

salt density.

1-5-4 Isotopic Element

Stable isotopic elements, δO and δS , have been determined to assume the mineralization mechanism by the investigations of the origin and behavior of the ore solution associated with the mineralization in the area. Table 2-1-3 shows the result of the determination.

Table 2-1-3 Result of Determination of δO and δS isotopes

No	Samp. No	δO (0/00) VS SMOW	δS (0/00) VS SMOW	Remarks
1	D-107	+13.4		Quartz vein in Ocoita
2	B-59	+14.1		Quartz segregation vein
3	B-60	+16.3		Quartz vein in sandstone
4	B-64		+14.9	Las Guias bornite ore
5	B-65		+19.1	Las Guias bornite ore
6	B-66		+18.9	Las Guias bornite ore
7	B-67		+18.8	Las Guias bornite ore
8	B-68		+19.4	Las Guias bornite ore
9	B-69		+18.9	Las Guias bornite ore

Judging from the result of the determination, the origin and character of the ore solution are summarized as follow.

* δO shows high values of 13.4% to 16.3% to SMOW, and it suggests that the primary ore solution reacted with surrounding sedimentary or metamorphosed rocks through its transference process.

* δS shows high values of 18.8% to 19.4% to CDT except for B-63, and it suggests that the sulfuric acid ions were trapped in the deep ground, reduced by some heat source, transferred, transformed to hydrogen sulfide through the process, and finally homogenized to the stable isotopic ratio. Through a series of the process, Cu ions were solved in the ore solution, and sulfide ore minerals such as bornite and chalcocite were deposited under a low temperature condition controlled by some suitable geological structure to precipitate copper minerals. Therefore, the alteration associated with the

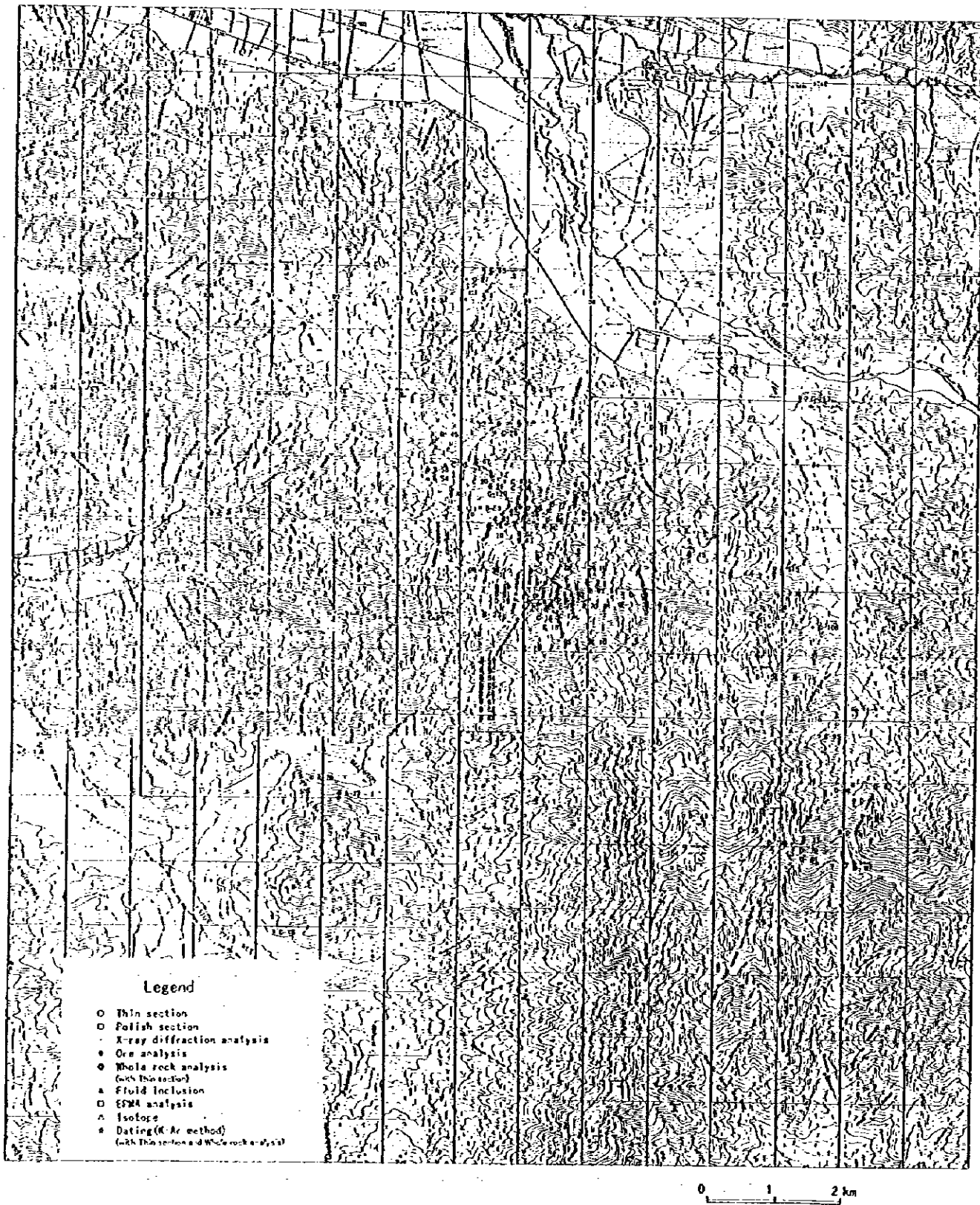


Fig. 2-1-13 Locality map of Sampling sites of X-ray diffraction test, thin section etc.

mineralization is very weak, and limited in very small zones.

It is presumed that the low temperature and weakly acidic ore solution seeped into the surrounding rocks having many open spaces, and deposited copper minerals there. The Ocoita is porous rock containing large-amounts of plagioclase phenocrysts, and some parts of the Ocoita show heterogeneous brecciated rock faces, which fine-grained Ocoita fills between large brecciated fragments. The ore shoots in the Las Guías Deposit sit in such parts of the Ocoita. Also the Ocoita shows higher content of copper compared with other rocks, and it supports the hypothesis that the ore solution seeped into the porous Ocoita, and deposited copper minerals there.

Fig. 2-1-13 shows the location of the samples for the above mentioned various laboratory tests.

1-6 Interpretation

1-6-1 Characteristics of Mineralization

Mineralization occurred in the area is summarized as follows.

(1) Sixty-five percent of the total 30 mineral occurrences confirmed in the area this time is concentrated in the Upper Horqueta Member, however, no phenomenon to indicate the direct genetic relation between the Ocoita and mineralization in the geology and geochemistry in the area has been found. Also, it does not appear that the distribution of the mineral occurrences is controlled by some tectonic elements such as fault.

(2) Principal mineral occurrences and associated alteration are as follows.

* Net-work or disseminated mineral occurrences of secondary minerals mainly composed of malachite: This type of mineral occurrences occupy most of occurrences found in the area except the bornite-chalcocite occurrence in the Las Guías Mine. The mineralization has been abruptly ceased in the edges to the both sides and depth, and no phenomenon to transform to barren quartz veins or alteration zones is seen. No alteration except regional diagenesis has been occurred in the spots.

* Net-work or disseminated mineral occurrences mainly composed of bornite and chalcocite in the Las Guías Mine: No alteration mineral except regional diagenesis minerals is seen in the spot.

* Very small-scale chalcopyrite-pyrite quartz veins in the andesites: Some impregnation of secondary copper minerals is seen in this primary mineral occurrences. The occurrences are associated with minor-amounts of alteration minerals such as sericite and kaolin.

* Net-work or disseminated mineral occurrences of chalcopyrite and pyrite in the Lo Prado Formation: The mineralization are accompanied by silicification and argillization.

* The result of X-ray analysis for samples taken by regular pattern method from the Las Guías Mine area has revealed that no alteration mineral exists in the samples except diagenesis minerals.

* Common constituent minerals appeared in the occurrences are bornite, chalcocite, chalcopyrite, hematite, malachite, chrysocolla, azurite, atacamite, etc. Under the microscope, it appears that bornite, chalcocite, and chalcopyrite replaced parts of host rocks, and a little alteration minerals are seen nearby the edges of the ore minerals.

* Close paragenesis of bornite-chalcocite-digenite, colloform structure, and exsolution structure of djurleite from chalcocite indicate mineralization under low temperature.

(3) Summary of the liquid inclusion test result is summarized as follow.

* Homogenization temperature of the chalcopyrite-pyrite bearing quartz is 200 to 265 degree, that of the barren quartz is about 170 degree, and that of the barren quartz and calcite vein of secondary genesis is about 130 degree. No homogenization temperature of the mineralized parts of the bornite and chalcocite in the Las Guías Mine is obtained.

* It is supposed that three kinds of solutions, having higher than 10%, 10 to 5%, and lower than 5% of the salt density existed. No homogenized temperature of the bornite and chalcocite in the Las Guías Mine is obtained.

Judging from the above mentioned results, the hydrothermal activity in the area occurred several times with different temperature and salt density.

(4) Stable isotope elements, δO and δS , have been measured to investigate origin and behavior of ore solution relating to the mineralization and to assume ore-forming mechanism. The results are as follows.

* δO shows high values of 13.4 to 16.3‰ to SMOW. It suggests that the primary solution reacted to the sedimentary and metamorphosed rocks during transposing process in the ground.

* δS shows high values of 18.8 to 19.4‰ CDT, except Sample B-63. It suggests that sulfuric acid ion originated from the marine water was trapped in the deep ground, reduced by some heat source, transferred to other places, transformed to hydrogen sulfide during the process, and finally homogenized to the stable isotopic ratio. During a series of the process, it is resumed that copper ions were solved in the solution, and bornite and chalcocite minerals were deposited under the low temperature condition, controlled by the suitable geological structure.

(5) Stage of Mineralization

Based on above mentioned survey results, following ore-forming process is idealized. Fig. 1-1-1 shows a schematic diagram of ore-forming process for bornite-chalcocite ores in the Ocoita.

① Intrusion of the Ocoita -- Middle Cretaceous

The rock has undergone all mineralization.

② Primary replacement mineralization of bornite and chalcocite forming ore shoots of the Las Guías Deposit -- since Paleogene

The ore shoots exist in the Ocoita, being discordant to the surrounding sedimentary rock formations, and extend to the andesite dikes in the area. The geochemical copper content in the Ocoita is abnormally high compared with all other rocks in the area. From the microscopic observation results, it is judged that the copper minerals are of primary mineralization, replaced host rocks. It is presumed that the minerals were deposited under the low temperature condition, based on the mineral assemblage and traces of weak alteration around the ore minerals. Also, the phenomena suggest that the mineralization could be closely related with the physical character of the Ocoita, porous and heterogeneous. This type of mineralization forms relatively large-scale high grade ore deposits.

③ Primary mineralization of chalcopyrite-pyrite quartz vein -- since Paleogene

The veins exist in the underground of the Las Guías and Angelita Mines, and in the Lo Prado Formation. Judging from its occurrences, the mineralization is of presumably after the above mentioned bornite-chalcocite mineralization stage. These two mineralization are probably brought under the different physical and chemical conditions, judging from the different mineral assemblages. The geochemical survey result has revealed that the Au-Sb-Pb content in the Lo Prado Formation tends to higher than that in the Horqueta Formation, and it supports the above mentioned presumption. This type of mineralization is significantly small-scale, and no economical ore has been found yet.

④ Secondary copper mineralization mainly of malachite

This mineralization is overlapped previously mentioned all other mineral occurrences, being in the last stage. The occurrences of this type mineralization are controlled by cracks and druses in the bornite-chalcocite ore shoots and host rocks in the Las Guías Mine, and by spaces of cracks and banded structures in the chalcopyrite-pyrite quartz veins. These occurrences clearly show later stage one than other stages such as vein forming. It is quite possible that the mineralization was brought from existing primary ores through oxidation and transfer process. This type of the mineral occurrences are small-scale, and no economical one has been found yet.

1-6-2 Potential for Ore Deposit

Based on the geological, geochemical, and geophysical survey

Chapter 2 Geochemical Survey

2-1 Object and Contents of Geochemical Survey

The rock and soil geochemical survey has been performed to presume potential zones by integrated interpretation of the area together with the geological setting revealed by the geological survey. Total 410 rock samples and 152 soil samples have been taken from the area, and analyzed in a laboratory, to make clear the geochemical characteristics of the mineral occurrences, and to investigate the distribution of detected geochemical anomaly zones together with geological structure. The analyzed 15 elements for both rocks and soils are as follows; Au, Ag, As, Sb, Hg, Cd, Co, Cu, Fe, Pb, Mn, Mo, Ni, V, and Zn. Tables A-2 and A-3 show the assay results, and Fig. 2-2-1 shows the sample location.

Sixty-seven rock samples have been taken from the Lower Horqueta Member, and the number of the samples is few compared with those from the Upper Horqueta Member and Lo Prado Formation. The reason for that is due to the difference of the rock constituents for those formations; only andesite and andesitic pyroclastic rocks in the Lower Horqueta but many kinds rocks in the other formations. The average Cu content of the Upper Horqueta Member, excluded the Ocoita, is 34 ppm, and that of the Lower Horqueta Member is 38 ppm, showing only a little difference between them. The average Cu content of the all rocks except the Ocoita and granodiorite is 28 ppm, and that of the all rocks including the Ocoita is 33 ppm. Again no significant difference exists between them. Accordingly, no problem exists for statistical proceeding using the obtained data.

2-2 Survey Result

2-2-1 Rock geochemistry

Table 2-2-1 shows the fundamental statistical data for the samples, and Table 2-2-1, Table 2-2-2, Fig.2-2-2 and Fig. 2-2-3 show the related interpretation data.

① Relation between unit element concentration and mineral occurrence

Based on the various interpretation data, the relation between unit element concentration and mineral occurrence has been investigated. The correlation between Cu and Cd, and Cu and Mo, is not recognized by the correlation analysis, therefore Cd and Mo are excluded from the investigation.

* Au: Approximately 21% of the all analyzed samples show over the background value.

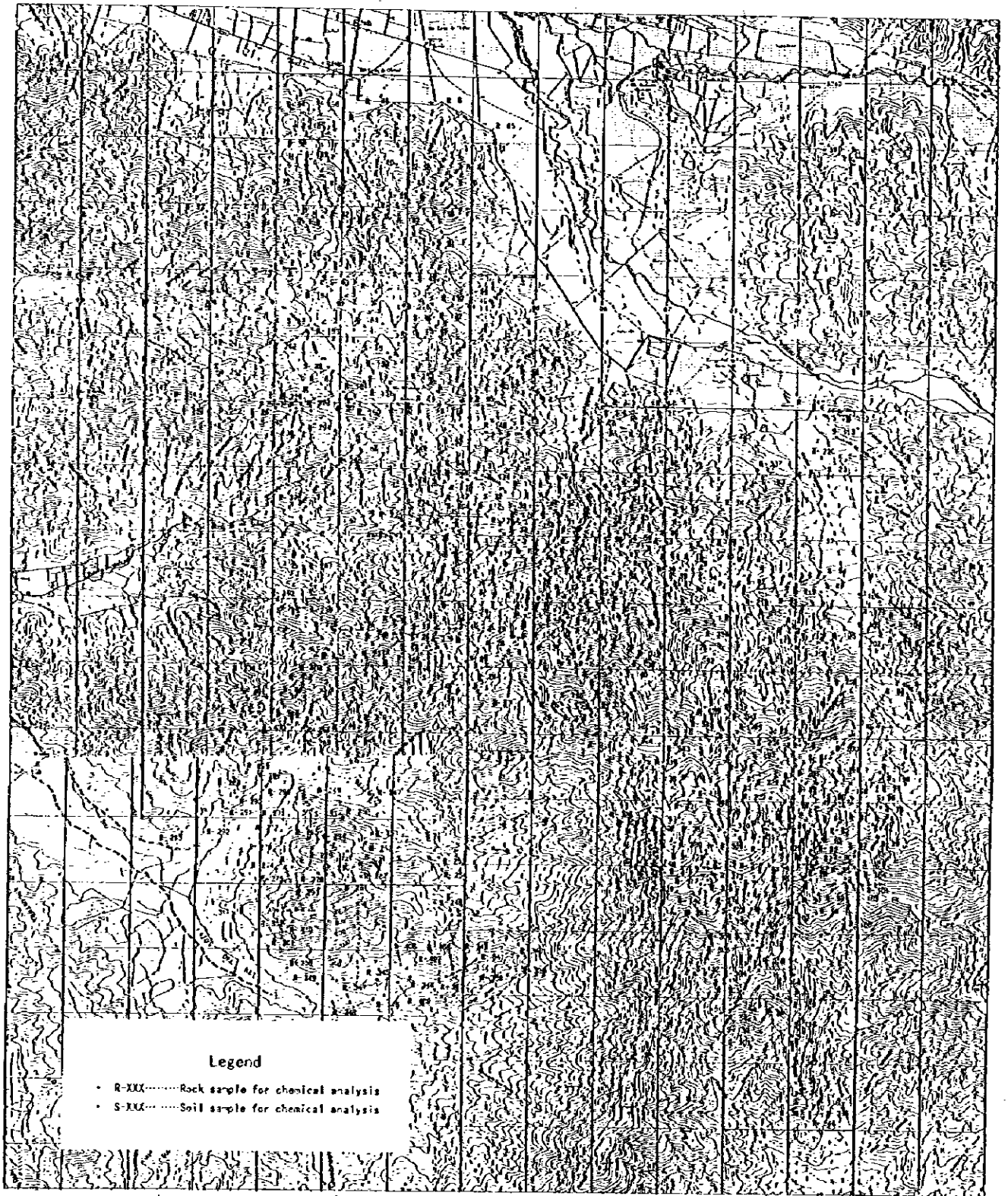


Fig. 2-2-1 Locality map of Sampling sites of geochemical survey (rocks and soils)

Table 2-2-1 Fundamental Statistical Values

Rock

Element	Au	Ag	As	Sb	Hg	Cd	Co	Cu	Fe	Pb	Mn	Mo	Ni	V	Zn
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm
Maximum	1.93	72	538	80	12	5.4	46	>10000	9.99	4320	8278	50	82	400	1971
Minimum	nd	tr	tr	tr	tr	tr	tr	tr	0.18	tr	1.89	tr	tr	tr	tr
Average	0.016309	0.920488	35.24878	3.271951	0.101098	0.129512	13.45366	287.6207	4.547024	44.47561	976.0916	3.153659	5.52439	99.13537	111.0634
Standard Deviasion	0.095904	5.142576	33.35147	5.452154	0.60033	0.344261	8.359528	1268.167	2.04453	221.7845	896.6099	4.700653	9.104428	67.26967	186.5665
Geometric Standard Deviasion	0.255786	0.333831	0.26163	0.171219	0.230994	0.142092	0.407138	0.746977	0.264903	0.450576	0.423711	0.392765	0.607119	0.432622	0.529951
Average of logarithm	-2.02791	-0.50714	1.466873	0.430894	-1.23658	-0.98525	0.998561	1.518015	0.395769	1.306458	2.841859	0.270274	0.333567	1.849521	1.788315
Geometric Mean	0.009377	0.311073	29.30033	2.695154	0.057998	0.103454	9.966926	32.96212	3.942477	20.25156	694.7984	1.863262	2.155593	70.71648	61.4208

Soil

Element	Au	Ag	As	Sb	Hg	Cd	Co	Cu	Fe	Pb	Mn	Mo	Ni	V	Zn
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm
Maximum	23.2	3.5	3060	24	3.7	5	33	3020	9.35	3380	7360	23	55	342	1336
Minimum	tr	tr	tr	tr	tr	tr	3	5	0.33	2	9.14	tr	tr	29	25
Average	0.163857	0.344805	61.66883	2.88961	0.089935	0.131818	18.23377	107.1688	5.179675	82.82468	1349.988	4.019481	5.915584	126.8442	175.8247
Standard Deviasion	1.868654	0.714353	244.6504	2.011606	0.325766	0.394853	6.813858	273.9738	1.501805	275.5785	841.5845	4.680319	7.111347	53.33016	197.9115
Geometric Standard Deviasion	0.368773	0.179321	0.28967	0.127895	0.219076	0.136907	0.200185	0.427305	0.170941	0.351238	0.280103	0.432465	0.522951	0.2095	0.327682
Average of logarithm	-2.00728	-0.56581	1.568741	0.429181	-1.25728	-0.98897	1.222151	1.743837	0.689079	1.664342	3.0598	0.372024	0.507528	2.058723	2.097673
Geometric Mean	0.009834	0.271762	37.13134	2.686462	0.055299	0.102573	16.87827	55.44171	4.887414	46.16806	1147.626	2.355182	3.217566	114.4782	125.2199

Table 2-2-2 Correlation matrix

Rock

STAT. BASIC STATS	* Significant (p<0.05)														
Element	AU	AG	AS	SB	HG ₁	CD	CO	CU	FE	FB	MN	MO	NI	Y	ZN
AU	1.00	.32*	.12*	.16*	.27*	.07	-.01	.21*	-.06	.19*	-.08	.11*	-.01	.01	.00
AG	.32*	1.00	.29*	.36*	.50*	.01	.06	.58*	.05	.25*	.10*	.09	.10*	.09	.16*
AS	.12*	.29*	1.00	.28*	.15*	-.03	.31*	.22*	.41*	.36*	.27*	.05	.19*	.36*	.40*
SB	.16*	.36*	.28*	1.00	.26*	-.02	-.09	.15*	.03	.18*	.05	.13*	-.03	-.01	.08
HG ₁	.27*	.50*	.15*	.26*	1.00	.18*	-.07	.24*	-.06	.24*	-.10*	-.02	-.01	-.07	.02
CD	.07	.01	-.03	-.02	.18*	1.00	-.09	-.02	-.06	.12*	.05	.05	-.06	-.04	.14*
CO	-.01	.06	.34*	-.03	-.07	-.09	1.00	.26*	.62*	.03	.43*	-.05	.35*	.75*	.34*
CU	.21*	.58*	.22*	.15*	.24*	.02	.26*	1.00	.14*	.15*	.16*	.05	.17*	.23*	.23*
FE	-.06	.06	.41*	.03	-.06	-.06	.62*	.14*	1.00	.14*	.43*	.05	.19*	.68*	.46*
FB	.19*	.25*	.35*	.18*	.24*	.03	.15*	.14*	.14*	1.00	.16*	.02	.05	.13*	.35*
MN	-.08	.10*	.27*	.05	-.10*	.05	.43*	.16*	.43*	.16*	1.00	-.03	.18*	.41*	.49*
MO	.11*	.09	.05	.13*	-.02	.05	-.05	.05	.05	.02	-.03	1.00	.12*	-.03	.06
NI	-.01	.10*	.19*	-.03	-.04	-.06	.35*	.17*	.19*	.05	.18*	.12*	1.00	.32*	.17*
Y	.01	.09	.36*	-.01	.07	-.04	.75*	.23*	.68*	.13*	.41*	-.03	.32*	1.00	.32*
ZN	.00	.16*	.40*	.08	-.02	.14*	.31*	.23*	.46*	.35*	.49*	.05	.17*	.32*	1.00

Soil

STAT. BASIC STATS	* Significant (p<0.05)														
Element	AU	AG	AS	SB	HG	CD	CO	CU	FE	FB	MN	MO	NI	Y	ZN
AU	1.00	.62*	.44*	.45*	.57*	.74*	-.18*	.09	-.01	.42*	.09	.14	-.02	-.17*	.20*
AG	.62*	1.00	.45*	.43*	.47*	.68*	.07	.41*	.14	.43*	.23*	.14	.08	.12	.32*
AS	.44*	.45*	1.00	.48*	.32*	.53*	.09	.24*	.20*	.56*	.26*	.27*	.22*	.07	.49*
SB	.45*	.43*	.48*	1.00	.38*	.60*	.01	.19*	.18*	.41*	.17*	-.02	-.02	.04	.29*
HG	.57*	.47*	.32*	.35*	1.00	.68*	-.02	.04	.07	.20*	.00	-.01	.07	.05	.12
CD	.74*	.68*	.53*	.60*	.68*	1.00	.06	.11	.11	.43*	.06	.11	-.00	.10	.25*
CO	-.18*	.07	.09	.01	-.02	.06	1.00	.40*	.44*	-.03	.27*	-.19*	.21*	.90*	.24*
CU	.09	.41*	.24*	.19*	.04	.11	.40*	1.00	.25*	.35*	.49*	.26*	.31*	.38*	.46*
FE	-.01	.14	.20*	.18*	.07	.11	.44*	.25*	1.00	.14	.17*	.15	.21*	.47*	.24*
FB	.42*	.43*	.56*	.41*	.20*	.43*	-.03	.35*	.14	1.00	.36*	.47*	.19*	-.05	.69*
MN	.09	.23*	.26*	.17*	.00	.06	.27*	.49*	.17*	.36*	1.00	.27*	.24*	.26*	.63*
MO	.14	.14	.27*	.27*	-.01	.11	-.19*	.26*	.15	.47*	.27*	1.00	.21*	-.10	.40*
NI	-.02	.08	.22*	-.02	.07	-.00	.21*	.31*	.21*	.19*	.24*	.21*	1.00	.19*	.42*
Y	-.17*	.12	.07	.04	.05	.10	.90*	.38*	.47*	-.05	.26*	-.10	.19*	1.00	.19*
ZN	.20*	.32*	.49*	.29*	.12	.25*	.24*	.46*	.21*	.69*	.63*	.40*	.42*	.19*	1.00



Rock

Fig. 2-2-2(1) Scatter diagram matrix



Soil

Fig. 2-2-2(2) Scatter diagram matrix

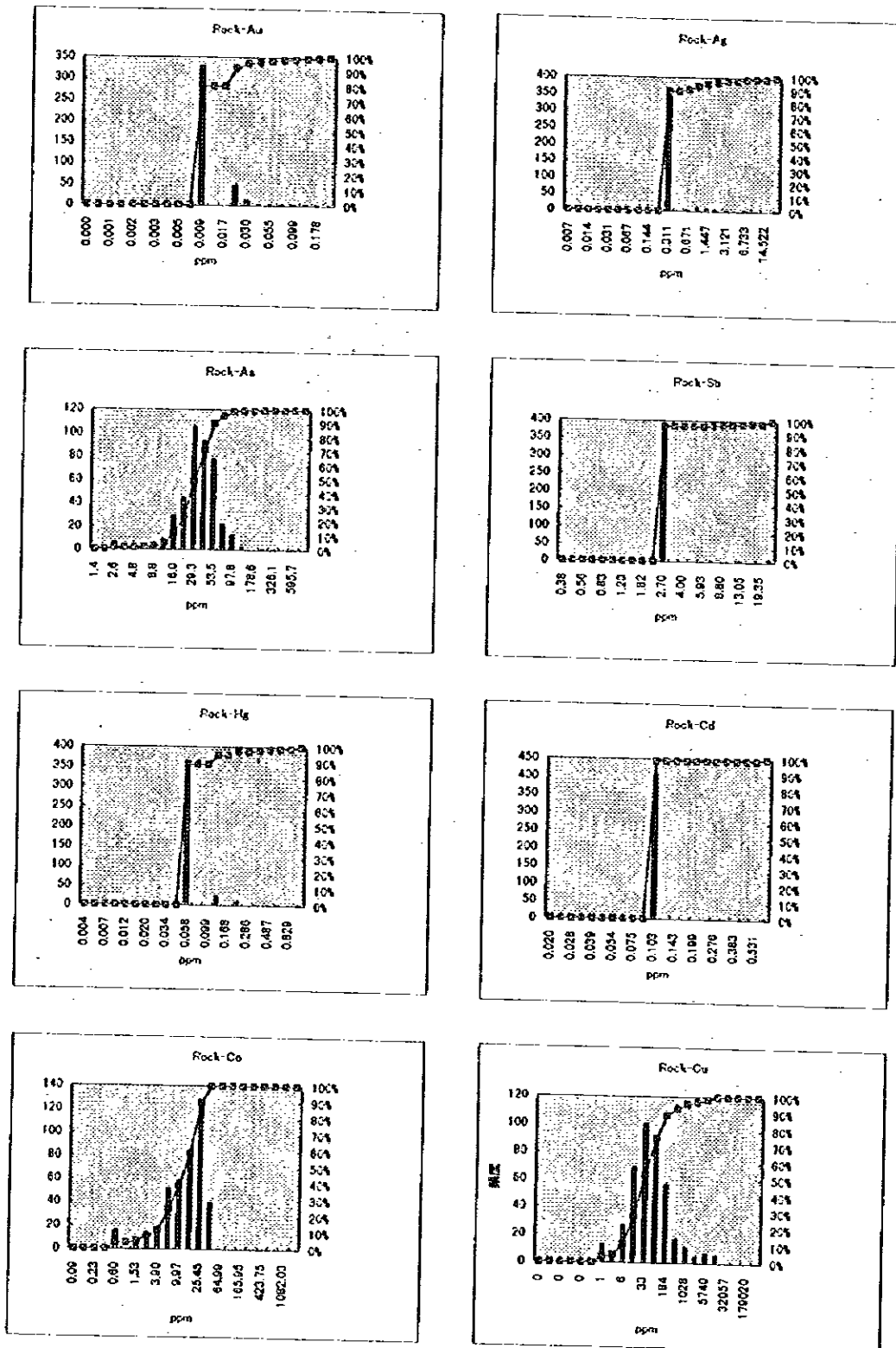


Fig. 2-2-3 Histograms and cumulative curve of element 1/4 (Rock Samples)

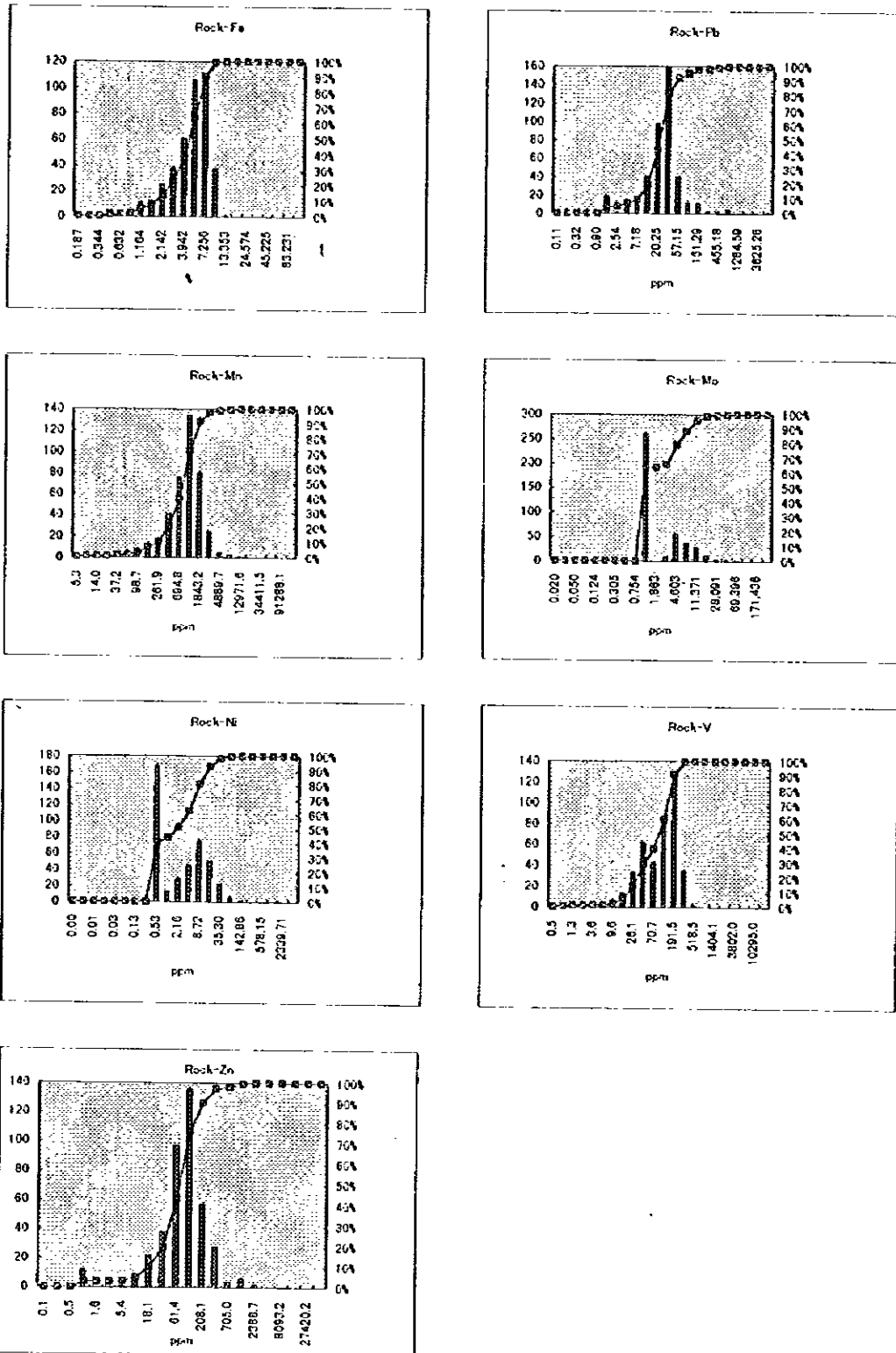


Fig. 2-2-3 Histograms and cumulative curve of element 2/4 (Rock Samples)

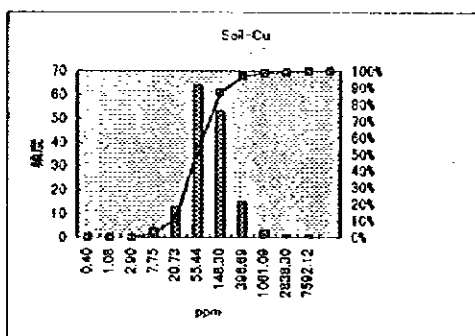
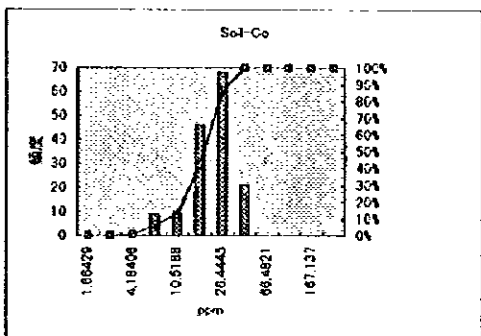
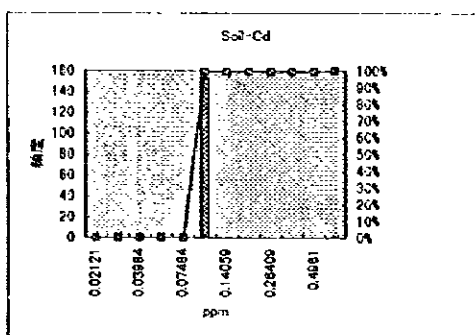
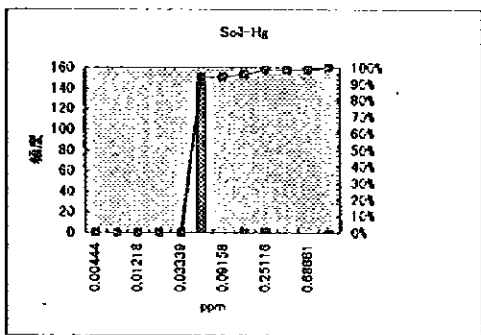
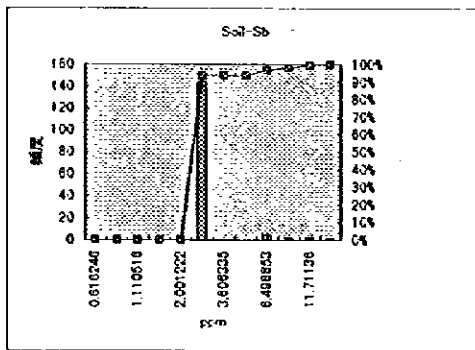
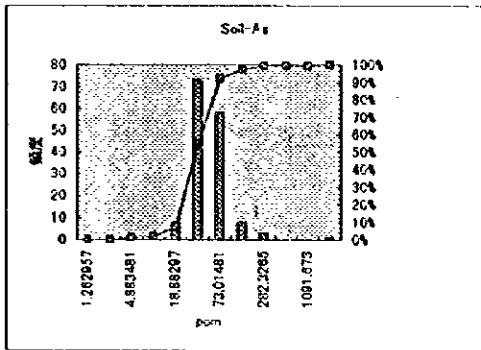
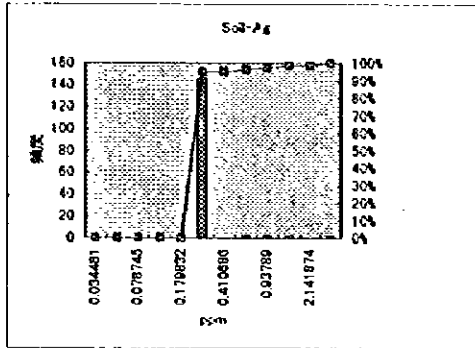
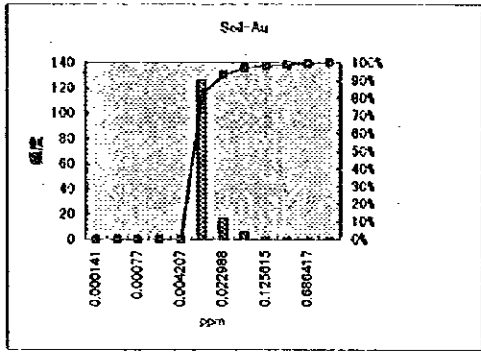


Fig. 2-2-3 Histograms and cumulative curve of element 3/4 (Soil Samples)

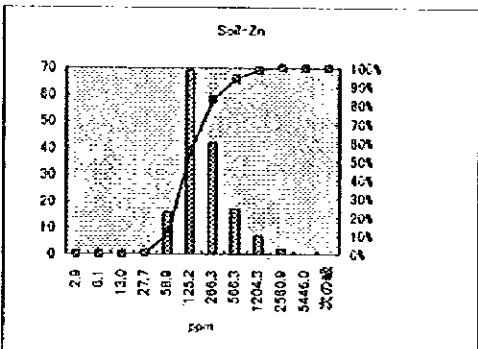
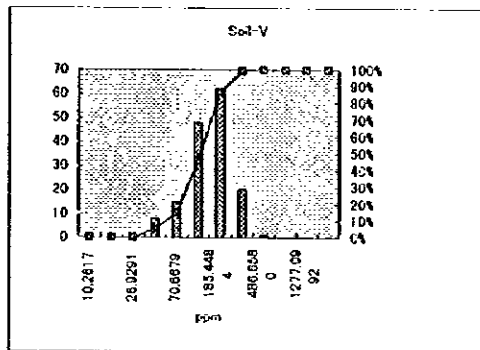
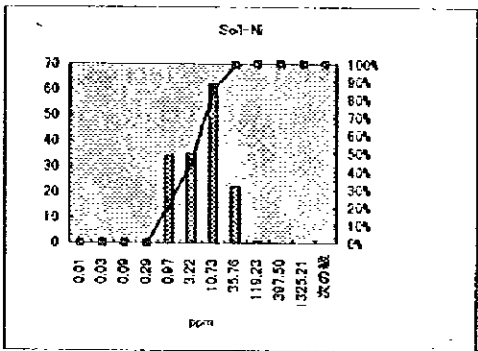
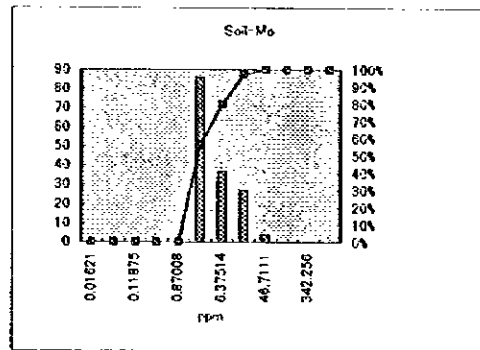
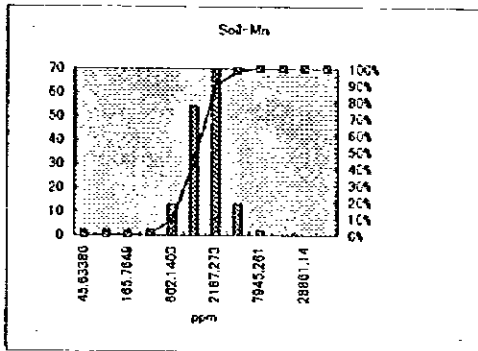
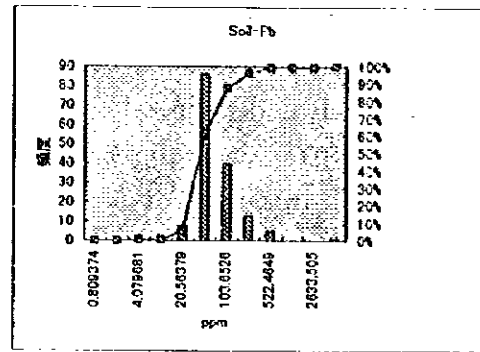
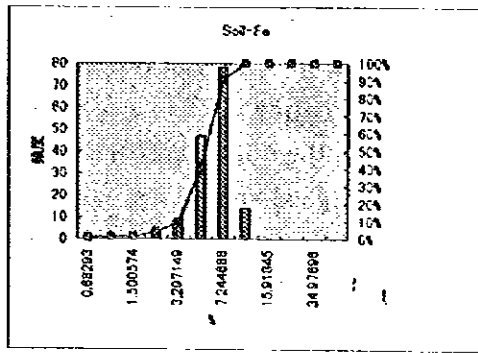


Fig. 2-2-3 Histograms and cumulative curve of element 4/4 (Soil Samples)

A concentrated part in the southeastern area corresponds to the mineral occurrences 26 to 27 (Cajon de Panama), 25-32, and 20-21. The concentrated part in the northern area corresponds to the mineral occurrences 2, 6, and 7, locating close to a fault. The concentrated part in the southwestern area corresponds to the mineral occurrence 32. The relations between other concentrated parts and geological setting are not clear. The correlation between the concentrated parts in the Horqueta Formation and the oxide mineral occurrences are poor. It is judged that generally the correlation between the Au content and mineral occurrence is almost none.

* Ag: Approximately 10% of the all analyzed samples show over the background value. The concentrated part in the northern area corresponds to the mineral occurrences 5, 6, and 7, locating close to a fault. The concentrated part in the southern half of the area corresponds to the mineral occurrences 16, 25-32, and that in the eastern area does to 26, 27, and 23. It is judged that generally the correlation between the Ag content and mineral occurrence is almost none.

* As: The values show generally higher than that of the background. The concentrated part in the northern area corresponds to the mineral occurrence 7, that in the southeastern part does to 25-32 and 26-27. It is judged that generally the correlation between the As content and mineral occurrence is almost none.

* Sb: Approximately 5% of the all samples show over the background value. The concentrated part in the eastern half of the area corresponds to the mineral occurrences 7, 24, 26-27, 25-28, and 31. It is judged that generally the correlation between the Sb content and mineral occurrence is almost none.

* Hg: Approximately 10% of the all samples are over the background value. The concentrated part in the northern half of the area corresponds to the mineral occurrences 5-7, locating close to a fault. The concentrated part in the eastern area corresponds to the mineral occurrences 26-27, but that in the western area is unreliable due to a few samples. It is judged that generally the correlation between the Hg content and mineral occurrence is almost none.

* Co: All samples are lower than the background value. The concentrated part in the central area corresponds to a dense mineral occurrences zone. The concentrated part in the southeastern area corresponds to the mineral occurrences 25-32 and 21-23. The relation between the concentrated part in the northwestern area is not clear. Generally, the Co content tends to show high in the andesitic rocks of the Horqueta Formation, and low in the intermediate rocks of the Lo Prado Formation, and it is possible that the Co content reflects the difference of the rocks. It is judged that the correlation between the Co content and mineral occurrence is possibly weak.

* Cu: Generally the concentrated parts correspond to the mineral occurrences. The concentrated part in the southwestern area corresponds to the distribution of the granodiorite and dacite. The relation between the large-scale concentrated part in the western area and the geological setting there is not clear.

* Fe: The all samples are lower than the background value, and the relation between the concentrated parts and the mineral occurrences is not clear. The Fe content tends to relatively high in the andesitic rocks in the Horqueta Formation, and low in the intermediate rocks in the Lo Prado Formation. It is possible that the Fe content reflects the difference of the rocks.

* Pb: Approximately 5% of the all samples are higher than the background value. The concentrated part in the eastern half of the area corresponds to the mineral occurrences 21-22-23, 25-28-32, and 26-27. The Pb content tends to show low values in the secondary copper occurrence zone in the Horqueta Formation, but it is judged that generally the correlation between the Pb content and mineral occurrence is almost none.

* Mn: The all samples are lower than the background value, and the correlation between the concentrated parts and the distribution of the mineral occurrences is not clear.

* Ni: Approximately 60% of the all samples are over the background value. The concentrated parts are scattered in the area, and no correlation with the mineral occurrence zones. The Ni content tends to show high in the andesitic rocks of the Horqueta Formation, and low in the intermediate rocks of the Prado Formation. It is possible that the Ni content reflects the difference of the rocks.

* V: The all samples are lower than the background value, but relatively highly concentrated parts generally correspond to the distribution of the mineral occurrences. The relations between the large-scale concentrated zones in the western and southwestern area and the geological setting of the zones are not clear. The V content tends to show high in the andesitic rocks of the Horqueta Formation, and the intermediate rocks low of the Lo Prado formation. It is possible that the V content reflects the difference of the rocks. It is judged that the correlation between the V content and mineral occurrence is possibly weak.

* Zn: Approximately 10% of the all samples are over the background value. The concentrated part in the eastern area does not correspond to the mineral occurrence. The Zn content generally shows low in the andesitic rocks in the Horqueta Formation, and high in the intermediate rocks in the Lo Prado Formation, and it might represent the difference of the mineral content in both rocks. It is judged generally that the

correlation between the Zn content and mineral occurrence is almost none.

② Relation between copper anomaly and other element's concentration

The relation between the copper anomalies and the concentration of the other elements has been investigated to support further exploration programs, because the mineralization in the area is of copper. The study has been done based on the correlation coefficients of copper for the other elements presented in Table 2-2-1 and 2-2-2. Cd and Mo show less than 95% of the correlation coefficients to copper, therefore they have been excluded from the study. It has been defined that the copper anomaly value is over 77 ppm based on the fundamental statistic figures and referred to "Handbook of Geochemistry - Vol.3".

* Au: The concentrated part in the northern half area corresponds to a part of the copper anomaly in the mineral occurrences 5, 6, and 7. The concentrated part in the southern half area corresponds to the copper anomaly in the mineral occurrences 20, 25-32, 26-27, and 33. The Au content tends to show relatively low value in the secondary copper occurrence area. The relation between the large-scale concentrated part in the western area and the geological setting there is not clear. It is possible that the concentrated part in the southwestern area reflects the distribution of the granitic rocks. The other Cu anomaly zones are not accompanied with Au concentration. It is, accordingly, judged that generally the correlation between the Au and Cu contents is none.

* Ag: The concentrated part in the northern area corresponds to the Cu anomaly zone in the mineral occurrence 5, that in the eastern area does to the mineral occurrence 23, that in the central area does to the mineral occurrence 16, and that in the northern area does to the mineral occurrence 25. The other Cu anomaly zones are not accompanied with any Au anomaly. It is judged that the correlation between the Ag and Cu contents is none.

* As: The concentrated part in the eastern half area weakly corresponds to the Cu anomaly zone in the mineral occurrence, but that in the western half does not. It is judged that the correlation between the As and Cu contents is almost none.

* Sb: The concentrated part in the northern area corresponds to the mineral occurrence 7, that in the eastern area does to a part of the Cu anomaly zone in the mineral occurrences 23, 26-27, and 25-32. The other Cu anomaly zones are not accompanied with any Sb concentration. It is, accordingly, judged that the correlation between the Sb and Cu contents is almost none.

* Hg: The concentrated part in the northern area corresponds to the mineral

occurrence 5-7, and that in the eastern area does to the Cu anomaly zone in the mineral occurrence 26-27. The other Cu anomaly zones are not accompanied with any Hg concentration. It is, accordingly, judged that the correlation between the Hg and Cu contents is almost none.

* Co: The concentrated parts almost correspond to the Cu anomaly zones in the mineral occurrences. The relation between the large-scale Cu anomaly zone in the western and southwestern areas and the geological setting is not clear. Generally, the Co content tends to show high in the andesitic rocks in the Horqueta Formation, and low in the intermediate rocks in the Lo Prado Formation. It is possible that the Co content reflects the difference of the rocks. Generally, the correlation between the Co and Cu contents is possibly weak.

* Fe: No correlation between the Fe concentration and Cu anomaly zones is recognized.

* Pb: The concentrated part in the eastern half area corresponds to the Cu anomaly zone in the mineral occurrence there, that in the southeastern area does to the Cu anomaly zone, however that in the western half area does not correspond to any Cu anomaly zone. The Pb content tends to show low in the secondary copper occurrence area. It is, accordingly, judged that the correlation between the Pb and Cu contents is none.

* Mn: The concentrated parts are obscure, and the correlation between the Mn and Cu contents is not clear.

* Ni: The most concentrated parts correspond to the Cu anomaly zones in the mineral occurrences, however, the reverse phenomena can be seen in some places. It is, accordingly, judged that the correlation between the Ni and Cu contents is possibly weak.

* V: The concentrated parts in the area, in spite of obscurely, correspond to the Cu anomaly zones in the mineral occurrences. It is judged that the correlation between the V and Cu contents is possibly weak.

* Zn: A part of the concentrated part in the eastern half area corresponds to the Cu anomaly zone in the mineral occurrence, in spite of obscurely. The concentrated part in the western half area is not accompanied with any Cu anomaly. Accordingly, it is judged that the correlation between the Zn and Cu contents is none.

In summary, the high concentration zones of Au, Ag, As, and Sb correspond to parts of the Cu anomaly zones, however, they are not effective pass finder elements. Only the Cu anomaly zones well correspond to the location of the primary mineral

occurrences in the area, and well reflect the location of the secondary copper occurrences in the western half area.

③ Investigation of Cu anomaly in Andesite in each Formation

The average Cu content in the andesitic rocks in the area for different categories are as follows: 33 ppm for the whole area, 38 ppm for the Lower Horqueta Member, 34 ppm for the upper Horqueta Member, 176 ppm for the Ocoita in the Horqueta Formation, 18 ppm for the Lo Prado Formation, and 81 ppm for the Ocoita in the Lo Prado Formation. Cu is concentrated into the andesitic rocks, especially in the Ocoita. It is presumed that the secondary copper minerals have been formed in the Horqueta Formation reflecting such high content.

Table 2-2-3 Geometrical Means of Principal Rocks

Rock	No.	Au (ppm)	Ag (ppm)	As (ppm)	Sb (ppm)	Hg (ppm)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	Pb (ppm)	Mn (ppm)	Mo (ppm)	Ni (ppm)	V (ppm)	Zn (ppm)
Horqueta F. Lower Mem.	67	0.010	0.3	32	3	0.1	0.1	17	38	4.65	12	831	2	3	101	64
Horqueta F. Upper Mem.	110	0.009	0.3	32	3	0.1	0.1	14	34	5.13	19	762	1	3	116	58
Lo Prado F.	159	0.010	0.3	27	3	0.1	0.1	6	27	3.15	24	650	2	1	44	61
Ocoita (in Horqueta F.)	15	0.009	0.4	43	3	0.1	0.1	26	177	6.23	23	1487	1	5	165	146
Lo Prado F. Tuff etc.	68	0.011	0.4	27	3	0.1	0.1	6	27	2.64	24	533	2	1	37	49
"Ocoita" (in Lo Prado F.)	19	0.009	0.4	39	3	0.1	0.1	13	81	5.21	30	996	3	2	115	129
Andesite (Intrusive)	24	0.009	0.3	40	3	0.1	0.1	20	67	5.41	30	928	2	4	135	116

④ Principal Component Analysis

The principal component analysis has been done to integrally investigate the geochemical survey results, to study the possible cause of the geochemical anomalies, and to interpret the relation between the mineralization and geological setting. In the study, the elements Au, Ag, Sb, Hg, Cd, and Mo have been excluded, because many samples of them show lower values than their detection limit value. Table 2-2-3 and 2-2-4, and Fig. 2-2-4 show the result of the study.

The accumulated contribution rate of the first principal component (P1) to the fifth principal component (P5) is 82.4%, and it well explains most of the assay results and the geochemical characteristic of the area. According to this result, the maps for the first to principal components have been made and studied. The study result is as follows.

* P1: Co, Fe, and V are highly appraised in the first principal component analysis. Highly marked areas generally tend to reflect the distribution of the andesitic rocks with some exception.

* P2: As, Pb, and Zn are highly appraised in the second principal component analysis, but the appraisal for Co, Fe, Ni, and V is low. It tends to represent that the high marked areas reflect the distribution of the Lo Prado Formation, and the low marked

Table 2-2-4 Result of principal component analysis

1. Rock

Engen value and contribution ratio

	Engenvalue	Contribution ratio(%)	Cumulative Engen value	Cumulative Cont. ratio(%)
P1	3.64335	40.48167	3.64335	40.48167
P2	1.27639	14.18208	4.91974	54.66375
P3	0.95260	10.58150	5.87234	65.24825
P4	0.79599	8.81430	6.66833	74.09255
P5	0.75199	8.35543	7.42032	82.44798
P6	0.56400	6.26667	7.98432	88.71465
P7	0.47613	5.29029	8.46044	91.00491

Principal component loading factor

	As	Co	Cu	Fe	Pb	Mn	Ni	V	Zn
P1	0.17000	0.21857	0.11546	0.21809	0.09338	0.17804	0.11769	0.22199	0.18261
P2	0.29148	-0.31677	0.13824	-0.13282	0.59689	0.02364	-0.21408	-0.25858	0.30019
P3	-0.07454	-0.00597	-0.65019	0.28101	-0.07862	0.35391	-0.60484	0.02136	0.20743
P4	-0.19665	0.07057	0.78858	0.06859	-0.28371	0.07364	-0.70656	0.02778	0.01296
P5	0.49034	0.15517	-0.12288	0.28525	0.18764	-0.70139	-0.37498	0.31017	-0.45261
P6	-0.90270	0.14852	0.00011	0.03376	0.82995	0.02603	-0.05045	0.40256	-0.28139
P7	-0.46591	-0.03971	-0.02745	0.43142	-0.12162	-0.88436	0.10779	-0.08363	0.93630

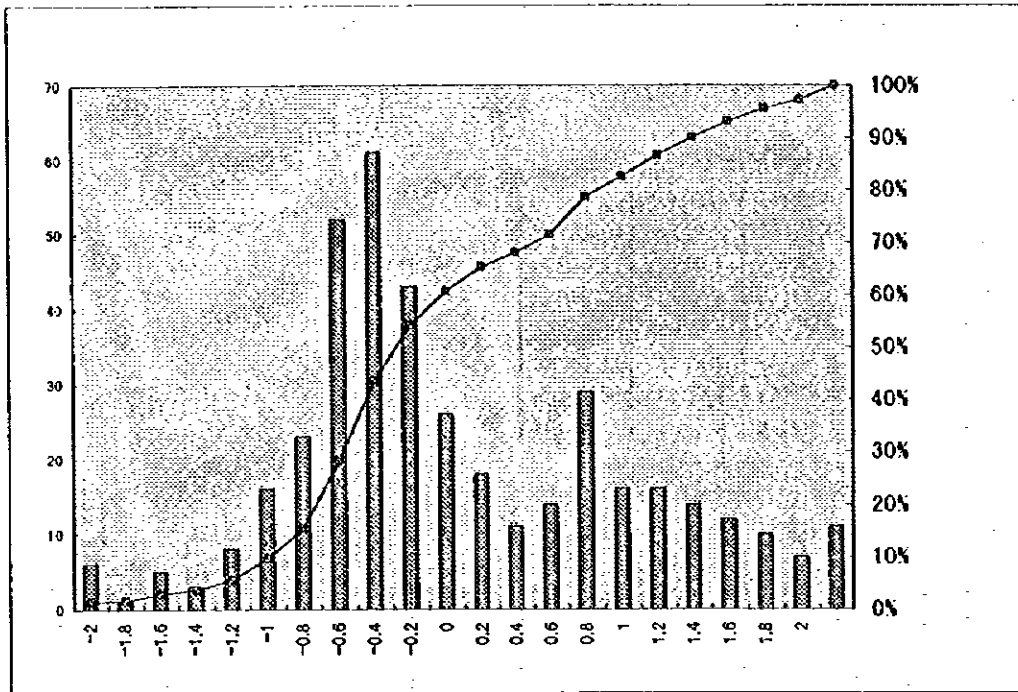
2. Soil

Engen value and contribution ratio

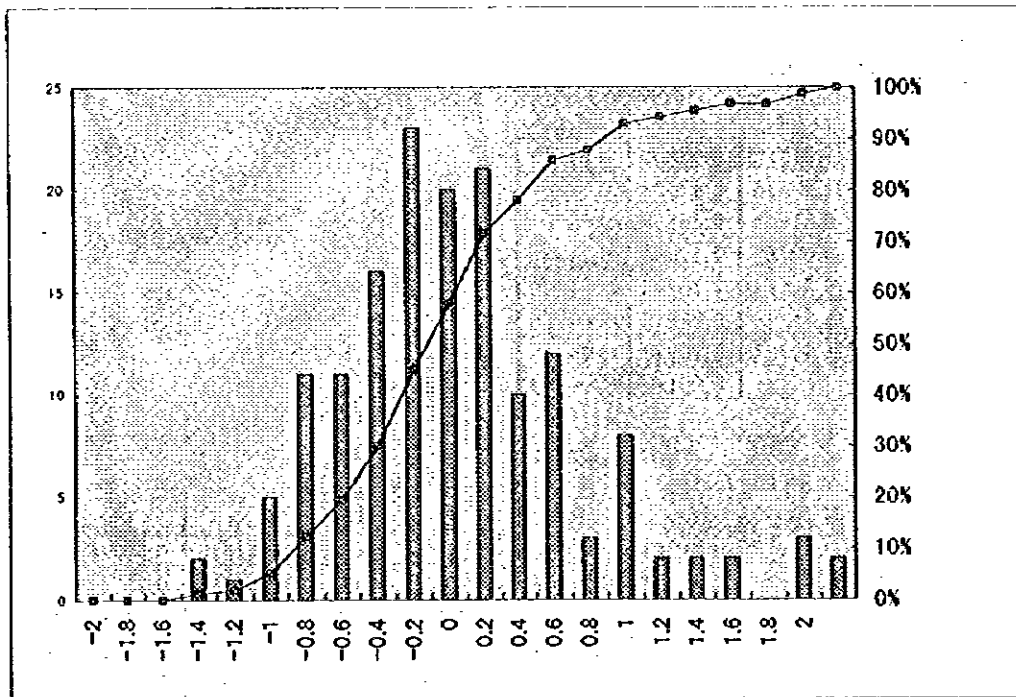
	Engenvalue	Contribution ratio(%)	Cumulative Engenvalue	Cumulative Cont. ratio(%)
P1	3.53800	39.31115	3.53800	39.31115
P2	1.93702	21.52246	5.47503	60.83361
P3	0.88365	9.81838	6.35868	70.65200
P4	0.81826	9.09182	7.17694	79.74382
P5	0.58651	6.51673	7.76345	86.26055
P6	0.52498	5.83306	8.28842	92.09360
P7	0.41830	4.64783	8.70673	96.74143
P8	0.19515	2.16834	8.90188	98.90977

Principal component loading factor

	As	Co	Cu	Fe	Pb	Mn	Ni	V	Zn
P1	0.51695	0.61868	0.71243	0.52600	0.58499	0.68587	0.51510	0.59286	0.80151
P2	-0.41281	0.69599	0.03267	0.37156	-0.62951	-0.16108	-0.06657	0.72611	-0.40258
P3	0.49188	0.01999	-0.34109	0.50837	0.19001	-0.45128	-0.13739	0.04312	-0.07765
P4	-0.06166	-0.10060	-0.09369	0.09187	-0.16178	-0.22901	0.83469	-0.10118	-0.00252
P5	0.35009	0.23367	-0.01260	-0.55658	-0.00192	-0.22453	0.07952	0.20109	-0.04694
P6	-0.01651	-0.08292	0.59181	0.05183	0.10015	-0.32949	-0.03312	-0.08381	-0.19160
P7	-0.36787	0.11060	-0.11380	-0.06938	0.36522	-0.25991	-0.00938	0.08161	0.21164
P8	0.02106	0.01930	0.05347	0.01106	-0.23536	-0.14032	-0.08435	-0.07936	0.32071



Rock Samples (P4)



Soil Samples (P1)

Fig.2-2-4 Histogram and cumulative curve of Principal Component

areas reflect the distribution of the Horqueta Formation.

* P3: Fe, Mn, and V are highly appraised in the third principal component analysis. The high marked areas are generally irregular, and its correlation with the geological setting and mineral occurrences is not clear.

* P4: Appraisal is high for Cu, but low for Ni in the fourth principal component analysis. The high marked areas cover the all mineral occurrence zones in general, and correspond to the Cu anomaly zones. The large-scale high marked areas are distributed in the central area and the northern central to northeast and southwest areas. They are not accompanied with any mineral occurrence.

* P5: Appraisal is high for As, Fe, and V, but low for Mn, Ni, and Zn in the fifth principal component analysis. The high marked areas are irregular, and its correlation with the geological setting and mineral occurrences is not clear.

In summary, it is judged that, among the five components, P5 is the most effective component to represent the geochemical characteristic of the copper mineralization. It is inferred that P2 represents subtle difference between the copper mineralization in the Lo Prado Formation and in the Horqueta Formation. The former contains slightly higher Pb and Zn content than that in the latter.

2-2-2 Soil Geochemical; Survey

The fundamental statistical data and related interpretation data for the soil geochemical survey has been described in the previous section.

① Relation between unit element concentration and mineral occurrence

Based on the fundamental statistical data and related interpretation data, the relation between the unit element concentration and mineral occurrences has been studied. In the correlation analysis, the correlation between the Cu content and Au, Hg, and Cd content is almost none, therefore, these elements have been excluded from the study.

* Ag: Approximately 95% of the all samples are lower than the detection limit value. Only the concentrated part in the east end of the area corresponds to the mineral occurrence 23 and 29. Accordingly, it is judged that the correlation between the Ag content and mineral occurrence is almost none.

* As: Approximately 80% of the all samples are higher than the background value. But the As concentrated parts do not always correspond to the mineral occurrences. The As content tends to low in the Horqueta Formation, and high in the Lo Prado Formation.

It possibly reflects the difference of the mineralization in both formations. It is, accordingly, judged that the correlation between the As content and mineral occurrence is almost none.

* Sb: The all samples are lower than the detection limit value, and no concentrated part exists in the area. It is judged that the correlation between the Sb content and mineral occurrence is none.

* Co: It tends to high in the northwestern area, and low in the southeastern area. The concentrated parts in the central area and eastern area roughly correspond to the mineral occurrence zones. The Co content generally does not correspond to the distribution of the mineral occurrences. The relation between the large-scale concentrated part in the northern area and mineral occurrence is not correspond. It is judged that the correlation between the Co content and mineral occurrence is almost none.

* Cu: The concentrated parts in the eastern half area correspond to the distribution of the mineral occurrences, but those in the western half area do not, rather tend to show low in the mineral occurrence zones. The relation between the large-scale concentrated part and geological setting is not clear. Accordingly, it is judged that the correlation between the Cu content and mineral occurrence is almost none.

* Fe: The Fe content is generally uniform, and no concentrated part is recognized. It is judged that the correlation between the Fe content and mineral occurrence is none.

* Pb: The concentrated parts do not correspond to the mineral occurrences. The Pb content rather tends to show low in the Horqueta Formation in the western half area, and high in the Lo Prado Formation. It is possible that the content reflects the difference of the character of the mineralization in both areas.

* Mn: No concentrated part is recognized in the whole area.

* Mo: Approximately 52% of the all samples are lower than the detection limit value. The concentrated part in the eastern half area, in spite of obscurely, corresponds to the distribution of the mineral occurrence. But the concentrated part in the western half area does not correspond to any mineral occurrence. The Mo content rather tends to show low in the Horqueta Formation, and high in the Lo Prado Formation, and it possibly represents the difference of the character of the mineralization in both formations. The concentrated part in the northwestern area is unreliable because of a few number of samples. It is judged that the correlation between the Mo content and mineral occurrence is almost none.

* Ni: Approximately 22% of the all samples lower than the detection limit. The concentrated part in the eastern half area roughly corresponds to the distribution of the

mineral occurrences. The concentrated part in the western half area does not correspond to any mineral occurrence. The Ni content rather tends to show low in the Horqueta Formation in the western area, and high in the Lo Prado Formation in the eastern half area. It possibly reflect the difference of the rocks. The concentrated part in the northwestern area is not reliable because of a few samples. It is judged that the correlation between the Ni content and mineral occurrence is almost none.

* V: Generally the concentrated parts roughly correspond to the distribution of the mineral occurrences, accordingly the V content possibly correlates to the mineral occurrence.

② Relation between copper anomaly and other element's concentration

The same method used for the rock geochemistry has been applied for the soil geochemistry. The anomaly value for Cu has been defined as 130 ppm using the following formula.

$$\text{Cu anomaly} = \frac{\text{average Cu for soil, 55 ppm}}{\text{average Cu for rock, 33 ppm}} \times \text{Cu anomaly for rock, 77 ppm}$$

Au, Hg, and Cd have been excluded from the study, because the correlation coefficient between Cu and these elements is almost none.

* Ag: Only a concentrated part corresponds to the Cu anomaly zone in the mineral occurrence 23 and 29, and no other part does not. It is judged that the correlation between the Ag content and Cu anomaly zone is none.

* As: Generally the correspondence between the concentrated parts and Cu anomaly zones is unclear, but it tends to low in the Cu anomaly zones. Accordingly, it is judged that the correlation between the As content and Cu anomaly zone is almost none.

* Sb: No correspondence is recognized between the Sb content and Cu anomaly zone.

* Co: The concentrated part in the central to northern area roughly corresponds to the Cu anomaly zone, however other parts are not clear. It is judged that the correlation between the Co content and Cu anomaly zone is none.

* Fe: The concentrated parts in the area are obscure in general, and the correlation between the Fe content and Cu anomaly zone is none.

* Pb: Only a concentrated part corresponds to the Cu anomaly zone in the mineral occurrence 23 and 29, but others do not correspond to any mineral occurrence. It is judged that the correlation between the Pb content and Cu anomaly zone is none.

* Mn: Generally the concentrated parts are obscure in the area, and it is judged that the correlation between the Mn content and Cu anomaly zone is none.

* Mo: No correspondence between the concentrated parts and Cu anomaly zones is recognized in the area. The concentrated part in the northwestern area is unreliable because of a few samples.

* Ni: The concentrated part in the central area roughly corresponds to the Cu anomaly zone in the mineral occurrences 11-13 and 19, and that in the eastern area again roughly does to the Cu anomaly zone in the mineral occurrences 25 and 23. But generally the concentrated parts in the area do not correspond to the Cu anomaly zones. It is, accordingly, judged that the correlation between the Ni content and Cu anomaly zone is none.

* V: The concentrated parts roughly correspond to the Cu anomaly zones, but it is unclear. It is judged that the correlation between the V content and Cu anomaly zone is possibly weak.

* Zn: Some concentrated parts exist in the eastern half area, but none in the western half area. The Zn content rather tends to show low in the Horqueta Formation in the western half area, and high in the Lo Prado Formation. It possibly reflects the difference of the rocks. It is judged that the correlation between the Zn content and Cu anomaly zone is almost none.

In summary, it is judged that the correlation between the unit element concentration and Cu anomaly zone in the soil is less reliable than that of the rock. Therefore, the rock geochemical survey is enough for copper exploration in the area.

③ Investigation of Cu content in andesitic rocks of different formation

The Cu content in the soil in the area principally does not exactly reflect the Cu content in the rocks, therefore the interpretation is eliminated.

① Principal component analysis

The principal component analysis has been performed for the soil geochemistry in the area.

The contribution rate of the first principal component, P1, to the fourth principal component, P4, is 79.4%, and its value is about same as that of the rock geochemistry. The result of the analysis is shown in the distribution map of the principal components P1 to P4, and the summary of that is as follows.

* P1: The all nine elements are highly appraised. The high-marked zones cover the almost all mineral occurrence zones, and also roughly correspond to the Cu anomaly zones. The large-scale high marked zone in the northwestern area is not accompanied

with any surface mineral occurrence.

* P2: Co, Fe, and V are highly appraised, but appraisal for As, Pb, and Zn is low. It tends to that the high-marked zones reflect the distribution of the Horqueta Formation, and the low-marked zones reflect that of the Lo Prado Formation.

* P3: As and Fe are highly appraised, but appraisal for Cu, Mn, and Ni is low. The relation between the distribution of the high-marked zones and mineral occurrences or geological setting is unclear.

* P4: Ni is highly appraised, but appraisal for Mn is low. The low-marked zones roughly correspond to the distribution of the mineral occurrences in the northeastern area, but the relation between the high-marked zones in the southwestern area and the distribution of the mineral occurrences or geological setting is unclear.

In summary, it is judged that, in the soil geochemistry, the first principal component clearly represents the geochemical characteristic of the copper mineralization in the area.

Figs. 2-2-5, 2-2-6, 2-2-7, 2-2-8, and 2-2-9 show the results of the geochemical studies. The results of the rock and soil geochemical surveys are summarized as follows.

* The Cu anomaly zones in the rock geochemistry well correspond to the distribution of the mineral occurrences, and well reflect the positions of the mineralization occurred. No clear relation is recognized between the concentration of the other elements and the mineral occurrences.

* The highly concentrated parts of Au, Ag, and Sb correspond to a part of the Cu anomaly zones, but generally no correlation between the concentrated parts of the other elements and Cu anomaly zones is recognized.

* Cu is concentrated in the andesitic rocks in the Horqueta Formation, especially in the Ocoita.

* Cu anomaly zones in the soil is smaller than those in the rocks in scale, and sit inside of the Cu anomaly zones in the rocks. Therefore the geochemical anomalies for soil can be represented by those for rock.

- In the principal component analysis, the high-marked zones for rock and soil correspond to the principal mineral occurrences and the Cu anomaly zones.

2-3 Relation between geochemical anomaly zone and mineralization

Figs. 2-2-5, 2-2-6, 2-2-7, 2-2-8, and 2-2-9 show the study results of the relations between the geochemical anomaly zones and high-marked zones extracted by the study, and the mineral occurrences. The interpretation and appraisal for the results are as follows.

(1) Cu anomaly zone: Nineteen anomalies, A-1 to A-19, cover around 80% of the all mineral occurrences in the area, and reflect them. It can be said that the Cu anomaly map itself is a good petro-chemical prospecting map for copper. Among these anomalies, some anomalies appeared in barren areas have been investigated and described in the following.

* Anomalies A-2 and A-3 are situated adjacent to Anomaly A-1, and can be a part of A-1.

* Anomalies A-5 and A-6 might represent one anomaly. The anomalies are of large-scale, and situated in the Lower Horqueta Member. Because the relation between the geology and mineralization in the area is not clear, these anomalies will be investigated together with other studies.

* Anomaly A-13 can be a part of Anomaly A-14 situated on the southwest of the anomaly.

* Anomalies A-12, A-16, and A-18 are not reliable because of a few numbers of samples.

(2) High-marked zones for rock geochemistry

Twenty-six high marked zones have been detected in the rock geochemistry. Among them, R-1, R-4, R-5, R-9, R-12, R-14, and R-16 show relatively large-scale distribution, and cover about 80% of the total mineral occurrences. It well reflects those mineral occurrences, and it can be said that the rock geochemical anomaly map is a good prospecting map for copper in the area. Accordingly, the anomalies appeared in barren areas will be described in the following.

* High marked zone R-2 is duplicated on an Au anomaly zone in the rock. In spite of no detail geologic setting data is available, it can be a good target for prospecting.

* High marked zone R-3 can be a part of R-4 situated on the southwest of the anomaly.

* High marked zone R-5 is of large-scale and situated in the Lower Horqueta Member. No relation between the anomaly and the geological setting, therefore, it will be investigated together with other studies.

* High marked zones R-21 and R-22 are not reliable because of a few numbers of samples.

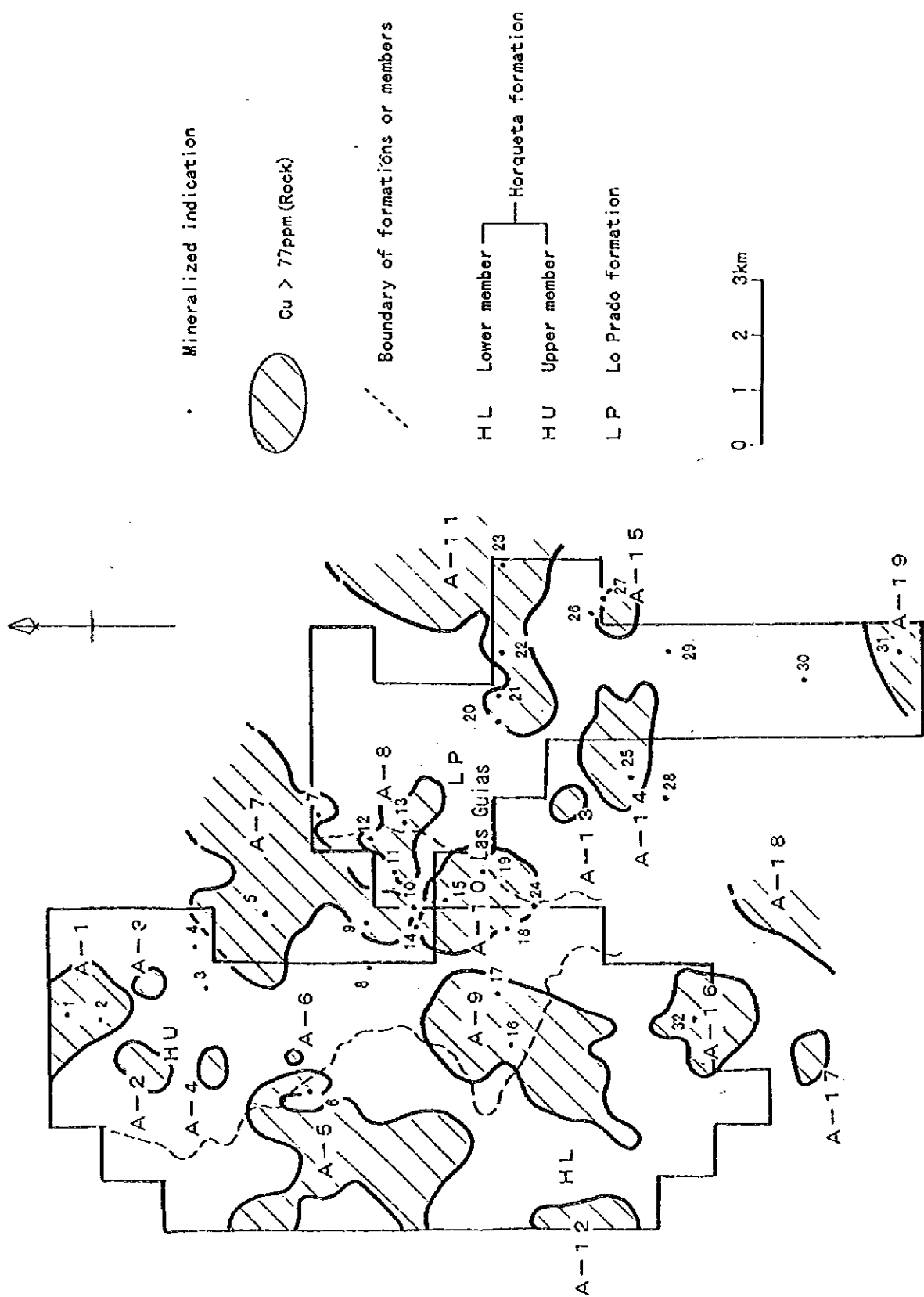


Fig. 2-2-5 Distribution map of Cu anomaly (rocks)

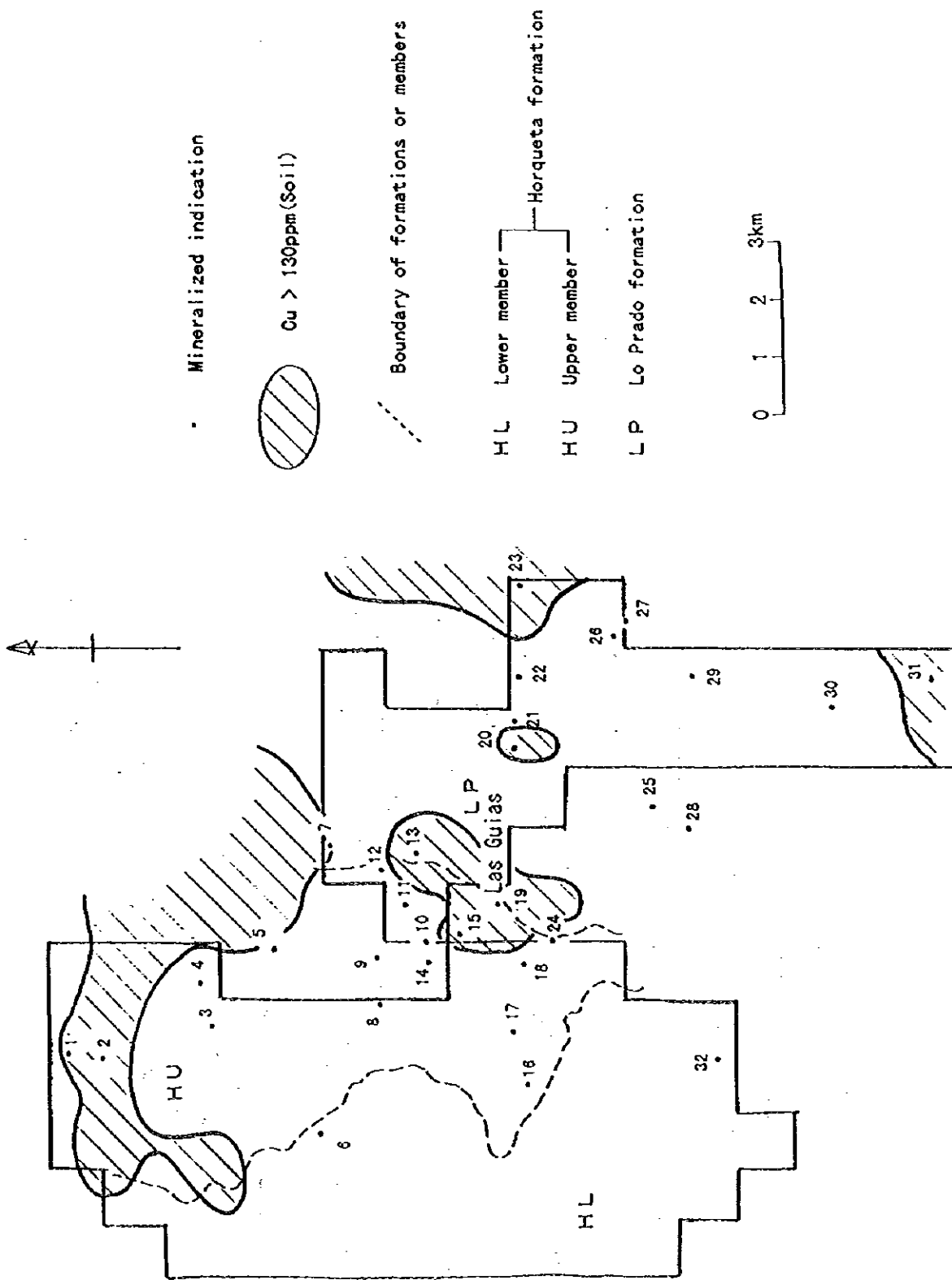


Fig. 2-2-6 Distribution map of Cu anomaly (soils)

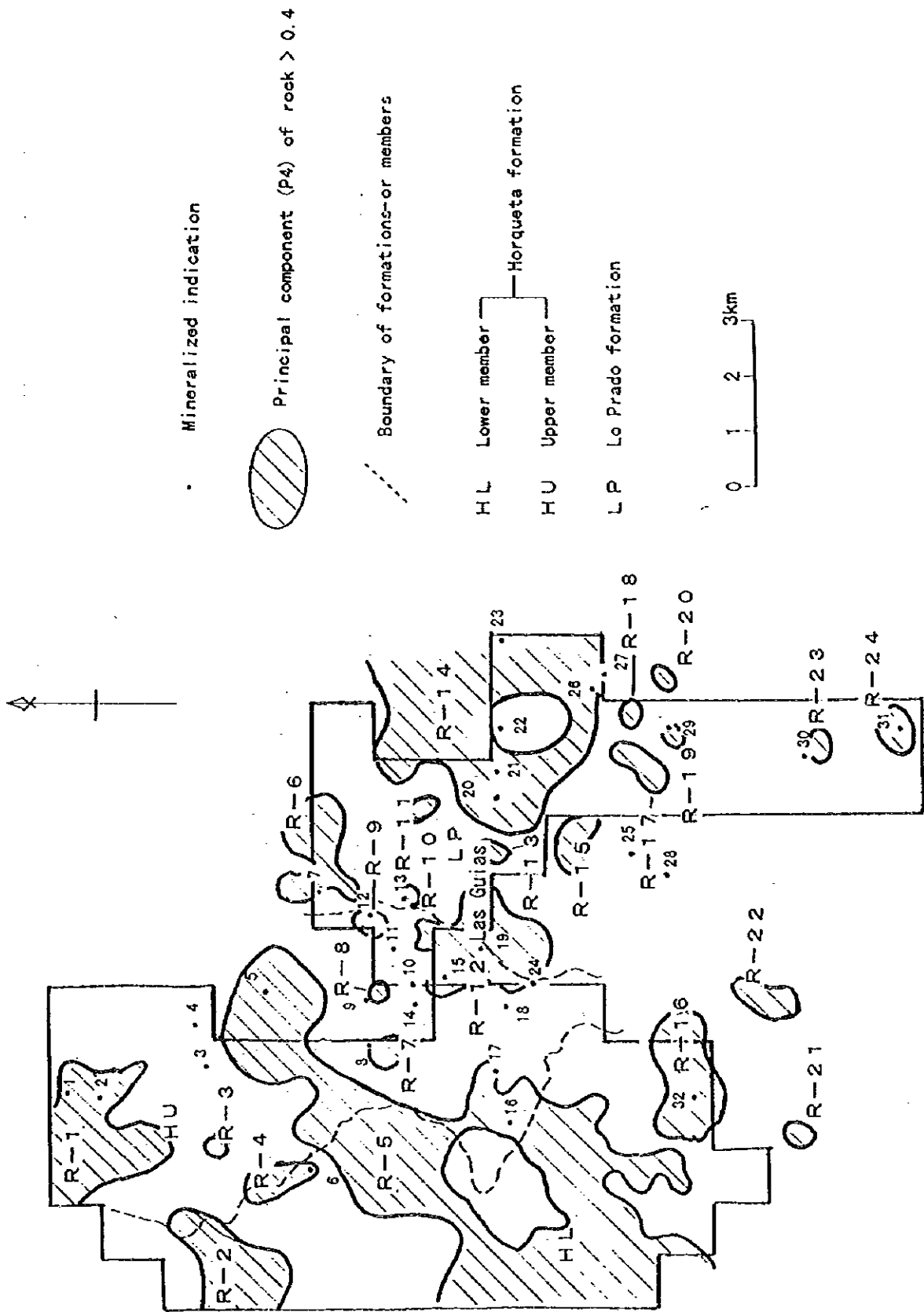


Fig. 2-2-7 Distribution map of principal component (rocks)

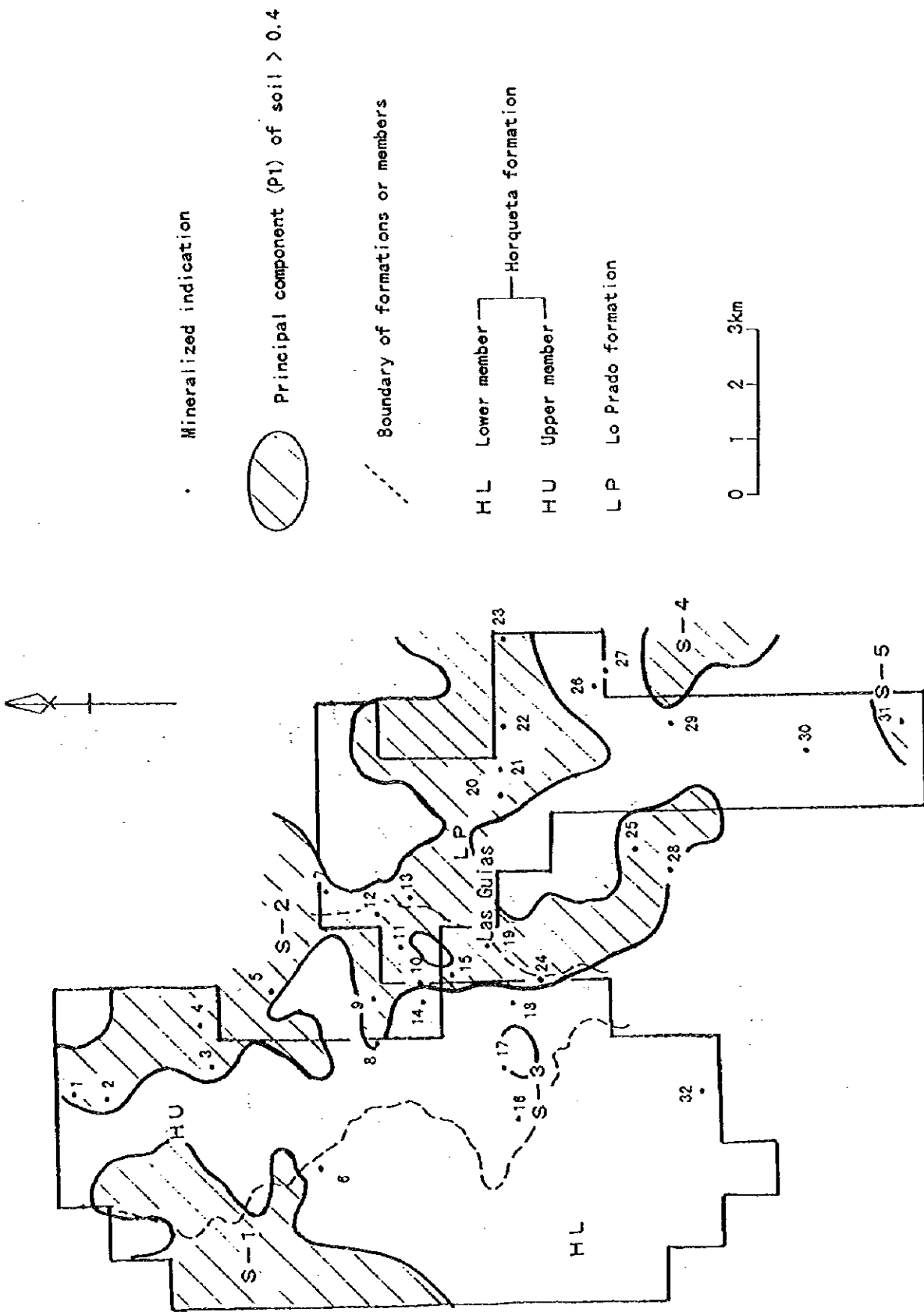


Fig. 2-2-8 Distribution map of principal component (soils)

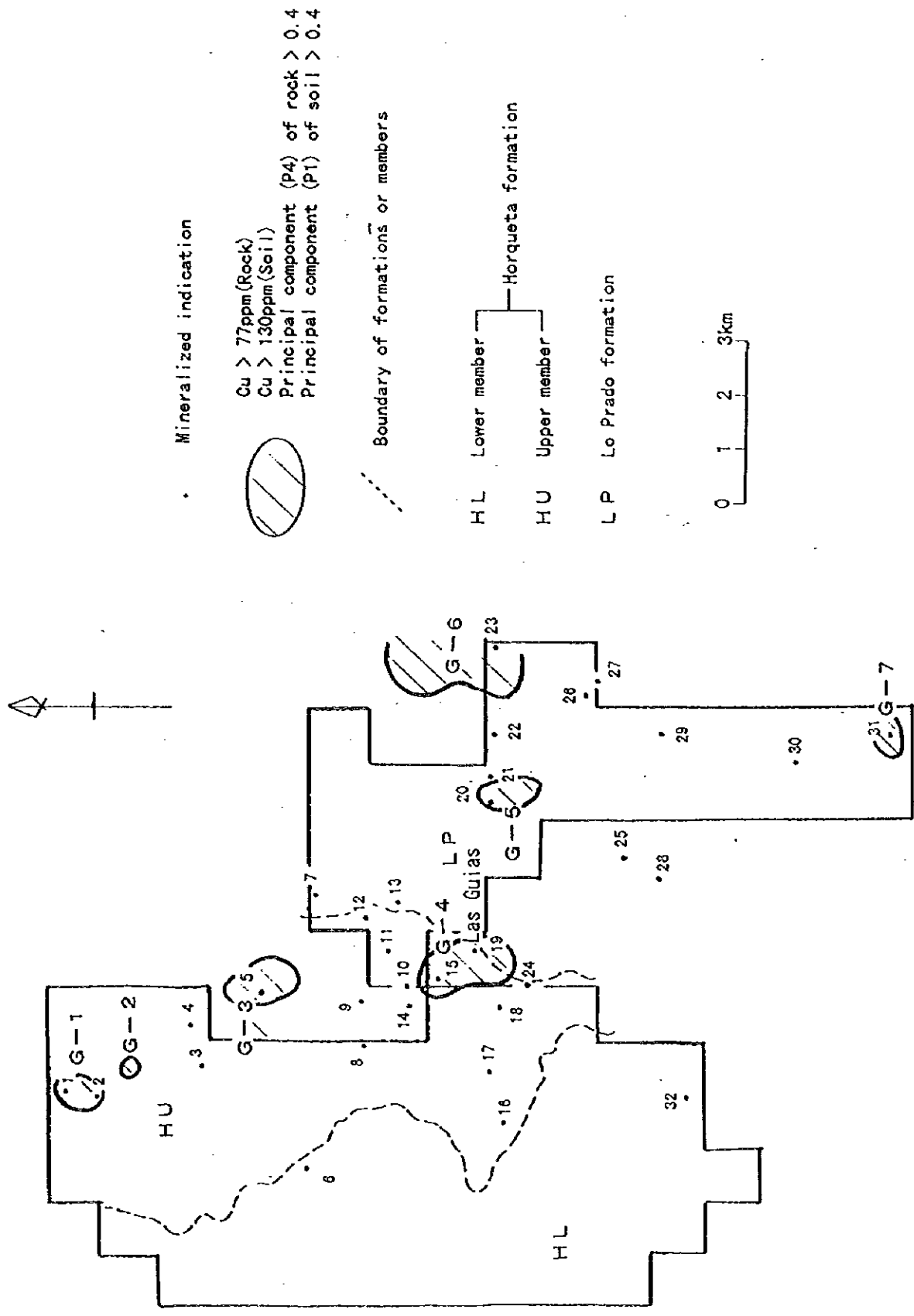


Fig. 2-2-9 Interpretation map of geochemical survey

(3) High marked zones for soil geochemistry

Five high marked zones have been detected in the soil geochemistry. Among them, S-2 covers about 75% of the total mineral occurrences, and well reflects those mineral occurrences. It can be said that the soil geochemistry map is a good prospecting map for copper in the area. Accordingly, the anomalies appeared in barren area will be described in the following.

* High marked zone S-1 is of large-scale and situated in the Lower Horqueta. No detail geological setting is known, therefore, it will be investigated together with other studies.

* High marked zones S-4 and S-5 are not reliable because of a few numbers of samples.

(4) Integrated interpretation

Some duplicative anomaly zones extracted from the above mentioned various categories have been extracted to select favorable prospecting targets. The appraisal for those targets is as follows.

* Anomaly zones G-1, G-2, G-3 can be unified to one. The anomaly zone is coincident to a high Au zone, and worth further prospecting. It is possible that the presumed mineral occurrence by the anomaly is associated with a dacite dome.

* Anomaly zone G-4 reflects the mineral occurrences in the Las Guias Mine, but the location of the anomaly is out of the mineral right area.

* Anomaly zone G-5 reflects a small-scale gold occurrence, but it is worth further prospecting.

* Anomaly zones G-6 and G-7 are not reliable because of a few numbers of samples.

In conclusion, the whole area, which contains many surface mineral occurrences and the Ocoita showing high content of Cu, forms itself an anomaly zone, and is a natural contamination zone. It could be, therefore, very difficult to utilize such geochemical survey methods for prospecting of buried mineral deposits. But, if there are some mineral occurrences like as same type and scale mineralization above mentioned, they should be recognized by the geochemical survey exploration method.

Chapter 3 Geophysical Survey

3-1 Purpose of the Survey and Methods Employed

Prior to the field survey, it was determined that areas of potential mineralization would be areas in which anomalously low resistivities and high chargeabilities were observed. The induced polarization (IP) method was first employed as an expedient method of shallow regional geoelectrical mapping to delineating these areas and subsequent transient electromagnetic (TEM) investigation of the anomalous areas was performed to provide additional detail and greater depth of penetration.

The topography of the survey area is rugged and the vegetation is dense with thorny trees prohibiting passage. Survey lines were therefore set along a relatively straight dirt road and through passable areas. In some parts of the survey lines are bent, Fig.2-3-1.

Rock samples were collected in the survey area and the electrical properties of the samples were measured. These results were correlated with field data to determine areas of potential mineralization.

Specifications of the survey and equipment used for the survey are as the following tables.

Table 2-3-1 Survey Specifications

	IP method	TEM method
Length of survey lines	20.3 km	20.3 km
Number of survey lines	10 lines,	10 lines
Method of measurement	time domain IP	loop-loop method
Electrode	dipole-dipole array	central loop and out loop
Electrode spacing Loop size	electrode spacing (a) : 50m	Tx loop size: 60m by 60m. survey station: center of a Tx loop and between 60m and 200m from a center of Tx loop.

Table 2-3-2 Time-domain IP survey equipment

Generator	Honda ET-4500, Max power: 4500 vA.
Transmitter	Chiba Electronics, CH-96T and 96PA, output max.: 900v, 15A
Receiver	Scintrex, IPR-12, 8 channel, input range: 50 μ v~14v.
Current Electrode	Buried copper net.
Potential Electrode	Porous-pot electrode. Cu-CuSO ₄

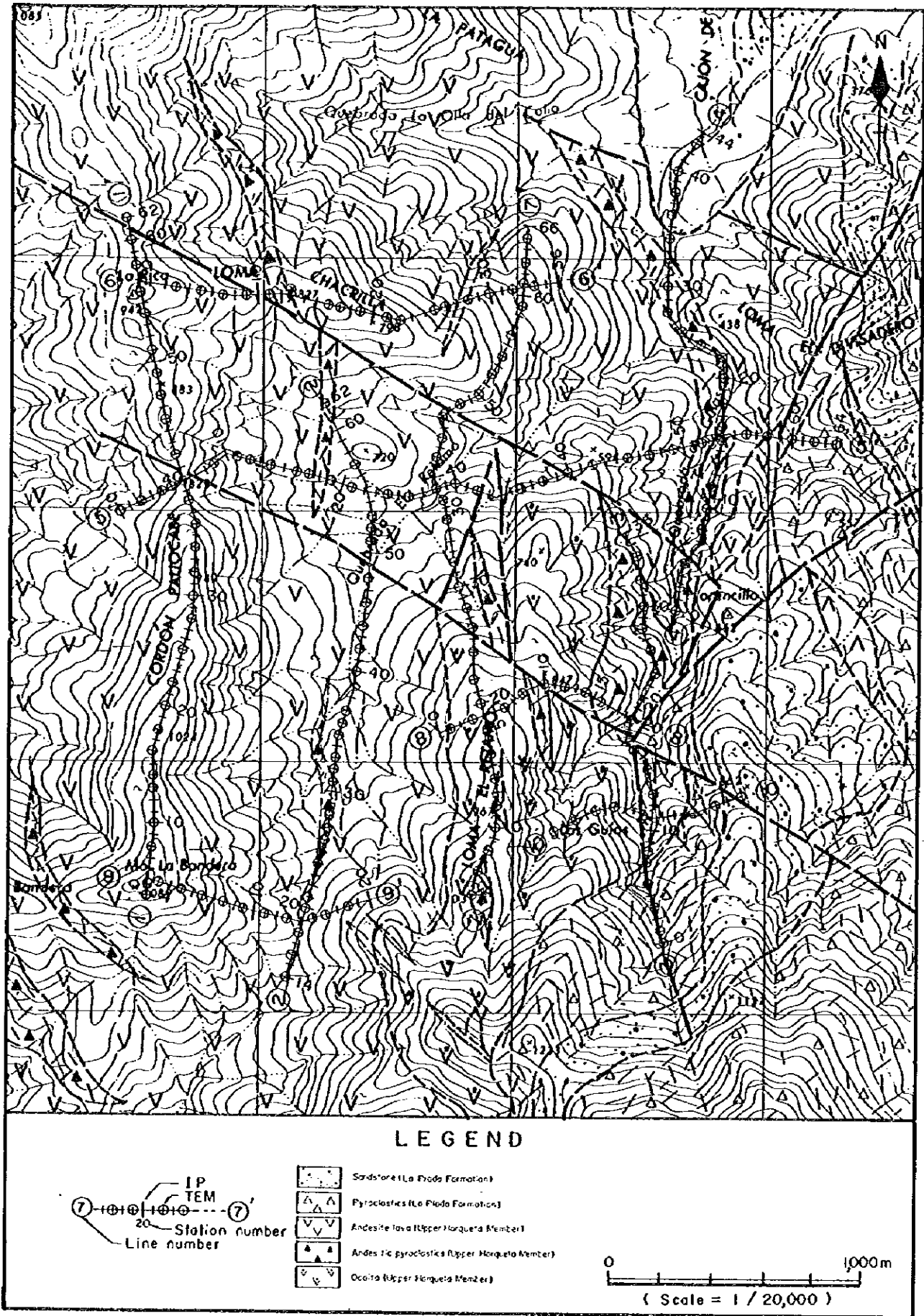


Fig.2-3-1 Location Map of the surveyed Lines and Geology

Table 2-3-3 TEM survey equipment

Transmitter	GEONICS EM57, Out-put: Max 20A., Frequency:25Hz(HI) & 2.5Hz(LO), Elapse time: 115 μ sec for a source loop of 8 turns and 5m x 5m, Quartz clock, 13 kg with a Generator power source.
Receiver	GEONICS PROTEM-D, Sampling: 86.7 μ sec to 7.03 m sec for HI & 867 μ sec to 70.3 m sec for LO. 20 channels, Battery power source.
Source loop	Generally, 100 m by 100m square and single turn changed due to topography and vegetation.
Receiver Coil	Air cored coil, moment: 200 m ² , Frequency:60kHz

3-2 Measurement of Physical Properties

(1) Rock test

Typical rock samples, samples of mineralized rock with malachite, and ore with bornite-calcocite samples were collected in the survey area. The resistivity and chargeability of the samples were later measured in laboratory tests.

2cm to 3cm cubes cut from the samples were immersed in water for a few days. The resistivity and chargeability of these samples were then measured by the time-domain IP method, as was done in the field.

A total of 40 samples were tested by this method.

(2) Time-Domain IP Survey

(i) Survey line and topographic survey

Electrodes are generally set along a straight line for dipole-dipole array. Topography of the survey area is rugged and vegetation is dense with thorny trees which prohibits us to pass through. Therefore we set survey lines along relatively straight dirt road and trespassable area. Some part of the survey lines are bent.

Topographic survey along survey lines are originated from some points standing-out on the 1:25,000 map with a chain and a pocket-compass.

Spacing between survey stations is 50 meters.

TEM measurement is carried out along the same lines and stations.

(ii) IP measurement

Induced polarization method, abbreviated as IP method, is to measure electrical polarization of rocks in the ground. There are two ways of measuring IP phenomenon, as time-domain and frequency-domain. If we

measure IP effect of extremely wide range of frequencies and long time range of transient potential decay, frequency-domain measurement and time-domain measurement are equivalent through Fourier transform. Economically it is not feasible to measure IP phenomenon in very wide range of frequencies. Recently, advancement of computer technology made time domain measurement, which contains more information, more popular. This survey used time domain measurement.

One of major noise source of IP measurement is electromagnetic coupling between cables connecting current electrodes and connecting potential electrodes. This survey used dipole-dipole electrode configuration which gives smallest electromagnetic coupling between cables.

Apparent resistivity of dipole-dipole configuration can be calculated by the following formula where electrodes are set along a straight survey line.

$$\rho_a = n(n+1)(n+2)\pi a \frac{V}{I}$$

where π : the ratio of the circumference of a circle to its diameter
3.14159....

V: measured potential difference (volt)

I: current (ampere).

a: electrode spacing (m)

n: electrode separation index.

Because survey lines are not straight for this survey, apparent resistivity for interpretation is calculated by the following equation by using real geometric distribution of electrodes.

$$\rho_a = 2\pi \left[\frac{1}{C_1 P_1} - \frac{1}{C_1 P_2} - \frac{1}{C_2 P_1} + \frac{1}{C_2 P_2} \right]^{-1} \frac{V}{I}$$

where C_1, C_2 : positions of current electrodes

P_1, P_2 : positions of potential electrodes

V: measured potential difference (volt)

I: current (ampere).

IP effect is measured in time domain. Square wave current is made to flow through current electrodes and change of potential difference between

potential electrodes is measured. Potential difference abruptly change to very small after termination signal current flow, then gradually decays to zero. Chargeability is defined as a ratio of potential difference with signal current flow (V_p) and potential difference at some time after signal current being turned off (V_{av}). Chargeability is an index showing IP effect of a ground. Actually potential difference at some time after signal current being turned off, V_{av} , is defined as an average of potential decay curve over a few hundreds of second as the following equation.

$$V_{av} = \frac{\int_{t_1}^{t_2} V_p(t) dt}{(t_2 - t_1)}$$

For this survey, we measured potential difference decay between 450 m sec and 1770 m sec after termination of current flow

(3) TEM Survey

Frequency-domain electromagnetic method, on which frequency of source electromagnetic field is selected for different depth of survey target, has been widely used. Benefiting from recent development of electronics and computer science, time-domain electromagnetic method, also known as transient electromagnetic method, comes in widely used. TEM (Transient Electromagnetic also known as TDEM, Time-domain Electromagnetic) method measures transient magnetic field by a coil sensor on the ground surface, after source DC electric current in a source loop on the ground surface is abruptly turned off. A transient electromagnetic field is created by eddy current induced in the ground by abrupt removal of magnetic field in the atmosphere. The measured transient magnetic field is converted to resistivity distribution in the earth.

On TEM method, a transient electromagnetic signal is measured after a source current is turned off. Because electromagnetic field is measured only after source current is removed, measurement is carried out in an environment without primary electromagnetic field, which does not contain any information of underground geoelectrical structure and is a noise signal for geophysical survey. Therefore depth of survey can be independent from geometrical factors of measurement, like a radius of a source loop and distance between a source loop and a receiving coil. Many kinds of TEM equipment for different purposes are marketed, and are widely used for exploration of minerals and underground water.

Major advantages of TEM method are as follows.

● Because measurement can be carried out by a sensor coil put on the ground surface, resistivity distribution can easily surveyed in a area where electrode grounding is difficult, like desert and areas covered with outcropping hard rocks, permafrost layer.

● TEM method is more sensitive to underground resistivity changes than DC resistivity method and frequency-domain electromagnetic method, like CSAMT.

● TEM measurement is not influenced by near surface resistivity change and topography so much as DC resistivity measurement or CSAMT measurement. TEM method is free from static shift problem which makes DC resistivity survey, CSAMT survey and MT survey very difficult to interpret as underground geoelectrical structure.

● Portable battery-operated TEM equipment in a market made TEM survey easy in areas without easy access.

● Many kinds of interpretation programs for TEM data, are available. They are a layered earth inversion program, Occam's inversion program a plate program and a three-and-two dimension program.

Before the survey started, survey parameters are tested. Size of a source loop are decided to be a 60 meters square. During the survey, size and shape of a loop are changed to fit surrounding topography.

Transient electromagnetic field is measured at a center of a source loop and one-and-half to three times of a source loop diameter away from a center of a source loop.

Measurement is carried out as follows

● Source current is about 10 amperes with frequency of 25 Hz and a square wave form.

● When a receiving station is near to a source loop, a receiver is connected to a transmitter by a cable for synchronization. For a receiving station being some distance away from a source loop, synchronization between a transmitter and a receiver is obtained by quartz oscillators.

● At a receiving station, vertical component of magnetic field is measured by an air-core coil. Transient magnetic field is measured at equally spaced twenty gates between 86.7 micro seconds and 7.03 milli seconds. Transient signal is continuously stacked at least 60 seconds, equivalent to 3000 stacks, at each station. A survey result

is displayed at a survey site as a magnetic field decay curve. If a decay curve is contaminated by noise, measurement is repeated.

● Results are stored in a receiver and transferred to a personal computer via a RS232 cable at a camp site.

3-3 Data calculation method

(1) IP Survey

Plot the observed data at resistivity and chargeability to pseudosection and distribution (Fig.2-3-2(1)~Fig.2-3-5(5)). Apparent resistivity is considered to horizontal difference and calculated by aforementioned formula.

After that 2D-inverted to chargeability and resistivity each survey line. The computer program used for inversion is RESIXIP2D by Interpex, Golden CO, USA.

(2) TEM Survey

Measured transient voltage is converted to a time rate of magnetic field change (dB/dt).

$$\frac{dB}{dt} = \frac{V_0 \cdot 19200}{E \cdot 2^n}$$

where E (m^2): a moment of a receiving coil

and n : a gain of an amplifier

A time rate of magnetic field change is converted to an apparent resistivity by the following equation. The following equation convert magnetic field at later time of transient curve to a resistivity value approximated to subsurface structure and is called as a late-time apparent resistivity formula.

$$\rho_a = \frac{\mu_0 \cdot 0.4 \cdot T_{xm} \cdot \dot{u}^2}{4 \cdot t \cdot \dot{e}_1 \cdot \frac{dB}{dt} \cdot \dot{u}}$$

where μ_0 : magnetic permeability of free space

t : time after a source current is turned off

T_{im} : a moment of a source loop (a product of a loop area and a source current.)

Apparent resistivity values obtained by the aforementioned equation are inverted to an horizontally layered earth. The computer program used for inversion is TEMIX-XL by Interpex, Golden CO, USA.

The inversion program assumes horizontally layered earth and requires initial earth model. Responded magnetic field is calculated by a computer as if TEM measurement is carried out over the initial model. The calculated results are compared with real measurement. An initial earth model is modified to make difference of real measurement and calculated results minimum. The earth model with the minimum difference is most suitable earth model for the measurement.

3-4 Results

(1) Geoelectrical properties of rock samples

The geoelectrical properties of the rock samples, as determined from laboratory tests, are summary of below. Complete results for each of the samples are included in the A-3.

Table 2-3-4 Summary of geoelectrical properties of rock samples

rock name (number)	resistivity (Ω m)	chargeability (mv/v)
andesite (16)	1210 to 8850	0 to 1
Ocoita (16)	1320 to 4980	1
Ocoita (ore) (8)	19 to 1930	0 to 57

Andesite and barren Ocoita formation samples had mean resistivities of 4390 Ω m and 4100 Ω m, respectively and low chargeability. Ocoita samples bearing bornite-chalcocite, however, had a mean resistivity of 54 Ω m and a mean chargeability of 45mv/v. It is obvious that the geoelectrical properties of ocoita bearing bornite-chalcocite is significantly different from other rocks in the survey area. Therefore, it is possible to find a shallow bornite-chalcocite type deposit in the of Ocoita formation by geoelectrical surveying.

(2) IP method

Chargeability pseudosections and maps are presented in Fig.2-3-2(1) through 2-3-3(5). Apparent resistivity pseudosections and maps are presented in Fig.2-3-4(1) through 2-3-5(5). While chargeability values are

generally low in the survey area (2 to 4 mv/v), there are zones of high chargeability (over 10 mv/v). Apparent resistivities in this area generally ranged from 500 to 1000 Ω m, with small anomalously conductive and resistive zones.

In the following discussion of the results, resistivity values shall be classified as follows:

under 600 Ω m	Conductive (layer)
600 to 2000 Ω m	Medium resistivity (layer)
over 2000 Ω m	Resistive (layer)

This classification will be employed in discussion of the TEM results as well.

Two dimensional forward modeling results for each of the survey lines are given in Fig.2-3-6(1) through (10). From this analysis the shallow resistivity structure has been determined and the presence of some highly chargeable bodies (over 10 mv/v) have been detected. The shallow resistivity structure consists of three layers. There is a conductive layer (300 Ω m) at the surface, underlain by a less conductive layer (600 Ω m) with a layer of medium resistivity (1500 Ω m) at depth. The depth of the boundary between the secondary conductive layer and the deep resistive layer is 100 to 200m beneath surface.

The location and electrical properties of the anomalous bodies are given in the following table;

Table 2-3-5 Summary of IP anomaly body

Location			property	
line number	point number	depth	charge-ability (mv/v)	resistivity (Ω m)
1	43 to 47	near surface to -50 m	15	600
2	20 to 29	near surface to -150 m	15	300 to 600
2	32 to 40	near surface to -150 m	15	300 to 600
2	56 to 60	-50 to -150m	15	300 to 600
3	9 to 10	near surface to -100 m	20	300 to 1500

4	6 to 20	near surface to -100 m	15	600
5	16	near surface to -50 m	15	300
5	28 to 33	near surface to -100 m	15	300
5	29	under surface to -100 m	30	300
5	51 to 55	-50 to -150 m	15	200
5	60 to 63	near surface to -150 m	15	5000
6	20 to 22	near surface to -150 m	30	600 to 1500
7	8 to 16	near surface to -200 m	10	1000
7	39 to 50	near surface to -200 m	15	300
7	40	near surface to -200 m	30	300
8	5 to 10	near surface to -200 m	15	300
9	13 to 15	near surface to -100 m	20	300

Most of the stored energy involved with IP is chemical, involving variations in the mobility of ions (or the normal IP effect) and variations caused by a change from ionic to electronic conduction where metallic minerals are present (interfacial polarization); the latter is usually the larger effect. The first of these phenomenon is commonly caused by clay minerals, while the latter is caused by metallic mineralization of rock.

Some of the IP anomalies detected in the survey area are located near andesite dikes or pyroclastic rock which is not argillized. These may indicate the presence of sulfides or other metallic minerals rather than clay minerals.

The chargeability of bodies within the Ocoita zone, however, are 10 to 30 mv/v less than the average chargeability of rock samples taken from Las Guias mine (45mv/v). This means that the potential ore grade of these bodies is lower than that of ore from the Las Guias mine.

The deep resistivity structure of the survey area cannot be determined from the IP measurements due to limitations of this prospecting method.

S

N

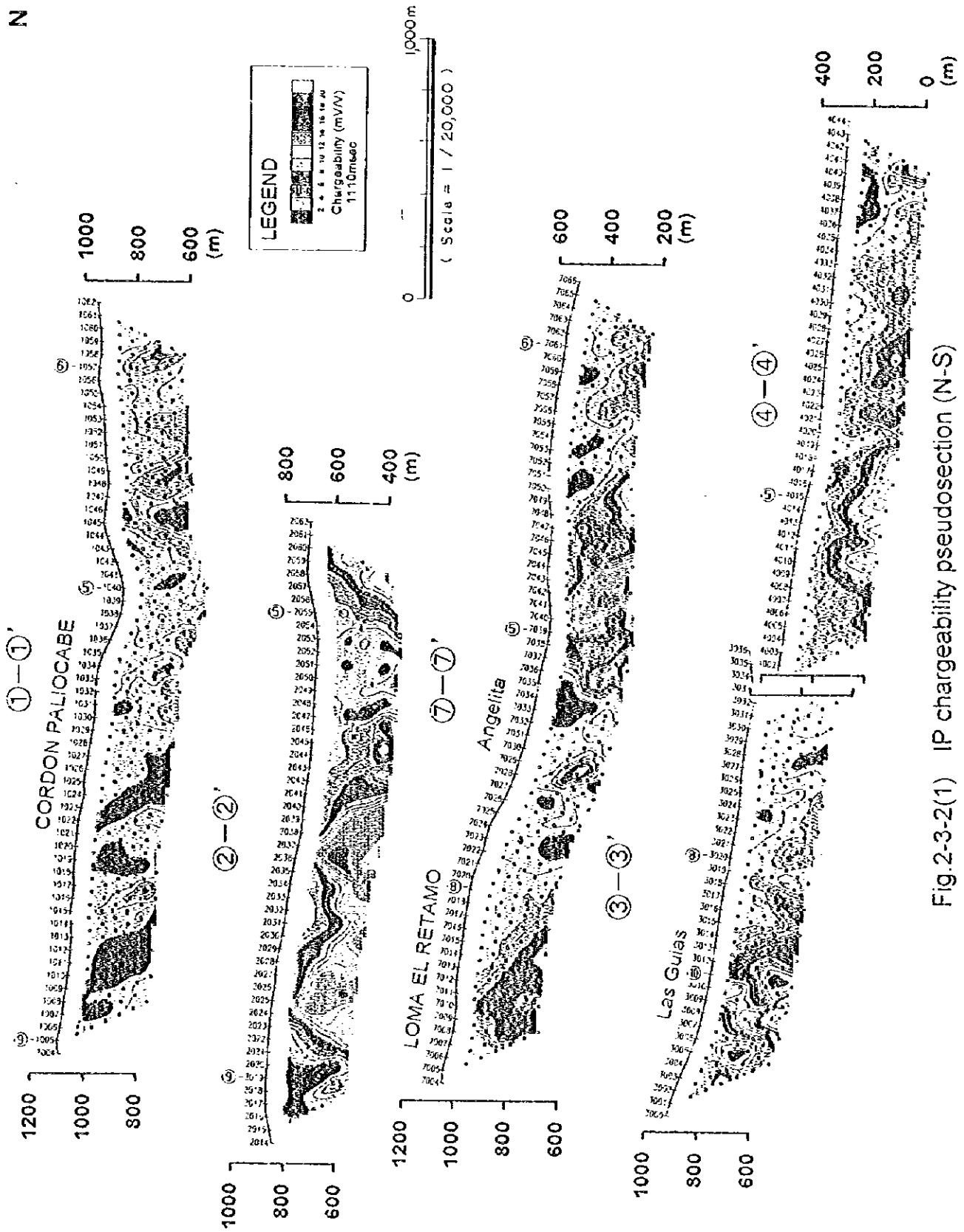


Fig.2-3-2(1) IP chargeability pseudosection (N-S)

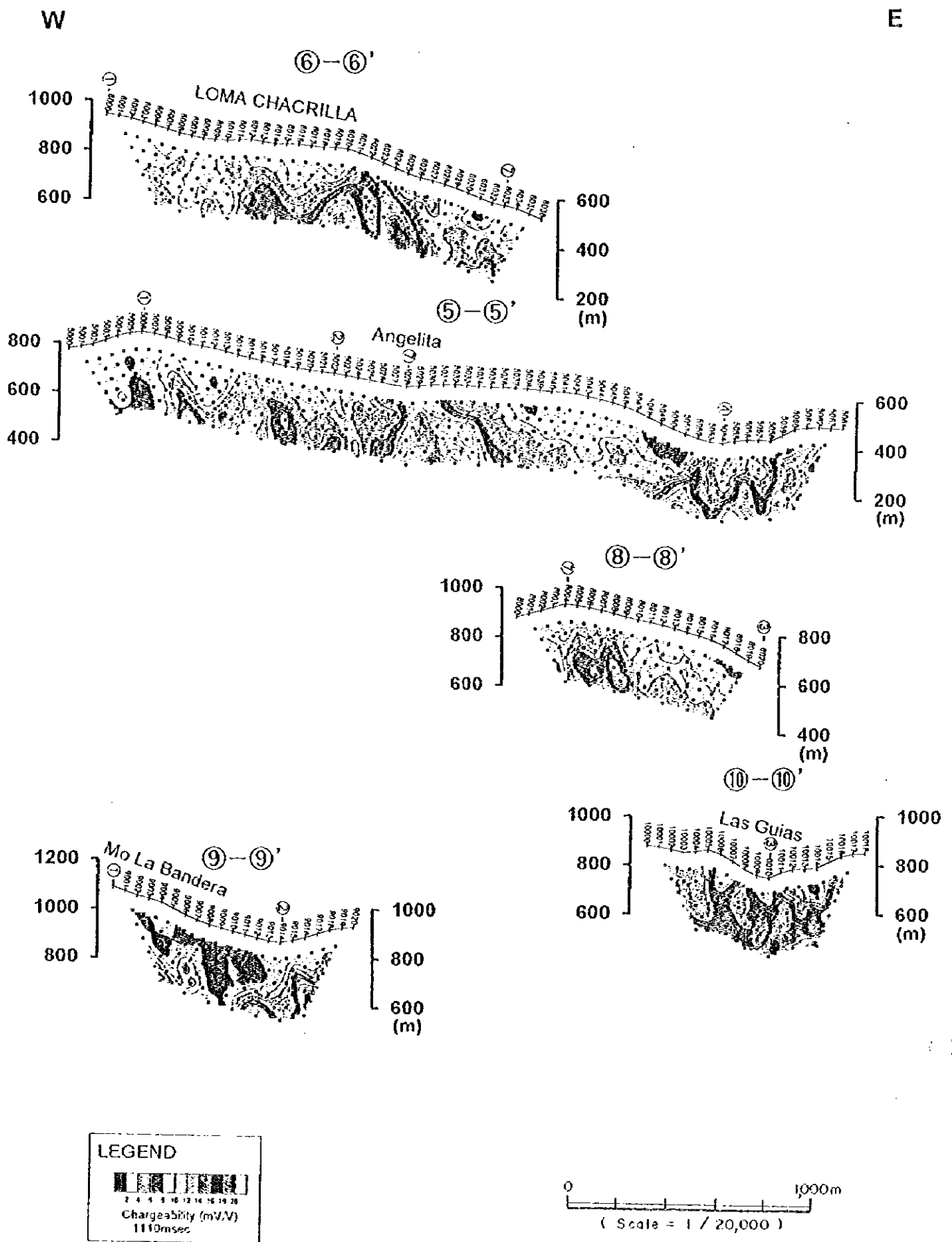


Fig.2-3-2(2) IP chargeability pseudosection (E-W)