PART II
GEOCHEMICAL SURVEY

1. GENERAL REMARKS

Geochemical reconnaissance survey for stream sediments is one of the most effective prospecting methods to delineate promising area for mineral resources from a wide unsurveyed area, particularly in case of ore deposits with widely extended mineralized zones, like porphyry copper type. This conception is sufficiently supported by the experiences obtained from the Eastern Mindanao and the Northeastern Luzon Projects. Based on these experiences, geochemical stream sediments survey was adopted for the first phase as one of the high priority task in the Northwestern Luzon Project.

The geochemical survey in Phase I was carried out jointly with the geological survey in an area of 4,300km^2, and 1,067 stream sediment samples were collected from most branches of main rivers which were previously selected as the geological and geochemical survey routes covering the same area as equally as possible. Cu and Zn were selected as the indicator elements because the most promising ore deposit in this survey area is a porphyry copper type. Consequently all collected samples were analyzed quantitatively for Cu and Zn by the atomic absorption method.

As a result of this survey, 10 geochemical anomalous zones were detected in the survey area as shown in Table II-1 and Fig. II-3.

In addition, 50 soil samples were taken along the National

Road, Route 6, in this phase as reference for geochemical soil survey which will be conducted in Phase II and/or III. These samples were also analyzed quantitatively for Cu and Zn by the same method.

The details of the geochemical survey results will be described hereafter.

Table II - 1 Summary of Geochemical Survey Results

Name of Anomalous Zone	Area (km^2)	Cu			Zn			Nature of Anomaly	Geology	Mineralized Zone
		Number of Anomalous Points		Maximum	Number of Anomalous Points		Maximum			
		more than t'	more than t	Value (ppm)	more than t	more than t"	Value (ppm)			
Solsona River	42	8	1	239	1	1	99	Cu	Gabbro	Solsona mineralized zone
Palsuguan River	100	18	3	194	14	6	311	Cu-Zn	Mainly Licuan Group F.II , Tineg F., gabbro and quartz diorite	Palsuguan mineralized zone Hercles Mineral prospecting area may be located in this zone.
Malanas River	44	4	0	99	8	1	219	Cu-Zn	Licuan Group F.II , and Tineg F. in western part	A part of Lacub mineralized zone
Bucloc River	192	20	4	157	1	0	129	Cu	Quartz diorite	Bucloc, Ikmin and a part of Boliney mineralized zones Binulawan Mining Association area is located in this zone.
Upstream of Bucloc River	25	3	0	106	4	1	565	Cu-Zn	Licuan Group F.II and quartz diorite	Local pyrite dissemination only
Layacan River	89	5	3	1066	9	3	944	Cu-Zn	Tineg F. and Licuan Group F.I	Layacan and Eastern Layacan mineralized zone
Balilian River	56	4	1	153	8	3	332	Cu-Zn	Tineg F., Licuan I and Q-dio in southern end	Only local pyritization in Tineg For.
Binuan River	27	7	0	104	1	1	246	Cu	Licuan Group F.II and granodiorite	Lenneng mineralized zone
Upstream of Tineg River	11	4	3	368	3	1	218	Cu-Zn	Mainly quartz diorite and Licuan Group F.II	Eastern Tineg mineralized zone
Upstream of Binongan River	60	4	3	292	6	4	510	Cu-Zn	Licuan Group F.II and quartz diorite	Dora mineralized zone is located in western margin of this zone.

2. SAMPLING AND ANALYSES

2-1 Sampling

In principle, silty sediments (under 80-mesh fraction) deposited in the active channels of streams were collected as geochemical samples. Numerous tributaries of the main rivers which were previously chosen as the geological and geochemical survey routes were sampled instead of the main stream in order to get much and better information from a more wider area.

In the selection of sampling site, the survey routes and the sampling intervals were considered very carefully so that it would cover the whole area as equally as possible.

About 10 to 20 grams of sediments per sample were collected by direct sieving under the water. Care was taken to avoid contamination of the sample with organic materials and bank sediments to minimize sampling errors.

The samples collected from each site were placed in vinyle bags for delivery to the base camp, and after drying, each sample was divided into two packs, one for the Bureau of Mines, Philippines, and the other for chemical analyses in Japan.

2-2 Analyses

All collected samples were analyzed quantitatively for Cu and Zn in Japan by the atomic absorption method. The analytical procedure is mentioned as follows.

1 gram of sample was taken and digested with 5ml of concentrated HNO_3 and 3ml of $HClO_4$ in a sandbath until white vapor appeared. After cooling, dissolution was accomplished by addition of 5ml of HNO_3 (1:2). The solution was made up to exactly 20ml by adding distilled water. The sample solution is filtered and the filtrate was analyzed by the atomic-absorption spectrophotometry using a wavelengths of 3247 Å for Cu and 2139 Å for Zn.

3. COMPILATION AND INTERPRETATION OF RESULTS

3-1 Compilation of Analytical Results

The analytical data of 1067 stream sediments collected in the survey area were treated to delineate the geochemical anomalous zones by adopting the simplified statistical treatment method of LEPELTIER (1964).

Based on the geology of sampling sites, all data were divided into five geological units, namely the Licuan Group, Tineg Formation, Mabaca Formation, Alava Formation and plutonic rocks. However, the number of samples in the Mabaca (23 samples) and Alava (20 samples) formations are not sufficient for the above-mentioned method, hence the three units, the Licuan Group, Tineg Formation and plutonic rocks were individually treated statistically for Cu and Zn.

Fig. II-1 shows the cumulative frequency distributions of Cu and Zn in each geological unit. From this graph, the mean background values (b) of Cu and Zn are obtained from abscissa of 50% -probability. The threshold or upper limit of normal background values of Cu and Zn are shown respectively as abscissas of 2.5% -probability and as abscissas of winding points in each geological unit.

The mean background and threshold values of Cu and Zn in the three units are shown in Table II-2.

Table II - 2 Mean Background and Threshold Values of Each Geological Unit

Geological unit	Mean background value(b)		Threshold value(t)		Number of samples
	Cu	Zn	Cu	Zn	
Licuan Group	38ppm	73ppm	112ppm	120ppm	317pcs
Tineg Formation	33	86	122	120	155
Plutonic Rocks	29	45	130	120	552

According to the above table, it is obvious that there are no variations in mean background values of Cu and threshold values of Cu and Zn for the different geological units although small differences are recognized in mean background values of Zn. Consequently all data were collectively analyzed without dividing into the three geological units.

Cumulative frequency distributions of Cu and Zn in total data are shown in Fig.II-2. Regional mean background and threshold values can be obtained from this graph in the same way as in Fig. II-1. The general trend of geochemical anomalies becomes complicated when the anomalies are isolated, therefore the value, t' cooresponding to abscissas of 2.5%-probability for Cu and t'' of 7.5%-probability for Zn were used as subsidiary threshold values to make up the distribution map of geochemical anomalies. The values of 2t and 2t'' are also represented to give an impression of very high values on the same map.

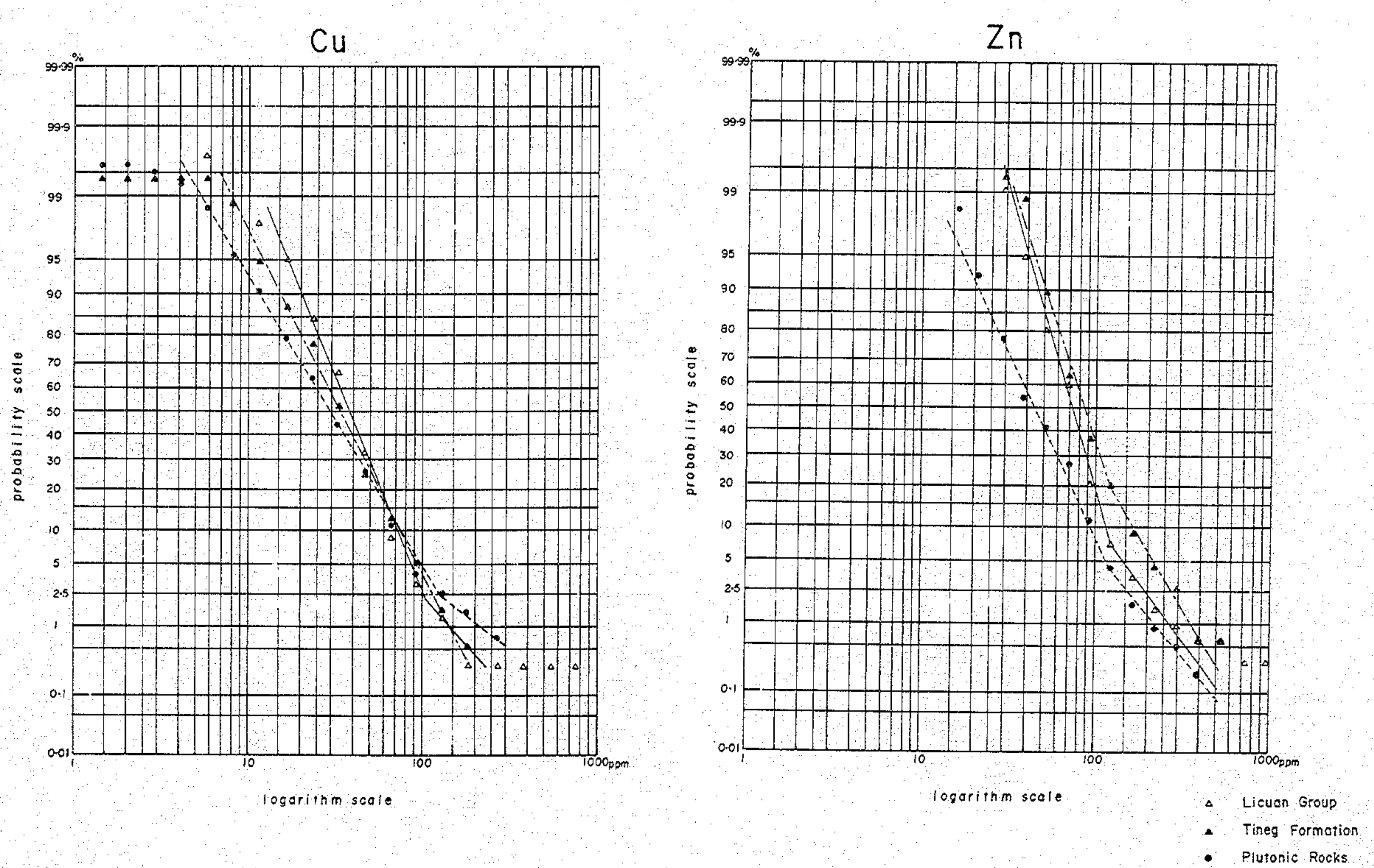


Fig. II - 1 Cumulative Frequency Distribution of Cu and Zn in Each Geological Unit

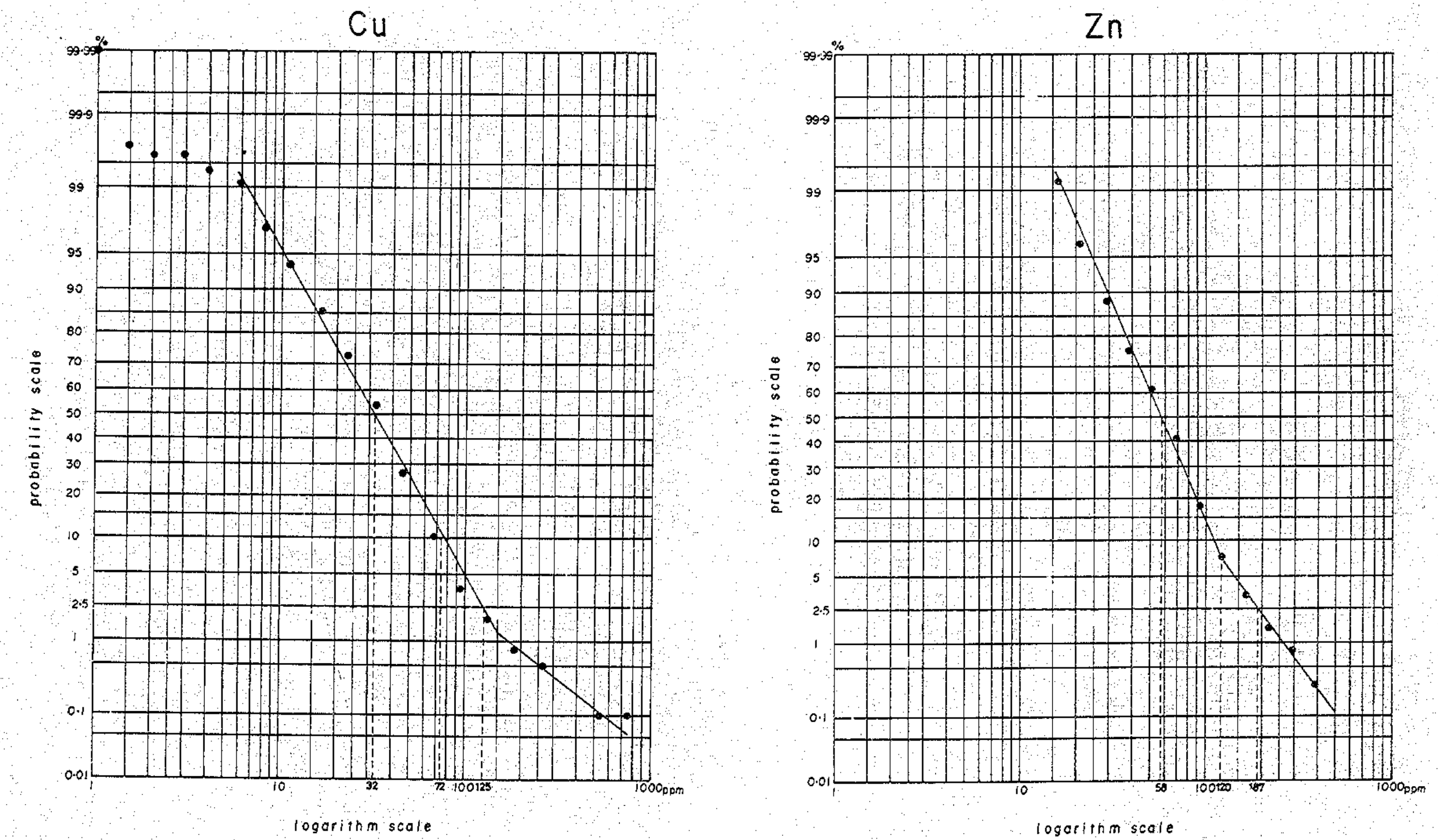


Fig. II - 2 Cumulative Frequency Distribution of Cu and Zn in Whole Area

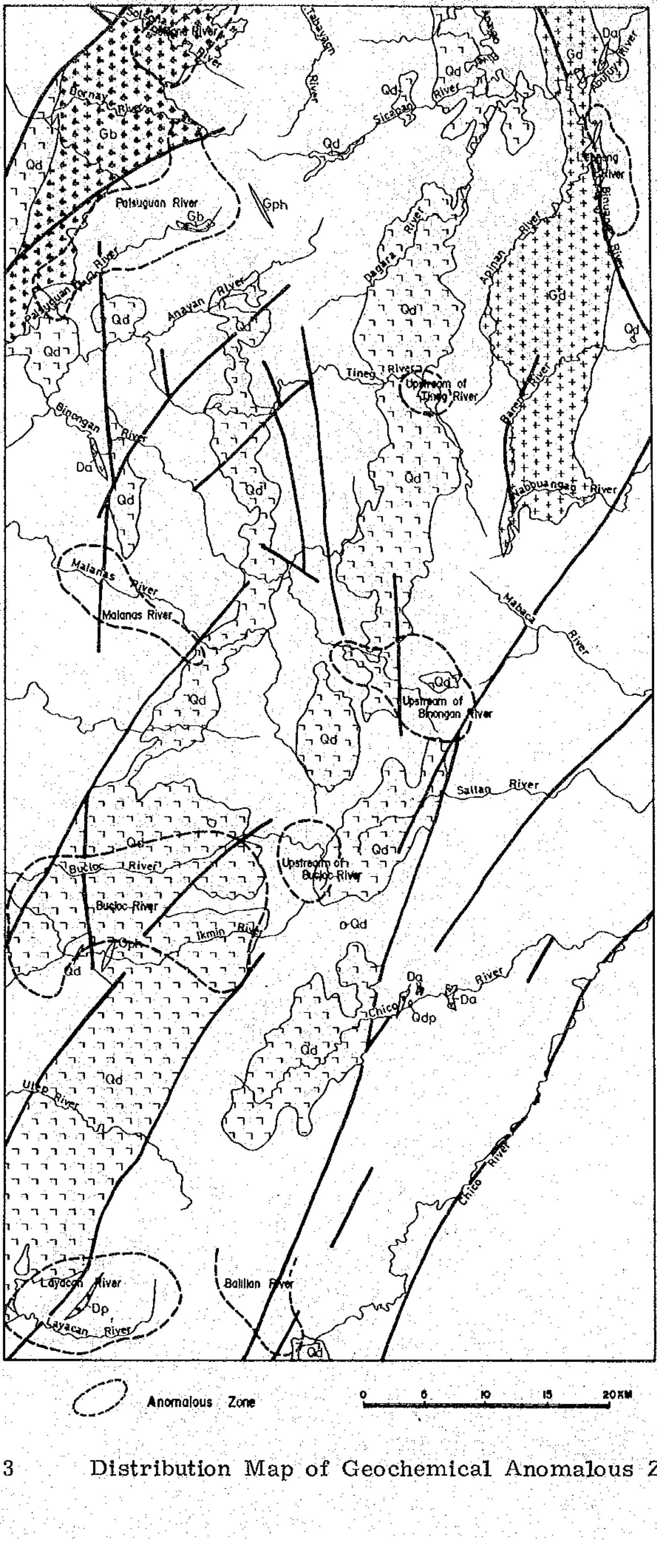


Fig. II - 3 Distribution Map of Geochemical Anomalous Zones

The regional mean background, threshold and subsidiary threshold values are shown in Table II-3.

Table II - 3 Regional Mean Background and Threshold Values in Whole Area

	b	t'	t	t''	2t	2t''	Number of samples
Cu	32ppm	72ppm	125ppm	ppm	250ppm	ppm	pcs 1,067
Zn	58		120	187		374	

b : Mean background value
t : Threshold value
t', t'' : Subsidiary threshold values

Generally the various representation methods had been used to draw the geochemical anomalies on the map. Here the anomaly was drawn with an area of sampled river basin patterned with the combination of the kind of indicator elements, and the intensity of anomaly based on the idea that the metal contents of stream sediments at the sampling site are influenced by sediments flowed from the whole of its basin. In this case, it can be deduced that the geochemical anomaly obtained from certain sample lies within the basin including its sampling site. Therefore the pattered anomalous zone has an advantage of showing directly the area that should be surveyed in next phase. On the contrary, overestimating the anomalous zone is avoided because evaluation it by one sample is considered parallel to the evaluation of basin without considering its scale. During the estimation of the anomalies, the relation between its intensity and the scale of the basins should be carefully considered.

3-2 Distribution of Geochemical Anomalous Zones

Many geochemical anomalies were obtained from the results of the statistical treatment of the analytical data. In this report, "anomalous value" was defined as the value higher than the subsidiary threshold value t' (72ppm Cu) and the threshold value t (120 ppm Zn).

The distribution of geochemical anomalies is shown in PLII-1. From this map, ten zones consisting of many anomalies closely distributed and/or some anomalies with high values were selected as the principal anomalous zones in the area.

1) Solsona River anomalous zone

This anomalous zone is situated in the middle to upper streams of the Solsona River. The zone is composed mainly of Cu anomalies which are not so intense but closely distributed. The maximum values are 239ppm Cu and 99ppm Zn. The zone overlies the area where gabbro is distributed. A chalcopyrite-pyrite-quartz vein (15cm in width, Cu: 19.90%) forming a portion of the aforementioned Solsona mineralized zone, was also observed in this anomalous zone along the Solsona River.

2) Palsuguan River anomalous zone

This anomalous zone is one of the main anomalous zones in the area, widely distributed in the middle to upper part of the Palsuguan River. The zone is composed of Cu and Zn anomalies which are not so intense, but closely distributed. The maximum values are 194ppm Cu and 311ppm Zn. In the eastern part of this zone, andesite lava of Licuan Group and lapilli tuff of Tineg Formation are mainly distributed, while in the western part, quartz diorite and gabbro are exposed. Pyrite-dissemination, silicification and epidotization are recognized in various places along the main stream of the Palsuguan River. A small amount of disseminated chalcopyrite is observed in the quartz diorite.

3) Malanas River anomalous zone

This anomalous zone is situated in the middle to lower part of the Malanas River, and composed of Cu and Zn anomalies. The maximum values are 99ppm Cu and 219ppm Zn. In the main part of the zone, andesitic rocks of the Licuan Group are extensively distributed, and small amounts of pyroclastic rocks of the Tineg Formation and quartz diorite also occurred in the western and eastern margin of this area. Although remarkable mineralization is not observed in the main part of the zone, a small amount of pyrite dissemination forming a part of the aforementioned Lacub mineralized zone was recognized in the east end of the zone.

4) Bucloc River anomalous zone

This anomalous zone extends over the basins of the Bucloc and Ikmin rivers. The zone is composed mainly of many Cu anomalies which are not so intense and not so closely distributed. The maximum values in the zone are 157ppm Cu and 129ppm Zn. The zone is mainly located in quartz diorite mass. In the central part of the zone, both Bucloc and Boliney mineralized zones mentioned before are localized consisting mainly of disseminated pyrite and chalcopyrite. In the western part, on the other hand, the Ikmin mineralized zone consisting mainly of disseminated pyrite and pyrite-quartz veins are confirmed. In the Binulawan Mining Association claim located in the Boliney mineralized zone, geochemical samples could not be collected due to the firm resistance of the owner.

5) The upper stream of the Bucloc River anomalous zone

This anomalous zone is situated in the upper stream of the Bucloc River. It is marked by intense Zn anomalies in contrast to the above-mentioned Bucloc River anomalous zone. The maximum values are 106ppm Cu and 565ppm Zn. In the zone, andesite lava and its pyroclasitic rocks of the Licuan Group are widely scattered, and in the east end of the zone, quartz diorite is distributed. A remarkable mineralization is not observed in the zone, with the exception of a small amount of disseminated pyrite in andesite lava.

6) The Layacan River anomalous zone

This anomalous zone is situated in the middle to upper part of the Layacan River. The zone is composed of Cu and Zn anomalies accompanied by very high values, but distributed sporadically. The maximum values in the zone are 1,066ppm Cu and 944ppm Zn. Both values are the highest one in the survey area. In the zone, basalt lava and pyroclastic rocks of the Licuan Group and dacitic pyroclastic rocks of the Tineg Formation are acknowledged. In the western half of this zone, the Layacan mineralized zone which consists of chalcopyrite-bornite vein (20cm in width, Cu 32.76%) and pyrite dissemination along cracks in basalt lava, and pyrite dissemination around diorite porhyry dike was distinguished. In the eastern part of the zone, a remarkable mineralization is not observed.

7) The Balilian River anomalous zone

This anomalous zone is situated in the lower reaches of the Balilian River, a branch of the Chico River. The zone is composed of Cu and Zn anomalies which are not so intense, but closely distributed. The maximum values are 153ppm Cu and 332ppm Zn. In the zone, basalt lava of the Licuan Group Formation I and pyroclastic rocks of the Tineg Formation are localized. A remarkable mineralization as well as partial silicification and pyritization in the Tineg Formation were observed.

8) The Lenneng River anomalous zone

This anomalous zone is situated along the eastern side of the Lenneng River from Barrio Lenneng to Barrio Badbad. The zone is composed of Cu and Zn anomalies. The maximum values are 164ppm Cu and 246ppm Zn. The zone is composed of granodiorite and pyroclastic rocks of the Licuan Group Formation II. Pyrite dissemination accompanied by a small amount of chalcopyrite is partly observed in quartz diorite porphry dikes intruding the granodiorite in the northern part of this zone. A small amount of malachite stain accompanying with pyrite dissemination is also partly observed in the granodiorite near the Barrio Lenneng.

9) The upper stream of the Tineg River anomalous zone

This anomalous zone is situated in an area of approximately 11km^2 in the upper most part of the Tineg River, west side of Mt. Sandig. The zone is composed of a few but relatively intense anomalies of Cu and Zn. The maximum values are 368ppm Cu and 246ppm Zn. The zone is in the quartz diorite mass where several silicified zones are discernible and partly accompanied by dissemination and micro-veinlets of pyrite.

10) The upstream of the Binongan River anomalous zone.

The anomalous zone is situated upstream of the Binongan River, the central part of the survey area. The zone is composed of relatively intense anomalies of Cu and Zn. The maximum values are 292ppm Cu and 510ppm Zn. In this zone, andesite lava of the Licuan Group intruded by quartz diorite are distributed. Around the intrusive contact between the andesite lava and quartz diorite, the Dorao mineralized zone which consists of pyrite disseminations accompanied by a small amount of chalcopyrite is localized. The stream sediment sample indicating the maximum value of Cu were taken from a small creek near an outcrop of the pyrite-dissemination.

11) The other anomalies

Besides the anomalous zones mentioned above, there are many anomalies in various places such as the basin of the Apayao River, the Bulney River, the middle part of the Tineg River, the middle part of the Binongan River, the mouth of the Baren River and so on. However, neither anomaly is closely distributed.

According to the data provided by the Bureau of Mines, Philippines, there are some geochemical anomalies of stream sediments in the upper stream of the Saltan River and the upper stream of the Pasil River in the unfeasible area for the Phase I survey. And it is reported that the anomalies in the Pasil River ranges from 40ppm to 1,200ppm Cu and from 105ppm to 350ppm Zn.

3-3 Geochemical Soil Survey

Geochemical soil survey was experimentally conducted along the National Road, Route 6, from Barrio Longbao to the boundary between Abra and Kalinga-Apayao Provinces in Phase I as geochemical guides for the Phase II survey. The survey route which is approximately 50km, pass through the southern part of the Lacub mineralized zone consisting of highly silicified zone with pyrite dissemination at 2km southwest of Licuan. However no prominent mineralized zone with copper minerals were observed in this route.

Consequently it was clarified that the analytical values, particularly Cu contents are closely related to the geology of sampling sites although the relation between the analytical values and the mineralized zones can not be confirmed definitely.

Geology of the survey route consists of quartz diorite exposed about 8km along the road at the central part of the route, andesite lava and its pyroclastic rocks of the Licuan Group Formation II distributed in both flanks of quartz diorite, pyroclastic rocks of the Tineg Formation overlying the Licuan Group in the eastern part and the Mabaca Formation consisting of andesitic pyroclastics exposed in the western end of the route. Soil samples were collected at average interval of approximately 0.6km in quartz diorite distribution zone and about 1km in the other rocks.

Fig. II-4 shows the relation between the analytical values of Cu and Zn and the geology of the sampling sites. During the preparation of the graph, the amount of scatter in the analytical data are so much that the data were treated by 5 points and 9 points moving average methods to smooth the curve of the values.

From this figure, it is obviously recognized that the analytical values of Cu have higher grade in quartz diorite mass distributed in the central portion of the survey route. In the Licuan Group Formation II, the Cu values have the tendency to decrease with distance from quartz diorite mass. This tendency has been revealed also by the geochemical survey for soil conducted in Phase III of the Northeastern Luzon Project. Consequently it can be assumed that this phenomena exemplify one of the characteristics of the plutonic rocks distributed in the Cordillera Central although the number of the analytical data is not enough. It seems that geochemical soil survey can be effectively used to detect mineralized zones and/or plutonic masses which is accompanied by mineralized zone in areas covered by thick forest. In case of Zn, no prominent relation like Cu is recognized.

On the other hand, higher values of Cu and Zn were obtained from western contact zone between the quartz diorite and the Licuan Group Formation II. This zone is located partly in the Lacub mineralized zone and it is considered that these high values were derived from that mineralized zone.

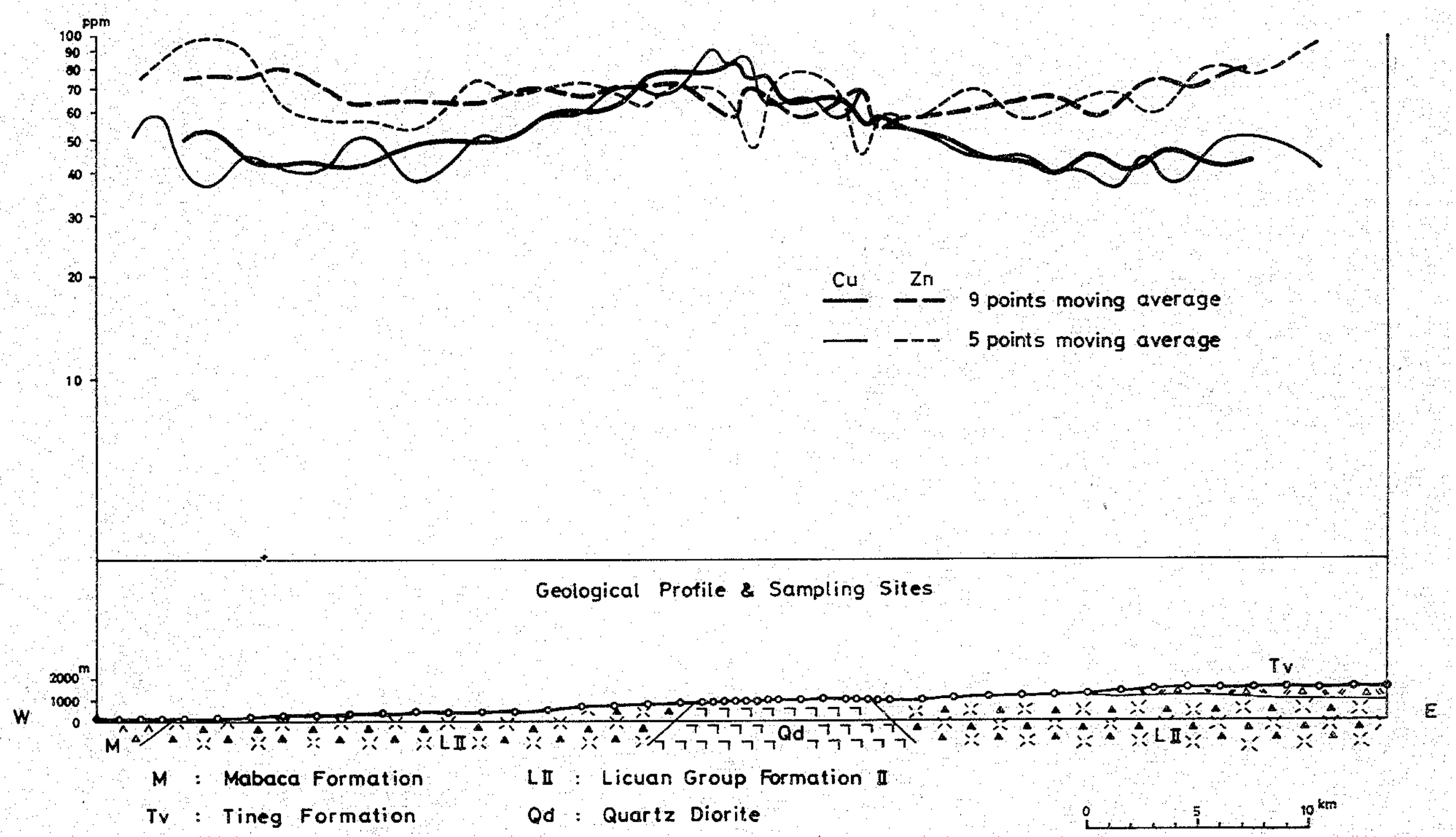


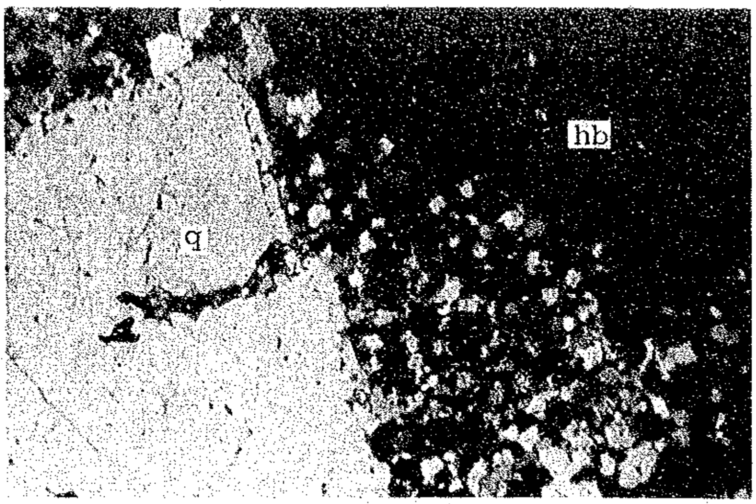
Fig. II - 4 Results of Geochemical Soil Survey

APPENDICES

Fig. A-1 Microphotography of Thin Section

Abbreviation

q	:	Quartz
or	:	Orthoclase
pl	:	Plagioclase
ca	:	Calcite
hb	:	Hornblende
au	:	Augite

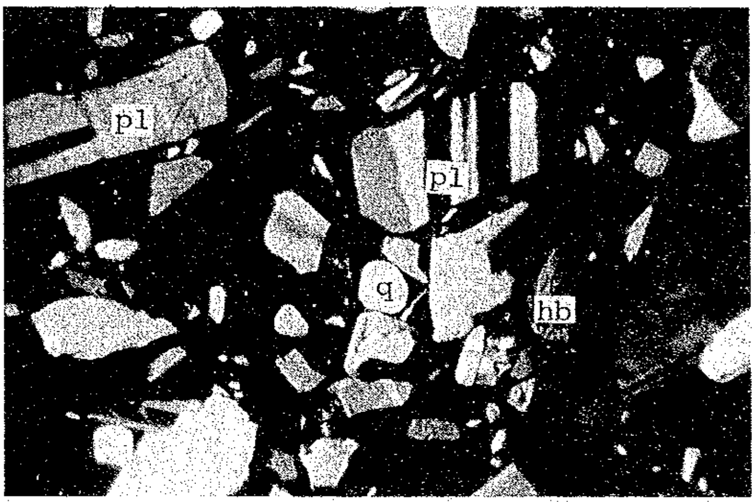


0 0.1 0.2 0.3 0.4mm

P-117(a)

Granodiorite porphyry

Cross nicol

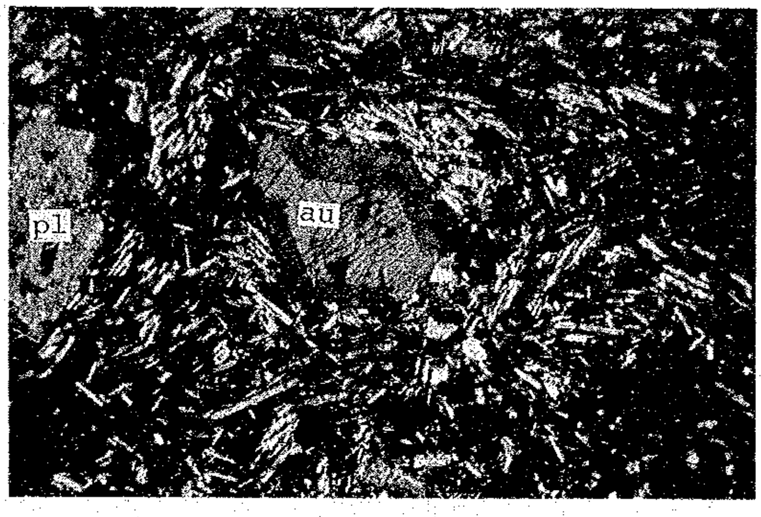


0 0.1 0.2 0.3 0.4mm

P-121

Dacitic welded tuff

Cross nicol

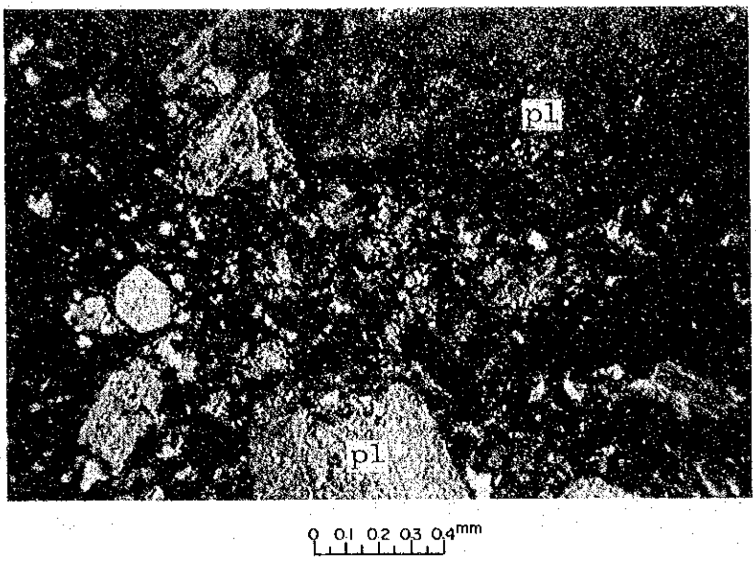


0 0.1 0.2 0.3 0.4mm

b-313

Andesite

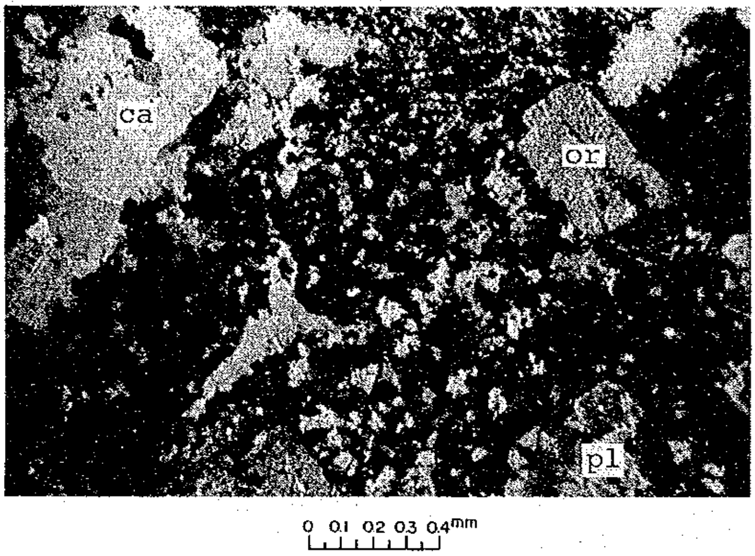
Cross nicol



e-304

Altered andesite

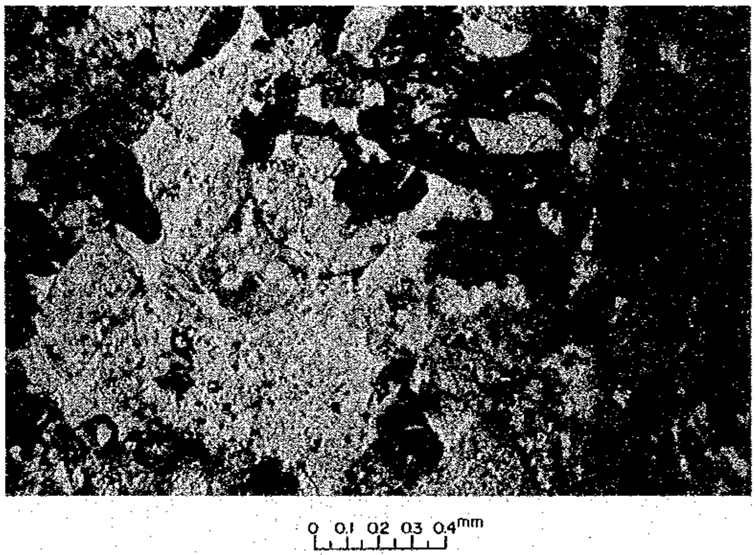
Cross nicol



f-318

Dacitic tuff

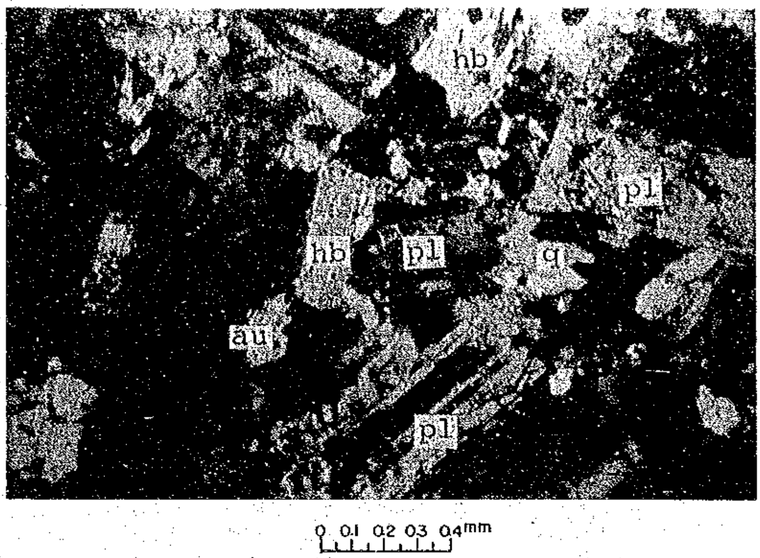
Cross nicol



f-501

Andesitic tuff

Open nicol



f-549

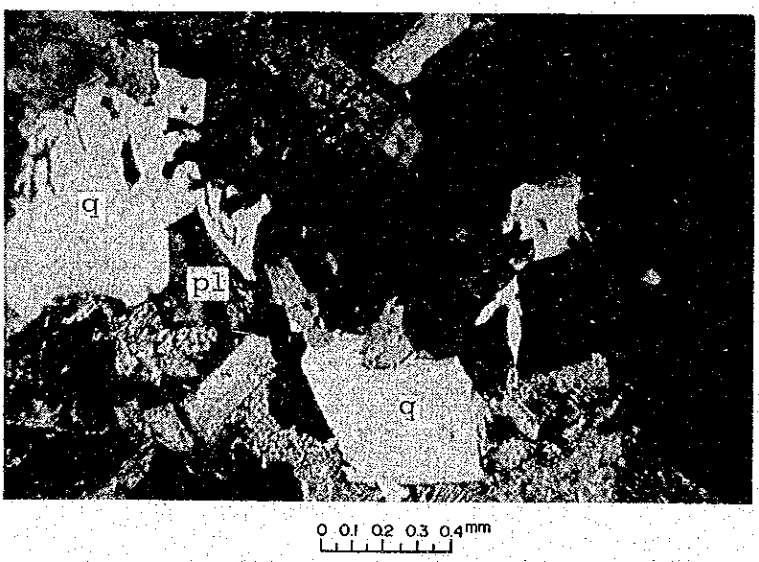
Quartz diorite

Cross nicol

g-512

Gabbro

Cross nicol



m-533

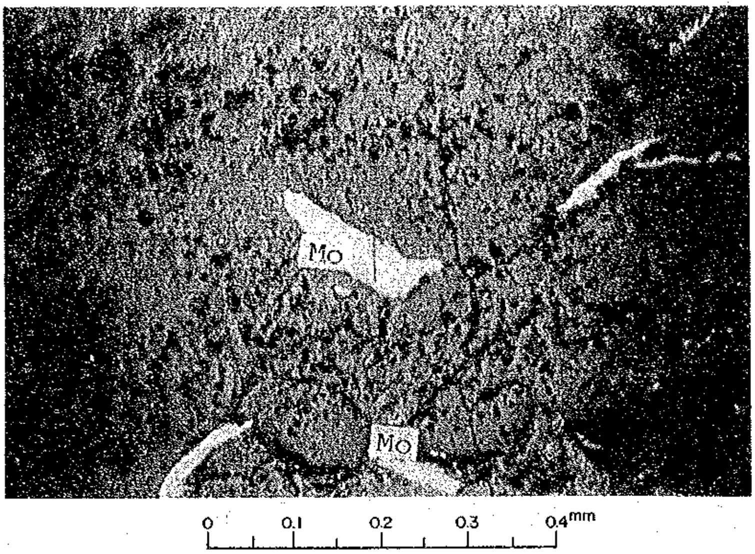
Granite

Cross nicol

Fig. A-2 Microphotography of Polished Section

Abbreviation

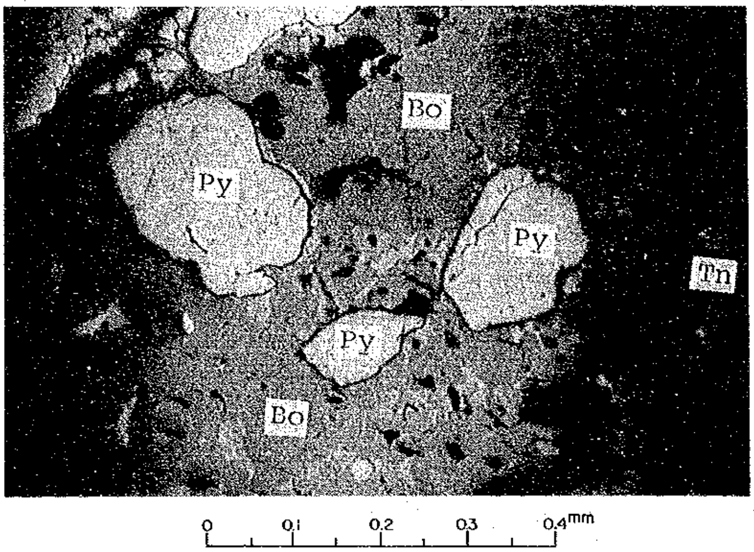
Cp	:	Chalcopyrite
Bo	:	Bornite
Tn	:	Tennantite
Cv	:	Covelline
Ml	:	Malachite
Sp	:	Sphalerite
Ga	:	Galena
Mo	:	Molybdenite
Au	:	Native gold
Py	:	Pyrite
Hm	:	Hematite
As	:	Arsenopyrite
Q	:	Quartz



b-119

Molybdenite dissemination

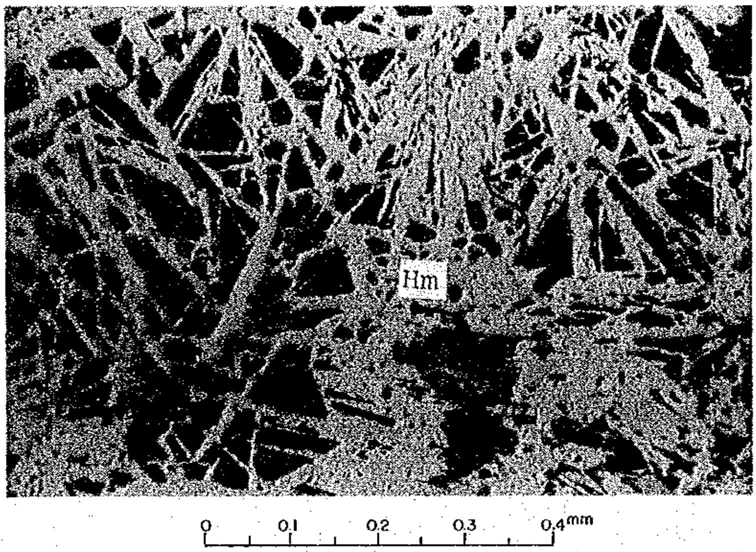
Open nicol



m-107

Bornite rich Cu-ore

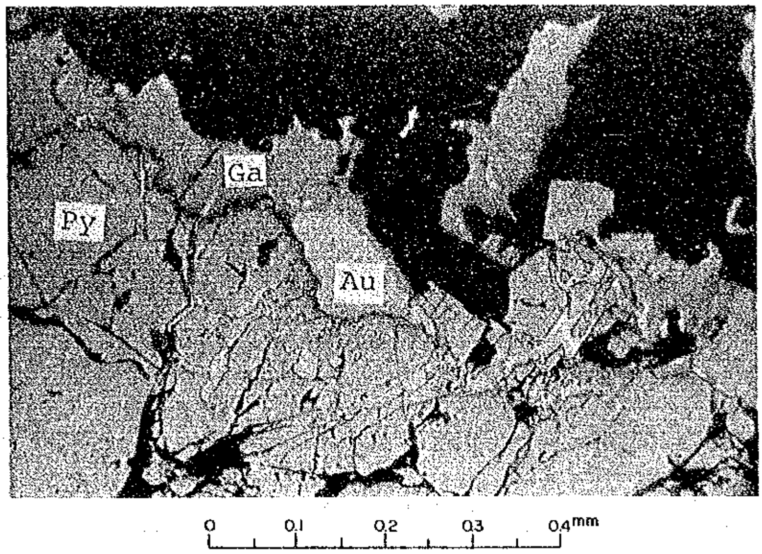
Open nicol



b-306

Specular hematite

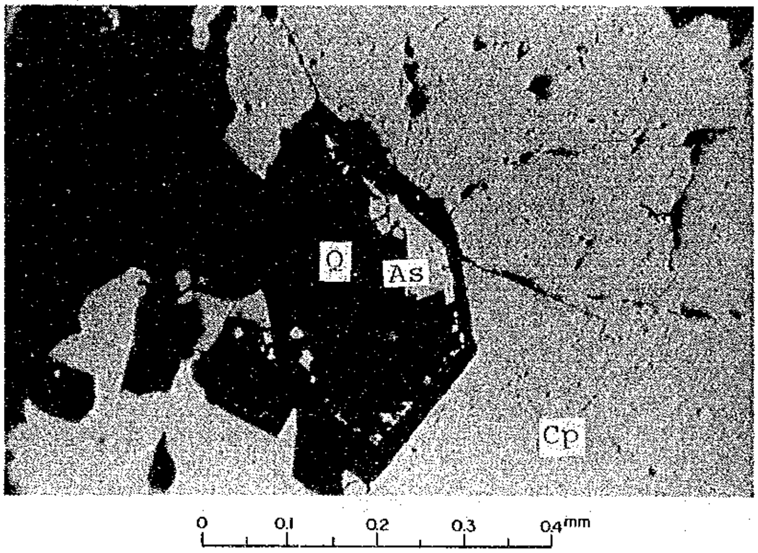
Open nicol



a-529(a)-1

Native gold

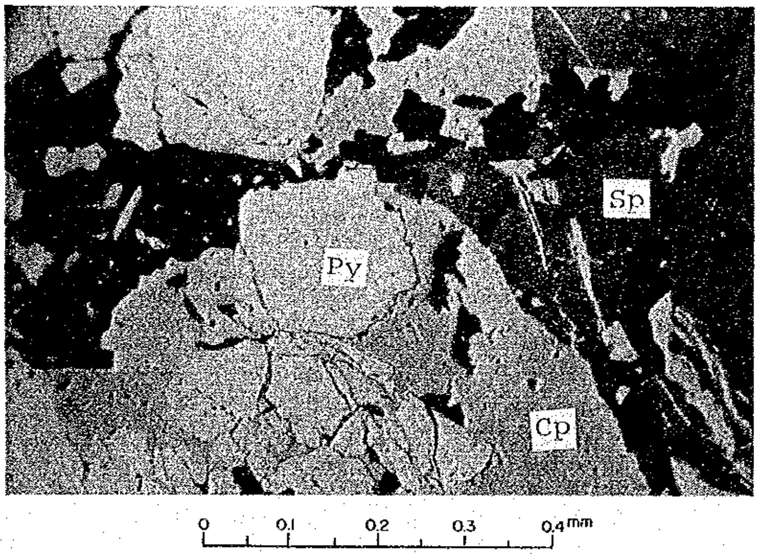
Open nicol



a-529(a)-4

Chalcopyrite ore

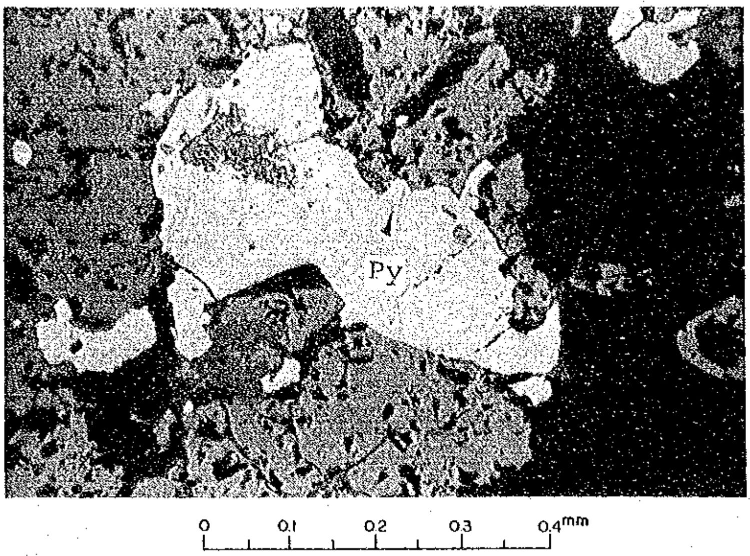
Open nicol



a-530

Chalcopyrite and Sphalerite ore

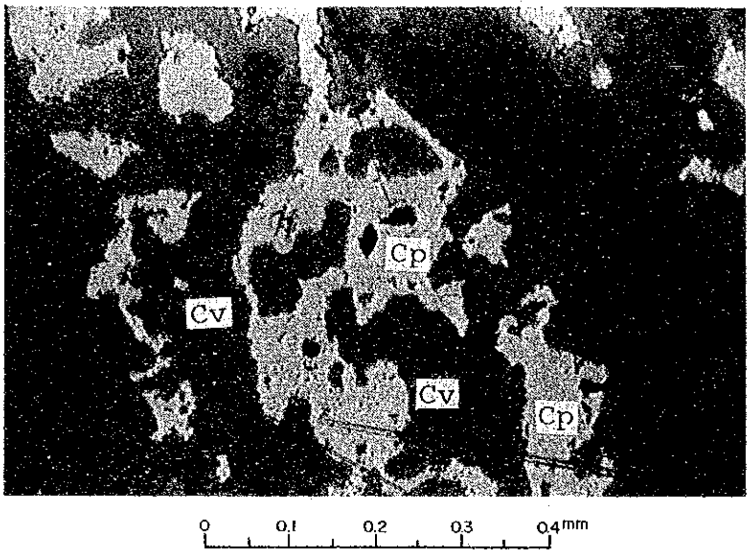
Open nicol



e-568

Secondary pyrite

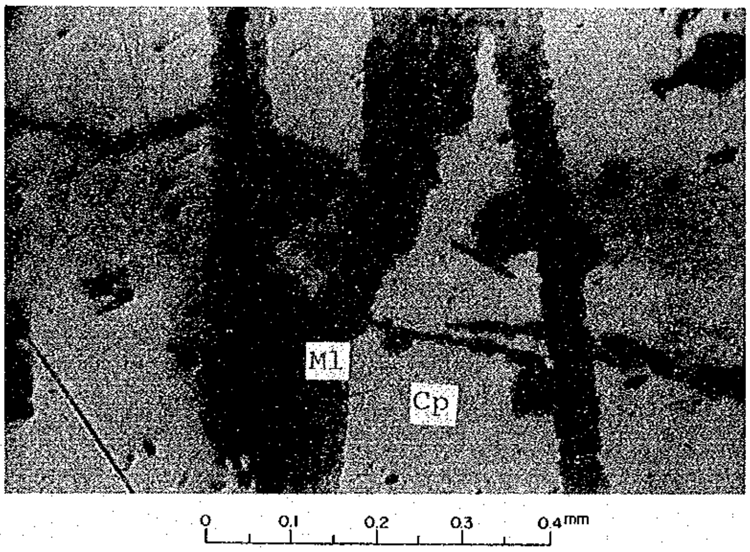
Open nicol



f-536

Secondary enriched
Cu - ore

Open nicol



m-601

Massive chalcopyrite

Open nicol