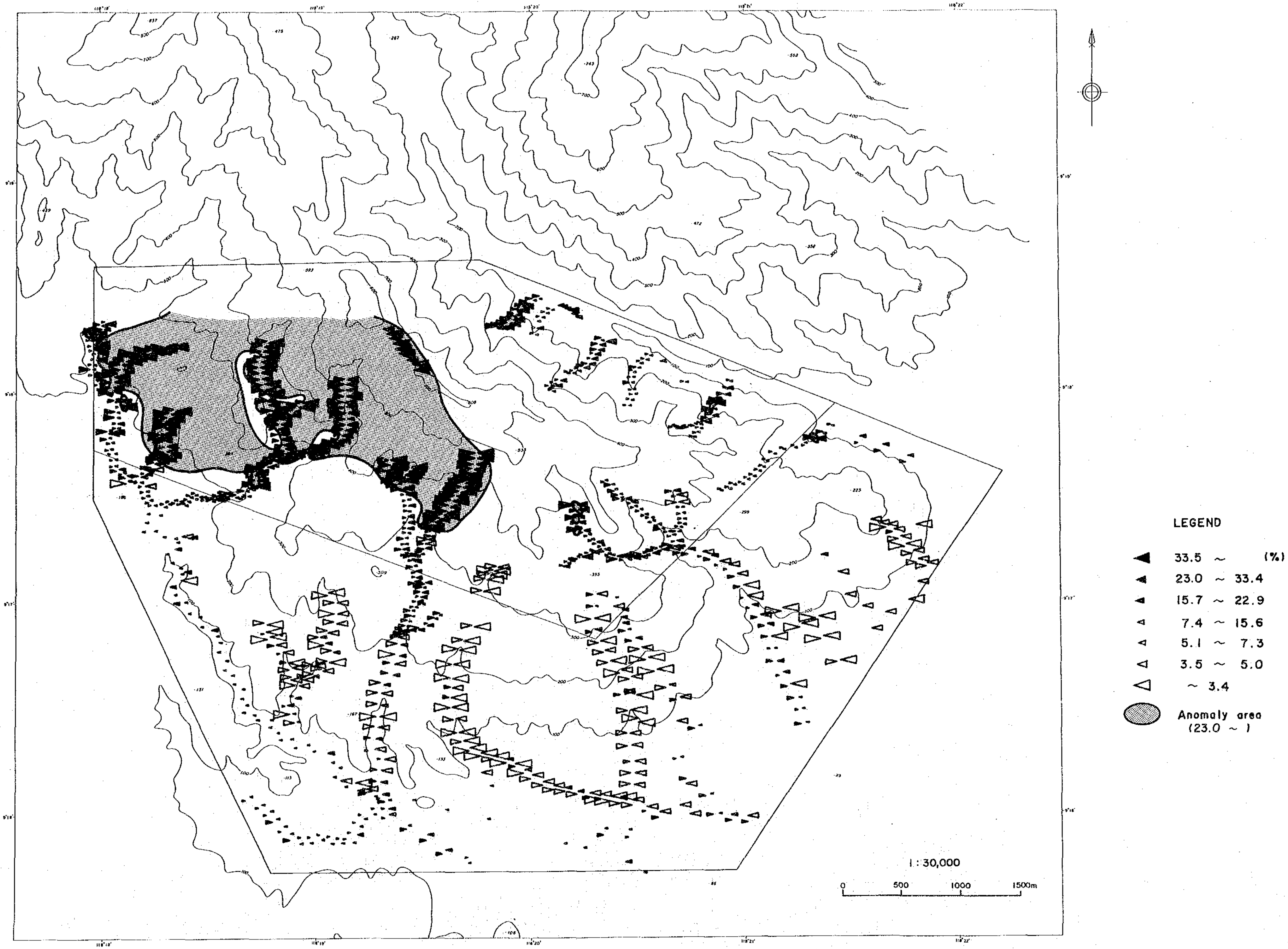


Fig.47 Fe content of soil samples in area B-1

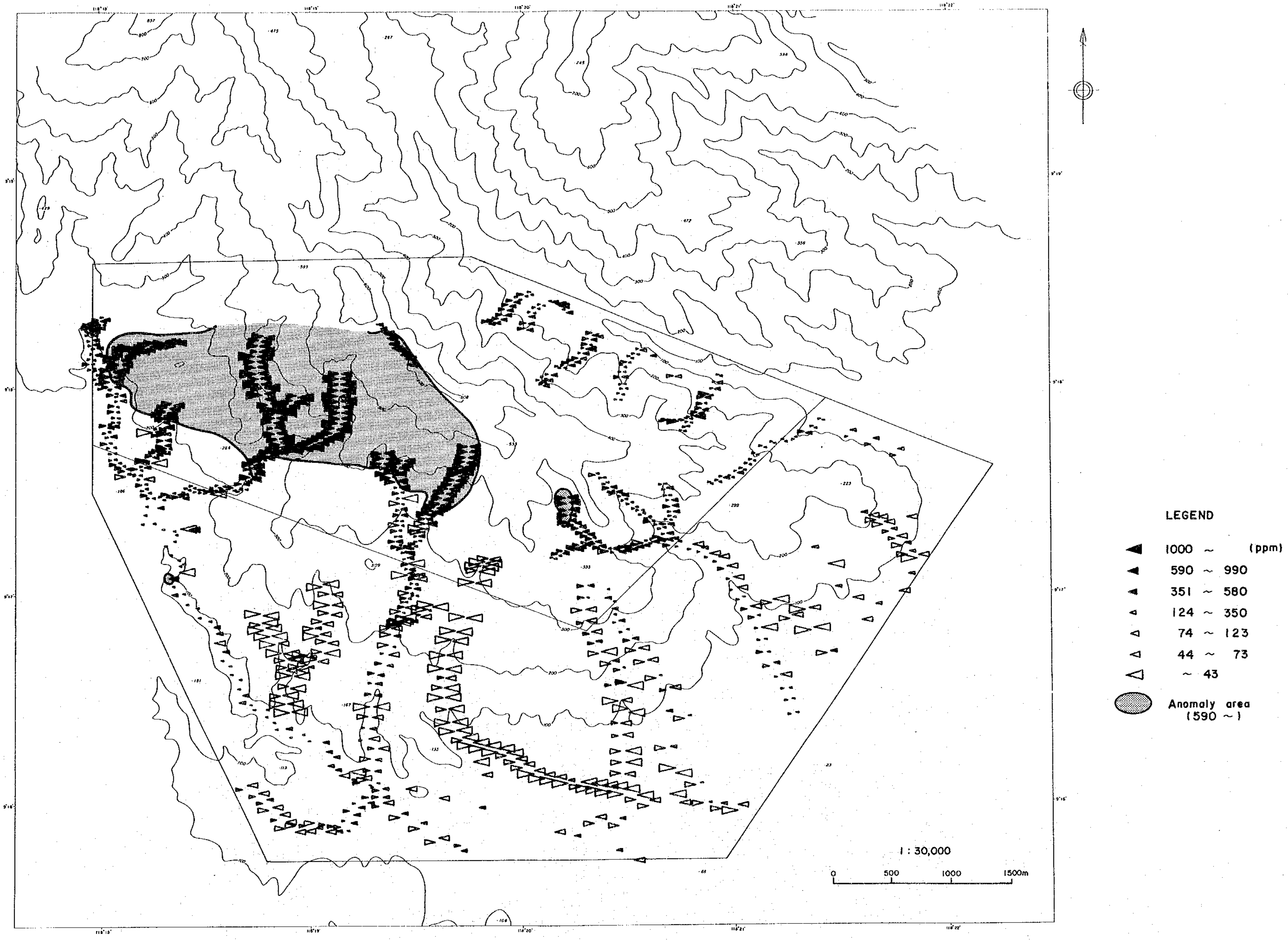


Fig.48 Co content of soil samples in area B-1

and Au compared with the other samples.

The high scores area of component 1 is found in the area from transitional zone to peridotite. On the other hand the low scores area of component 1 is gabbro and basalt areas. Unusually high scores samples are found in the west part of the peridotite distributed area.

The low scores of component 2 are found in the middle of Malinao River's tributary. The high scores of components 2 are distributed in the upper stream of Malinao River, where basalt is distributed.

4) Results of soil geochemistry

Interpretation map (Fig.54) shows the anomaly areas of Cr, the anomaly area of principal component 1, which summarizes the values of Ni, Cr, Fe and Co, and the distribution of dunite.

The promising areas for Ni and Cr is located in the northwest of area B-1. Numerous anomalies concentrated in this area. A rather large dunite mass underlies this area, and this dunite body includes many chromite occurrences.

2-2-3 Rock geochemistry

Many kinds of rocks are exposed in this area. Chemical analysis was conducted to check the differences in metal concentration in the different kinds of rocks. The same elements with that of soil geochemical survey are analyzed for rock geochemistry. The number of rock samples is 250. These data are divided into seven groups by rock types.

A: Basalt and basaltic pyroclastics
B: Gabbroic rocks
C: Harzburgite and lherzolite
D: Dunite
E: Chromitite
F: Pyroxenite
G: Metamorphics

Only a few chromitites have high Pt, Pd, and Au content. Other rock types have very low Pt, Pd and Au. Peridotites have high Ni and Cr content, and while the other rock types have very little Ni and Cr. Peridotite contains ten times of Cr and Ni compared with the other rock types. In the peridotites, dunites have higher Cr and Ni content than harzburgite. The chromite deposits of both the massive and banded types occur in the peridotite, particularly in dunite, in this area.
The Co content is rather high in peridotite. Values of Cr and Fe in peridotite are much lower than those indicated by the soil surveys but with few exceptions. It is suggestive of the superficial concentration of chromite and iron-oxide in soils.

2-2-4 Additional soil geochemical survey in B-area

A float of massive sulfide ore was discovered before in basalt area --in the southern part of B-area, but the location of discovery is not clear.

The elements related to chromium were analyzed for soil geochemical survey in B-area,

however the elements related to massive sulphide ore were not analyzed. The 101 soil samples in basalt enclosed area in B-area were selected for additional chemical analysis of elements related to sulphide ore. Ag, As, Hg, Sb, Cu, Pb and Zn were analyzed to check the potential of the area for existence of sulphide ore.

All data of Ag and Sb are below-detection-limit. The samples, which have high content of As, Hg, Cu, Pb and Zn, are selected by means of percentile. The selected samples of 5 percent probability have 3 ppm or more of As, 108 ppm or more of Cu, more than 10 ppm of Zn (detection limit is 10 ppm), or 97 ppm or more of Zn. These samples are plotted in Fig. 64 with the raw data.

The high Cu and Zn content area is located 6 kilometers northeast of Aboabo. The high As values are found to the west of Aboabo.

These data may indicate the potential for sulphide mineralization in the northeast area of Aboabo, but the result of geological survey done in this area show no mineral indications. Therefore we can not decide whether this area is really an anomaly area or not.

Table 8 Statistic quantities of rock samples in B-area and area B-1

	Rock type	number	range	median	linear* mean	linear* std. dev.	logalithmic* mean	logalithmic* 10^{mean}	logalithmic* std. dev.
Pt (ppb)	basalt	n=27	<5 - 5	<5	2.6	0.5	0.409	2.6	0.057
	gabbroic	n=31	<5 - 35	<5	4.8	6.2	0.538	3.4	0.278
	harzburgite	n=90	<5 - 30	<5	4.6	5.2	0.521	3.3	0.283
	dunite	n=86	<5 - 65	<5	5.0	7.6	0.546	3.5	0.285
	chromitite	n=5	<5 - 870	5.0	181.0	344.6	1.166	14.7	0.959
	pyroxenite	n=8	<5 - 80	<5	18.4	26.3	0.834	6.8	0.592
	metamorphics	n=3	<5 - 20	5.0	9.2	7.7	0.799	6.3	0.375
Pd (ppb)	basalt	n=27	<2 - 12	<2	2.0	2.2	0.174	1.5	0.283
	gabbroic	n=31	<2 - 110	<2	11.6	21.6	0.511	3.2	0.657
	harzburgite	n=90	<2 - 32	<2	3.9	6.4	0.287	1.9	0.440
	dunite	n=86	<2 - 50	<2	3.5	6.2	0.293	2.0	0.391
	chromitite	n=5	2 - 3200	2	644.8	1277.6	1.133	13.6	1.242
	pyroxenite	n=8	<2 - 106	4	22.0	33.4	0.858	7.2	0.673
	metamorphics	n=3	2 - 16	6	8.0	5.9	0.761	5.8	0.369
Au (ppb)	basalt	n=27	<2 - 4	<2	1.1	0.6	0.033	1.1	0.125
	gabbroic	n=31	<2 - 4	<2	1.5	1.0	0.117	1.3	0.212
	harzburgite	n=90	<2 - 4	<2	1.0	0.3	0.010	1.0	0.070
	dunite	n=86	<2 - 8	<2	1.2	0.9	0.040	1.1	0.148
	chromitite	n=5	<2 - 520	<2	105.0	207.5	0.603	4.0	1.063
	pyroxenite	n=8	<2 - 18	<2	3.8	5.5	0.307	2.0	0.413
	metamorphics	n=3	<2 - <2	<2	1.0	0.0	0.000	1.0	0.000
Ni (ppm)	basalt	n=27	10 - 100	51	47.4	20.6	1.625	42.2	0.226
	gabbroic	n=31	27 - 2460	70	395.8	593.8	2.164	146.0	0.598
	harzburgite	n=90	36 - 4010	2000	2056.3	672.6	3.260	1819.9	0.296
	dunite	n=86	58 - 39000	2120	4469.7	6974.9	3.426	2666.5	0.389
	chromitite	n=5	1640 - 12700	3400	5072.0	3969.3	3.593	3921.7	0.300
	pyroxenite	n=8	100 - 1200	170	426.3	417.4	2.442	276.7	0.388
	metamorphics	n=3	150 - 1400	170	573.3	584.6	2.518	329.3	0.445
Cr (ppm)	basalt	n=27	<100 - 230	100	90.0	45.4	1.903	80.0	0.208
	gabbroic	n=31	<100 - 3500	130	341.3	668.4	2.209	161.7	0.437
	harzburgite	n=90	140 - 6100	1900	1970.2	766.3	3.258	1813.0	0.204
	dunite	n=86	<100 - 136000	3900	7848.5	16572.3	3.543	3487.7	0.577
	chromitite	n=5	108000 - 192000	142000	39400.0	30289.3	5.135	136313.7	0.091
	pyroxenite	n=8	<100 - 2900	1100	1148.8	971.7	2.722	527.6	0.677
	metamorphics	n=3	130 - 1900	140	723.3	832.0	2.513	325.8	0.542
Fe (%)	basalt	n=27	2.1 - 7.5	4.3	4.6	1.2	0.644	4.4	0.113
	gabbroic	n=31	0.5 - 7.1	3.1	3.0	1.8	0.370	2.3	0.331
	harzburgite	n=90	1.6 - 6.4	4.5	4.4	0.7	0.639	4.4	0.085
	dunite	n=86	1.9 - 7.2	4.9	4.9	0.8	0.684	4.8	0.079
	chromitite	n=5	0.2 - 3.8	2.0	2.1	1.2	0.180	1.5	0.423
	pyroxenite	n=8	0.4 - 8.6	1.5	3.1	2.8	0.304	2.0	0.418
	metamorphics	n=3	1.1 - 1.6	1.2	1.3	0.2	0.108	1.3	0.070
Co (ppm)	basalt	n=27	27 - 63	42	41.9	9.8	1.610	40.7	0.103
	gabbroic	n=31	29 - 122	48	59.1	26.2	1.735	54.3	0.173
	harzburgite	n=90	40 - 117	91	89.7	14.2	1.946	88.2	0.084
	dunite	n=86	23 - 160	98	97.0	20.4	1.975	94.4	0.110
	chromitite	n=5	25 - 209	67	88.6	62.8	1.848	70.5	0.293
	pyroxenite	n=8	26 - 167	37	68.5	46.0	1.742	55.2	0.284
	metamorphics	n=3	35 - 68	35	46.0	15.6	1.640	43.7	0.136

*:Half of the detection limit value is used for the below-detection-limit data.

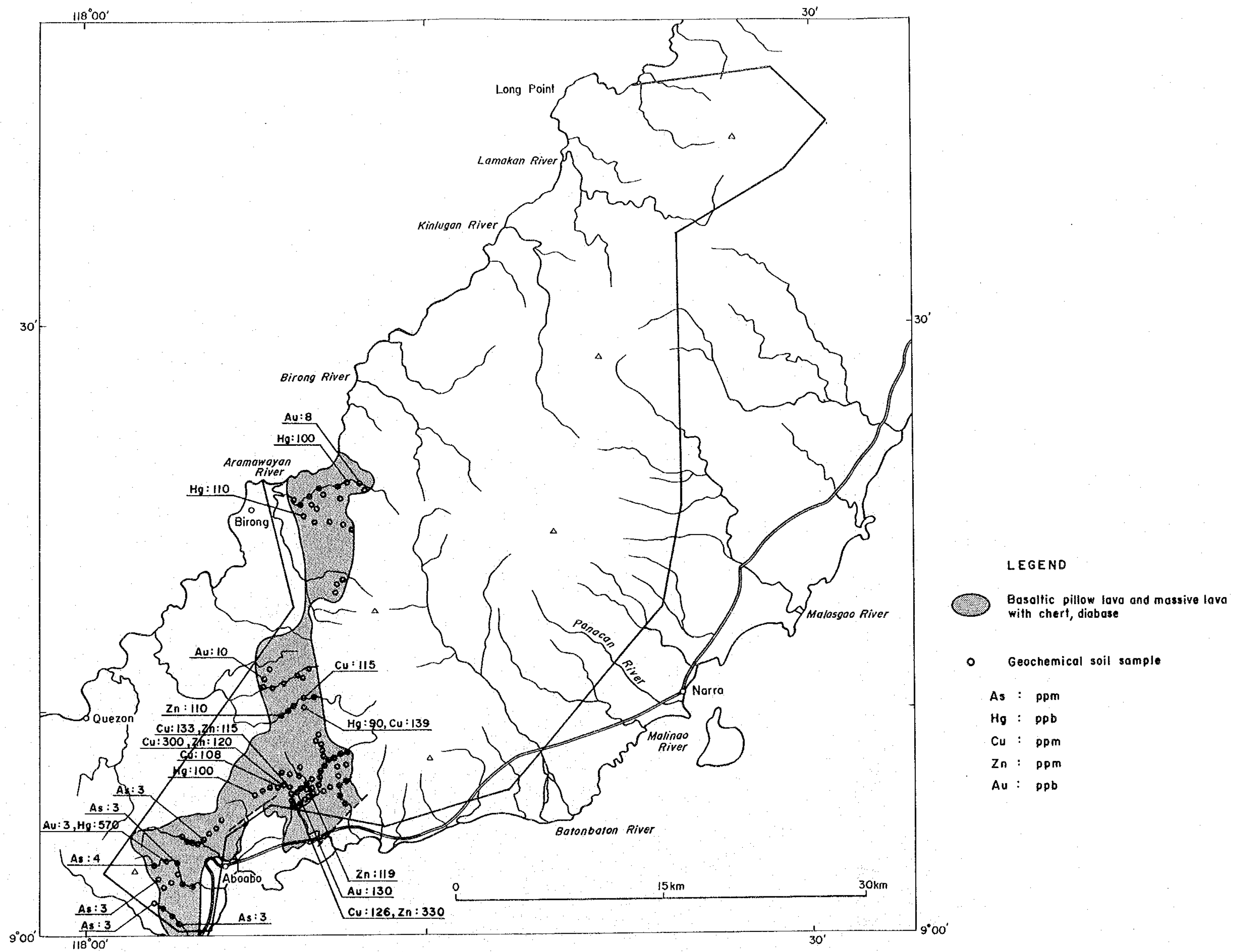


Fig.49 Element contents of soil samples in basalt area,B-area

2-3 Test pitting survey in detailed survey area B-1

2-3-1 Mariwara area

Test pitting survey was carried out at the Mariwara area in the upper stream of Marinao River northwestern portion of area B-1 (Fig.50). This chromium anomaly area was extracted last year by Phase 1 follow-up survey. Transition zone and cumulate dunite are distributed in the area, and chromite dissemination and bands are observed in many places within this. The electron microprobe study in Phase 1 survey shows that the chromite of this dunite is high aluminum and low chromium type.

Five survey lines were set in N-S direction to crosscut the general E-W trend of dunite body. The spacing between lines was set 100 meters, and the interval between pits was generally 25 meters along the line. More pits were sunk in distance of 5 to 10 meters around the mineralized pits to confirm the extension of mineralization. Locations of pits are shown in Fig. 51.

Though no outcrop of chromite ore was found on surface, floats of massive and leopard type ore are found in the branch of Marinao River. The analysis of this floats shows 30.50% Cr_2O_3.

Almost all pits reached to basement and dunite was recognized in every pit. Chromite mineralization was recognized in 13 pits.

Mineralized zone from NH044 pit to NH045 pit in the north of the area consists of chromite dissemination and thin bands. Channel sample was collected in width of 0.6 meter crossing chromite band in NH086 pit which is 10 meters south of NH045, and obtained 3.09 % Cr_2O_3.

Mineralized zone from NH014 pit to NH017 pit in the west consists of chromite dissemination and thin band. The mineralized dunite (NH-16) shows 4.23 % Cr_2O_3.

Massive chromite ore was found in NG034 pit within mineralized zone in the central portion of the area (Fig. 52). This ore body is 1.4 meter wide and 2 meters long, and 1.4 meter channel sample shows 26.70 % Cr_2O_3. Platinum related elements are also high content in this mineralized zone. Soil samples collected from the pit bottom show Pt; 1,600 ppb and Pd; 3,400 ppb for NG034 pit, Pt; 1,200 ppb and Pd; 740 ppb for NG100.

Several chromite bands ranging in width from 2 to 6 centimeters are recognized in the east. The analysis of channel sample 1.0 meter wide shows 17.20 % Cr_2O_3.

Fig.50 Location of test pits in area B-1

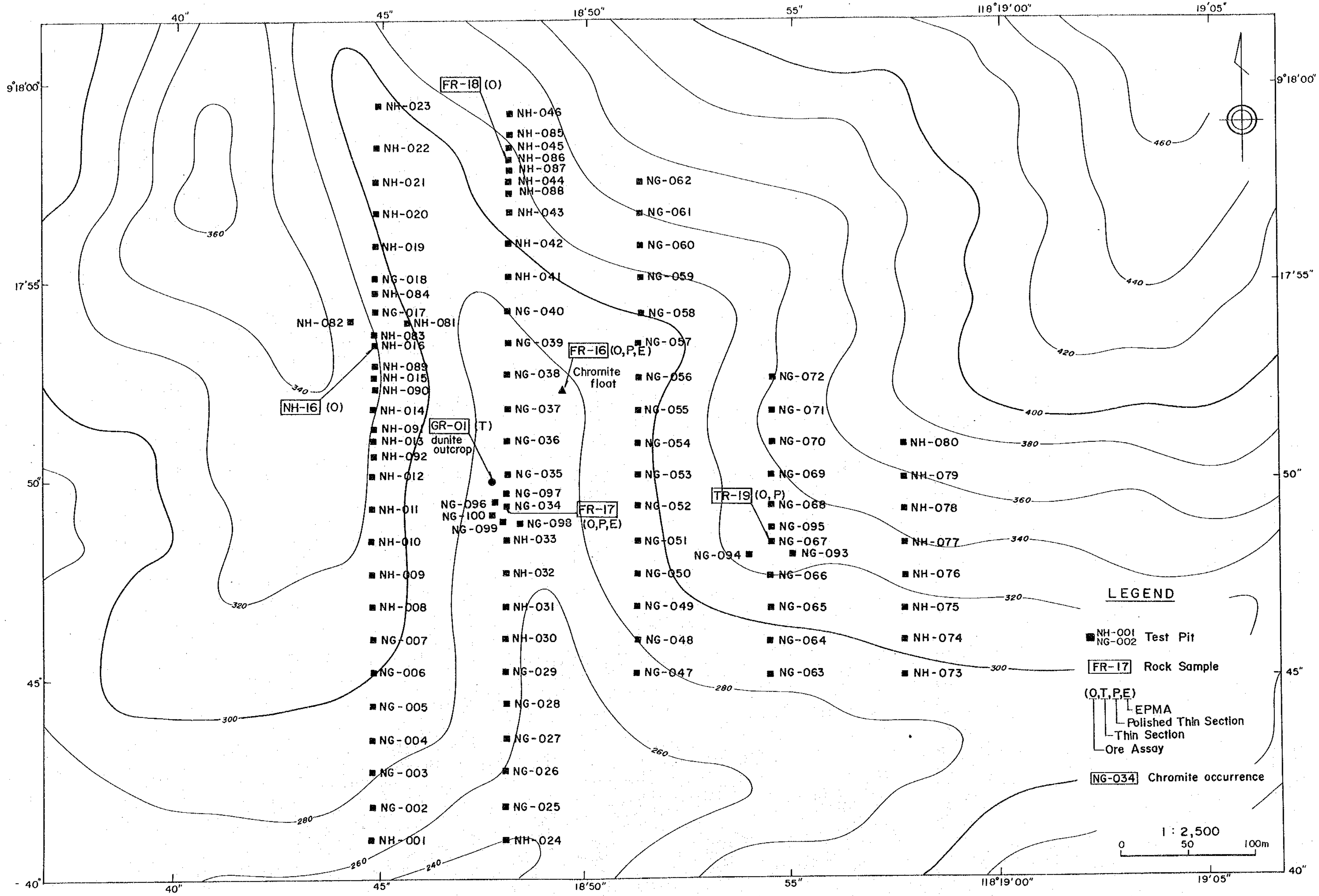


Fig.51 Location of test pits in Mariwara area

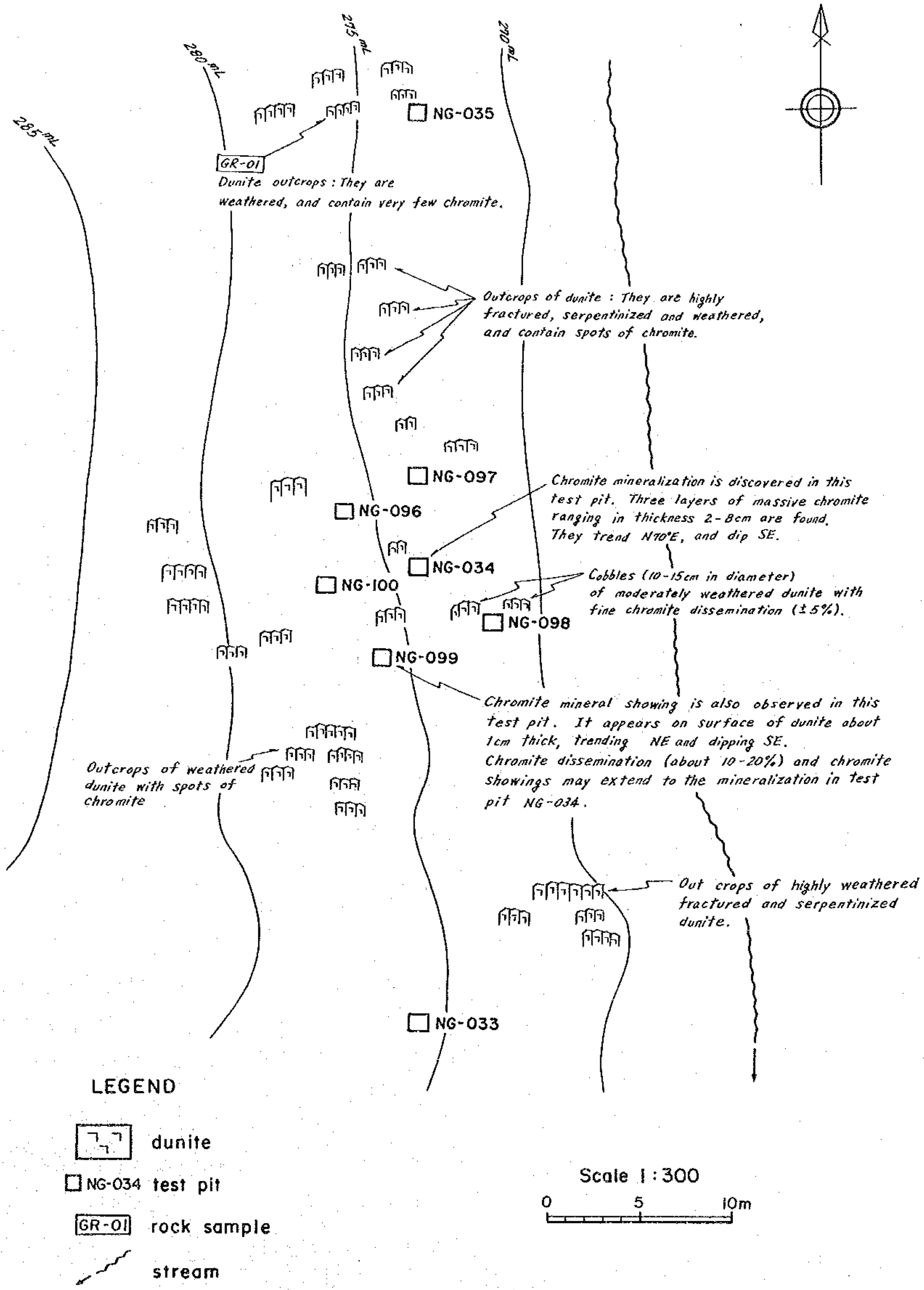


Fig.52 Detail from NG035 to NG033

2-4 Discussion

The Palawan Ophiolite is thrust over the Panas Formation in this area. The Palawan Ophiolite is composed of the Mt.Beaufort Ultramafics, the Sultan Peak Gabbro, and the Espina Basalt from the bottom. The Inagauan Metamorphics, which were probably formed during the thrust movement, exist in between the Panas Formation and the Ophiolite sole.

The major mineral occurrences in the area are of chrome and nickel. The Mt.Beaufort Ultramafics host for these occurrences. No mineral occurrence of the Cyprus type was found in the basalt this time in spite of its possibility.

Two kinds of chrome occurrences exist in the area, one is associated with cumulate-dunite near the layered gabbro and the other is associated with the dunite tectonite in harzburgite. The former has typical occurrences in the catchment area of the Malinao River, west of Narra, and the latter typically occurs in the Norsophil Mine and the Berong area. The successive detailed geochemical survey in area B-1, the catchment area of the Malinao River, which was selected as a potential area for Cr and Ni mineralization as based on the results of the geochemical survey, has revealed the distribution of dunite bodies. The dunite containing disseminated chromite is mainly distributed in the northeastern part of the detailed survey area. No new mineral occurrence has been found in the area, but some potential for blind ores exists judging from the evidence of the past operation record for massive ores.

Regarding nickel minerals, no new significant occurrence has been discovered except for one weak indication, about 1% Ni contents, in a test pit in the central B-1 area.

In the geochemical survey in the B-area, volume ratios of heavy minerals were investigated by panning in sites as well as soil sampling. This method is effective in case enough water is available in sites, and to promptly delineate favorable areas for further works at the early stage of the survey. The seven elements assayed in the soil geochemistry can be classified into two categories based on their behavior. One is a group of Ni, Cr, Fe, and Co, related to chrome, and the other is a group of Pt, Pd, and Au related to precious metals. Interpretation of the geochemical anomalies of the both categories have led to the delineation of five potential areas; the upper stream area of the Malasgao River, the surrounding area of the Norsophil Mine, and the upper stream area of the Malinao River --in the east coast; and surrounding area of the Long Point, and Berong area --in the west coast(Fig.53).

The results of the soil geochemical survey in the B-area have led to the selection of detailed survey area B-1, the upper stream area of the Malinao River. As a result of the geochemical survey done in area B-1, the two groups, related to chrome and precious metals respectively, show geochemically different behavior. The group relating to chromium is concentrated in transitional zones from gabbro to peridotite and peridotite distribution areas, while the group related to precious metals is concentrated in basalt distribution areas such as the upper stream area of the Malinao River and in the southern most part of the area B-1(Fig.54). The survey has revealed that the northwestern area is a potential for chromite deposits. This area is largely underlain by dunite, and contains most of the known chromite mineral occurrences. Accordingly this area is judged as a high potential area for new chromite ore deposits.

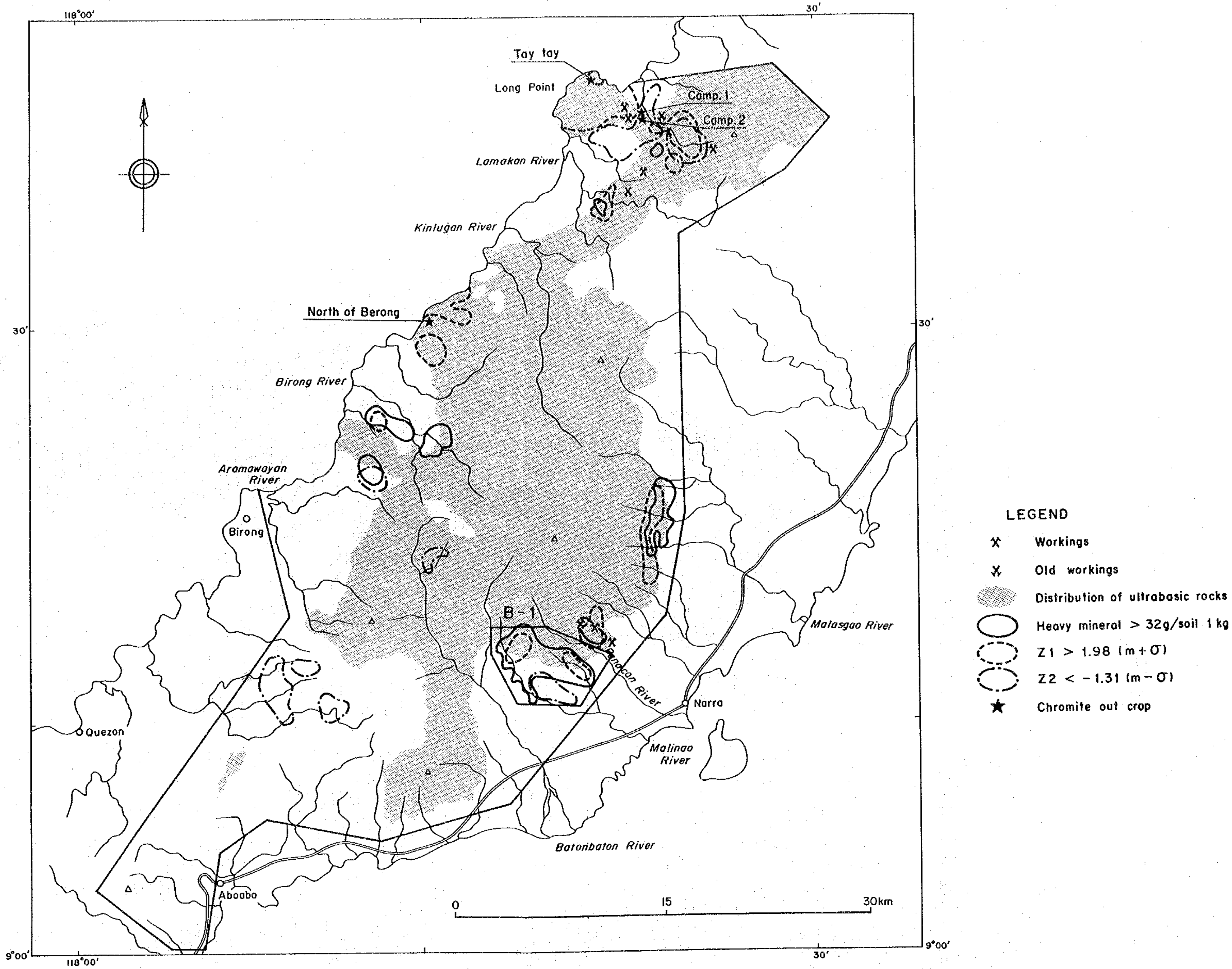


Fig.53 Interpretation map of B-area

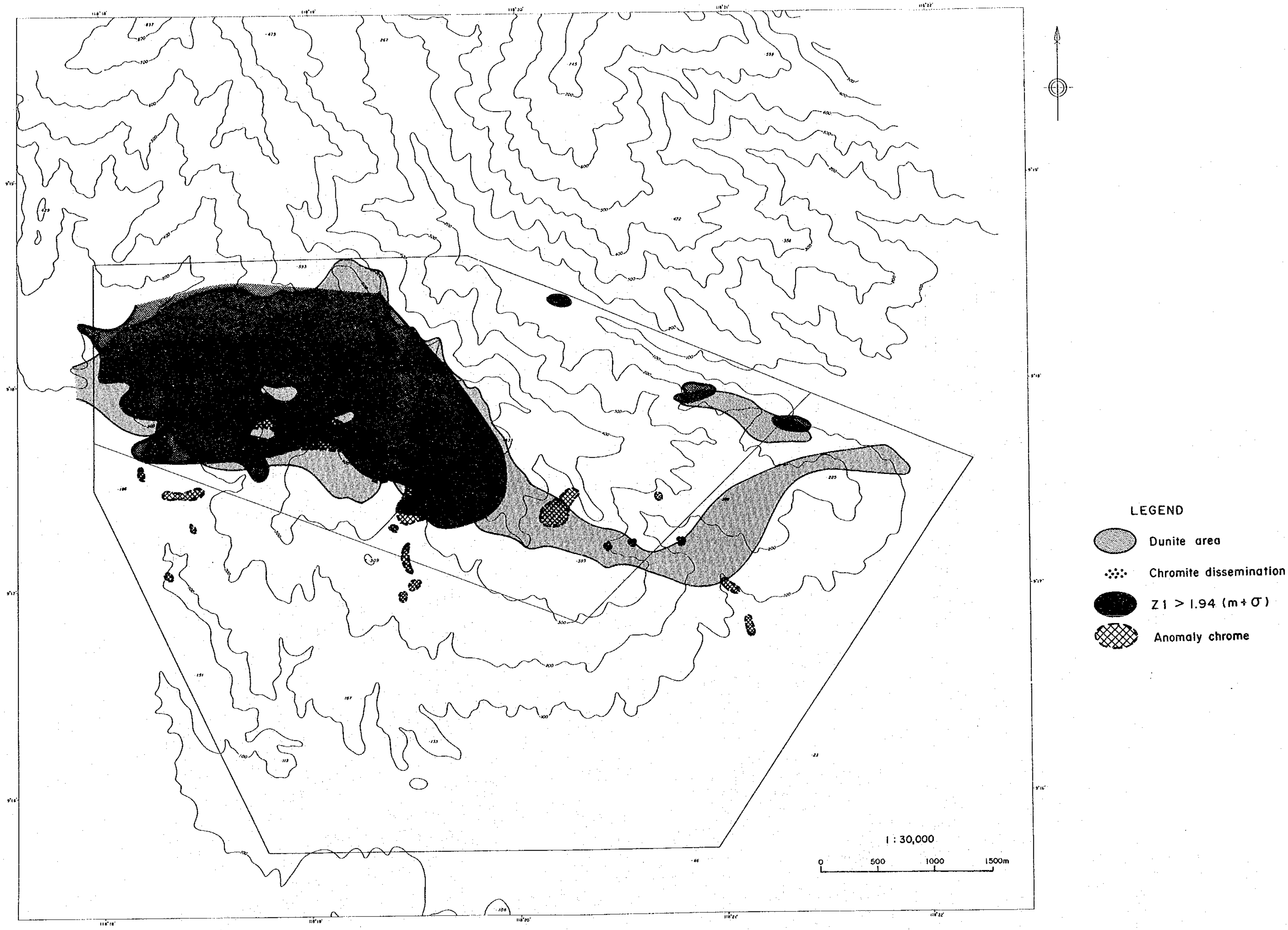


Fig.54 Interpretation map of area B-1

Chapter 3 C-area

3-1 Geology

3-1-1 Outline of geology

The area is underlain by the Palawan Ophiolite, which thrust over this area, and unconformably overlying Quaternary sediments(Fig.55).

The Palawan Ophiolite consists of harzburgite and dunite of the Mt. Beaufort Ultramafics, the Stavely Range Gabbro, and the Espina Basalt intercalated cherty rocks.

Previously, it was believed that basaltic rocks were dominant in this area. But the results of this survey have revealed that the ultramafic rocks, which were thrust over the basalt, gabbro, and cherty rocks, are dominantly distributed in the survey area centered by the backbone range.

The Quaternary consists of sand and gravel, and is distributed in the lowlands in the northern survey area.

3-1-2 Detailed geology

1) Mt. Beaufort Ultramafics

The Mt. Beaufort Ultramafics are dominant in the northern and southern part of this survey area. *It is mainly composed of harzburgite accompanied by dunite.*

The fresh harzburgite is greenish gray in color, but it has generally undergone intense weathering, turning its color to pale brown. The rock consists mainly of intense serpentinized olivine and orthopyroxene, with subordinated amount of clinopyroxene, plagioclase, and chromite.

Dunite is distributed in the harzburgite in the middle part of the Tagusao River and the middle part of a tributary of the Panitian River. It is dark greenish gray in its fresh parts, but pale gray in its weathered parts. The outcrops are usually weathered strongly, turning their color to light gray to greenish gray. It consists mainly of olivine and small amounts of orthopyroxene and chromite. It has undergone intense serpentinization.

2) Stavely Range Gabbro

The Stavely Range Gabbro consists of olivine gabbro, and is distributed in small areas in the northwestern end and the southeastern end of the survey area. The rock is fine to medium grained, and grayish green. It mainly consists of plagioclase and clinopyroxene, accompanied by olivine and orthopyroxene. Olivine is usually strongly serpentinized.

3) Espina Basalt

The Espina Basalt is largely distributed in the northern, eastern, and western survey areas. It is either massive or pillow lava, and gray to grayish green in fresh parts. The intensively weathered parts are usually reddish brown. The rock near Marirong has partially been altered to laterite. Where the pillow structure is clear, the size of the pillows is 10 cm to several meters in diameter.

In the middle part of the Tagusao River and the middle part of the Panitian River, cherty shale

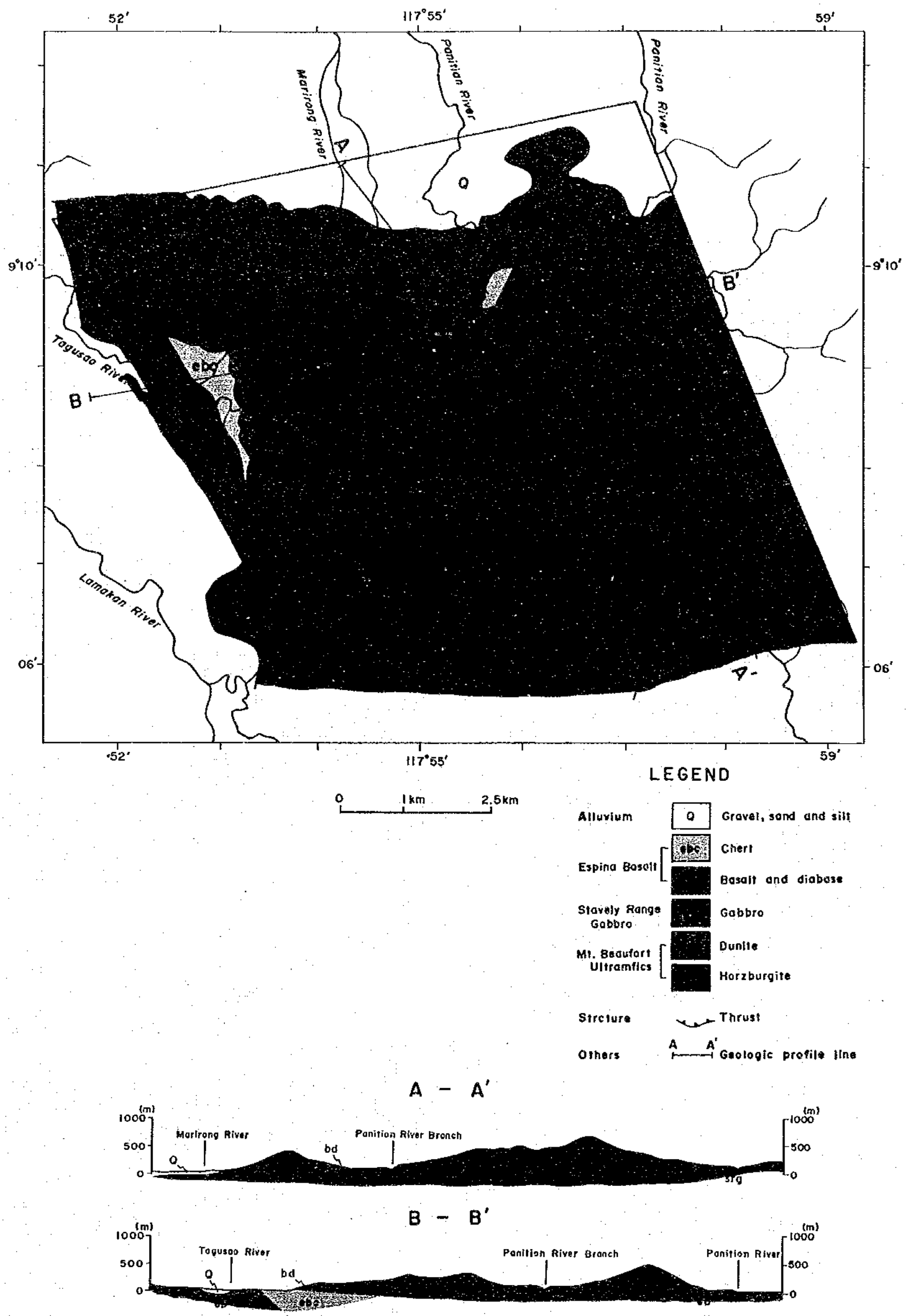


Fig.55 Geologic map and profile in C-area

Age	Geologic Column	Rock Description	Formation/Rock Unit	Mineral Showings
Quaternary	Q	Gravel, sand and silt	Alluvium	
Late Cretaceous	eb, ebc	Basaltic pillow lava, massive lava, interbedded chert	Espina Basalt	
		inffered stratigraphic		
	Srg	Isotropic gabbro	Stavely Range Gabbro	
		inffered stratigraphic		
	bh, bd	harzburgite, dunite tectonite	Mt. Beaufort Ultramafics	

Fig.56 Schematic geologic map in C-area

and chert are observed at the top of the basalt layer. They are phyllitic, and greenish gray to reddish brown.

3-1-3 Geological structure

The geological structure of the C-area are ascribed to the emplacement of the ophiolite.
The low angle thrust fault in this area is the one bordering the bottom of the Mt. Beaufort Ultramafics. Another thrust between the Stavely Rang gabbro and Espina Basalt is found as inbricated structure of the ophiolite suit.

3-1-4 Mineralization

Previously, it was thought that basaltic rocks of the Espina Basalt were extensively distributed in the area, judging from existing old data. The main reason that this area was chosen as one of the survey areas was that the area should have a potential for Cyprus type ore deposits. This survey have revealed that the distribution of basaltic rocks are restricted in distribution and the sulphide mineralization did not found.
Though the dominant distribution of the harzburgite and dunite may show that this area has a potential for chromite mineralization, no chromite indication was seen..

3-2 Geochemical Survey

3-2-1 Soil geochemistry in C-area

1) Sampling
Soil geochemical survey was conducted in combination with geological mapping at the scale of 1:10,000. About 1 kilogram of soil samples from B horizon were taken from opposite banks above the highest water level of the stream.

2) Pathfinder elements and chemical analyses.
The C-area was mapped as a basalt enclosed area. The geochemical survey was conducted to determine the presence of eight elements related to copper sulphide ores: copper(Cu), lead(Pb), zinc(Zn), gold,(Au), silver(Ag), arsenic(As), antimony(Sb) and mercury(Hg).
Cu, Pb and Zn were analyzed in PETROLAB while Au, Ag, As, Sb and Hg analyses were done in Chemex Labs. Ltd.

3) Data analyses
The method of basic statistical analysis and principal components analysis were used in this survey. All Ag values are below-detection-limit.

(i) Statistical analysis
The range, median, mean and standard deviation(σ) are shown in Table 9. The ranges indicate a low content and a very small variation.

Table 9 Basic statistic quantities of soil samples in C-area

element	range	median	linear mean	linear std. dev.	logarithmic mean	logarithmic 10^mean	logarithmic std. dev.
Cu (ppm)	5 - 200	45	46.6	25.4	1.593	39.2	0.283
Pb (ppm)	5 - 144	5	8.9	14.3	0.815	6.5	0.259
Zn (ppm)	20 - 152	69	71.6	23.1	1.831	67.8	0.148
Au (ppb)	0.5 - 9	0.5	1.1	1.1	-0.101	0.8	0.297
As (ppm)	0.5 - 29	1	1.6	2.1	0.101	1.3	0.236
Sb (ppm)	0.1 - 1	0.1	0.2	0.2	-0.848	0.1	0.261
Hg (ppb)	10 - 130	60	61.0	22.4	1.751	56.4	0.186

(ii) Element content map

The content of each sample is classed by mean value and standard deviation, and plotted on the element content map (Fig. 57 to Fig. 59).

Threshold for C-area is considered as mean value (m) and as standard deviation (σ), and the point of m+1.0σ was adopted as threshold.

(iii) Principal components analysis

The covariance matrix obtained from standardized ((raw value - mean)/(standard deviation)) data set is equal with correlation coefficients matrix. We have used the correlation matrix as initial matrix for principal components analysis.

The eigenvalues above 1.0 are component 1, 2 and 3, and these components explain 60 percent of information. The scores are calculated from weight vector are shown on scores distribution maps (Fig. 60 and Fig. 61).

According to the factor loading matrix, positive scores of component 1 shows the copper related elements; Cu, Pb and Zn. This score in basalt area are higher than that in ultramafic rocks area. Cu and Au are negative and Hg is positive in component 2. Hg is negative and As is positive in component 3.

(iv) Result of soil geochemistry

The soil geochemical survey has revealed relatively high anomalous values for each element, however no relation between those anomalous values was found.

3-2-2 Geochemical survey of heavy mineral sand from stream sediments

1) Sampling and chemical analysis

Heavy mineral sand was collected from stream sediments by means of panning. And the

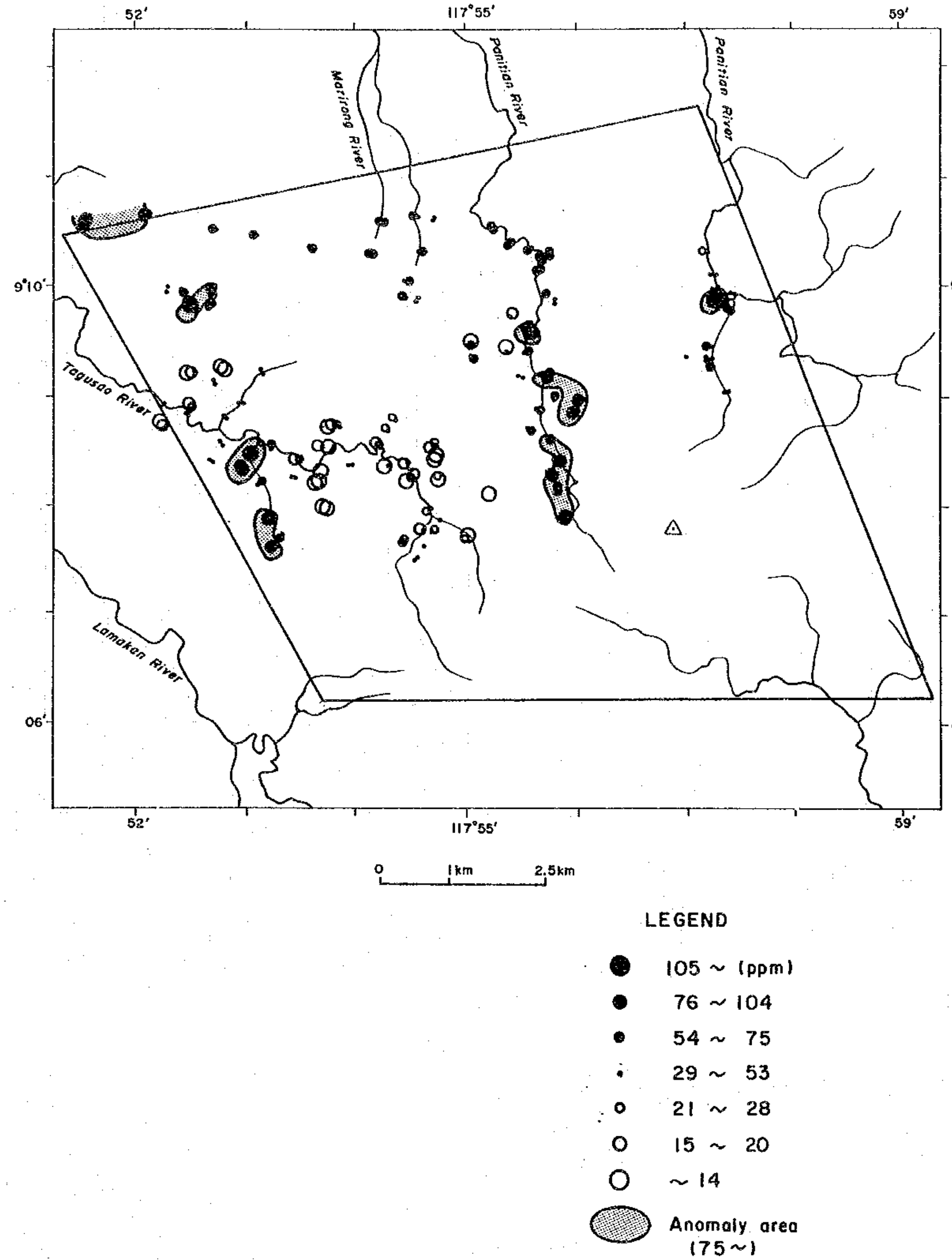


Fig.57 Cu content of soil samples in C-area

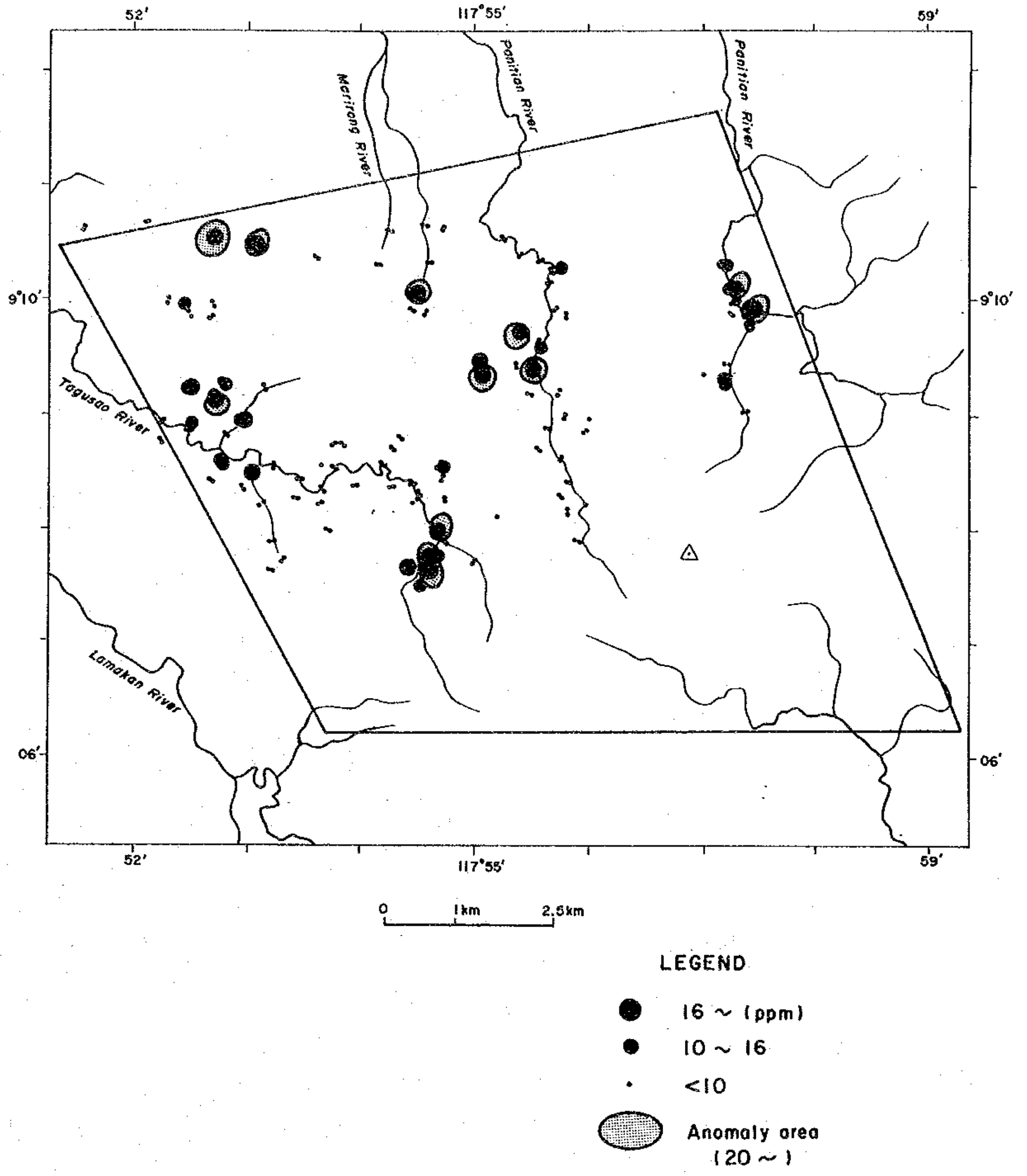


Fig.58 Pb content of soil samples in C-area

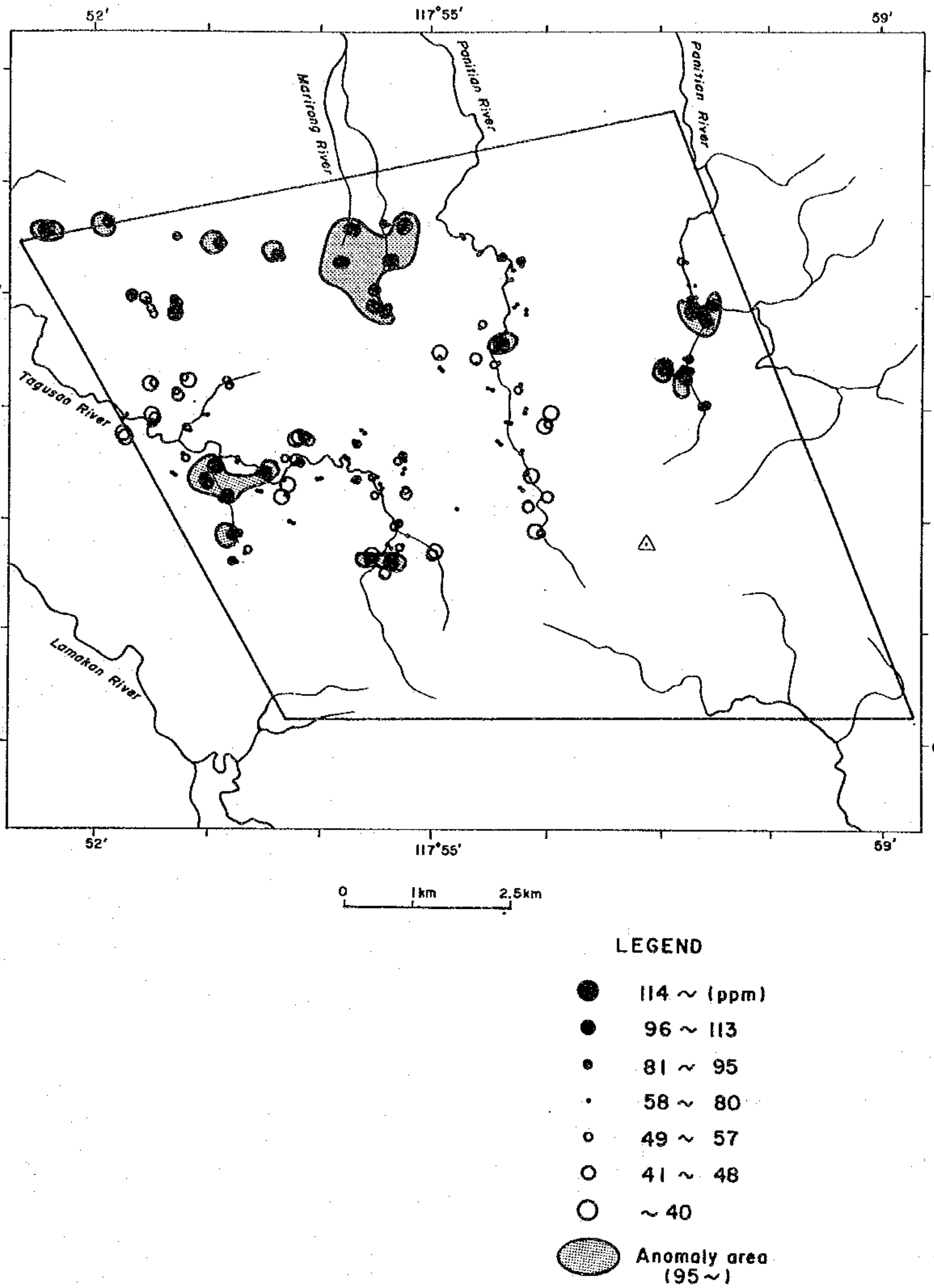


Fig.59 Zn content of soil samples in C-area

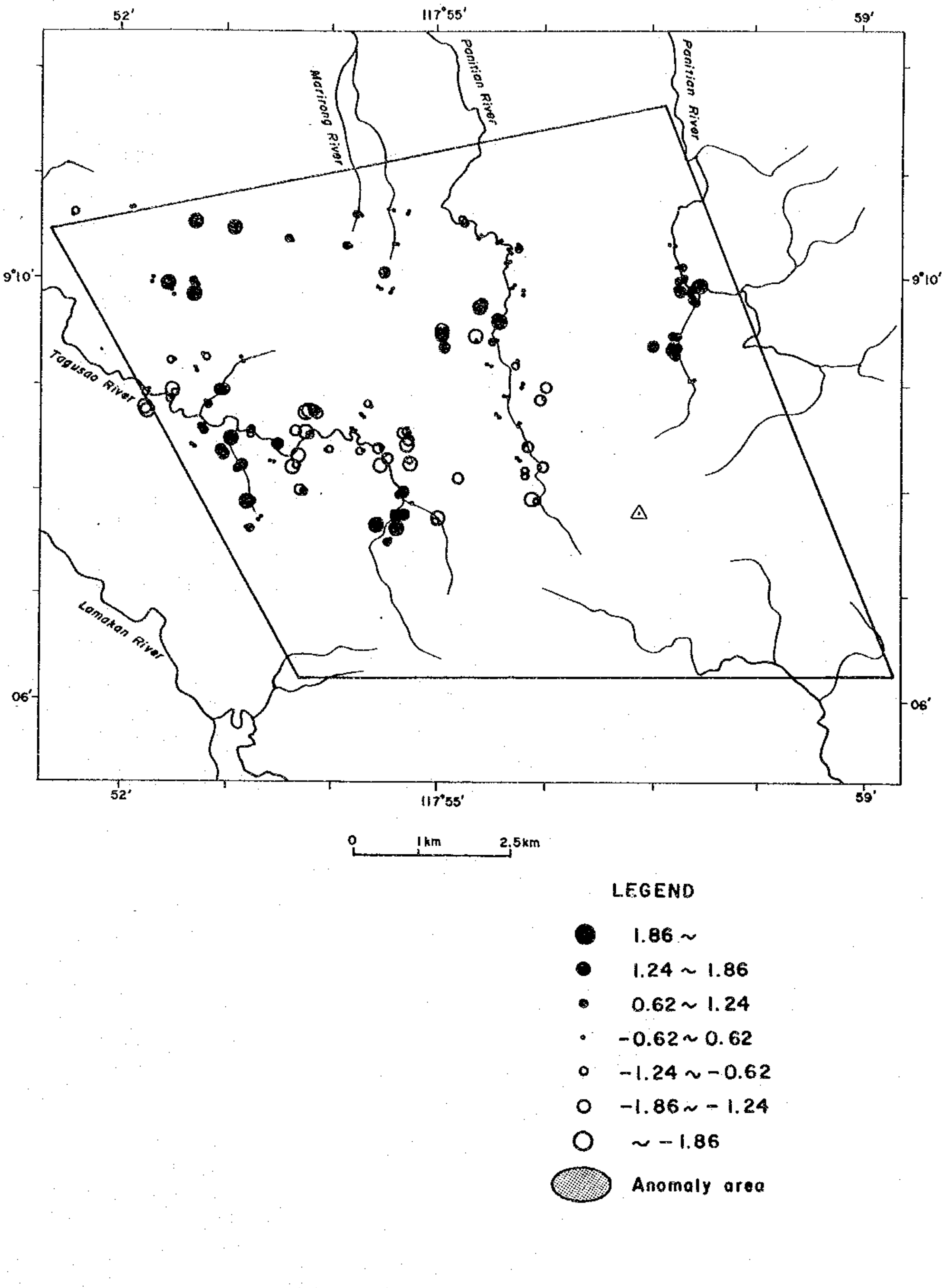


Fig.60 Scores of principal components analysis in C-area(Z1)

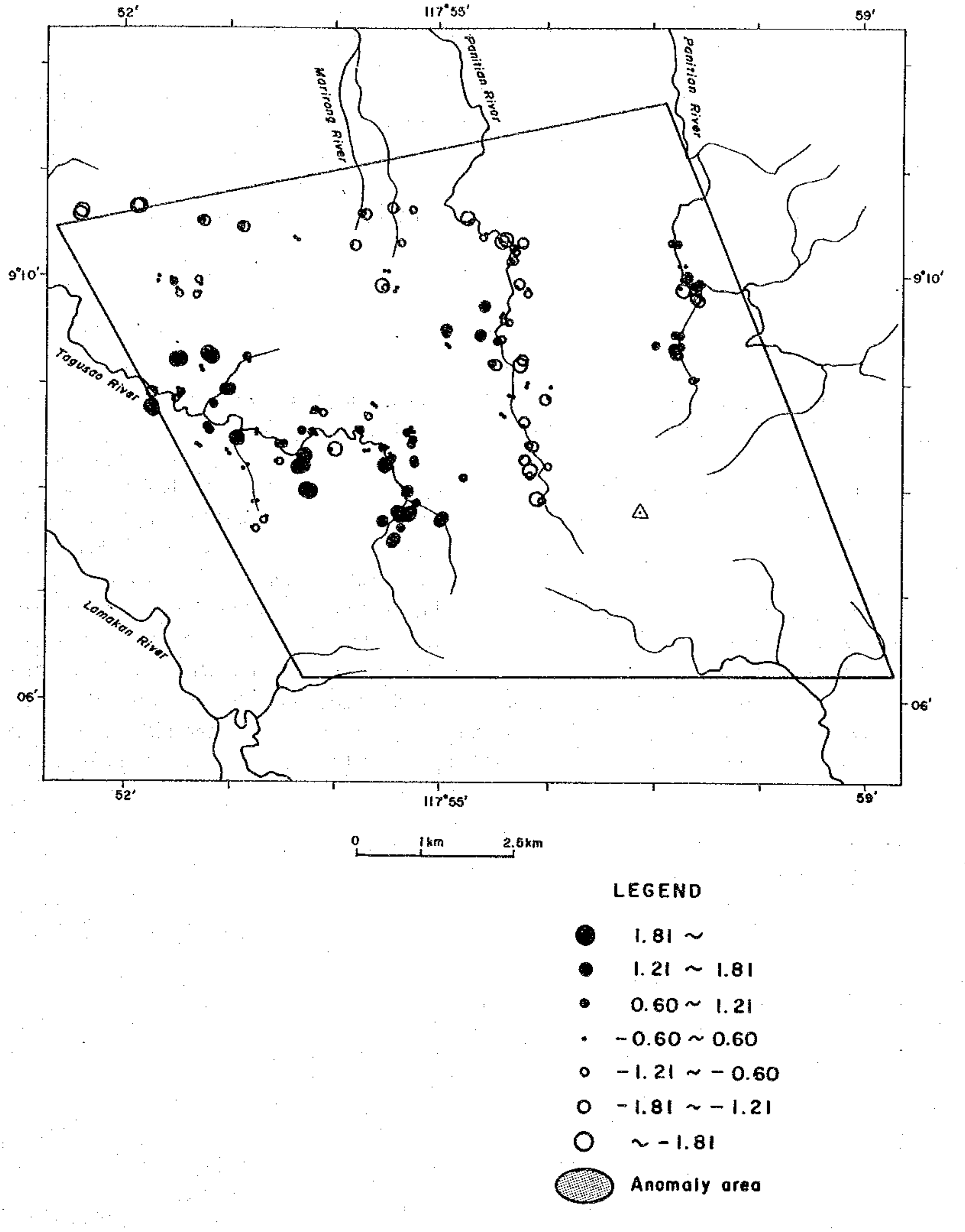


Fig.61 Scores of principal components analysis in C-area(Z2)

chemical analysis of Au and Ag was conducted. The number of samples are 44.

2) Results of chemical analysis

The results of chemical analysis are shown in Appendix 33.

All raw data of Ag are below-detection-limit. Only 5 data for Au is above-detection-limit, and the maximum value for Au was only 6 ppb.

This result is suggestive of no gold and silver deposits in C-area.

3-3 Discussion

Previously, the C-area was mapped as a basalt enclosed area. But the results of this year's geological survey have revealed that the area was largely, about 70 %, underlain by an ultramafic nappe, especially in the upstream areas, overlying the low relief basalt areas.

The geochemical survey was conducted for elements related to copper ores, because the report of the stream sediment geochemical survey previously done yielded a geochemical anomaly related to sulphide minerals. The present survey found no indication for sulfides in the basalt areas, nor chromite indication in the ultramafics.

The soil geochemical survey has revealed relatively high anomalous values for each assayed element. However no mineralization related to those anomalous values was found. The results of the panning survey of stream sediments have revealed no gold and silver indications. Because almost them are less than detection limits. The maximum value for gold was 6 ppb.

The results of the surveys done in the area show no good indication for mineralization. In conclusion, the potential for the mineral deposits in this area is classified as very low.

Chapter 4 Laboratory works

4-1 Result of X-ray diffraction of heavy mineral sand in soil samples

The outlines of geochemically anomalous areas are identified by means of the weight of heavy mineral sand in soils. These areas are almost overlapping with the anomalous areas detected from the soil geochemical survey. The results show that the weight of the heavy mineral sand in soil is a good indicator in identifying the geochemical anomaly.

Since the heavy mineral sand in soil might be composed of several kinds of minerals in addition to chromite, it is necessary to check the kind and amount of minerals of the heavy mineral sand. The heavy mineral sands were checked by means of X-ray diffraction.

The 509 samples of heavy mineral sand were collected from soils by means of panning in A-area, and 2,037 samples are obtained in B-area. Some 29 samples of heavy mineral sand were selected for X-ray diffraction examination from detailed survey area A-1, and another 21 samples from detailed survey area B-1.

The amount of minerals is shown by semi-quantitative means of Chromite Index in Table 18. Chromite Index is treated similarly as the Quartz Index (Hayashi, 1979). Quartz Index is as follows:

$$QI=Im/IqX100$$

where Im is the strongest X-ray intensity of a mineral in the examined sample and Iq is that of pure quartz. Chromite Index used the peak of Norsophil Mine's chromite instead of pure quartz.

In area A-1 samples, chromite, magnetite, ilmenite, hornblende, orthopyroxene and clinopyroxene were detected by X-ray diffraction examination of heavy mineral sands. Chromite has the strongest Chromite Index at all samples. Though magnetite is checked by a magnet and is found somewhat in all samples, magnetite was detected in 10 samples by X-ray diffraction study, and they are sporadically distributed in area A-1. Ilmenite was detected in one sample from near gabbro distribution area. Therefore it appears that this ilmenite derived from gabbro.

Chromite, magnetite, hornblende, orthopyroxene and clinopyroxene have been detected in area B-1 by X-ray diffraction examination. Chromite has the strongest chromite index at all samples. Though magnetite was found in all samples by a magnet, magnetite was detected in only one sample through X-ray diffraction.

The above results show that anomalous areas delineated through the weight of the heavy mineral sand indicate the areas having the high content of chromite in soil.

4-2 Chemical composition of rock samples

The major oxides compositions of 135 rock samples from area A, B, C, A-1 and B-1 are shown in Appendix 34. The analyzed oxides are SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, and LOI(loss on ignition). ICPW normative minerals are also shown in Appendix 34.

The elements related to chromium in ultramafic rocks are also analyzed in geochemical rock

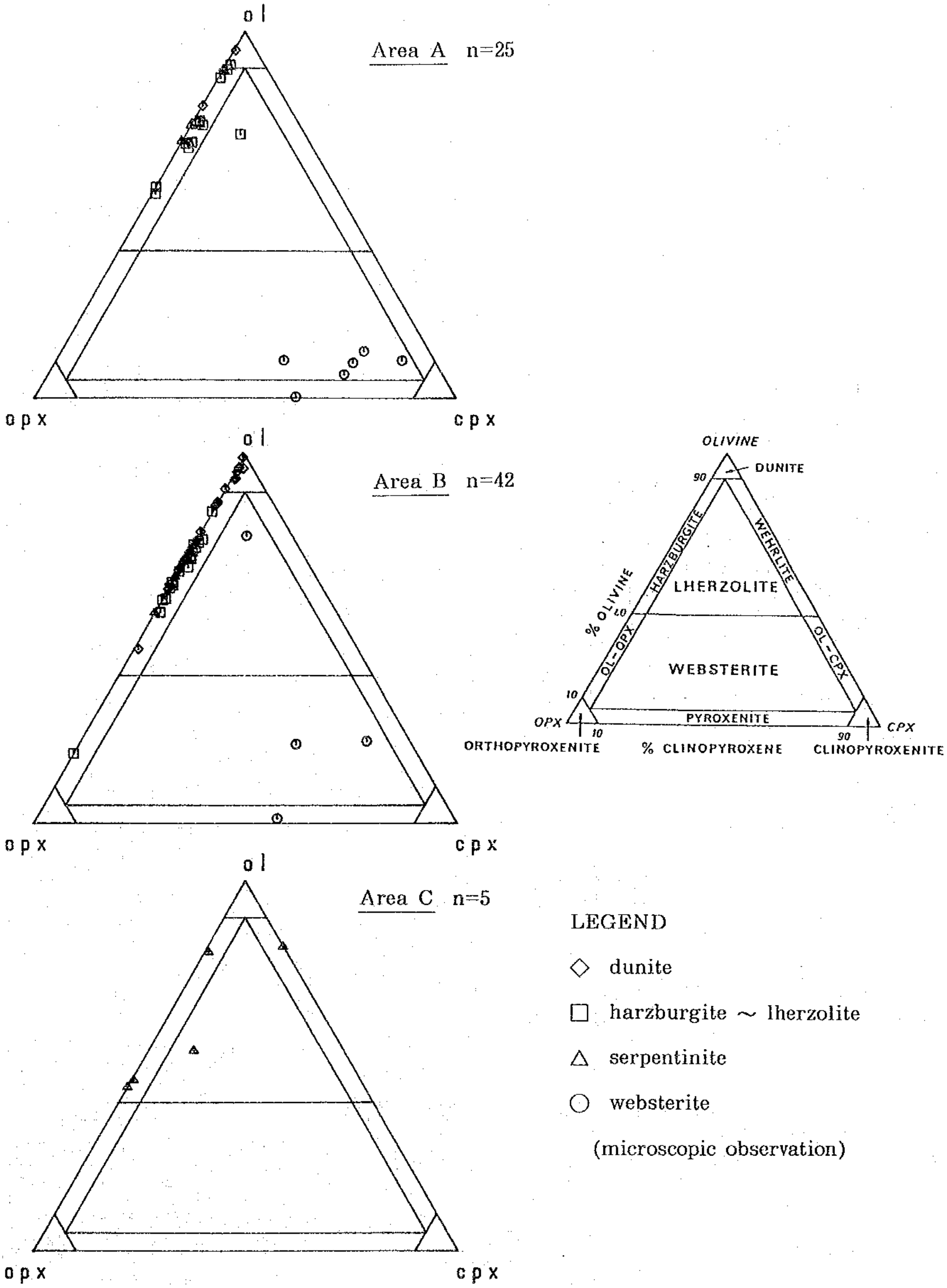


Fig.62 Classification of ultramafic plutonic rocks, used ICPW Norm results

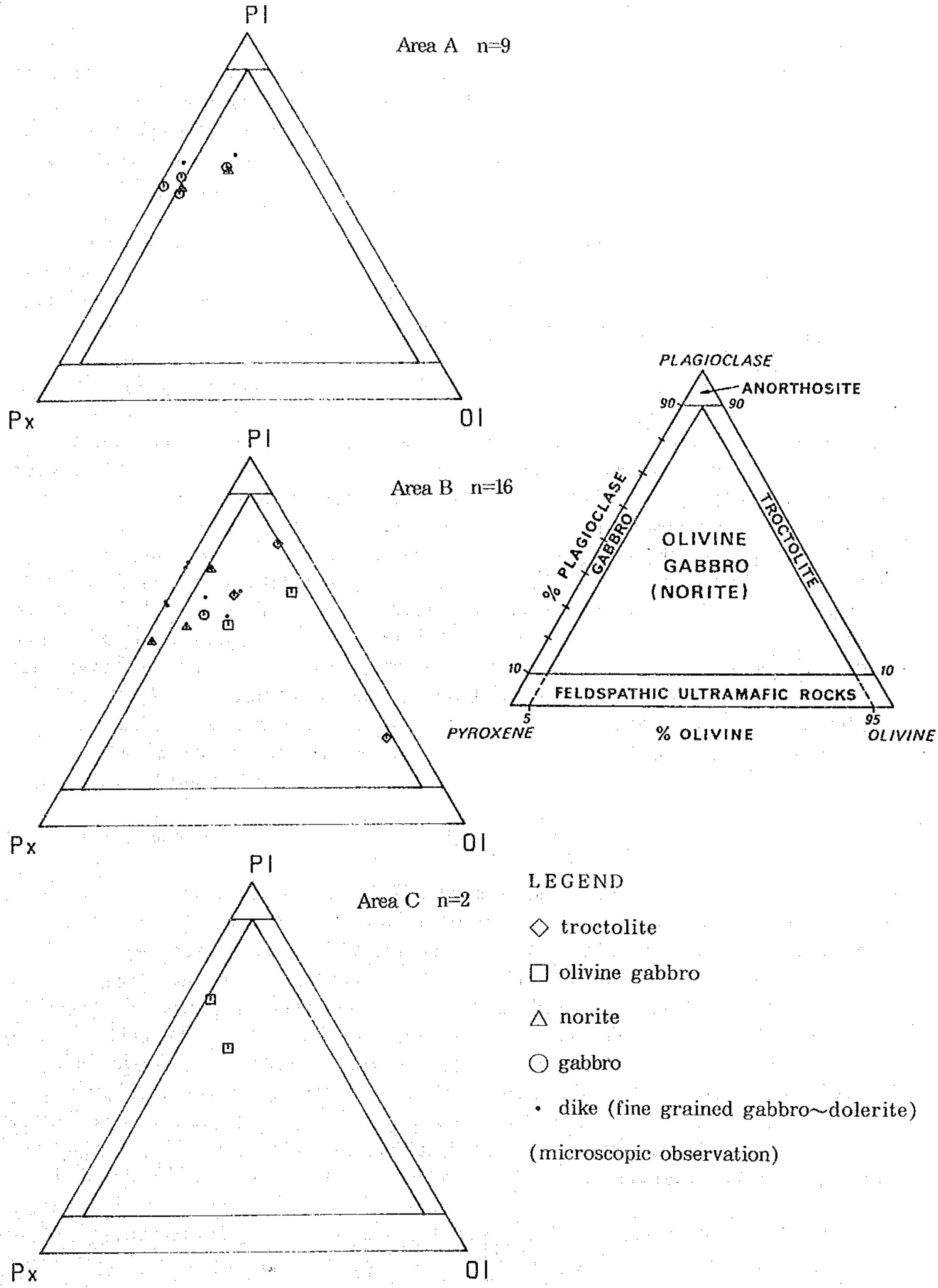


Fig.63 Classification of mafic plutonic rocks, used ICPW Norm results

survey. CrO_2 and NiO are added in Appendix 34, because the content of chromium and nickel can not be disregarded for ultramafic rocks in this survey.

Rock types were determined by megascopic and microscopic observation. The rock types for analyzed specimens are as follows;

Area A (10 specimens): Peridotites (harzburgite, lherzolite, dunite)

Area A-1 (32 specimens): Basalt, dolerite, porphyrite, gabbro, olivine gabbro, peridotite, pyroxenite

Area B (50 specimens): Basalt, basaltic pyroclastic rocks, dolerite, gabbro, olivine gabbro, peridotite, pyroxenite

Area B-1 (22 specimens): Dolerite, olivine gabbro, peridotite

Area C (21 specimens): Basalt, andesite, chert, ferrugenious rocks, serpentinite

4-2-1 Description of rock samples

Ultramafic rocks contain less than 10 % feldspar and effectively no quartz. Nomenclature is based on the relative proportions of olivine, orthopyroxene, and clinopyroxene.

In South Central Palawan almost all types of ultramafic rocks except websterite are shown on olivine-orthopyroxene line, and these rocks are effectively clinopyroxene free (Fig. 62).

In A-area, the peridotite is composed mainly of harzburgite and dunite, with subordinate amount of lherzolite. Websterite in A-area is richer in clinopyroxene and poorer in olivine than websterite in B-area. In B-area, the peridotite is composed of harzburgite and dunite. One websterite sample that carries hornblende is found in the area of lherzolite. The peridotite samples of C-area were strongly serpentinized, their rock types are from harzburgite to lherzolite.

The mafic plutonic rocks are subdivided according to the relative proportions of plagioclase, pyroxene, and olivine. Gabbroic rocks in A-area are classified into gabbro to olivine gabbro based on Fig. 63. Those in B-area are classified into gabbro to troctolite. Those in C-area are classified into olivine gabbro.

4-2-2 Variation diagram

Variation diagram is shows in Fig. 64. The results are as follows;

LOI indicates the amount of volatile components in rocks, and it may be regarded as the degree of alteration of peridotite. The presence of more than 10 percent of LOI in peridotites' samples suggests an extensive serpentinization of peridotite in South Central Palawan.

The peridotites samples have low CaO. Chemically harzburgite and dunite are dominant in this area. Clinopyroxene is found in some peridotite microscopically. As serpentinization leaches CaO, the serpentinized peridotite containing clinopyroxene sometimes show low CaO.

The gabbro masses have lower SiO_2, TiO_2 and FeO, higher Al_2O_3, MgO and CaO than gabbroic dikes, and about the same amount of Fe_2O_3 and Na_2O.

The gabbro dikes have similar composition in spite of their differences in grain size.

The basalts (Espina Basalt) are richer in Fe_2O_3 and K_2O and poorer in FeO than gabbroic dikes.

No significant differences were found between the composition of Sultan Peak Gabbro, except for the presence of troctolite, and that of Stavely Range Gabbro, though these masses are

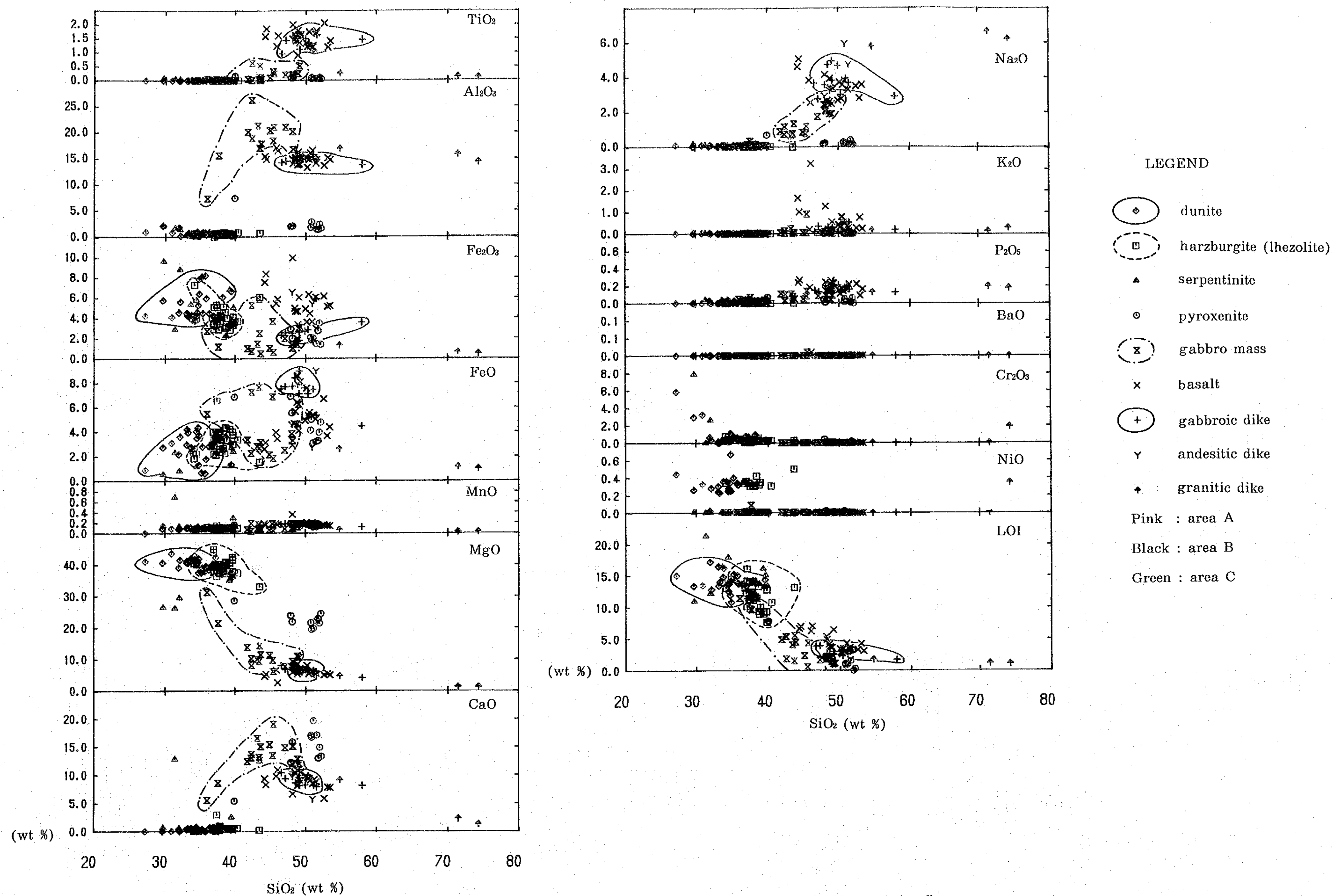


Fig.64 Variation diagram

located separately. The composition of troctolite is intermediate between gabbro, dunite and harzburgite.

4-3 Chemical composition of chromite

Chromite series is one series of spinel group minerals. The end-member of chromite is magnesiochromite ($MgCr_2O_4$) and chromite (ferrochromite, $FeCr_2O_4$). Natural chromites contain a considerable amount of Al and Fe^{3+} replacing Cr. These minerals are often called chromian spinel. Chemical composition of chromite determines directly the grade of ore, because chromite ores are economically divided into three grades due to the wide compositional variation of chromite. Chromite is also extremely sensitive to bulk composition, mineralogy and petrogenesis of the host rocks.

Chromites were analyzed with the electron microprobes for chromitites taken from representative mineral showings in this survey. Fe^{3+} and Fe^{2+} were calculated so that $R^{3+} : R^{2+} = 2 : 1$ in the spinel formula. Core and rim of each grain were analyzed to detect chemical zoning, but there is no apparent chemical zoning.

The Cr/(Al+Cr) versus $Mg/(Fe^{2+}+Mg)$ diagram and Al_2O_3 versus Cr_2O_3 diagram is shown in Fig.65 and 66 .Chromitites from area B-1 have Cr/(Al+Cr) ratios of 0.18-0.56, and the low ratios are found mainly in the middle area. On the other hand, chromitites from A-area,area A-1 and B-area except area B-1 have Cr/(Al+Cr) ratios of 0.58-0.88 Chromites from area A-2 have wide Cr/(Al+Cr) ratios of between 0.36 and 0.83. Those from area A-3 have the ratios of 0.81-0.83. Chromites from the Mariwara area have the ratios of 0.47-0.48. This variation in the Mariwara area is included in the range of area B-1 chromites (0.18-0.56) decided by the Phase 1 survey.

It is reported by Rammlmair et al. (1987) that the chromites from the chromitites occurrence in the Central Palawan ophiolite show the entire variation in major-element chemistry for alpine-type (podiform) chromitites in ophiolite complexes, and Cr/(Al+Cr) values of chromite increase from a shallow level of ophiolite complex to a deeper level, gabbro zone (0.38-0.5), cumulates and diapirs dunite of immediate gabbro lower contact (0.5-0.64), a shallower tectonite level of ophiolite complex (0.64-0.78), and a deep tectonite level (0.78-0.90). These compositional distributions and spatial separation are also found in Zambales. For example, Acoje Mine produces metallurgical-grade ore whereas the Coto district yields refractory-grade ore. In Zambales, Leblanc and Violette (1983) report that the Al-rich chromite pods are contained in the peridotite which underlie the gabbroic cumulates whereas the Cr-rich chromite pods related to deeper peridotite.

The Cr/(Al+Cr) ratios of chromites from area B-1 are lower than those from almost other areas. On the basis of geological survey, the chromitite occurrences in area B-1 are located in a cumulate dunite whereas other chromitite occurrences are distributed in dunite pockets in the harzburgite tectonite, therefore the chromite compositions correspond to the level in ophiolite sequence in these survey areas. The wide range of chromite compositions from mineral occurrences in area A-2 may result from the complicated geology around Nagtabon Pass.

The grade of chromite ore is inferred from the Al_2O_3-Cr_2O_3 diagram of chromite composition (Fig.40). Economically the grade of chromite ore is divided into metallurgical-grade

(Cr_2O_3 > 48 %), chemical-grade (Cr_2O_3 > 45 %), and refractory-grade (Cr_2O_3 > 30 %, Cr_2O_3+Al_2O_3 > 60 %). The mineral occurrences are classified as follows;

Metallurgical-grade
Area A-1:Upper Pananlagan
Area A-2:Nagtabon No .1, Nagtabon No .2
Area A-3:Pagasa 1, Pagasa 4
Mineral showings in area-B except those in area B-1

Chemical-grade
Area A-1:Tagkawayan
Area A-2:Easternmost

Refractory grade
Area A-2:Maranat, Nagtabon No .3
Area B-1:Mariwara

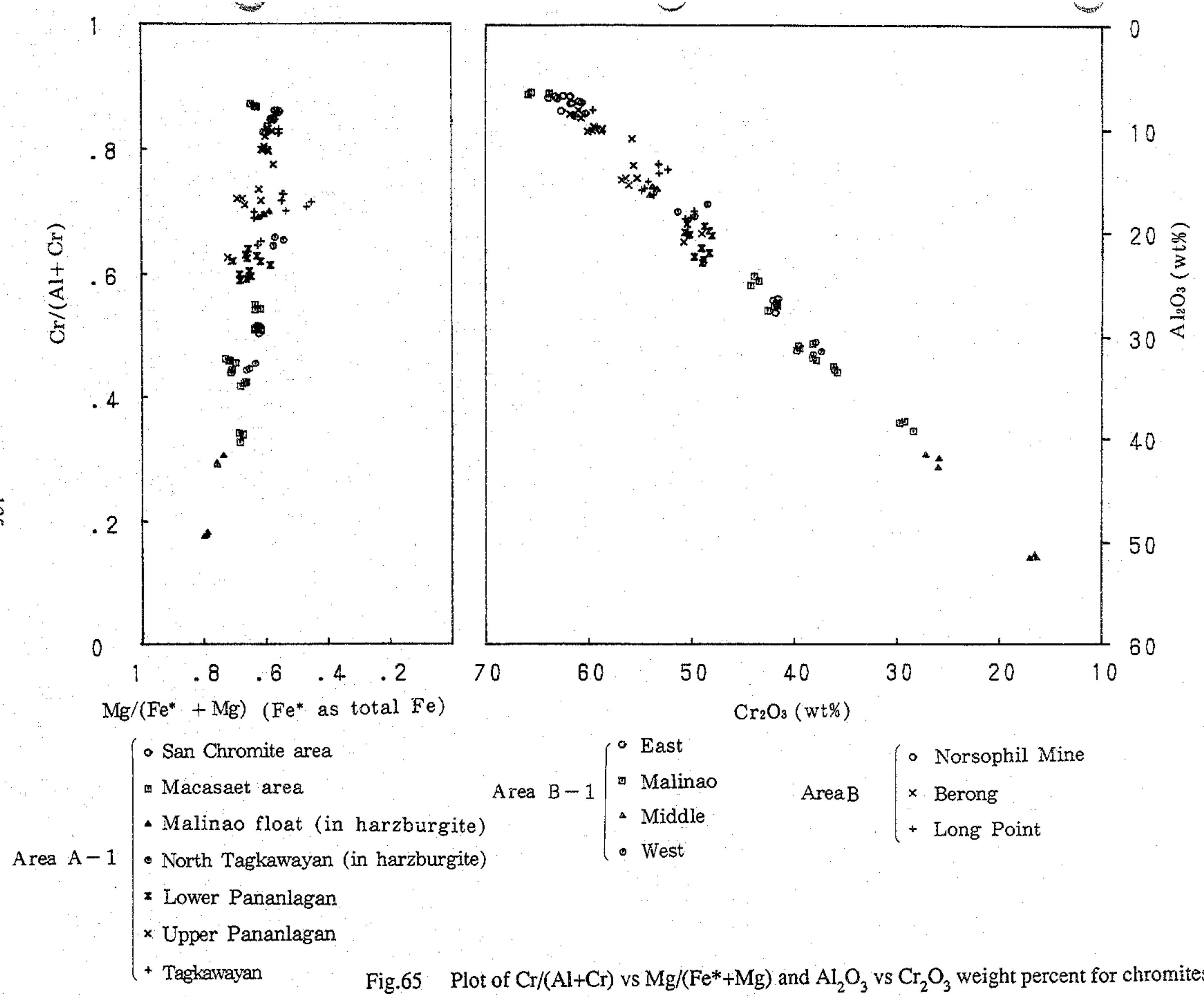
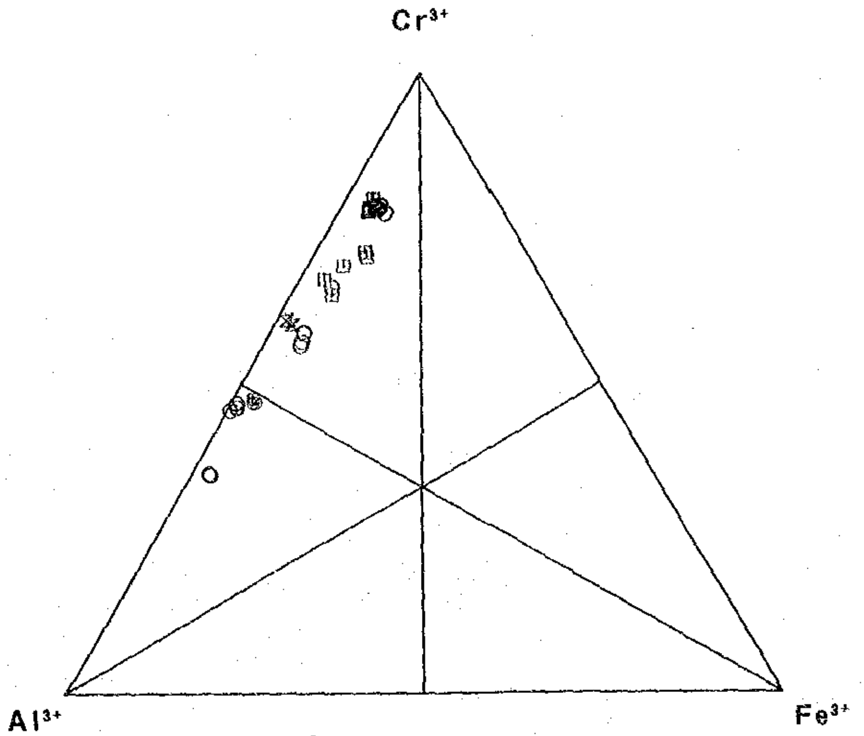


Fig.65 Plot of Cr/(Al+Cr) vs Mg/(Fe*+Mg) and Al_2O_3 vs Cr_2O_3 weight percent for chromites



Cr - Al - Fe^{3+} triangular plot for the chromites

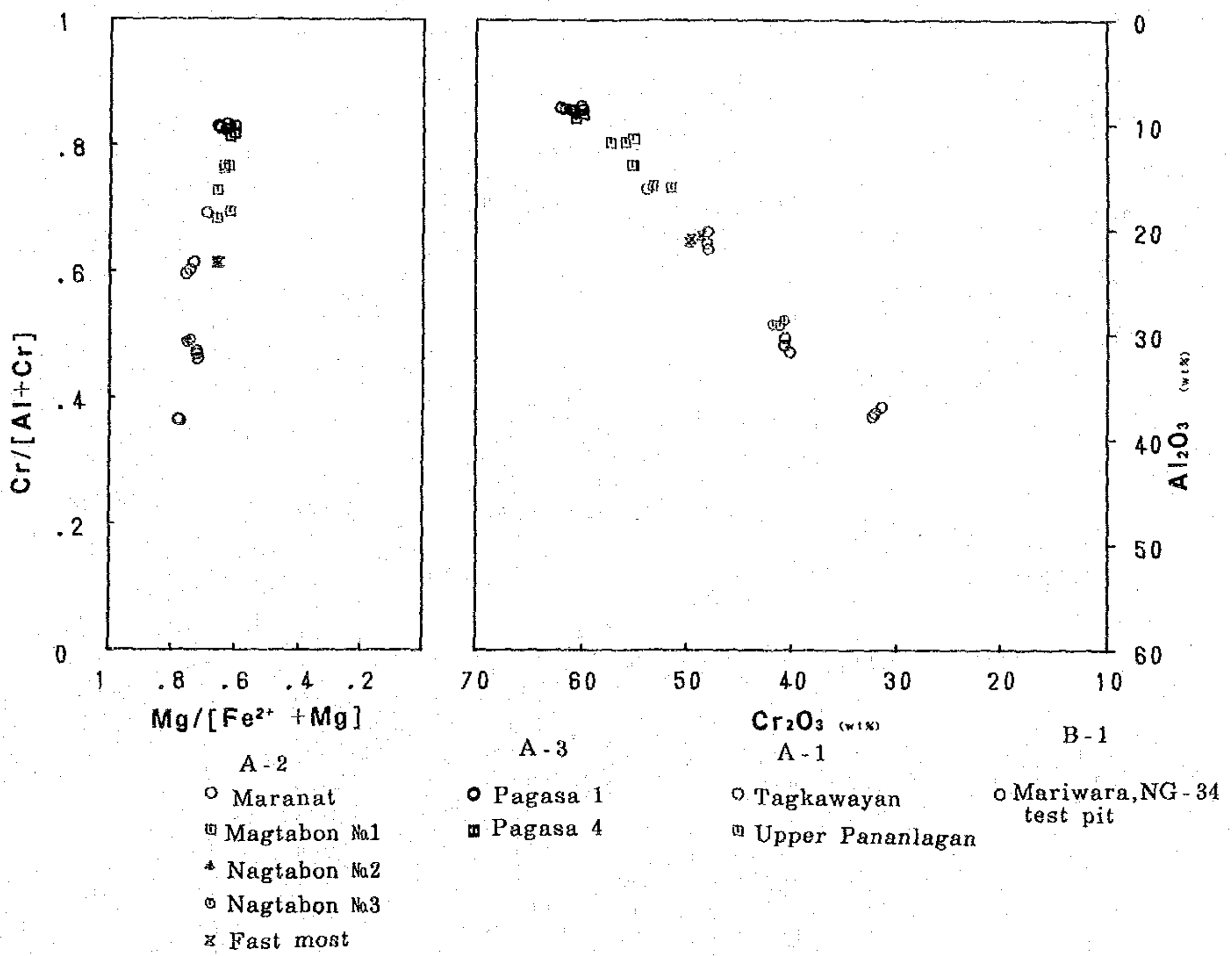


Fig.66 Plot of Cr/(Al+Cr) versus $Mg/(Fe^{2+}+Mg)$ and Al_2O_3 versus Cr_2O_3 weight percent for chromite

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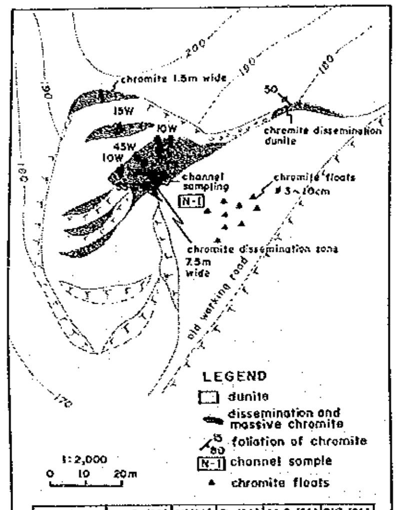
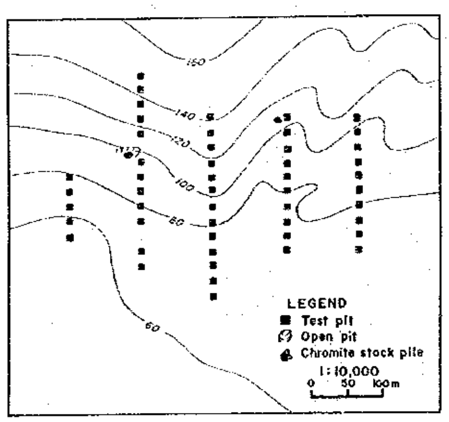
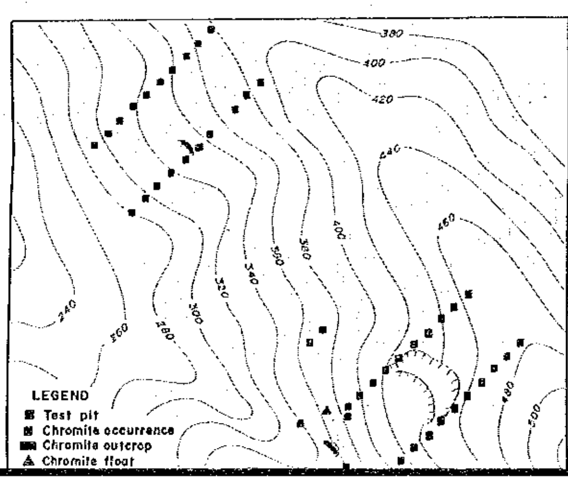


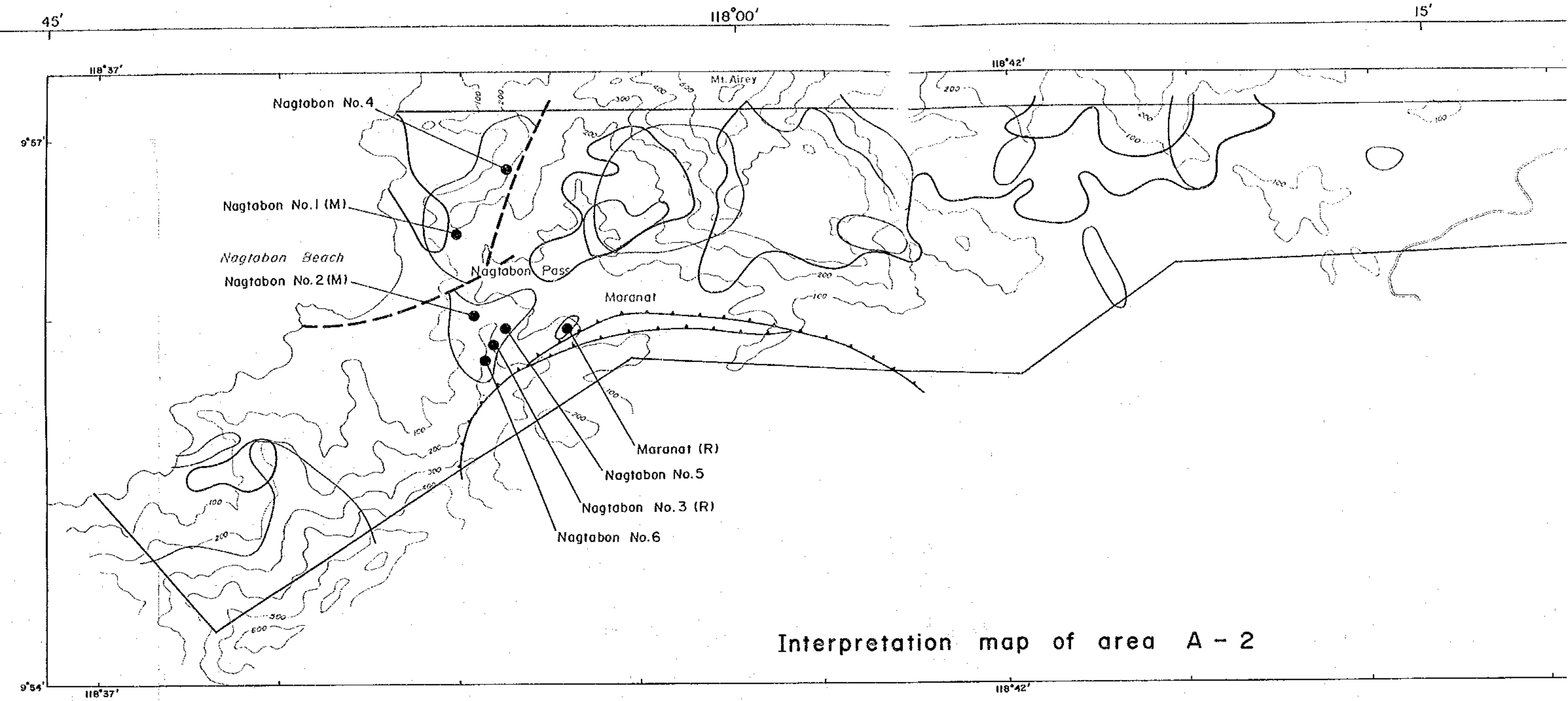
Sample No.	Cr_2O_3(%)	Ni(%)	Fe(%)	Al_2O_3(%)	SiO_2(%)
N - I	12.59	0.23	7.70	4.49	31.78

Map of the Nagtabon No.1 old working

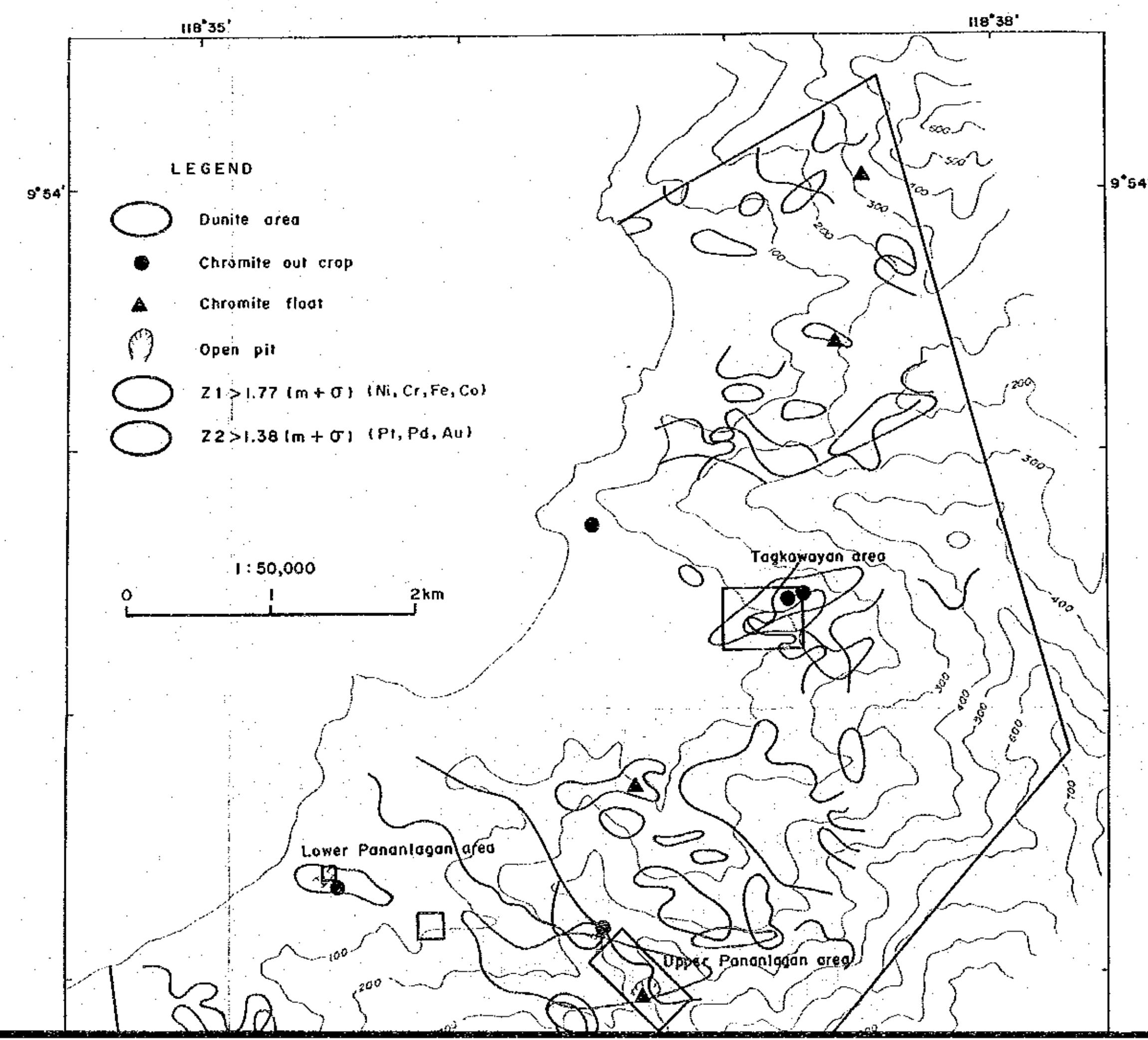


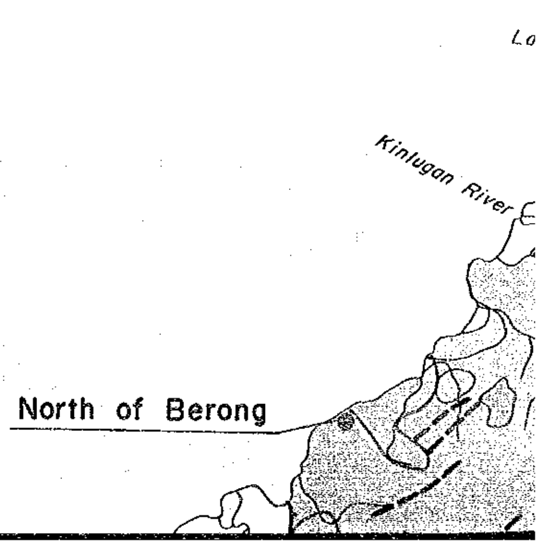
Location of test pits in the Tagkawayan area



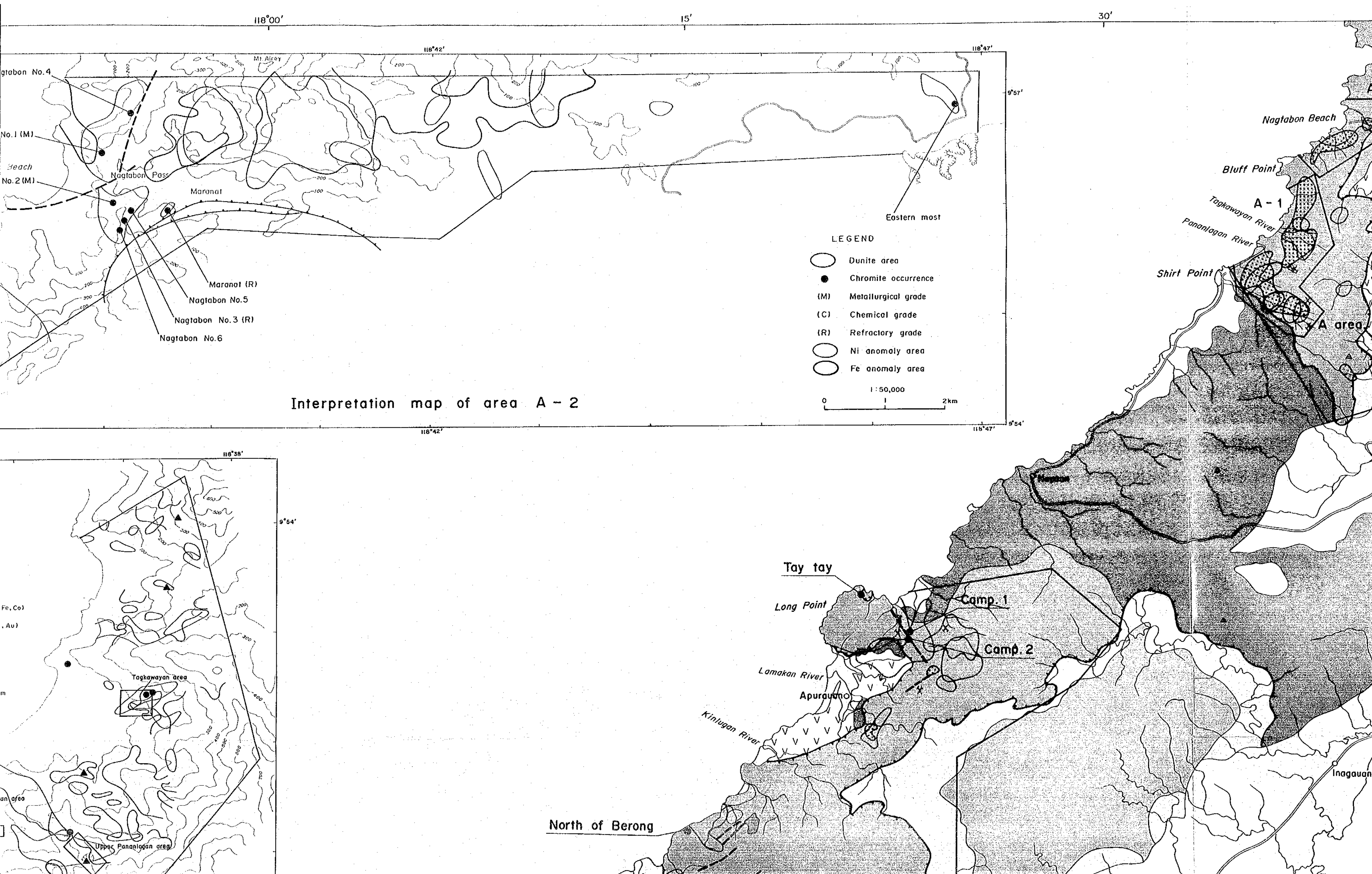


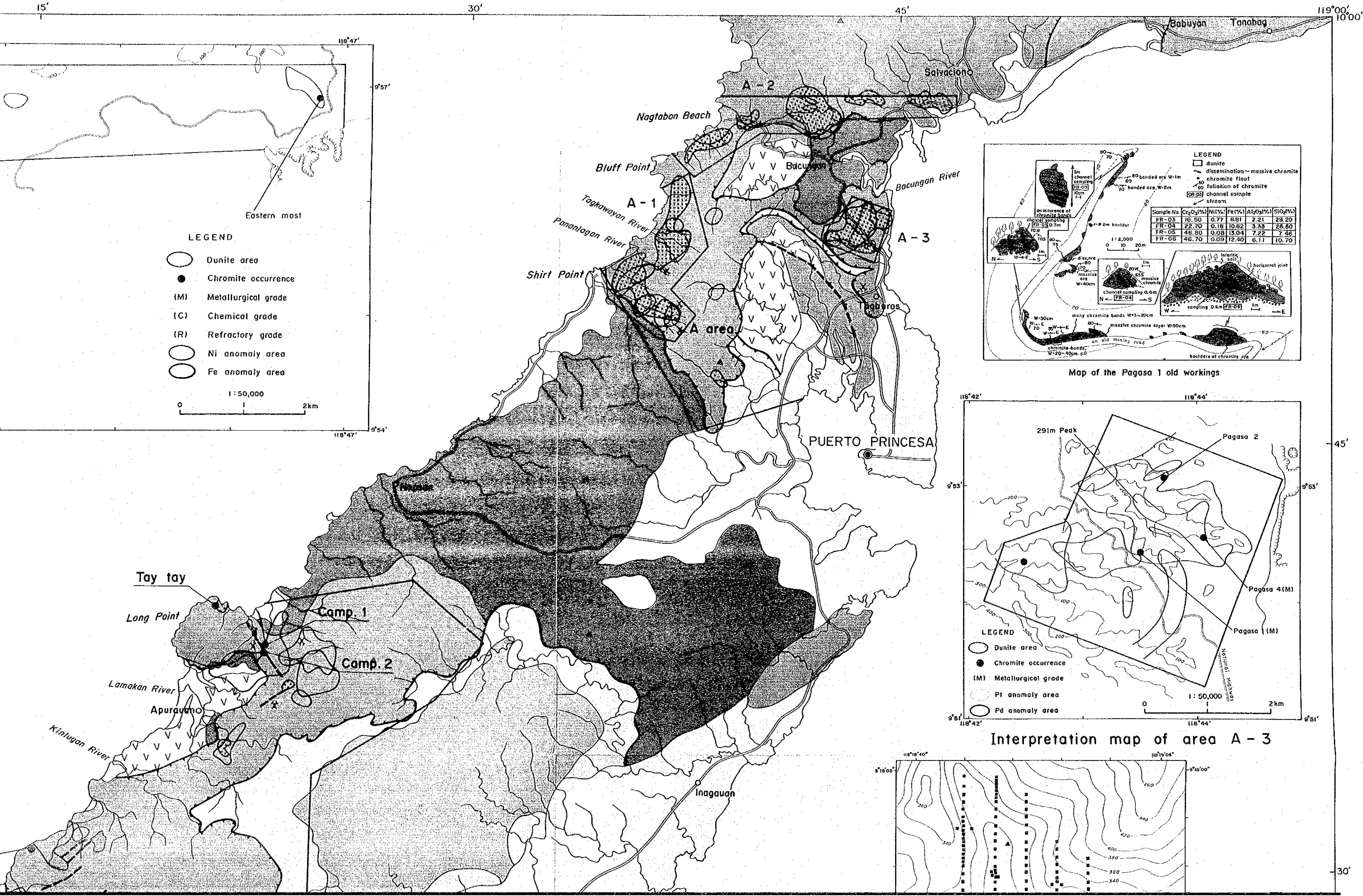
Interpretation map of area A-2





North of Berong

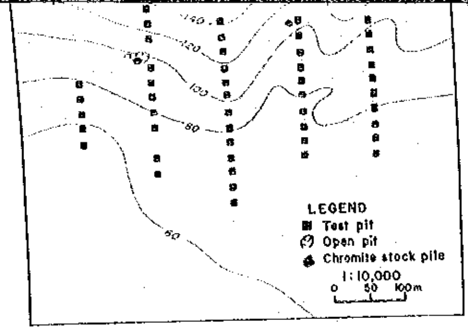

118°00'
15'
30'
118°42'
118°47'
9°57'
9°54'
Mt Airey
Nagtabon No. 4
No. 1 (M)
Beach
Nagtabon Pass
No. 2 (M)
Maranat
Maranat (R)
Nagtabon No. 5
Nagtabon No. 3 (R)
Nagtabon No. 6
Eastern most
LEGEND
Dunite area
Chromite occurrence
(M) Metallurgical grade
(C) Chemical grade
(R) Refractory grade
Ni anomaly area
Fe anomaly area
1 : 50,000
0
1
2km
Interpretation map of area A - 2
118°38'
Tagkawayan area
Upper Pananlogan area
Nagtabon Beach
Bluff Point
A - 1
Tagkawayan River
Pananlogan River
Shirt Point
A area
Tay tay
Long Point
Camp. 1
Camp. 2
Lamakan River
Apurauano
Kinlugan River
North of Berong
Inagauan



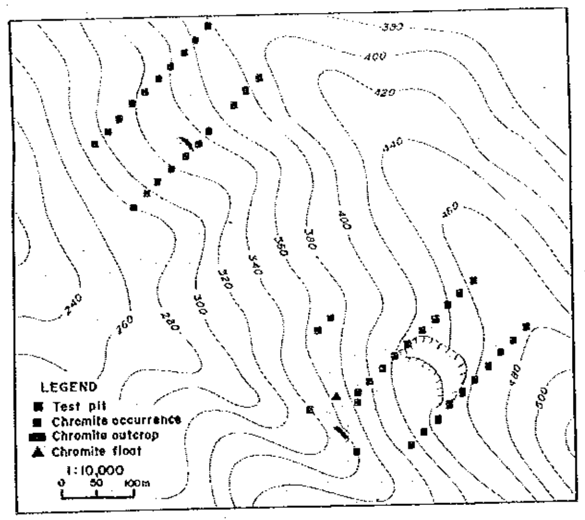
Sample No.	Cr_2O_3(%)	Ni(%)	Fe(%)	Al_2O_3(%)	SiO_2(%)
FR-03	16.50	0.77	8.81	2.21	29.20
FR-04	22.70	0.18	10.82	3.33	26.60
FR-05	46.80	0.08	13.04	7.22	7.46
FR-06	46.70	0.09	12.40	6.11	10.70

Map of the Pagasa 1 old workings

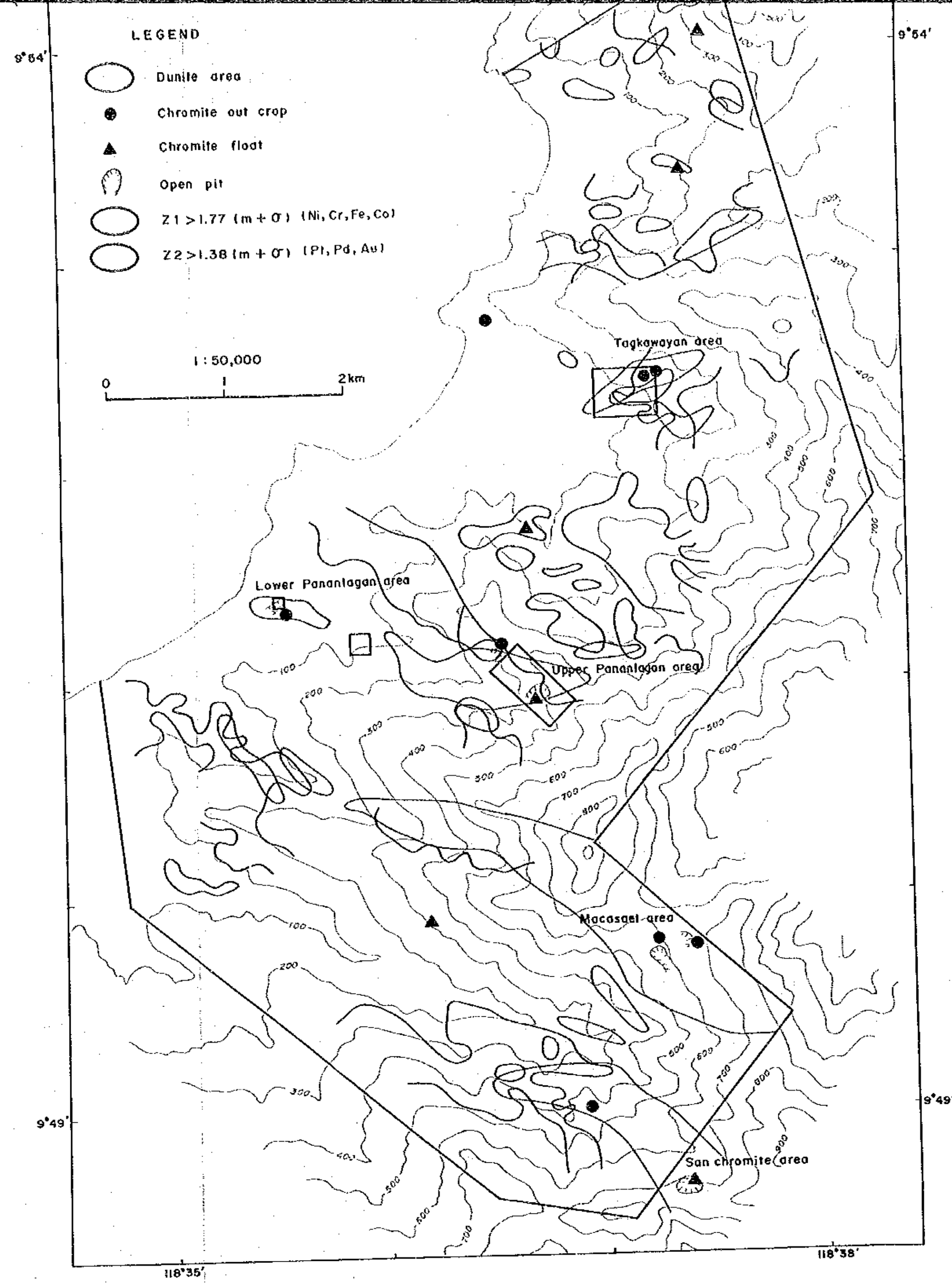
Interpretation map of area A - 3



Location of test pits in the Tagkawayan area



Location of test pits in the Upper Pananlagan area



Interpretation map of area A - 1

LEGEND

Miocene and Quaternary sedimentes

Eocene turbidites

Basalt

Gabbro

Ultrabasic rocks Harzburgite and Dunite

Metamorphic sandstones and shales

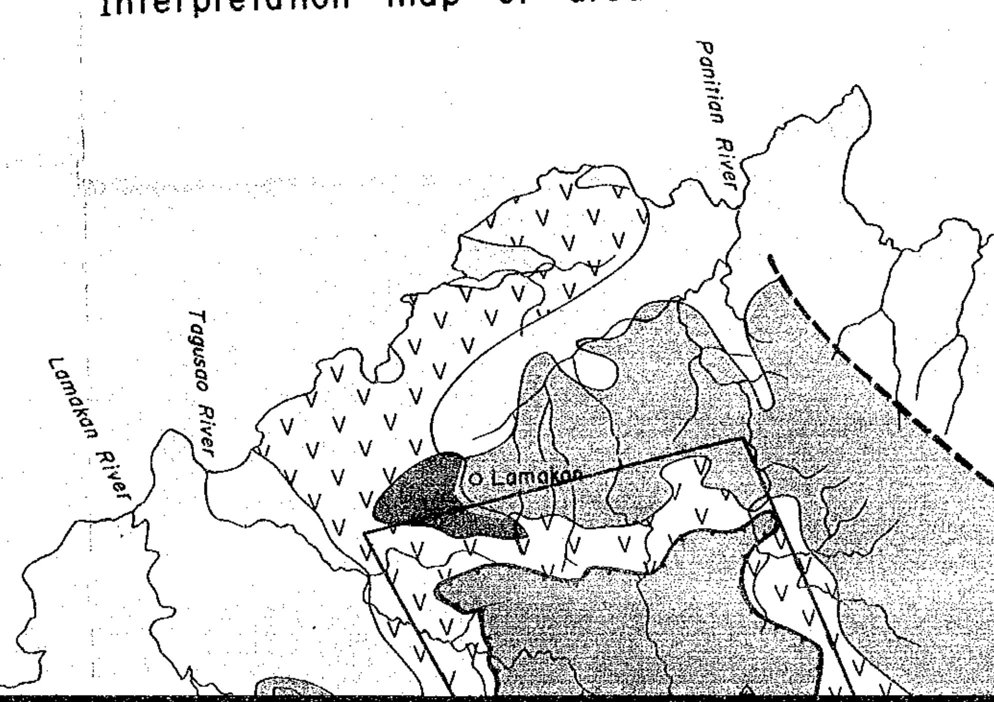
Fault

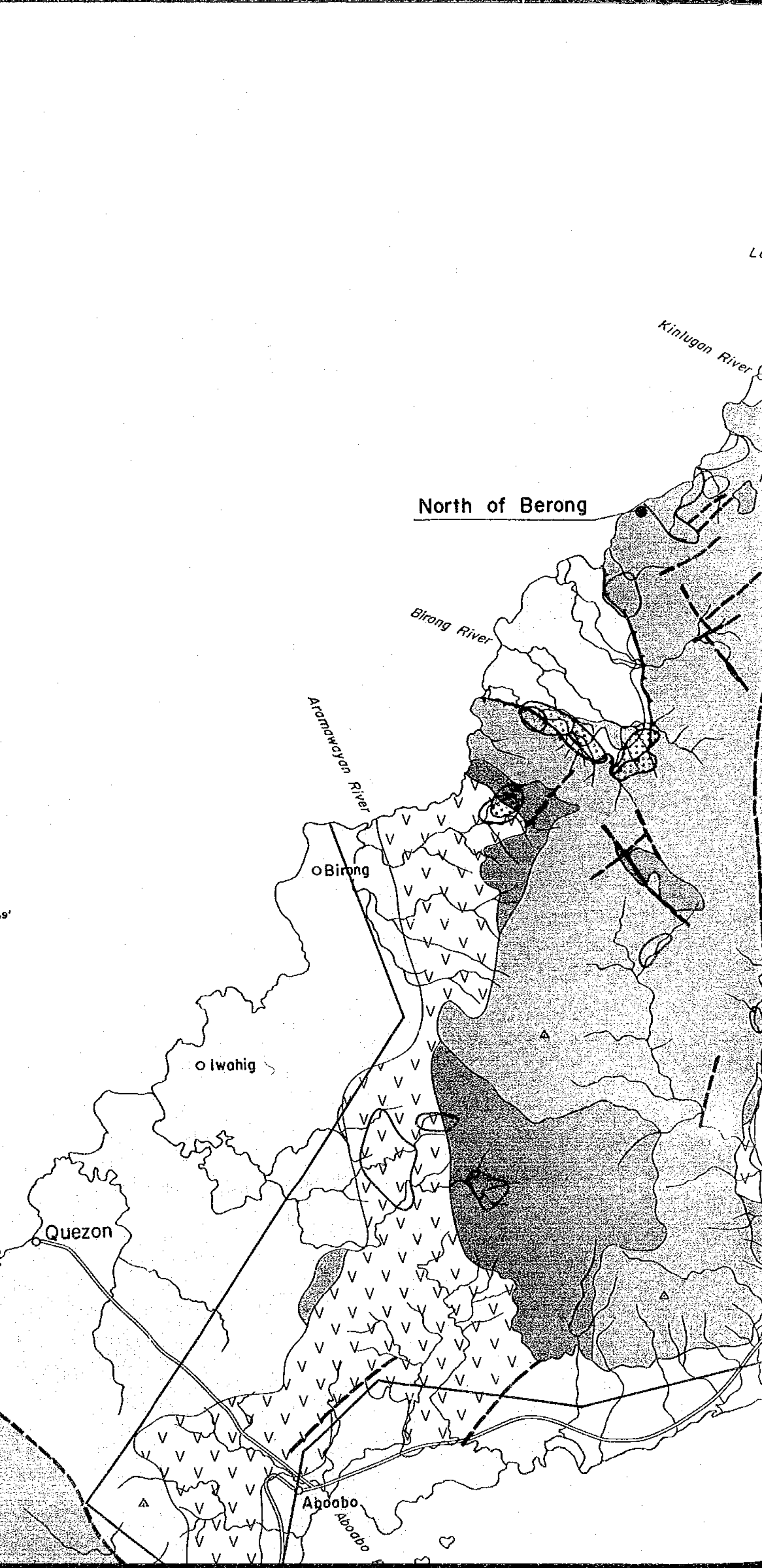
Thrust

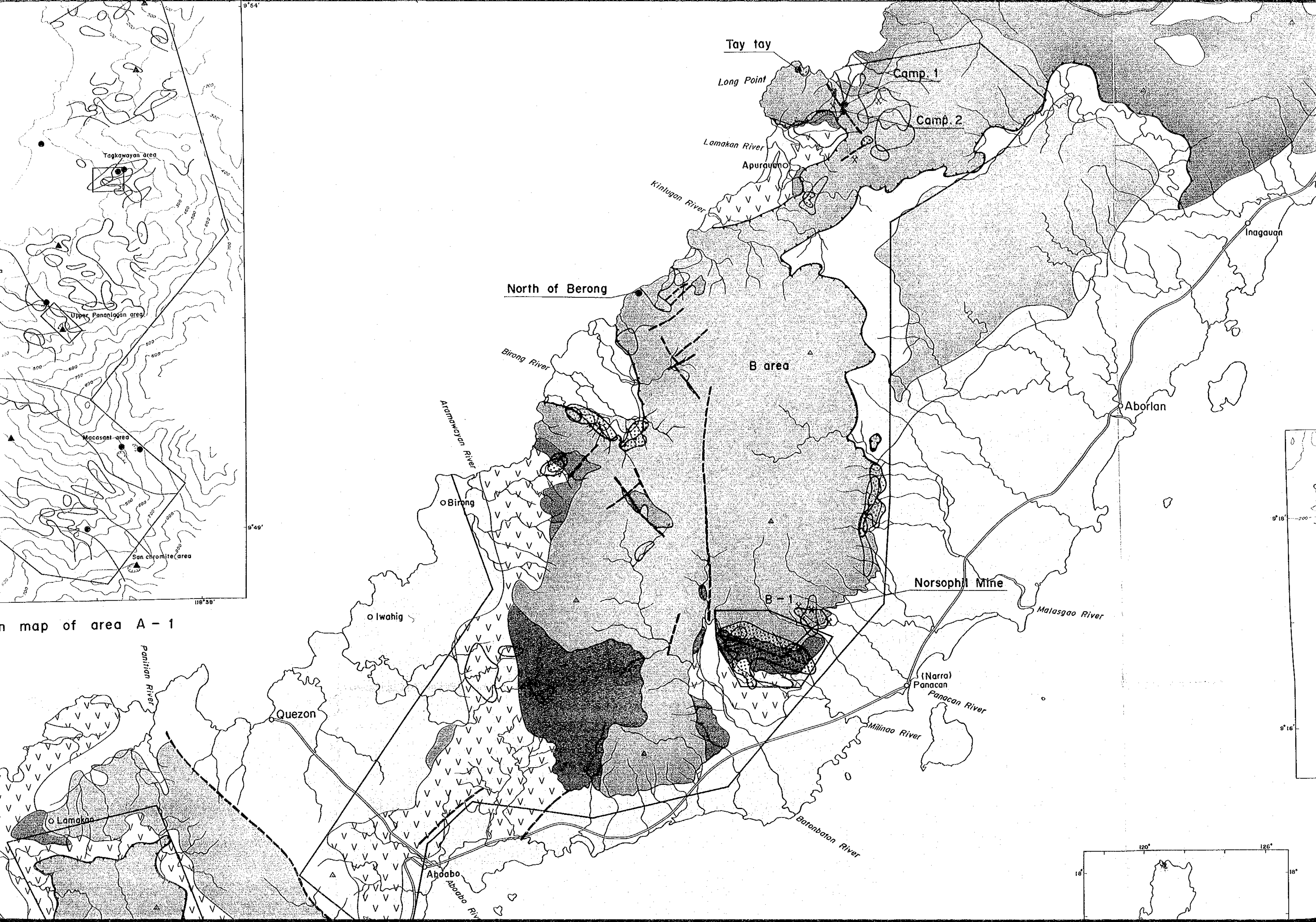
Survey Area

Heavy mineral >32g / soil 1kg

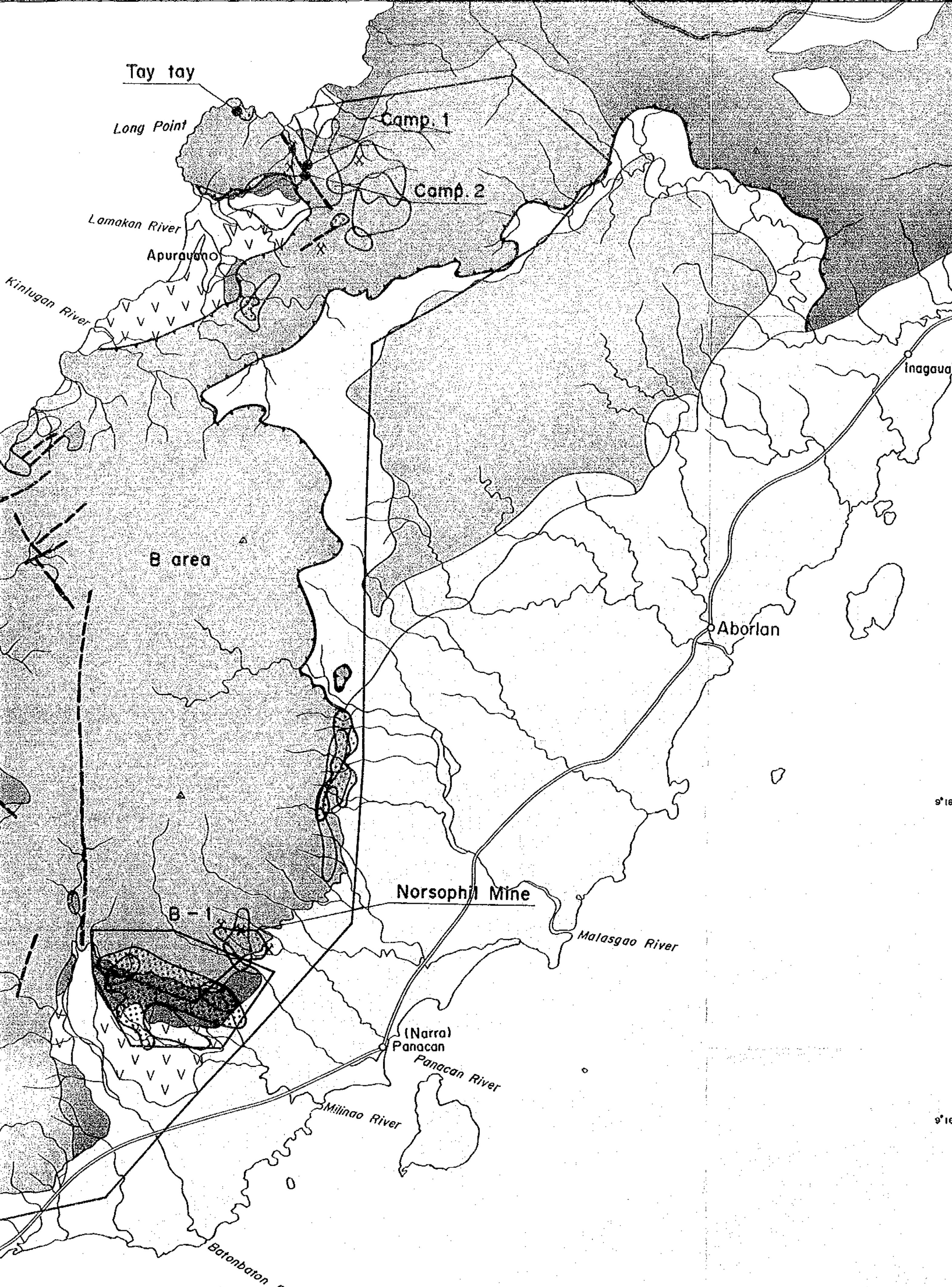
Z1 > 1.98 (m + σ) (Ni, Cr, Fe, Co)

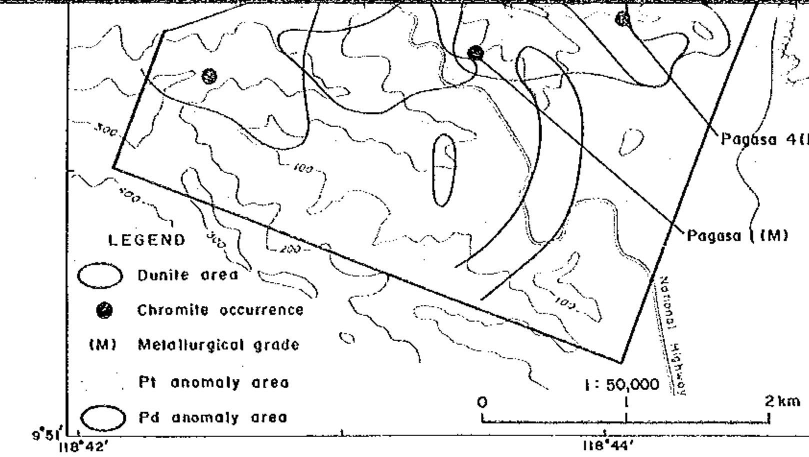




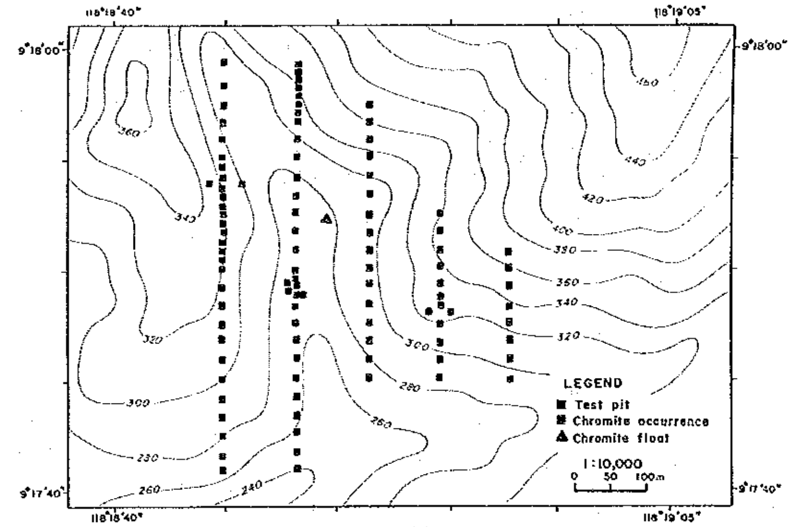


Tay tay
Long Point
Camp. 1
Camp. 2
Lamakan River
Apurauan
Kinlugan River
North of Berong
Birong River
B area
Aramawayan River
Birong
Norsophil Mine
B-1
Malasgao River
Inagauan
Aborlan
(Narra)
Panacan
Panacan River
Milinao River
Iwahig
Quezon
Panitian River
Lamakan
Aboabo
Aboabo River
Batonbaton River
Tagkawayan area
Upper Pananiagan area
Macasaet area
San chromite area
9°54'
9°49'
118°38'
9°18'
9°16'
120°
126°
18°
n map of area A − 1

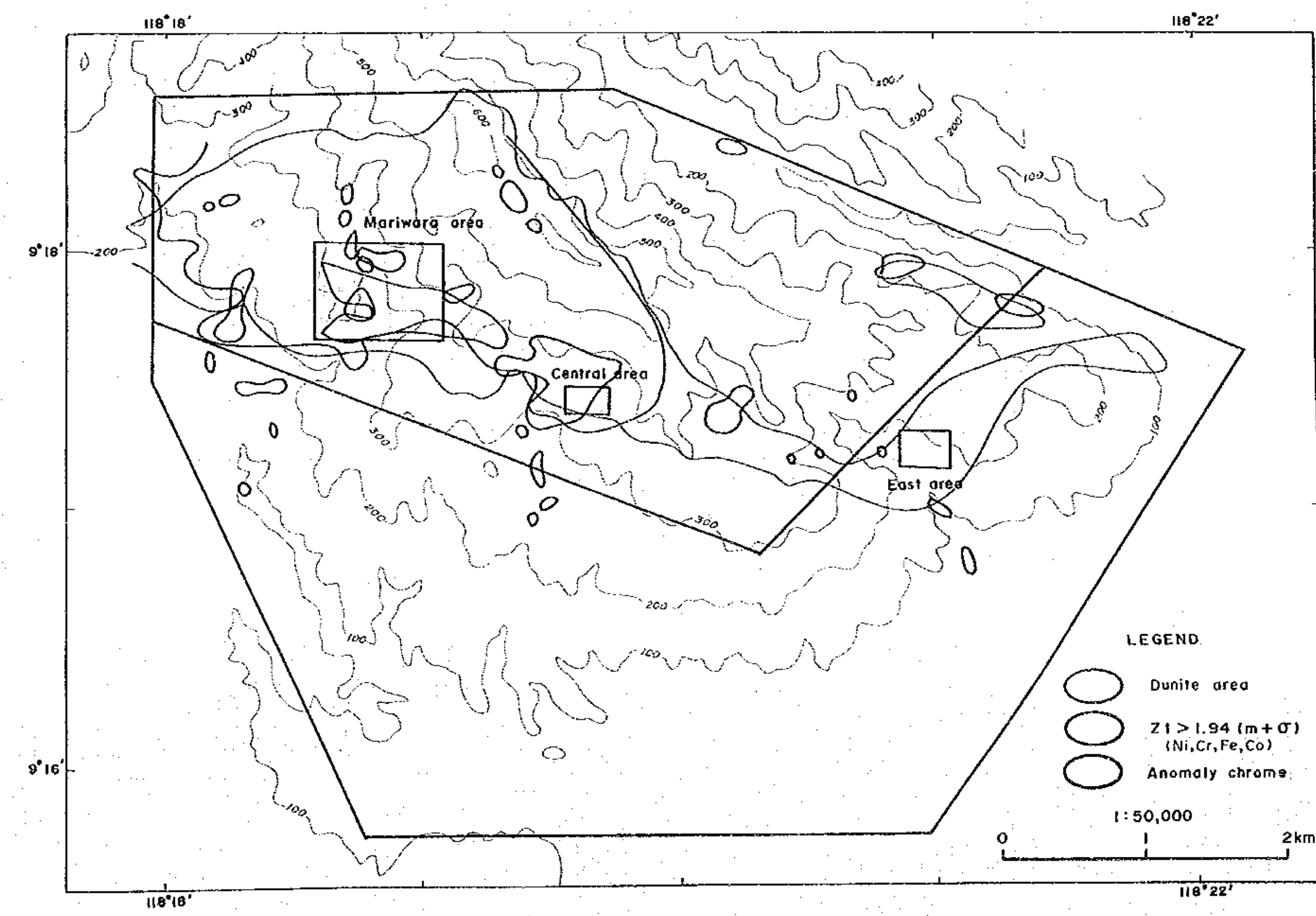




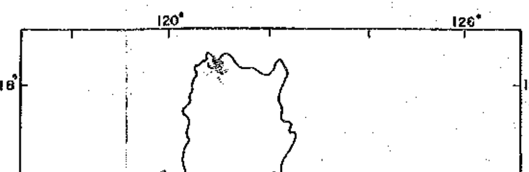
Interpretation map of area A - 3



Mineral occurrences and test pits in the Mariwara area



Interpretation map of area B - 1



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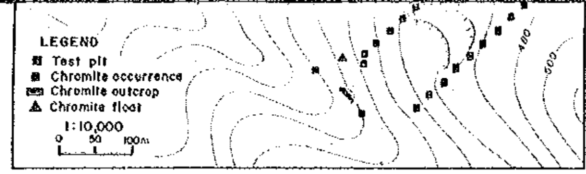
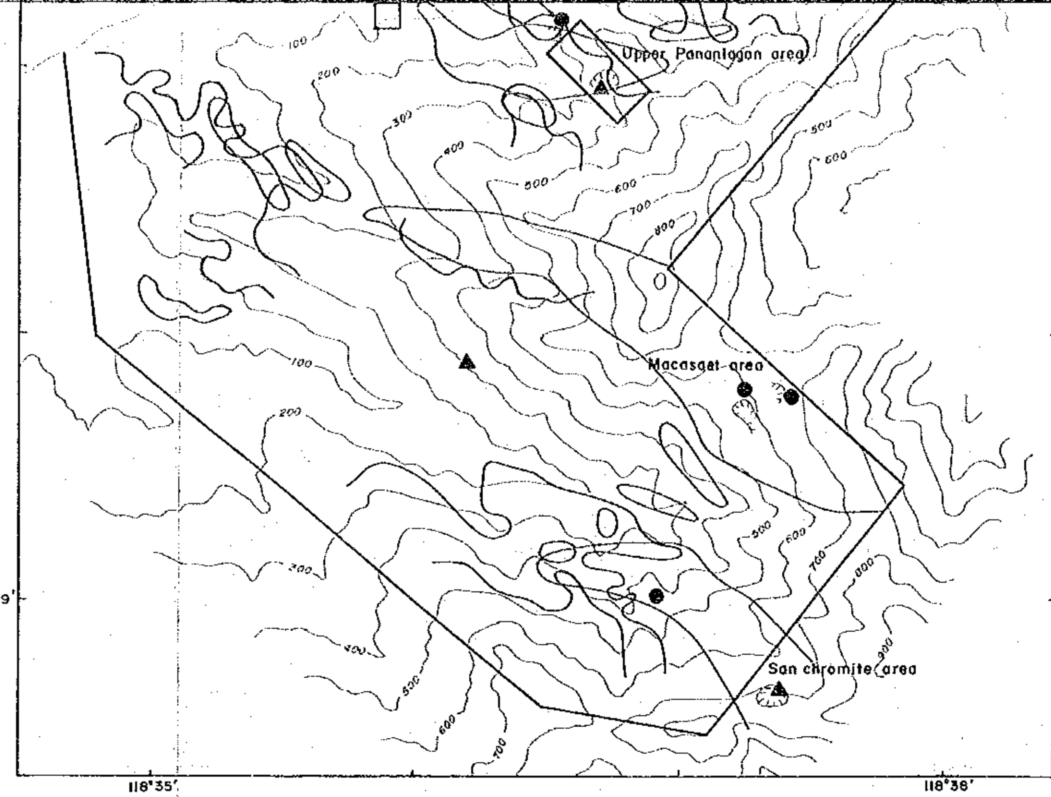
1993.1



Location of test pits in the Upper Panantagan area



Interpretation map of area A - 1