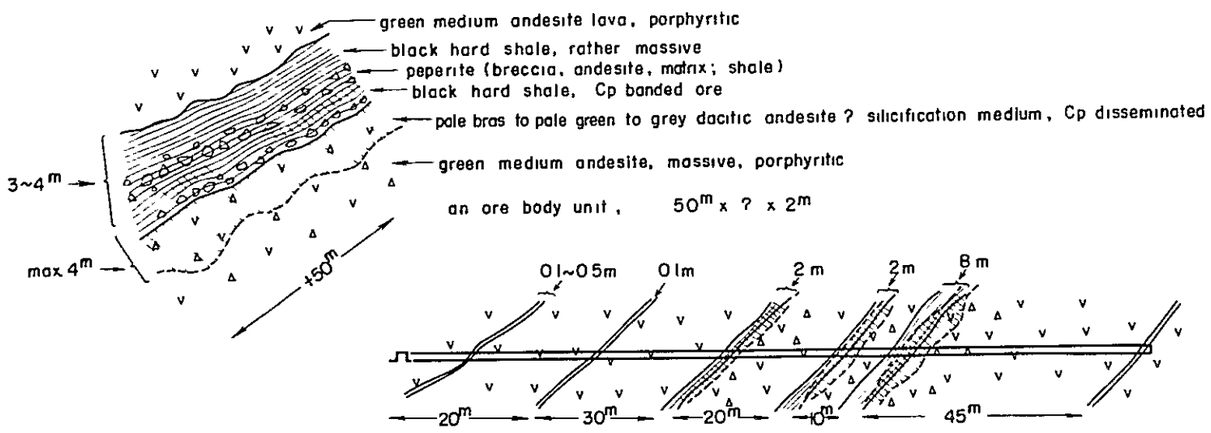
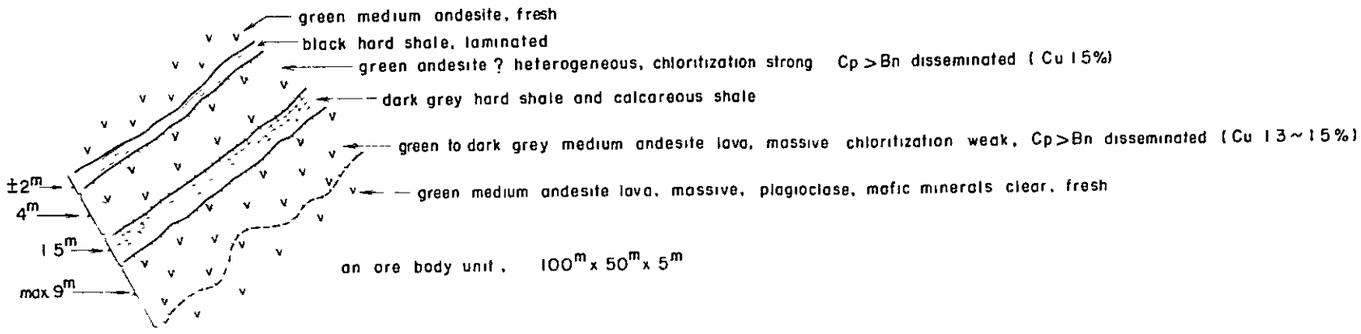
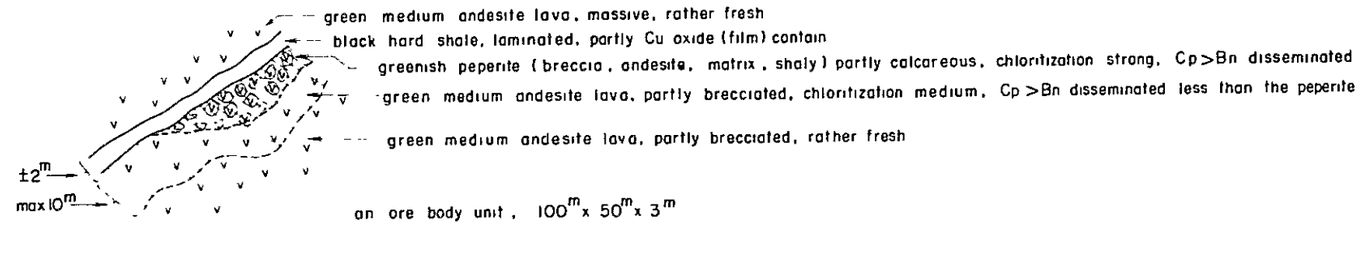


Fig 4-1 Detailed Sketches of Some Important Ore Deposits

(14) Las Animas Mine (Cerro Morado Formation)



(13) Blanqueado Mine (Cerro Morado Formation)



(21) El Salado Mine (Veta Negra Formation)

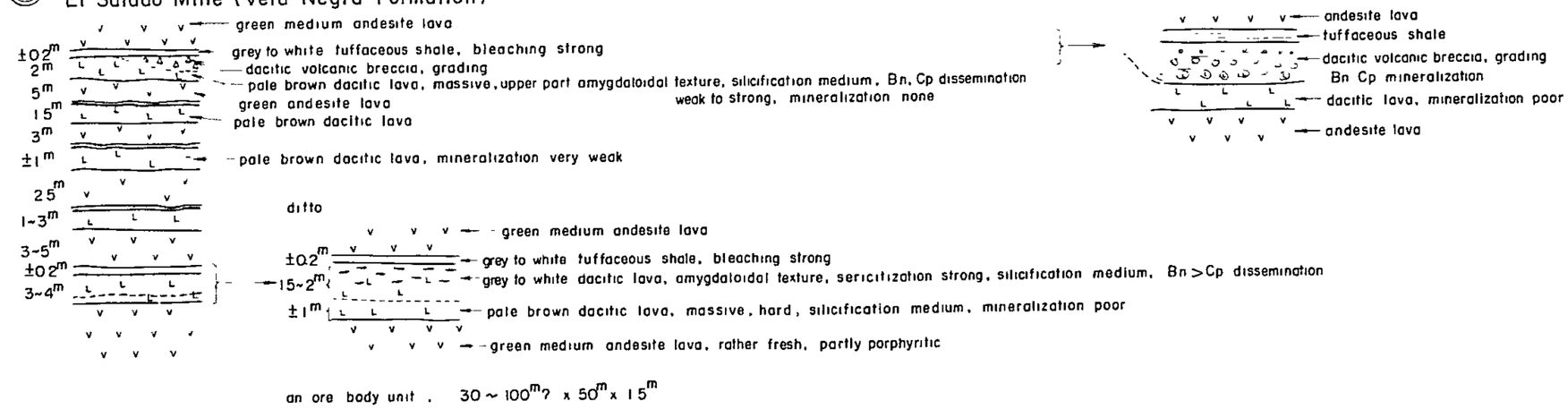


Fig 4-2 Detailed Sketches of Some Important Ore Deposits

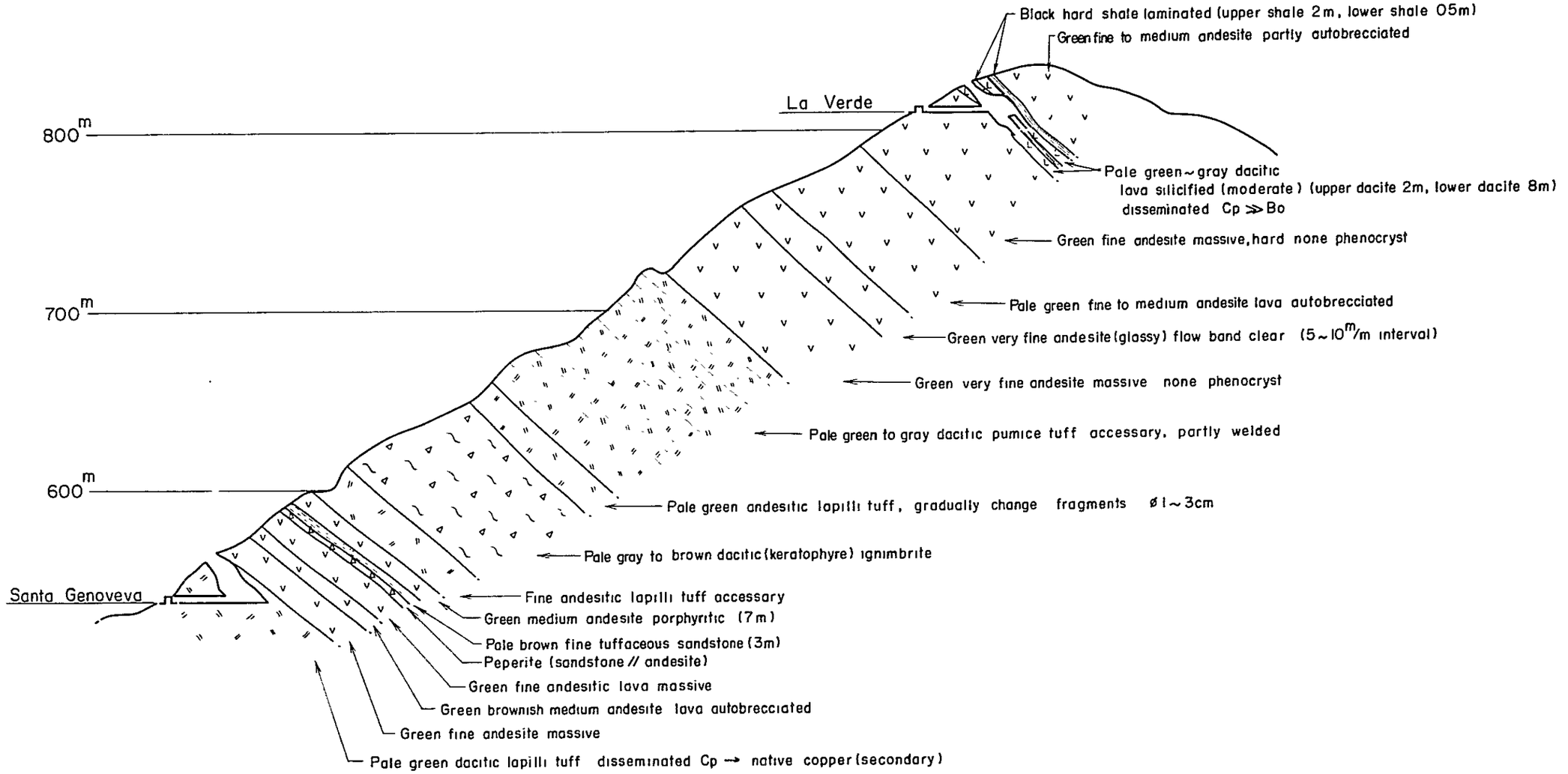


Fig. 5 Geological Profile from Santa Genoveva to La Verde
(W — E)

Table 1 Geological Features of Copper Ore Deposits in the Western Region of Santiago, Chile (Investigated in 1980)

NAME OF MINE	SITUATION: THE NAME OF MAP AND LOCALITY	SITUATION: COORDINATION AND ALTITUDE	FORMATION	COUNTRY ROCK (HW=HANGING WALL ROCK FW=FOOT WALL ROCK)	TYPE OF ORE DEPOSIT	ORE MINERALS	GANGUE MINERALS	SCALE OF ORE BODY	ORE GRADE	SPECIAL ITEMS	OPERATION	REFERENCES	
PEUMO	Cabildo ** Cabildo	32°30'08" Lat S 71°06'24" Long W 815m	La Prado	Andesitic tuff (HW Calcareous shale peperite FW Andesite)	Strata bound and disseminated partly massive	Chalcopyrite (Bornite Chalcocite) Pyrite	Epidote Calcite Chlorite	Length 10m Width 7m Thickness 2m	Cu 1-4%	Several inaccessible levels	Small mining 50-60 t/day	Chilean and Japanese Mission 1980	5
GUAYACAN	Cabildo ** Cabildo	32°31'48" Lat S 71°05'00" Long W 1060m	La Prado	Porphyritic andesite Peperite Calcareous shale (HW Black shale FW Andesite)	Strata bound and disseminated	Chalcopyrite (Bornite) Pyrite	Epidote Calcite	Length 100m Width 50m Thickness 15-20m	Cu 8%	Stratification N20°W/25°E	*** Pirquinero system 20 t/day	Ditto	F
FARELLON DELIRIO	Cabildo ** Cabildo	32°33'38" Lat S 71°04'00" Long W 1250m	La Prado	Acidic tuff Volcanic breccia (HW Andesite lava FW Andesite lava)	Pseudo-stratiform and disseminated	Chalcopyrite Pyrite, Bornite Chalcocite (Cu Oxide)	Epidote Calcite	Length 20m Width 5m Thickness 4-5m	Cu 5-10%	Stratification N35°W/20°E	Inactive	Ditto	7
BLANQUEADO	Ñihue * Catemu	32°40'01" Lat S 70°54'19" Long W 1200m	Cerro Morado	Andesite breccia Peperite (HW Shale FW Andesite)	Stratiform and disseminated partly network	Chalcopyrite Bornite Chalcocite (Pyrite)	Calcite	Length 60m Width 9m Thickness 1-3m	Cu 1.2-3%	Stratification N65°E / 4°E	Inactive Cia Minera Catemu State Co Operator of private	Ditto	4
AN MAS	Ñihue * Catemu	32°40'07" Lat S 70°54'39" Long W 900m	Cerro Morado	Andesite breccia (HW Calcareous shale FW Andesite)	Stratiform and disseminated	Chalcopyrite Bornite Chalcocite Covellite) Pyrite	Calcite	Length 80m Width 80m Thickness 9m	Cu 3-8.4%	Stratification N-S/15°E	Production 1978 60,000 t 1979 60,000 t 1980 50,000 t Cia Minera Catemu State Co Operator of private	Ditto	6
ROMERO	Ñihue * Catemu	32°40'01" Lat S 70°54'15" Long W 1.7m	Cerro Morado	Peperite Dacitic breccia (HW Shale FW Andesite)	Pseudo stratiform and disseminated	Chalcopyrite Galena	Calcite	Length 200m Width 90m Thickness 6m	Cu 1.3-8%	Stratification N5°W/15°E	In preparation 80 t/day Cia Minera Catemu State Co Operator of private	Ditto	8
EL SALADO	Ñihue * Catemu	32°44'46" Lat S 70°58'05" Long W 700m	Veta Negra	Rhyolite Welded tuff (HW Porphyritic andesite FW Andesite lava)	Pseudo-stratiform Disseminated and massive	Bornite Chalcopyrite Covellite	Quartz	Length 300m Width 300m	Cu 2-3%	Repetition 6 times 6 mantos Stratification N-S°W/32°E	Private company 70-80 t/day	Ditto	24
ZOILA ROSA DE ELEFANTE	La Calera * Purehue	32°46'4" Lat S 71°04'17" Long W 630m	Veta Negra	Rhyolite (HW Tuff FW Volcanic breccia Andesite)	Pseudo stratiform (Amygdaloidal type)	Chalcocite Bornite Oxide Cu	Quartz Epidote Sericite	Length 8m Width 15m Thickness 2-3m	Cu 5%	Small open pit fluids structures N-S°W/65°W	Inactive Cia Minera Catemu State Co Operator of private	Ditto	23
LA FILOMENA	La Calera * Purehue	32°46'41" Lat S 71°03'25" Long W 740m	Veta Negra	Sandstone (HW Ocoite Porphyritic andesite FW Andesite lava)	Stratiform	Malachite Chalcopyrite (Bornite)	Quartz Limonite	Inaccessible	Cu 5%	Inaccessible Stratification N-S°W/32°E	Abandoned mine Private company	Ditto	24
LA VERDE	La Calera * Higueras	32°48'52" Lat S 71°06'14" Long W 8.5m	La Prado	Dacite lava Peperite (HW Shale, Welded tuff FW Ignimbrite Andesite)	Pseudo stratiform Disseminated (Fissure enrichment)	Chalcopyrite Bornite Chalcocite	Sericite Quartz	Length 70m Width 2m Thickness 7m	Grade at fissure zone Cu 30-40%	2 ore bodies and fissure zone enrichment (N65°W 70°S N45°W 60°S) Stratification N10°W/25°E	Pirquinero system 0.7 t/day Cia Minera Catemu State Co Operator of private	Ditto	25
SANTA GENOVEVA (SANTA ROSA)	La Calera * Higueras	32°49'04" Lat S 71°06'30" Long W 500m	La Prado	Rhyolite (ignimbritic) (HW Rhyolitic tuff FW Quartz porphyry)	Vein Disseminated ?	Bornite Pyrite Native Cu in oxide zone	Quartz Chlorite	Length 80m Width 30m Thickness 5m	Cu 0.5-3.0%	Oxide zone Fault zone 2m N50°W 65°SW	Pirquinero system Cia Minera Catemu State Co Operator of private	Ditto	28
EL SAUCE	Lliulliay * Tobon-Las Chicas	32°55'56" Lat S 70°53'8" Long W 480m	Las Chicas	Calcareous shale (HW Shale FW Shale)	Disseminated (Enrichment along the strike fault)	Chalcopyrite Bornite Pyrite	Calcite	Length 25m Width 0m Thickness 6m	Cu 1.5%	Fault N20°-40°W/55°E Stratification N15°E-20°W/38°NE	Dressing by small plant Capacity 50 t/day Inactive mine Private company	Ditto	29
RAMAYANA	Quebrada Alvarado * Quebrada Alvarado La Dormida	33°04'16" Lat S 71°0'40" Long W 380m	Veta Negra	Dacite Aphanitic andesite	Vein	Chalcopyrite Pyrite	Quartz Calcite Sericite Epidote	Length 200-300m Width 100m Thickness 10m	Cu 2-3%	10 Inaccessible Levels	Inactive at 1973 Private Company	Ditto	31
EL BOLIVIANO	Tiltil * Tiltil	33°05'42" Lat S 70°57'30" Long W 750m	Las Chicas	Dacite-rhyolite (HW Andesite ? FW Andesite)	Disseminated Amygdaloidal type	Chalcopyrite Bornite Chalcocite Cu oxide	Quartz Calcite	Inaccessible	Oxide Cu 30-40%	Inaccessible	Private Company 30-40 t/day	Ditto	32
FORTUNA ALTO	Tiltil * Tiltil - Polpaico	33°08'24" Lat S 70°55'23" Long W 720m	Las Chicas	Peperite Shale (HW Andesite breccia FW Andesite lava)	Pseudo stratiform and disseminated	Chalcopyrite Bornite	Calcite Barite	Length 8m Width 5m Thickness 2m	Cu 2.0%	Fault vein Barite Stratification N 0°E 40°E	Inactive Private Company	Ditto	40
FORTUNA BAJO	Tiltil * Tiltil - Polpaico	33°08'24" Lat S 70°55'12" Long W 690m	Las Chicas	Lapilli tuff Tuff (HW Shale FW Andesite)	Stratiform ?	Copper oxide	Calcite	Length 10m Width 2m Thickness 2m	Cu 3.0%	Small open pit Stratification N25°E/35°SE	Inactive Private Company	Ditto	4
TRINCHERA	Laguna de Aculeo * Naltagua	33°45'17" Lat S 70°57'47" Long W 550m	Veta Negra	Skarn (HW Porphyritic Andesite FW ?)	Contact	Chalcopyrite Bornite Hematite	Garnet Quartz Calcite	Inaccessible	Unknown	Inaccessible	Abandoned mine Private Company	Ditto	54
BUITRE	Laguna de Aculeo * Naltagua	33°45'24" Lat S 70°58'03" Long W 530 m	Veta Negra	Skarn (HW Porphyritic Andesite FW Andesite)	Contact	Chalcopyrite Bornite Hematite Magnetite	Garnet Quartz Calcite	Length 15m Width 5m Thickness 3m	Cu 1.5%	Stratification NS/40°E	Inactive Private Company	Ditto	53
VENUS	Laguna de Aculeo * Naltagua	33°45'32" Lat S 70°59'40" Long W 600m	La Prado	Shale Peperite (HW Dacitic andesite FW Andesite lava)	Strata-bound and disseminated (partly massive)	Chalcopyrite Pyrite Bornite (Malachite Azurite)	Quartz Calcite	Length 14-30m Width 9-15m Thickness 2-3m	Cu 2.0%	At least 3 times repetition of above sequence Stratification N10°E / 34°SE	Pirquinero system 10 t/day	Ditto	52
PEUMO	Laguna de Aculeo * Naltagua	33°45'46" Lat S 70°59'58" Long W 610 m	La Prado	Shale (HW Andesite lava FW Andesite lava)	Strata-bound Generally finely banded partly veinlet disseminated	Chalcopyrite (Bornite) Pyrite	Calcite Quartz	Width 1.8m	Cu 1.5-2.0%	Inaccessible Stratification N10°E/40°NE	Inactive Private Company	M Sumito A Dávila M Herve 1977	50
CONSUELO	Laguna de Aculeo * Naltagua	33°46'03" Lat S 70°59'57" Long W 880 m	La Prado	Peperite Muddy ls (HW Fossiferous shale FW Andesite lava)	Strata-bound and partly massive network	Bornite Chalcopyrite	Calcite	Length 50m Width 20m Thickness 3-7m	Cu 2.5-3.0% Peperite Cu 1.2% Shale	Stratification N10°E/40°E	Pirquinero system 80-100 t/month	Chilean and Japanese Mission 1980	51
MASCOTA	Chotqui * Carmen Alto-Melipilla	33°46'07" Lat S 71°01'02" Long W 730 m	La Prado	Shale (HW Andesite FW Andesite lava)	Stratiform Vein ?	Chalcopyrite Bornite	Quartz	Inaccessible	Cu 1.5-2.0%	Inaccessible Stratification N10°E/40°E	Inactive Private Company	Ditto	49
MANTOS NEGROS	Chotqui * Pahacabe	33°49'00" Lat S 71°01'16" Long W 640m	La Prado	Porphyritic andesite (HW Muddy ls ? FW Andesite)	Pseudo-stratiform and disseminated	Malachite Chrysocolla (Cu oxide)	Calcite	Length 5m Width 3m Thickness 1.5m	Cu 1.5% ±	Stratification N45°E/20°E	Abandoned mine Operation 1965-1966 Private Company	Ditto	58
ABUELITA MOSTAZA	Chotqui * Pahacabe	33°49'00" Lat S 71°01'16" Long W 400m	La Prado	Limestone	Stratiform and disseminated	Chalcopyrite Bornite	Calcite	Length 15-50m Width 12m Thickness 2-3m	Cu 1.5-2.0%	Stratification N10°E/40°E	Only limestone exploration Private Company	A Dávila 1977	59

* Topographic base 1:50 000 IGM (1969)

** Topographic base 1:100 000 IGM (1955)

"pirquinero" *** a private miner

Table 2 - 1 Geological Features of Copper Ore Deposits in the Western Region of Santiago, Chile

(Compiled by A Dávila, 1980, UTE)

NAME OF MINE	SITUATION: NAME OF THE MAP AND LOCALITY	SITUATION: COORDINATION AND ALTITUDE	FORMATION (MEMBER)	COUNTRY ROCK	TYPE OF ORE DEPOSIT	ORE MINERALS	GANGUE MINERALS	SCALE OF ORE DEPOSIT	ORE GRADE	SPECIAL ITEMS	OPERATION	REFERENCES
EL SAUCE	*La Ligua Cabildo	32° 27' 16" Lat S 71° 04' 11" Long W 660 m	La Prado	Limestone	Psudostratiform Partly massive Contact ?	Chalcopyrite Pyrite	Garnet		1.8 – 2.2% Cu	Several levels Relict stratification Dressing by small plant Capacity 1,000 t/day	500- 700 t/day Private company	A Dávila 1968 (verbal com.) (62)
LOS MAQUIS NORTE	*La Ligua Cabildo	32° 27' 26" Lat S 71° 04' 00" Long W 625 m	La Prado	Limestone and shale	Strata bound Disseminated	Chalcopyrite Pyrite			1.8% Cu	Several levels	Private company Inactive mine	Ditto (63)
LOS MAQUIS SUR	*La Ligua Cabildo	32° 27' 44" Lat S 71° 03' 52" Long W 520 m	La Prado	Limestone and shale	Pseudostratiform Disseminated and partly massive (Contact)	Chalcopyrite Pyrite Specularite	Garnet	Length 100 m Width 60 m Thickness 0.5- 3 m	1.5 – 2.0% Cu	Several levels Dressing by small plant Unknown capacity	Private company Inactive mine	(Carter 1961 Bol N°10 Instituto Investigaciones Geológicas Chile) (A Dávila 1980 verb. com.) (64)
EL SOLDADO	*Nogales S. Cobre Nogales	32° 38' 08" Lat S 71° 06' 09" Long W	La Prado	Tuff breccia limestone efusive and intrusive andesite	Irregular bodies Pseudostratiform Disseminated and rarely fine veinlets	Chalcocite Digenite Bornite Hematite Chalcopyrite Pyrite	Albite Quartz Chlorite Calcite Epidote		2.0% Cu	Several levels Dressing by middle plant Unknown capacity	Private company (EXXON)	(Ossandón 1976 Congreso Geológico Chileno PP E 53) (A Dávila 1980 verb. com.) (11)
CORRAL DEL ROMERO	*Nogales Cañón de Gomez Catemu	32° 38' 47" Lat S 71° 02' 30" Long W	Veta Negra (Dcoa)	Andesite volcanic breccia and acidic lava flow	Pseudostratiform Disseminated		Chlorite Epidote Silica			Outcrops	Private company	(A Dávila 1979 verb. com.) (65)
VETA NEGRA	*Nogales Cerro Chada e Cabildo	32° 38' 50" Lat S 71° 05' 5" Long W	Veta Negra (Purehue)	Red sandstone and black shale	Stratiform Disseminated						Private company Abandoned in 1958	(H Thomas 1958 Bol N°2 Instituto Investigaciones Geológicas Chile) (12)
LA REINA	*Nogales Cañón de Gomez Catemu	32° 38' 57" Lat S 71° 02' 00" Long W	Veta Negra (Dcoa)	Andesite and volcanic breccia	Disseminated	Bornite Hematite	Chlorite			Outcrops	Private company	(A Dávila 1979 verb. com.) (66)
MANTO BRON	*Nogales Quebrada La Fortuna Catemu	32° 40' 25" Lat S 71° 01' 13" Long W	Veta Negra (Dcoa)	Andesite and acidic lava flow and amygdaloida structure	Disseminated	Bornite Chalcopyrite Rare copper oxides Hematite	Epidote Chlorite		1.5 – 2.0% Cu		Private company Inactive mine	Ditto (67)
DABE	*Nogales El Carretón Nogales	32° 41' 13" Lat S 71° 05' 42" Long W 850 m	Veta Negra Purehue	Aphanitic and porphyritic andesite	Disseminated and rarely fine veinlets	Bornite			1.8 – 2.4% Cu	Outcrops	Private company	Ditto (68)
BRONCEADA	*Nogales El Carretón Nogales	32° 41' 50" Lat S 71° 06' 09" Long W 620 m	Veta Negra Purehue	Aphanitic porphyritic andesite and volcanic breccia	Pseudostratiform Disseminated	Bornite Chalcopyrite				Several outcrops	Private company	(Mäsonex S.V. 1975 Geología del Sector Sur Oriental del Cuadrangulo El Melón Provincia de Aconcagua V Región de Chile Depto de Geología U de Chile) (69)
ESCONDIDA	*Nogales El Carretón Nogales	32° 42' 00" Lat S 71° 06' 5" Long W 5[illegible] m	Veta Negra Purehue	Aphanitic and porphyritic andesite	Disseminated	Copper oxide				Several outcrops	Private company	Ditto (36)
LA MERCED	*Nogales El Carretón Nogales	32° 42' 44" Lat S 71° 05' 8" Long W 670 m	Veta Negra Purehue	Porphyritic andesite partly brecciated	Pseudostratiform Disseminated	Chalcocite Bornite	Epidote			Several short levels (6m)	Private company Inactive mine	Ditto (16)
COLIMBO LUCERO	*Nogales El Carretón Nogales	32° 42' 5" Lat S 71° 03' 26" Long W 520 m	Veta Negra (Dcoa)	Volcanic breccia porphyritic andesites and acidic lava flow	Disseminated	Bornite Chalcocite			2.5 – 3.0% Cu	Fluidal structure Inaccessible	Private company	(A Dávila 1969 verb. com.) (17)
CAQUI	*Nogales Rome o de a Sombra Purehue	32° 44' 31" Lat S 71° 04' 09" Long W 580 m	Veta Negra (Dcoa)	Volcanic breccia and andesite	Disseminated	Bornite Chalcopyrite				Outcrops	?	(A Dávila M Hervé 1976 verb. com.) (9)
LA BANDERA	*Nogales El Carretón Nogales	32° 44' 36" Lat S 71° 05' 03" Long W 300 m	Veta Negra (Dcoa)	Fluidal and amygdaloidal andesite volcanic breccia and fluidal dacite	Pseudostratiform Disseminated	Bornite Copper oxides			2.0 – 2.5% Cu	Several outcrops	Private company Inactive mine	(A Dávila 1977 verb. com.) (18)
EL MANZANO	*Nogales El Cobre Los Colonias	32° 44' 48" Lat S 70° 58' 33" Long W 790 m	Veta Negra (Dcoa)	Aphanitic andesite and acidic lava flow and andesite	Pseudostratiform Disseminated and massive	Bornite Chalcopyrite and Copper oxides				Repetion of strata Stratification N15°W/30°E	Private company Inactive mine	(A Dávila 1976 verb. com.) (37)
LA LIBERTAD	*La Calera Purehue Hijuelas	32° 46' 30" Lat S 71° 04' 39" Long W 650 m	Veta Negra (Dcoa)	Aphanitic and porphyritic andesite	Disseminated and veinlets	Chalcopyrite Pyrite			1.0% Cu		Abandoned mine	(Oyarzún B.J. Sandoval S.R. Dávila D.A. 1976 private report) (70)
CARMELITA	*La Calera Purehue Hijuelas	32° 49' 00" Lat S 71° 06' 00" Long W 520 m	Veta Negra (Purehue?)	Porphyritic andesite with intercalated sandstone	Disseminated	Chalcopyrite Pyrite			0.8 – 1.0% Cu		Abandoned mine Underwater (inaccessible)	Ditto (71)
INFIERNILLO	*La Calera Purehue Hijuelas	32° 49' 11" Lat S 71° 06' 20" Long W 760 m	Veta Negra (Purehue)	Aphanitic andesite and andesite	Disseminated and vein	Chalcopyrite Bornite			1.5 – 2.0% Cu	Stratification N10°W/44°E Vein N70°E/70°S N10°W/46°S	"Pirquineros system 300 t/month Cia Minera de Catemu State company	(A Dávila 1979 verb.com.) (25)
NEGRITA	*La Calera Purehue Hijuelas	32° 49' 57" Lat S 71° 05' 49" Long W 380 m	Veta Negra (Purehue)	Aphanitic and porphyritic lava and volcanic breccia	Disseminated in fractures	Chalcopyrite Pyrite			1.0 – 1.5 % Cu	Stratification NS-N10°W/44°E	Private company Inactive mine	(Oyarzún B.J., Sandoval S.R. Dávila D.A. 1976 private report) (72)
BRILLANTE (TILTIL)	*Quebrada de Alvarado Tiltil	33° 55' 45" Lat S 71° 30' 02" Long W 1,550 m	Veta Negra (Dcoa)	Aphanitic and porphyritic andesite andesite(lacate) and volcanic breccia	Pseudostratiform Disseminated and amygdaloidal minerals	Chalcopyrite Bornite Chalcocite	Chlorite Epidote	Length 30 m Width 12 m Thickness 2- 4 m	2.5 – 3.0% Cu	Stratification NS-N10°E/70°E	Private company Inactive mine	(A Dávila R Galatzoh 1979 verb com.) (32)
VERDEONES	*Quebrada de Alvarado Tiltil	33° 06' 14" Lat S 71° 00' 35" Long W 1680 m	Veta Negra (Dcoa)	Andesite and volcanic breccia	Disseminated	dornite Chalcopyrite				Stratification NS-N10°E/70°E	Abandoned mine	(A Dávila, M Hervé 1976 private report) (35)
CERRO NEGRO	*Quebrada de Alvarado Tiltil - Colinguay	33° 06' 27" Lat S 71° 01' 57" Long W 1780 m	Veta Negra (Purehue?)	Andesite and volcanic breccia acidic lava flow	Disseminated	Chalcocite Bornite Chalcopyrite				Outcrops Stratification NS-N10°W/40°E	?	(M Hervé 1976 private report) (34)

* Topographic base 1 50 000 (I.G.M. 1969)

Table 2-2

NAME OF MINE	SITUATION: NAME OF THE MAP AND LOCALITY	SITUATION: COORDINATION AND ALTITUDE	FORMATION (MEMBER)	COUNTRY ROCK	TYPE OF ORE DEPOSIT	ORE MINERALS	GANGUE MINERALS	SCALE OF ORE DEPOSIT	ORE GRADE	SPECIAL ITEMS	OPERATION	REFERENCES
CALETAS COLORADAS	*Ti[illegible]	33° 06 19 Lat S 70° 57 33 Long W 820 m	Las Chilcas	Rhyo dacitic lava flow andesite and volcanic breccia	Disseminated	Chalcopyrite, Pyrite Copper oxide				Outcrops		Dávila A 1976 Verbal comm (36)
ALAMO	*Tiltil Polpaico	33° 08 44 Lat S 70° 55 32 Long W 760 m	Las Chilcas	Aphanitic and porphyritic andesite dacitic lava flow	Disseminated	Chalcopyrite Pyrite					Inactive Private company	Dávila A 1979 Verbal comm (39)
LO AGUIRRE AND SAN ANTONIO	*Pudahue Pudahue	33° 26 23 Lat S 70° 55 14 Long W 700 m	Veta Negra (Ocoa)	Aphanitic and porphyritic andesite volcanic breccia dacitic lava flow	Pseudostratiform Disseminated and massive	Bornite Chalcopyrite Pyrite Copper oxide	Calcite, Epidote Chlorite	Reserves 11-12 million tons	2.2 % Cu	Stratification N8°W/60°E	Production 17,000 t/y Dressing by plant Compañía Minera Pudahuel	Davila A 1979 comm Levi, B 1968 (43) (44)
MANTO SANDOVAL	*Pudahuel Maipú	33° 29 34 Lat S 70° 54 27 Long W 680 m	Veta Negra (Ocoa)	Fossiliferous limestone	Stratiform Disseminated	Covellite Chalcocite Copper oxides		Thickness 2.5 m	1.7 % Cu	Stratification N20°-30°W/70°E	Several outcrops Private company	Perez, A L E 1970 Grade Thesis Depto Geologia U de Chile (45)
FUENTES	*Pudahuel Pudahuel	33° 29 38 Lat S 70° 54 35 Long W 740 m	Veta Negra (Purehue)	Limestone calcarenite calciturite tuffaceous sandstone	Stratiform Disseminated Veinlets	Chalcopyrite Bornite Chalcocite Covellite Specularite Pyrite Copper oxide	Calcite Sericite Quartz Feldspar	Length 270 m Width 60 m Thickness 1.5-5 m	1.2 % Cu	Stratification N30°W/60°E	Inactive Several levels Private company	Ditto (73)
LA VIRTUD	*Talagante Maipú	33° 53 [illegible] Lat S 70° 53 [illegible] Long W 680 m	Veta Negra (Ocoa)	Aphanitic and amigdaloidal andesite acidic lava flow	Disseminated and amigdaloidal	Bornite Chalcopyrite			2.0% Cu	Stratification N 25°W/40°E	Two levels Inactive Private company	Dávila A 1976 Private report (46)
LAS GUIAS (NALTAGUA)	*Talagante Naltagua	33° 44 04 Lat S 70° 59 07 Long W 350 m	La Prado	Limestone sandstone lutite limolite andesite	Strata bound Disseminated	Bornite Chalcopyrite Copper oxide					Inaccessible Private company	Davila A 977 Private report (74)
LAS VACAS	*Talagante Naltagua	33° 44 34 Lat S 70° 59 2 Long W 490 m	La Prado	Limestone sandstone lutite andesite	Strata-bound Disseminated and massive	Chalcopyrite Bornite				Stratification N10°E/34°E	Inactive Private company	Dávila A 1979 Verbo comm (47)
DIEZ HERMANOS	*Choiqu Carmen Alto	33° 45 48 Lat S 71° 04 58 Long W 350 m	La Prado	Andesite volcanic breccia	Disseminated Veinlets	Bornite Chalcopyrite				Outcrops	Abandoned mine	Dávila A 1976 verbal comm (48)
BRILLANTE (NALTAGUA)	*Choiqu Naltagua	33° 46 00 Lat S 71° 00 05 Long W 810 m	La Prado	Lutite sandstone andesite	Strata bound Disseminated Banded ore	Chalcopyrite Pyrite			1.5 - 2.0% Cu	Stratification N10°E/45°E	Inaccessible Private company	Dávila A 1977 Verbal comm (75)
EL GATO	*Choiqu Naltagua	33° 46 0 Lat S 71° 00 55 Long W 730 m	La Prado	Lutite sandstone andesite	Strata bound Disseminated	Chalcopyrite, Pyrite				Stratification N10°E/45°E	Inaccessible Private company	Dávila, A 1977 Verbal comm (76)
LA HECHICERA	*Choiqu Carmen Alto	33° 46 24 Lat S 71° 00 34 Long W 575 m	La Prado	Lutite sandstone andesite	Strata bound Disseminated	Chalcopyrite Pyrite					Inaccessible Private company	Dávila A 1977 Verbal comm (77)
LA DURA	*Choiqu Carmen Alto	33° 46 47 Lat S 71° 00 02 Long W 450 m	La Prado	Andesite volcanic breccia dacitic lava flow	Disseminated	Copper oxide				Fluidal structure	Inaccessible Private company	Dávila, A 1977 Verbal comm (55)
SAN ENRIQUE	*Choiqu Palocabe	33° 50 44 Lat S 71° 02 17 Long W 750 m	La Prado	Andesite and dacitic lava flow	Disseminated	Bornite Chalcopyrite				Outcrops Stratification N10°E/40°E		Oyarzun, J and Irarrazaval V 1977 Private report (61)
VIRGEN DEL CARMEN	*Choiqu Palocabe	33° 50 54 Lat S 71° 00 07 Long W 600 m	La Prado	Andesite volcanic breccia and acidic lava flow	Disseminated Amigdaloidal	Copper oxide				Outcrops Fluidal structure		Dávila A 1977 Verbal comm (61)
LAS GUIAS (PALIOCABE)	*Choiqu Palocabe	33° 51 18 Lat S 71° 05 24 Long W 760 m	La Prado	Aphanitic and porphyritic andesite ocpite volcanic breccia tuff marine sandstone	Vein Disseminated	Bornite Chalcopyrite			2.5% Cu		200 t/m Private company	Dávila, A 1977 Private report (60)

* Topographic base 1 50,000 (I G M 1969)

Table 3 Stratigraphy of Western Region of Santiago – Chile

ERA	PERIOD	EPOCH		FORMATION	MEMBER	ROCK FACIES	THICKNESS	DEPOSITS
MESOZOIC	TERTIARY					White, Reddish and Light Green Lava and Tuff also Conglomerate, Sandstone, and Shale (Continental)	6,500 m ±	UNKNOWN
	CRETACEOUS	UPPER	MIDDLE SENONIAN ?	LO VALLE				
			CENOMANIAN TURONIAN ?	LAS CHILCAS (klc)		Andesite Lava, Tuff and Breccia, Dark Brown Conglomerate, Sandstone and Shale (Continental)	6,500 m ±	FORTUNA BOLIVIANO SAUCE (TABON)
				CERRO MORADO		Andesite Shale, Limestone Andecitic (Ocoite) and Acidic (Rhyolite and Dacite Rocks, Continental Sandstone Lenses	MAX 3,000m 6,000 m ±	BLANCO EADO ANIMAS ROMERO SALADO ZOILA ROSA LA FILOMENA RAMAYANA LO AGUIRRE TRINCHERA
			APTIAN ALBIAN	VETA NEGRA (Kvn)	OCOA (kmo)			
					PUREHUE (kmp)	Porphyritic and Aphanitic Andesite and Red Sandstone (Continental)	600-2,600 m	BUITRE VETA NEGRA DABU LA MELCED
		LOWER	BARREMIAN HAUTERIVIAN		UPPER	Andesite and Acidic Rocks with Intercalations of Marine Sedimentary Rocks (Sandstone, Shale and Limestone)	13,000m ±	EL SOLDADO GUAYACAN PEUMO CONSUELO VENUS LA VERDE MASCOTA SANTA GENOVEVA MANTOS NEGROS FARELLON DELIRIO
			NEOCOMIAN	LO PRADO (klp)	MIDDLE	Green and Red Tuff and Breccia (Continental)	0-1,000m	SANTA TERESITA
					LOWER	Marine Sediments (Calcareous Sandstone, Black Shale and Limestone) and Volcanic Rocks (Andesitic and Acidic Rocks)	2,000m ±	LA PATAGUA CENTINELA
	JURASSIC			EL MELÓN CERRO CALERA				UNKNOWN

(THOMAS, 1958
CARTER AND ALISTE, 1962)

Chapter 3. Guide to Exploration

① Volcanogenic-syngenetic copper ore deposits are generally distributed in the Lo Prado Formation, the Veta Negra Formation, the Cerro Morado Formation, and the Las Chilcas Formation, cropping out in the investigated area.

② Ore horizons are irregularly embedded, as shown in Plate 3 and Fig. 3, from upper to lower part of each formation mentioned above. They are not recognizable as single ore zone which is continuously extended all over the area.

③ As aforesaid in Chapter 2–2, every ore deposit has almost same geological condition, in which an ore unit with various sedimentary rocks such as black shale, calcareous shale, limestone, tuff and sandstone and so on were formed and especially sedimentary rocks are the most important genetically.

Then, a remarkable point is considered as a change of volcanic rock facies from intermediate to acidic.

④ It is a noticeable fact that characteristic peperite or autobrecciated lava exits in the mineralized zone.

⑤ The ore deposits are conformable or quasiconformable to bedding plane of strata and show subvolcanic form partly.

⑥ Hydrothermal alterations related to the mineralization are scarcely recognized.

⑦ In most ore deposits, copper ore minerals are disseminated in fine-grained, and fill up groundmass or amygdules of lava partly, and in case of that the groundmass of country rock is darker in color, they look like common porphyritic lava.

Chapter 4. Selection of Area for Future Exploration

Geological survey was carried out by Thomas (1958) and Carter (1961) on the presently investigated area, however it has not yet been studied the detailed stratigraphical sequence of ore deposit or horizon and consideration of prospecting area.

A purpose of the mission i.e. selection of the area for future exploration has been carried out as follows considering the relationship between geological sequence and ore horizon, extent of the (exploration) area and condition of mining concession.

4-1 Basis of Recommendation

① The survey team investigated regional geology, 24 mines in practice and 53 ones in references, consequently ore horizon becomes clear and most of copper deposits are considered to be strata- bound volcanogenic (occasionally sedimentary) - syngenetic cooper ore deposit.

② On the basis of investigated data, the team prepared geological map and profile, detailed geological sketches of main ore deposits and table of all known copper deposits in the investigated area to examine and analyze a geological conditions of ore occurrence. As a result, it has become clear that ore horizon is closely related to the stratigraphical sequence of andesite-dacite-peperite (or breccia)-shale in asending order.

③ More than ten ore horizons are recognized and those are distributed widely in the investigated area, especially, following areas are considered to be important;

(a) northern part of the area distributing the upper Lo Prado formation corresponding to southern extension of El Soldado mine, Prehue member existing La Verde mine, the upper Ocoa member occurring El Salado mine and widespread Cerro Morado formation enbedding Las Animas and Blanqueado mines.

(b) The western area of Tiltil, which is underlain by Ocoa member embedded Cerro Negro, Manto, and Brillante ore deposits and Las Chilcas formation with Boliviano ore deposits.

and (c) whole southern area which is underlain by Lo Prado formation included Peumo, Consuelo and Las Güias Mines, above-mentioned areas are valuable in prospecting.

④ Unexplored area is widely developed around above-mentioned ore deposits except two or three mines, but the only small scale ore exploration and development is made, so, a systematic mineral exploration based on the economical geology had not been ever made.

⑤ So-called "volcanogenic-syngenetic ore deposit" may be concealed not only down-dip expansion but also strike direction along the ore horizon of copper ore deposits.

⑥ From central to southern part, granitic rocks are widely distributed, so, the area shall be entirely useless for exploration.

⑦ Mining concession

In northwestern part of the area, the El Soldado Mine of Exxon and other private mines have wide mining concession in scale, also around the Lo Aguirre Mine, the Pudahuel Company

has the mining right. While, it is confirmed that another parts of the area, are mainly belongs to public corporations.

4–2 Recommended area for Future Exploration

Considering the above-mentioned results, the area for future exploration is selected, which summs up to 1,470 km^2. This area is conveniently divided into following four parts for future exploration in consideration of differences in information of geology and ore deposits, exploration planning, locality condition, etc..

Area	Dimensions (km^2)
Catemu	320
Eastern Limache	380
Tiltil	400
Carmen Alto	370
Total	1,470

(1) Catemu

This area covers the southern and northern extension of several ore horizons in Cerro Morado formation cropping out at Las Animas mine, El Salado mine, etc., and also southern extension of ore horizon in which El Soldado mine, the biggest one in the investigated area, exists. Consequently this area is widely unprospected. Moreover most of the area exercised by State-owned concession.

(2) Eastern Limache

The investigation at present has not sufficiently covered this area to confirm the geology. And the mines in references not so many in number. The minority of mines is considered as locality condition and topography of the area. Nevertheless it is worth carrying out detailed geological survey since ore horizon in the Lo Prado and the Veta Negra formations seem to be continue from adjacent Catemu and Tiltil areas.

(3) Tiltil

Ore horizons are recognized in every formation from the Lo Prado to the Las Chilcas in this area. Southern and northern extension of ore horizons is not yet explored as described in the references. It is good circumstances that private concessions are scarcely settled in the area.

(4) Carmen Alto

Although many copper ore deposits have been discovered in the area, a few mines are operated in small scale at present.

Relation between geology and ore deposit is similar to those in above areas, the Lo Prado and the Veta Negra formations are widely distributed in the area. Especially, southern and northern extension of several ore horizons are not yet explored sufficiently. Mining concessions in the area are mostly State-owned ones and a few scattered private ones.

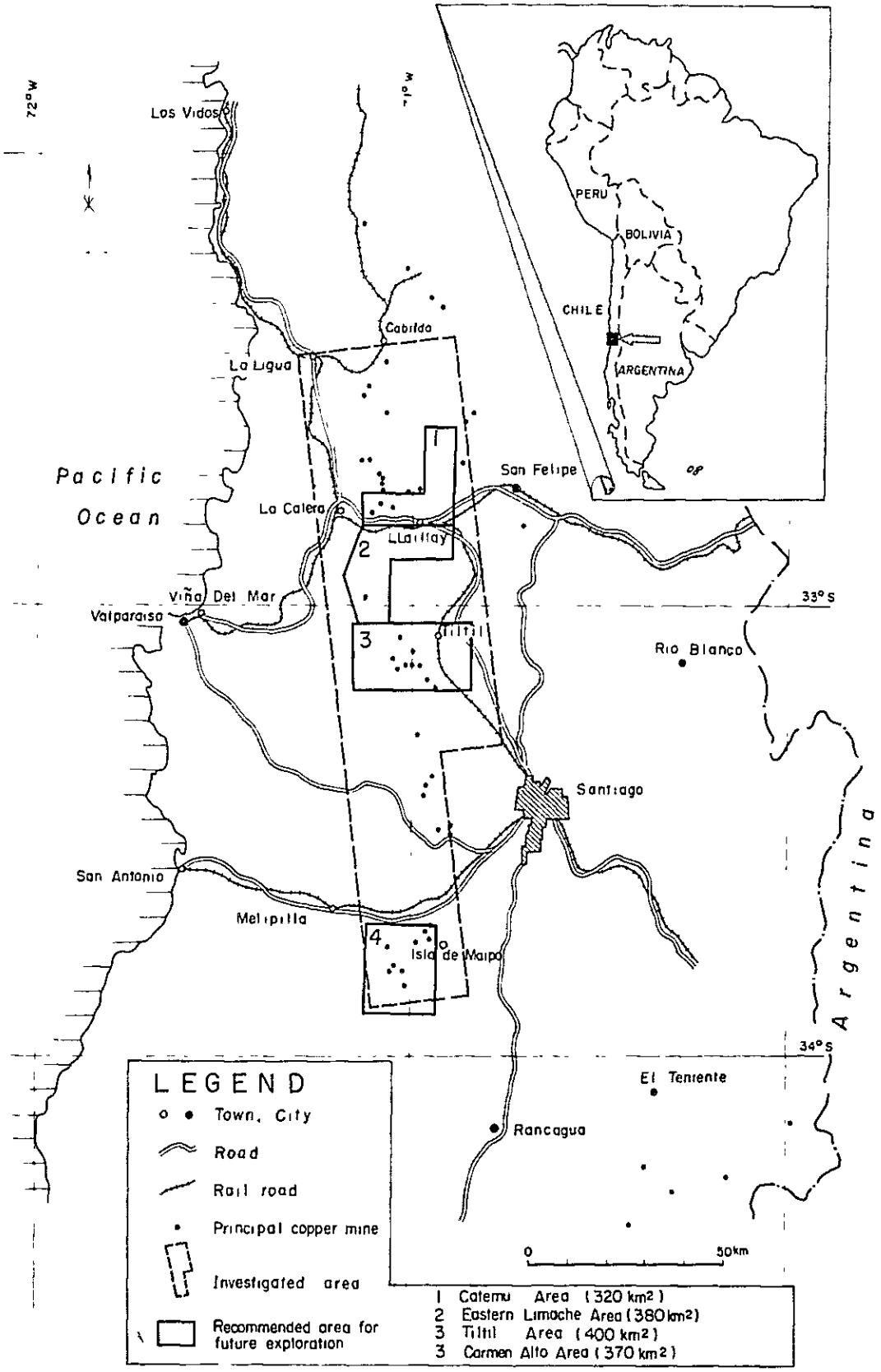


Fig 6 Recommended Area for Future Exploration

Chapter 5. Future Exploration

5–1 Planning of Future Exploration

The following is based on the planning of the future exploration on hopeful areas mentioned in Chapter 4, which are the exploration guide in Chapter 3 but also the experiences in volcanogenic-syngenetic copper ore deposits, especially "Kuroko deposit" (Black ore) in Japan that means the geological features of ore deposits such as a character of mineralization and a form of ore body or deposit, relation between ore horizon and rock facies or stratigraphic unit etc.. Moreover it takes in consideration of the planning such as topographic condition, vegetation, climate, locating condition, setting condition of mining concession etc..

Consequently exploration work is devided into three stages or three years' work. First stage is to select a more hopeful area out of four areas mentioned above, detailed prospecting survey is carried out to point out drilling target in second stage and then, drilling and additional survey finally.

5–2 Exploration Method

According to the exploration plan mentioned above, following methods are recommended.

	First Stage	Second Stage	Third Stage
Survey	Photogeology Geological Reconnaissance Survey Ore Deposit Survey Making Topographic Map	Geochemical Prospecting Geophisical Survey Detailed Geological Survey	Drilling Detailed Geological Survey
Remarks	Selection of more hopeful area out of 4 areas	Geochemical prospecting by stream sediments and partly rocks and soils analyzing Cu and Zn. Geophysical survey by DIGHEM-II Selection of the drilling sites	Mineralogical study and chemical analysis of drilling core Geophysical prospecting in drilling hole.

PART III

Chapter 1. Summary

1–1 Area and purpose of the geological Investigation

The investigation area occupies the eastern half of the coastal mountains situated to the west of Santiago, and have approximately 5,500 km^2 of extension ranging from La Ligua valley to Laguna de Aculeo which are respectively the northernmost and southernmost in the area.

The geological investigation has been carried out to select promising areas for further explorations and to plan exploration system concretely on the basis of the geological and economical investigations on the relations between Cretaceous formations and volcanogenic-syngenetic copper ore deposits.

1–2 Investigation Works

① The investigation works are composed of geological study, analytical inquiry and discussion on the geological informations.

② Study on general geology by excursion along main routes in the area.

③ Observation of occurrence and structural control of the ore deposits by geological survey of the important and relativety accessible ore deposits.

④ Summing-up and making various figures and tables based on the field investigation and geological references.

⑤ Selection of promising areas for further explorations and prospection planning.

1–3 Geology

The area is underlain by Lower and Upper Cretaceous formations and some Jurassic formations characterized by intense volcanic activity in Andes geosyncline.

They show monoclinal structure, striking north to south and dipping east.

The following 4 formations in ascending order relate to the mineralization of copper ore deposits.

1–3–1 Lo Prado Formation

Volcanic rocks: Mainly andesitic and decitic lava, pyroclastic rocks and ignimbrite.

Marine sedimentary rocks: Shale, limestone and sandstone.

1–3–2 Veta Negra Formation

Volcanic rocks: Mainly fine-grained or porphyritic andesite and characterized by the distribution of ocoite, contained large phenocrysts of plagioclase in Ocoa member in the upper horizon of the formation, and of a group of continental reddish andesite lava, breccia and tuffaceous sandstone in Prehue member in the lower part of the formation.

1–3–3 Cerro Morado Formation

The formation, intercalated unconformable between the Veta Negra Formation and the Las Chilcas Formation, is exposured in the northern part of the area, and consists of

continental sedimentary rocks, andesitic or dacitic lava and pyroclastic rocks.

1–3–4 Las Chilcas Formation

Base of the formation consists mostly of continental red sandstone and the upper part is composed of andesitic lava, tuff and basalt.

1–4 Ore Deposits

The copper ore deposits have mainly volcanogenic-syngenetic origin and are characterized with the following fact.

① Ore minerals: Chalcopyrite, bornite and chalcocite.

② Country rock: Andesite, dacite, peperite and shale.

③ Type of ore:
1) Dissemination ore that volcanic rocks has been mineralized homogeneously in groundmass or mainly in vesicule.
2) Veinlets of network in peperite.
3) Banded ore in shale.

④ Ore-bearing strata:

One unit of strata related to mineralization of andesite lava, dacite lava (partly ignimbrite), peperite (or volcanic breccia), muddy sedimentary rocks in ascending order. The mineralization is observed mainly in dacite or peperite (or volcanic breccia) and is often seen in underlain strata.

The ore bearing strata of more than two are present in a mine and in each of the four formations mentioned above.

⑤ Occurrence of ore deposits:

The ore deposits occur generally parallel to bedding plane of volcanic rocks, peperite and breccia in the bedded, massive or irregular form peperite and volcanic breccia.

⑥ Scale of ore deposits:

One unit of ore body each investigated mine has generally scale of 2 m to 10 m in thickness and 10 m to 300 m in horizontal extension. (dip-down extension is unknown)

⑦ Ore grade: The average of ore grade generally seems to be 1% to 3% of copper contents in the area.

1–5 Recommended Area for Future Exploration

The recommended areas for future exploration of 1470 km^2, i.e. Catemu, Eastern Limache, Tiltil, and Carmen Alto area, are selected as aforesaid in Chapter 4 being based on three points as correlation between ore deposits and geological statement, the expansion of unexplored zone, and the mining concession.

Chapter 2. Conclusion

From the general examination about the field investigation on geology and copper ore deposits, some figures and tables compiled from geological study, some published reports, and laboratory works, in the proposed area for exploration by the Government of Chile, the following conclusions are obtained.

① Principal copper ore deposits in this area can be classified genetically into volcanogenic-syngenetic one. Though a number of small ore deposits are opened in this area, any geological, economical or organized exploration has not been carried out except at the El Soldado mine and the Lo Aguirre mine. In consideration of the speciality of ore deposits, lateral continuity of ore deposits must be expected widely along the definite formation, so the recommended areas for future exploration of 1,470 km^2 can be selected in northern and southern part.

② From the generalized situation of the ore deposits, we suggest that the exploration methods must be carried out as follows.

The first stage: The most hopeful areas shall be extracted for the next detailed geological survey by means of photogeology and geological survey.

The second stage: Persuit of the ore-embedded horizons or the discovery of new concealed deposits shall be made by means of geochemical exploration and DIGHEM (Digital Helicopter Electromagnetic Method). Also, the decision of drilling sites must be made in this area.

The third stage A new discovery of ore deposit shall be made by diamond core-drilling.

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