2-5-4 Ore deposit and mineral showings

The principal ore deposits in the B-area are chrome deposits associated with the ultramafic rocks and nickel deposits associated with laterite resulted from the weathering of the ultramafic rocks.

Several chromite deposits and showings are distributed in the area. The Norsophil Mine is a typical one, and presently in operation.

The survey conducted by JICA-MMAJ (1989) in the Victoria Area, included in the B-area, revealed following six ore deposits and mineral showings.

West Coast: The upstream area of the Tagbolante River
The upstream area of the Berong River
East Coast: The upstream area of the Malasgao River
The upstream area of the Tarateon River
The upstream area of the Panacan River
The upstream area of the Malinao River

The mineral showings in the upstream area of the Panacan River and the upstream area of the Malinao River are in detailed survey area B-1. The former is chromite concentration in the weathered sandy dunite, and the latter is of chromite dissemination in the dunite.

This survey conducted in the B-area has revealed new occurrences in the following zones; Camp-1, Camp-2, Taytay, and north of Berong.

Detailed survey area B-1 was selected as a high potential area based on the facts that it is situated on the south of the Norsophil Mine and the existence of the dunite. The test pit survey has been conducted in the detailed survey area to confirm the distribution of the dunite and the existence of chromite occurrences, but no new mineral showings was found.

As for nickel, though the survey done by JICA-MMAJ (1989) revealed garnierite occurrences in the Norsophil Mine area, near Bethlehem, and near Berong, however the survey this time failed to find new occurrences.

1) Camp-1 and Camp-2

Camp-1 showings is located in the middle part of the river north of Long Point on the west coast of the B-area, and Camp-2 showings is located 500m upstream of Camp-1.

Chromite is associated with the small scale diapir-like dunite bodies intruded into the harzburgite. It is weathered badly turning to yellowish brown, and is softened. It has been mined out little by little by the local people. The mining face shows the harzburgite 1.3m to 1.6m deep from the surface, and below it lies the dunite. In the top 20cm of the dunite, chromite is disseminated, and below that massive chromite occurs.

2) Taytay

This occurrence is located on the northern slope of Long Point, and occurs in the weathered dunite. It is small scale, and the single unit is less than 1m thick and several meters long. Its continuity is poor. There are several mining faces, several meters wide and 5 to 10m long. It is presumed that only prospecting was conducted. No mining is being done there now. (Fig.43)

3) Northern Berong

The northern Berong showing is located on a slope facing the South China Sea, approximately 5 km northeast of the ore storage area of the Atlas Mine. The deposit is of lens shape chromite ore in the serpentinized ultramafic rocks. It is very small scale, approximately 1m thick and several meters long. There are two mining faces, 3m wide and 10m long.

4) Norsophil Mine

The mining activity was re-opened by Norsophil Metal Resources Inc. at the Norsophil Mine in 1990. The production of the crude ore is 250 tons/day, and its grade is 17% Cr_2O_3. The production of the concentrates is 2,000 tons/month, and its grade is 48% to 52% Cr_2O_3. The total number of employees is about 300.

5) South Central Part of the Detailed Survey Area B-1b

The area is located on the left bank in the middle of the Malinao River. Fifteen test pit were dug in the south central part of the detailed survey area B-1b, to find chromite showings, but

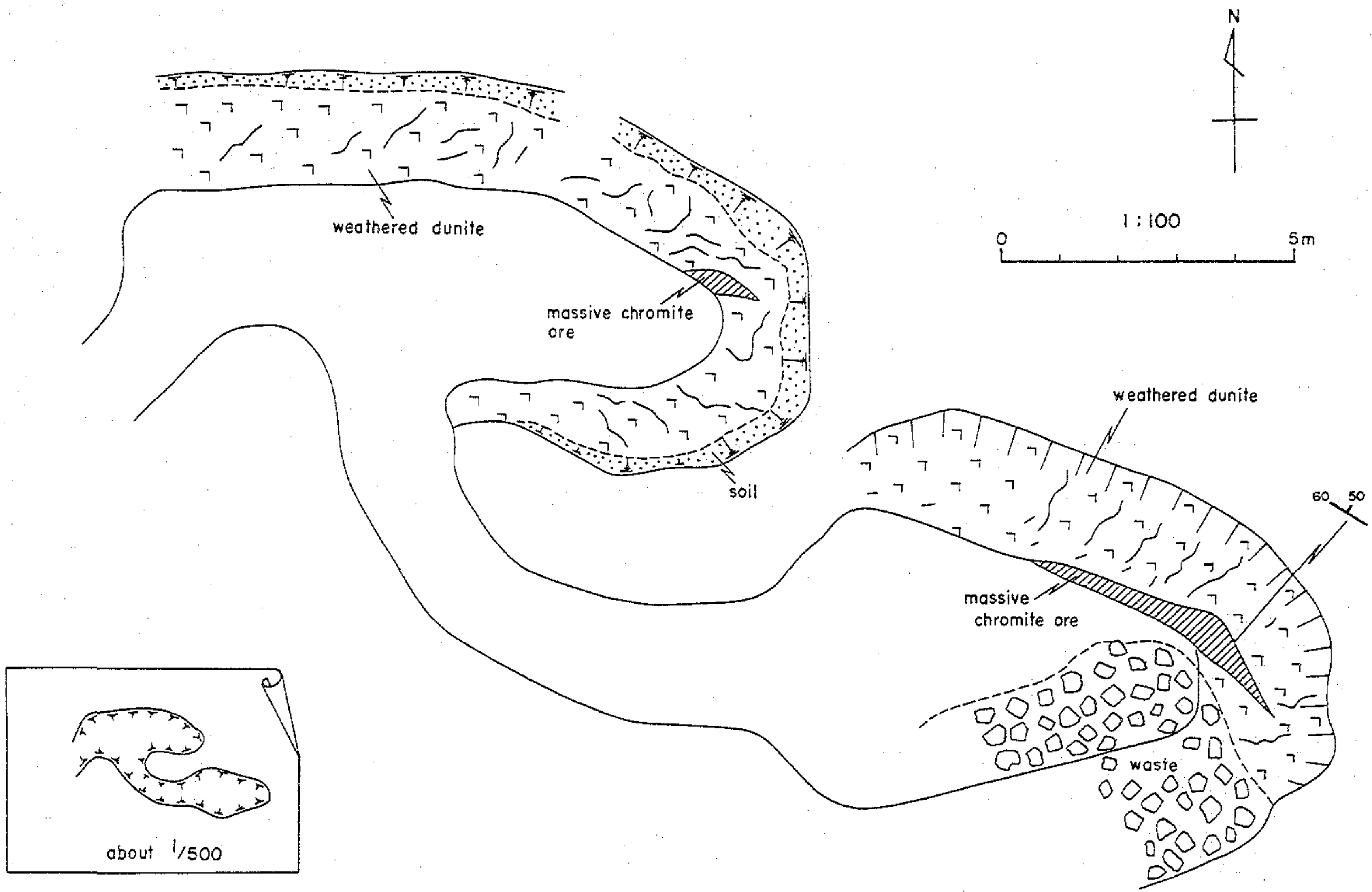

Fig. 42 Taytay chromitite outcrop in Long Point area

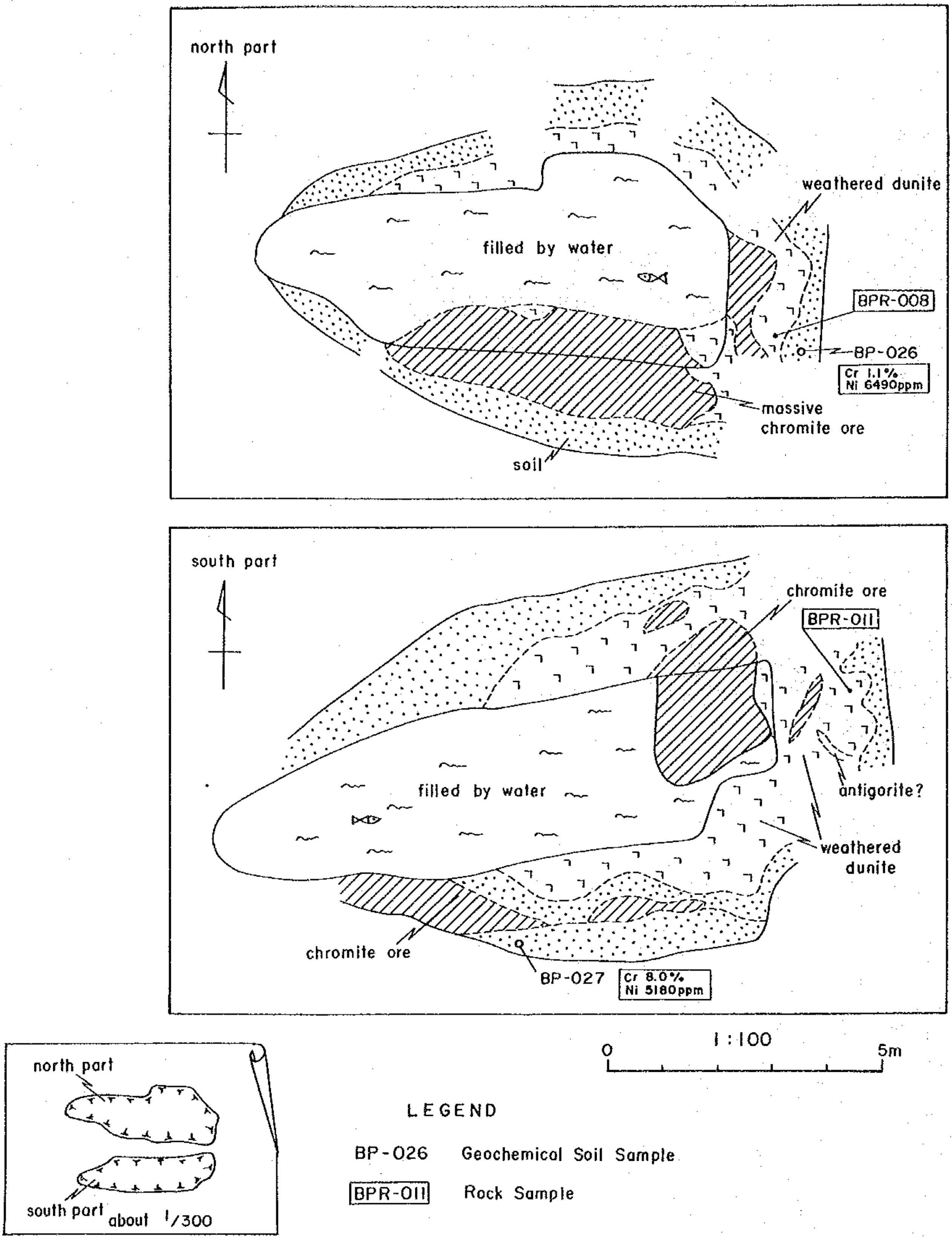

Fig. 43 Chromitite outcrop to the north of Berong area

failed to find the new showings.

This area is the anomalous area of the heavy minerals contained in the soil. The results of the geochemical assay of the samples from the test pits have revealed that all test pits had several percent of chrome content.

The area is underlain by laterite weathered from the ultramafic rocks. The laterite is 1m to 2m thick. In every sample taken from the test pits, has shown approximately 1% of Ni content. Ni content is similar in the samples taken from various depths.

In nine test pits, more than 100ppb of gold content have been found. The highest value is 600ppb in test pit PK04.

6) East Part of the Detailed Survey Area B-1a

A dunite distribution area extends from detailed survey area B-1b to B-1a. In that area, 15 test pits were dug to find new chromite showings, but the results were unsuccessful.

In nine test pits, over 1% of chromium content were found, but they are low compared with those in the B-1b.

The Ni grade found in this area is generally low. There are only four test pits which show a grade of over 0.5%, and the highest is 0.7% Ni.

Appendix 19 shows the assay results and profiles of each test pit.

2-6 Geochemical Survey

2-6-1 Soil geochemistry in B-area

1) Sampling

Soil geochemical survey was conducted in combination with geological mapping at the scale of 1:10,000. As chromite ore deposits in ultramafic rocks are the most important in this area, each sampling site along streams were predetermined mainly in the ultramafic rocks' area on the map.

Soil from B horizon had been taken from opposite banks above the highest water level of the stream. The heavy mineral sand was collected from 5 kilograms of soil by panning and checked the weight per 1 kilogram of soil. About 1 kilogram of soil samples from right and left bank was mixed for chemical analysis sample.

Collected soil samples were air-dried and screened with an 80 mesh sieve. About 100 g of -80 mesh fraction of each dried sample was divided into halves. One half was used for chemical analyses in the PETROLAB in Philippines while the other half was used for analyses in Chemex Labs. Ltd. in Canada.

The location map of the soil samples is shown in PL. 26.

2) Pathfinder elements and chemical analyses.

Chromite deposits associated with ultramafic rocks are known to exist in this area. As these ore deposits are associated with ophiolite complexes, seven elements were selected as pathfinder elements because of the high possibility of concentration: platinum (Pt), palladium (Pd), gold (Au), nickel (Ni), chromium (Cr), iron (Fe) and cobalt (Co).

The elements of Ni, Cr, Fe and Co were analyzed in PETROLAB while Pt, Pd and Au analyses were done in Chemex Labs. Ltd.

The results of sampling conditions and the analyses are shown in Appendix 22.

3) Data analyses

The method of basic statistical analysis and principal components analysis were used in this survey.

The combined data of B-area and A-area were used for data processing, and same statistical values and threshold were used for geochemical analysis in B-area and A-area, because both areas are mainly underlain by the Mt. Beaufort Ultramafics. The statistical values and thresholds are discussed in Chapter 1-6-1.

(i) Element content map

The content of each sample is classed by mean value and standard deviation, and plotted on the element content map (Fig. 45 to Fig. 51). The contour map and raw values of each element are shown in PL. 29 to PL. 35.

On the basis of the aforementioned thresholds (Chapter 1-6-1), anomalous values of each element are shown in element content map. The results are as follows:

Heavy mineral sand in soil: The amount of heavy mineral sand in gabbro and basalt areas is very little compared with that in ultramafic rocks area. The anomaly areas are only found in ultramafic rocks area. In the east coast, the anomaly areas are distributed in the upper stream of Malinao River, the area around the Norsophil Mines, and the upper stream of Malasgao River. In the west coast, the anomaly areas are distributed in the area around Berong area, and the anomalous values are sporadically found in the area around Long Point and Moorsom Point.

Pt: Generally Pt content is very low in B-area. The only and quite small anomaly area is recognized around Long Point.

Pd: The content of Pd is very low in B-area. The small anomaly areas are distributed in the upper stream of Malinao River and Baton-baton River in the east coast, and the area around Berong and Long Point in the west coast.

Au: Au content is very low in B-area. No significant anomaly areas are detected.

Ni: The content of Ni in gabbro and basalt areas is very low compared with that in ultramafic rocks area. The anomaly areas are only found in ultramafic rocks area. In the east coast, the anomalous values are sporadically found in the upper stream of Malinao River and Baton-baton

River. In the west coast, large anomaly areas are recognized around Long Point, and small anomaly areas are sporadically found in the area from Berong to Kinlugan River.

Cr: The Cr content in gabbro and basalt areas is very low compared with that in ultramafic rocks area. The anomaly areas are only found in ultramafic rocks area. In the east coast, the anomaly areas are distributed in the upper stream of Malinao River and the area around the Norsophil Mines, and some anomalous values are sporadically distributed in the upper stream of Baton-baton River. In the west coast, the large anomaly areas are recognized around Long Point.

Fe: The content of Fe is high in ultrabasic rocks area. In the east coast, some anomaly areas are found in the upper stream of Malinao River and Malasgao River. In the west coast the broad anomaly area is distributed around Long Point, and other anomaly areas are found in the area from Moorsom Point to Berong.

Co: The distribution of Co content is very similar with that of Ni and Fe. In the east coast the anomaly areas are found in Malinao River and around the Norsophil Mine. In the west coast the largest anomaly area is found around Long Point, and other anomaly areas are found in the area from Moorsom Point to Berong.

(ii) Principal components analysis

The results of the principal components analysis are discussed in Chapter 1-6-1, and these results mean that the samples with high scores on component 1 are generally enriched in Ni, Cr, Fe and Co and the samples with negative scores on component 2 are enriched in Pt, Pd and Au compared with the other samples.

The scores calculated from weight vector area shown on scores distribution maps (Fig. 52 to Fig. 53). The component 1 scores of more than $m+1\sigma$ and the component 2 scores of less than $m-\sigma$ area were picked up for anomaly.

The anomalous values of component 1 are only found in the ultramafic rocks area. In the east coast the anomaly areas of component 1 are distributed in the upper stream of Malinao River and Malasgao River, and the area around the Norsophil Mine. In the west coast the large anomaly area is found around Long Point, and other anomaly areas are found around Moorsom Point and

Berong.

The anomaly areas of component 2 are distributed in the middle stream of Malinao River and Baton-baton River in the east coast. In the west coast they are distributed on the east of Long Point, to the south of Berong, and to the east towards Iwahig.

4) Results of soil geochemistry

Interpretation map (Fig. 6) shows the anomaly areas of principal component 1 summarizing the content of Ni, Cr, Fe and Co, component 2 summarizing the content of Pt, Pd and Au, the anomaly areas yielded high amount of heavy mineral sand in soil and the ultramafic rocks area.

The promising areas overlapping with several anomaly areas are shown as follows:

East coast

1. The area in the upper stream of Malasgao River
2. The area around the Norsophil Mine
3. The area in the upper stream of Malinao River

West coast

1. The area around Long Point
2. The area around Berong

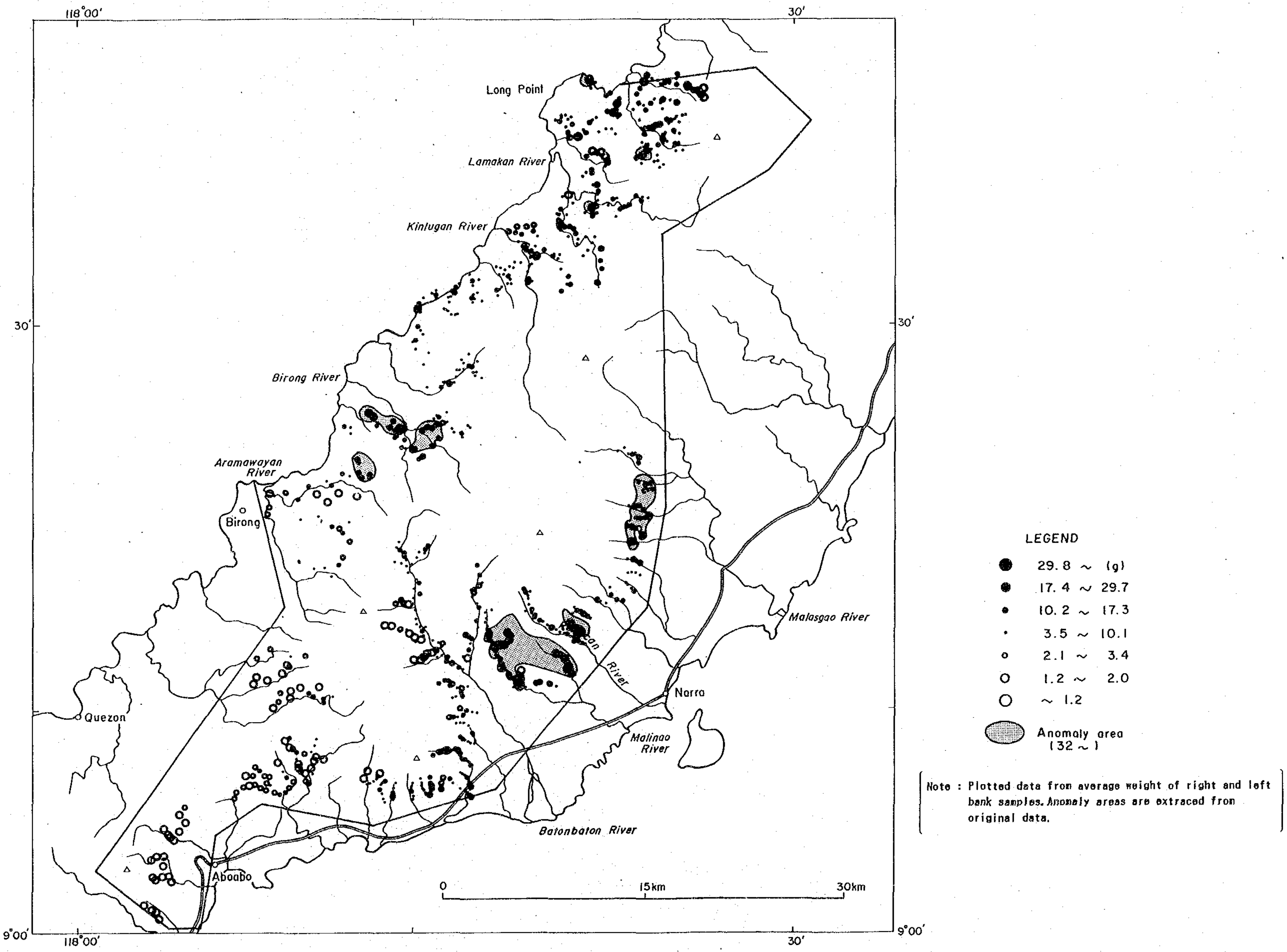

Fig. 44 Heavy mineral content of soil samples in area B

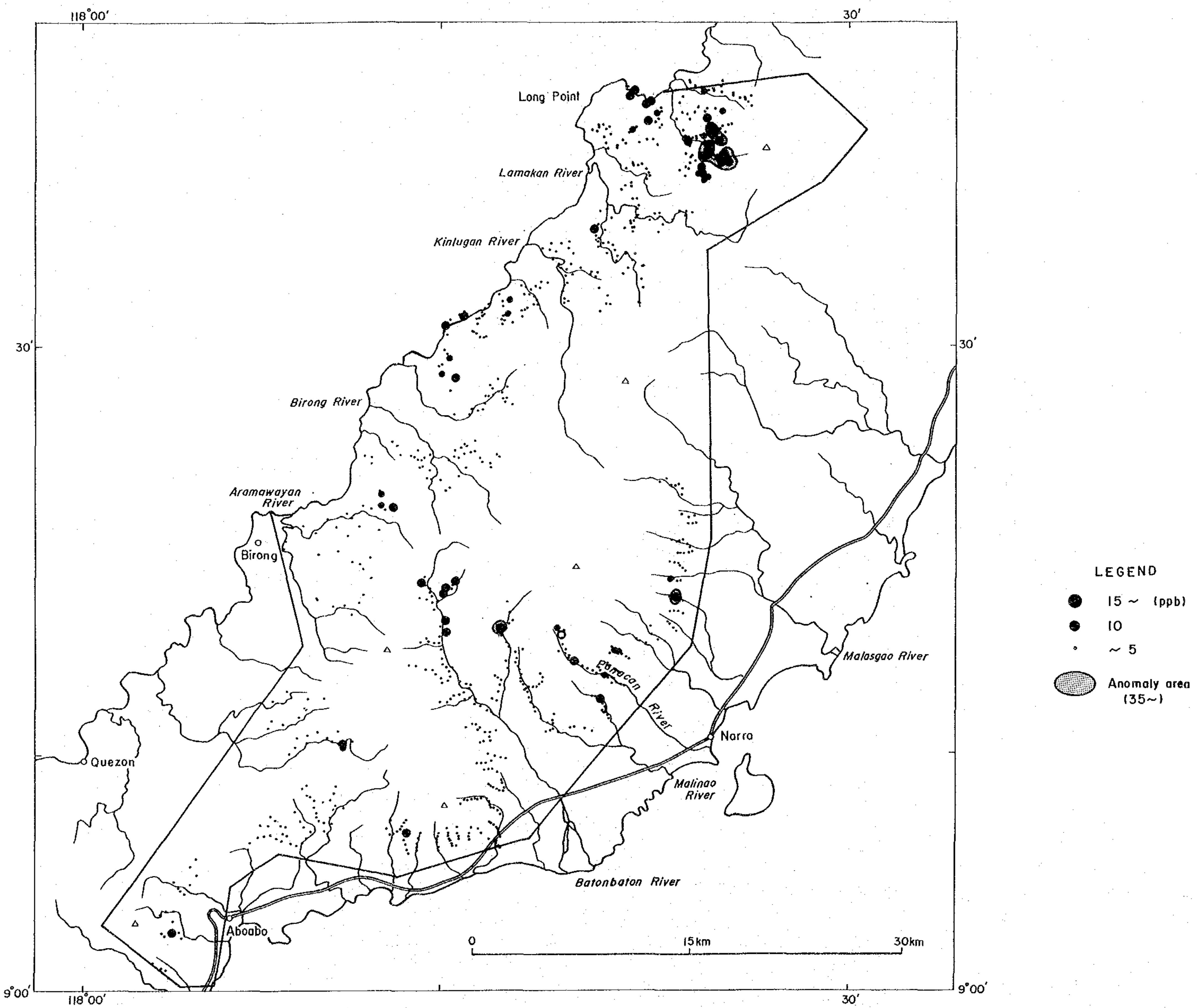

Fig. 45 Pt content of soil samples in area B

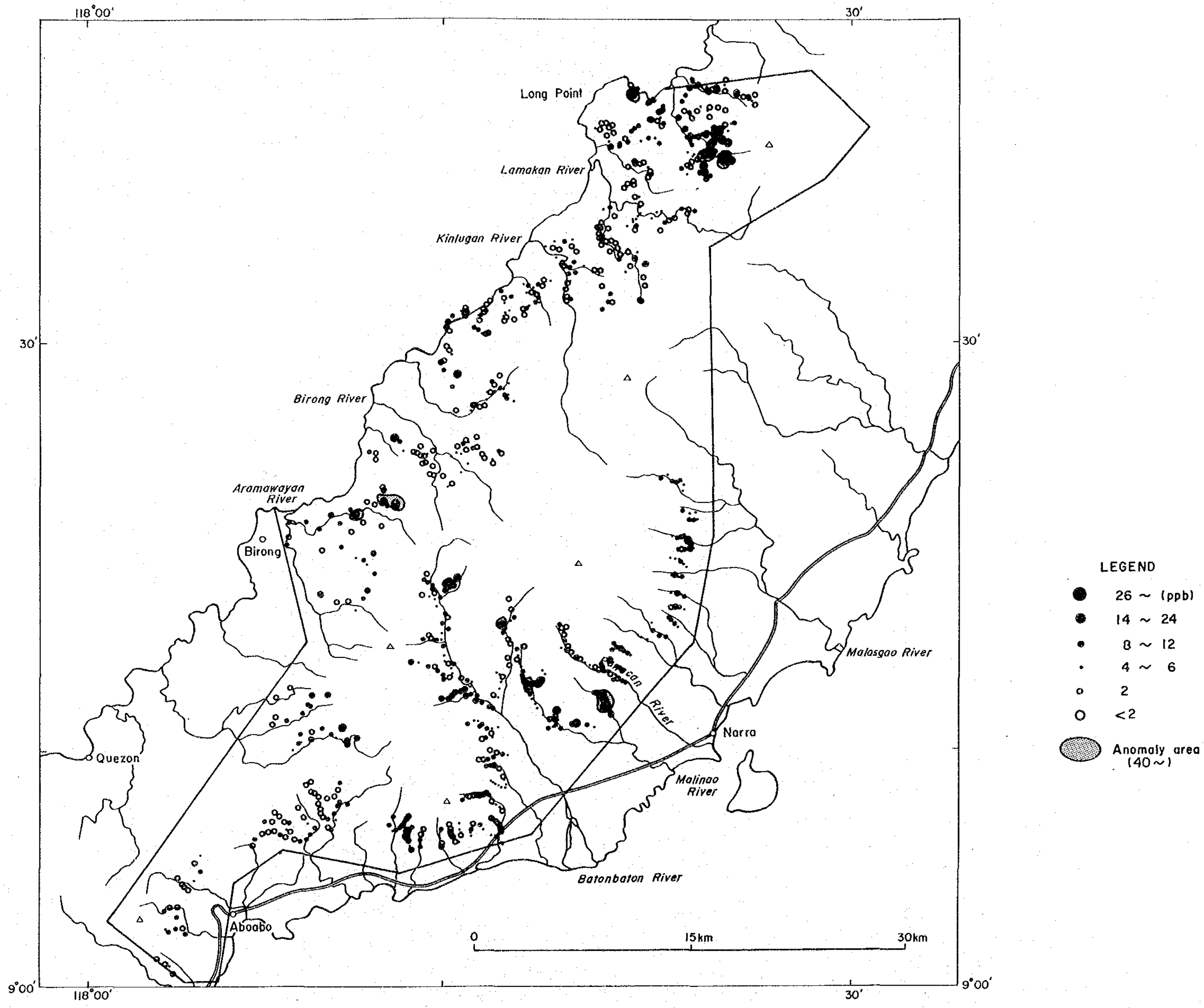

Fig. 46 Pd content of soil samples in area B

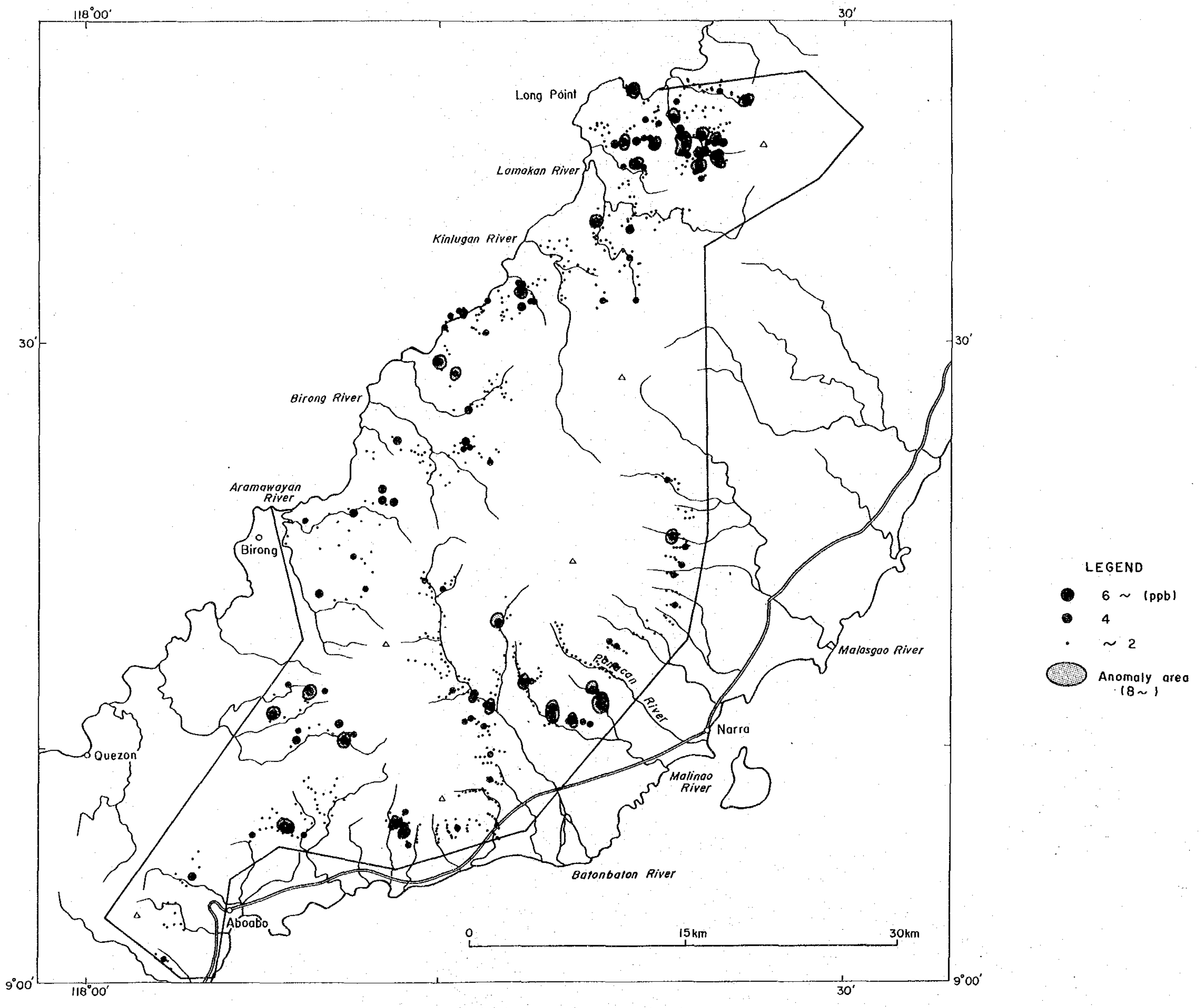

Fig. 47 Au content of soil samples in area B

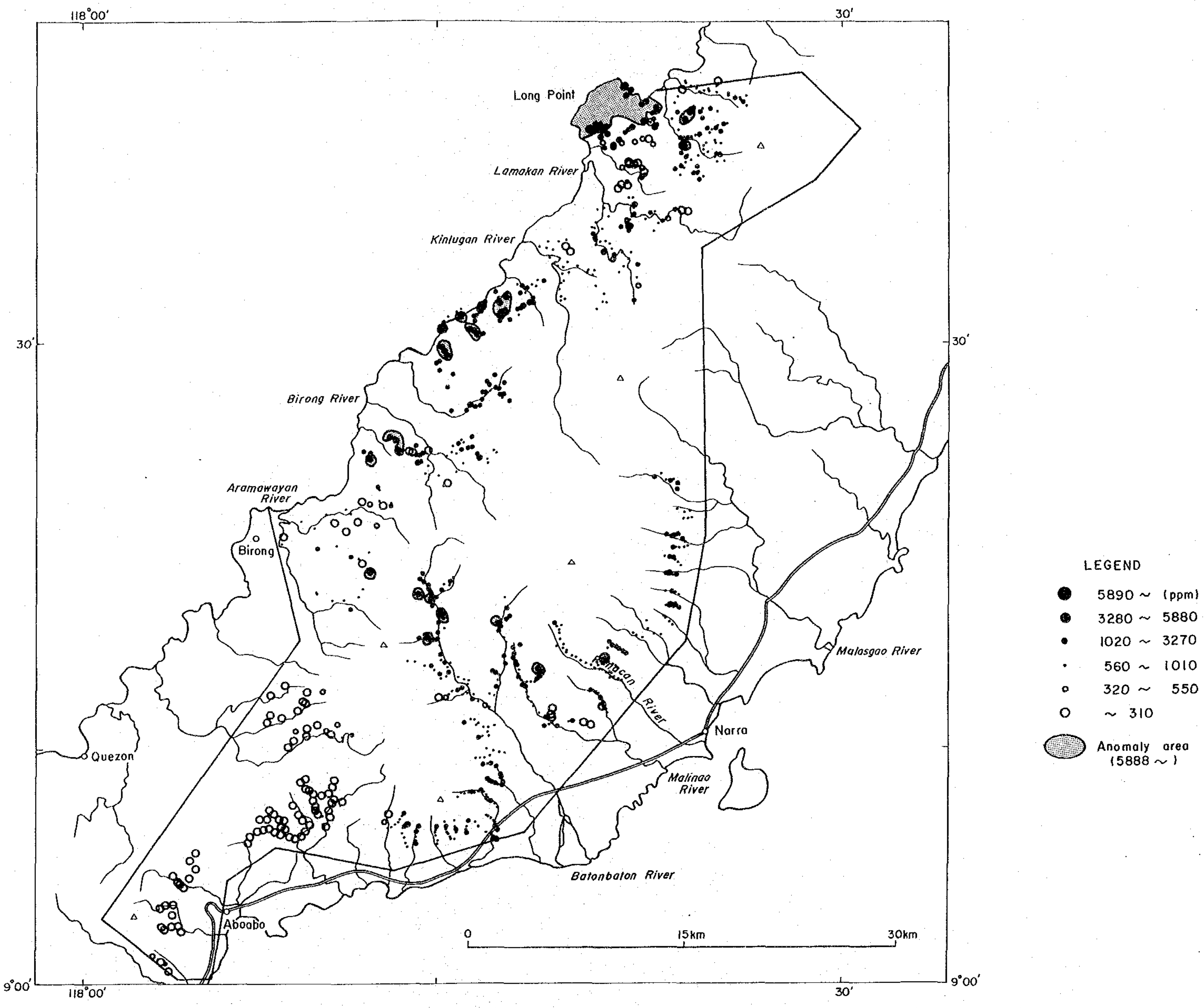

Fig. 48 Ni content of soil samples in area B

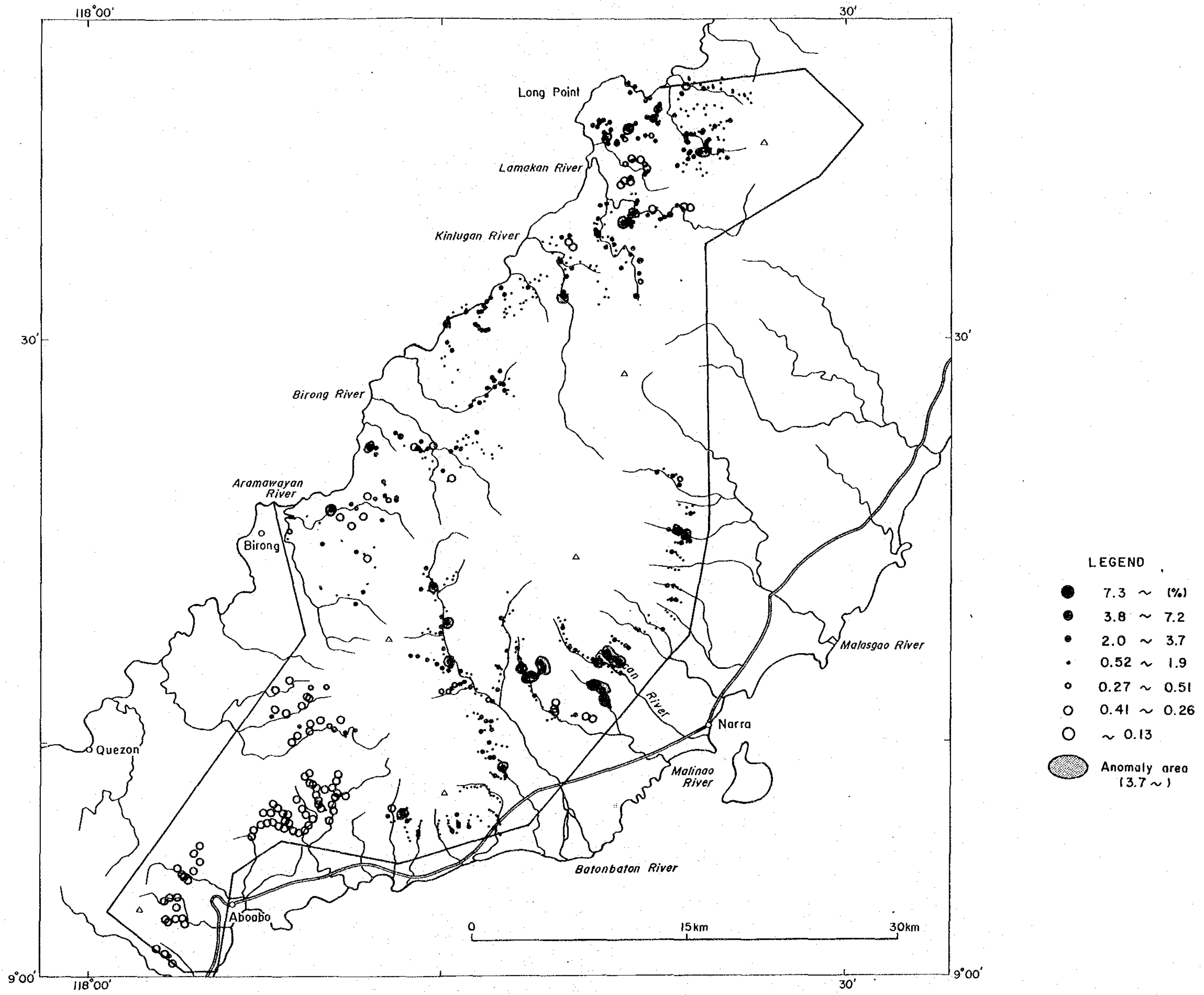

Fig. 49 Cr content of soil samples in area B

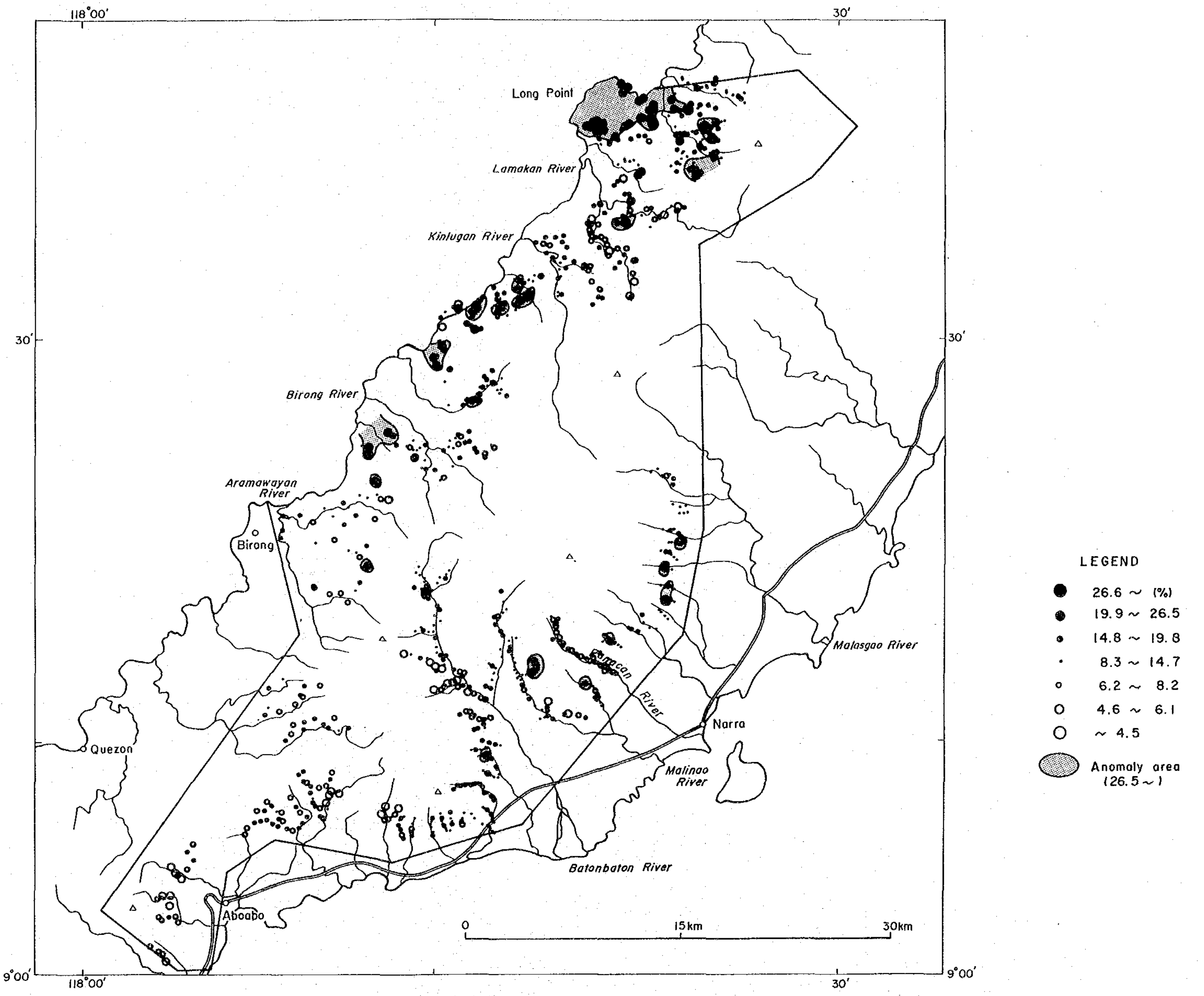

Fig. 50 Fe content of soil samples in area B

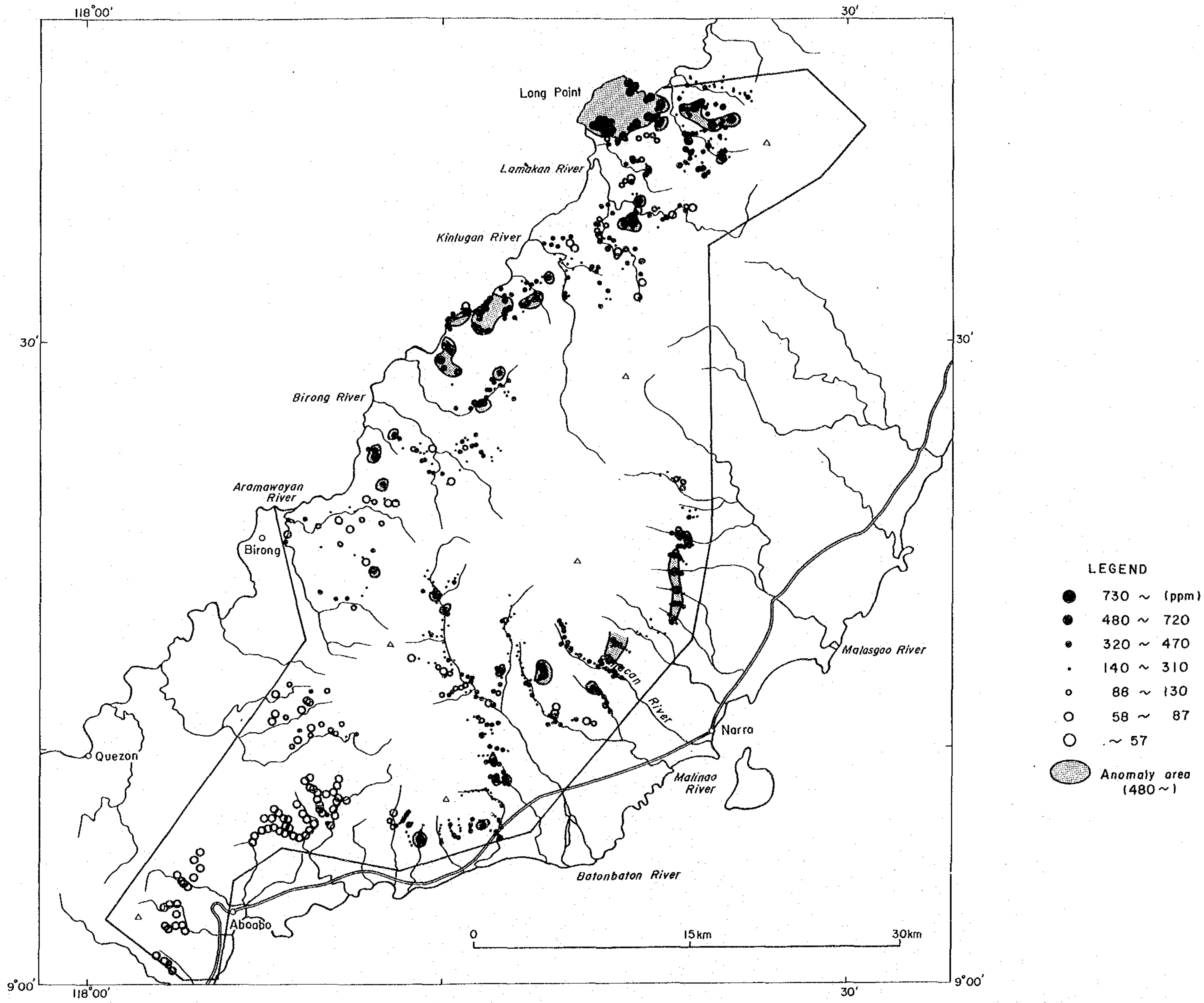

Fig. 51 Co content of soil samples in area B

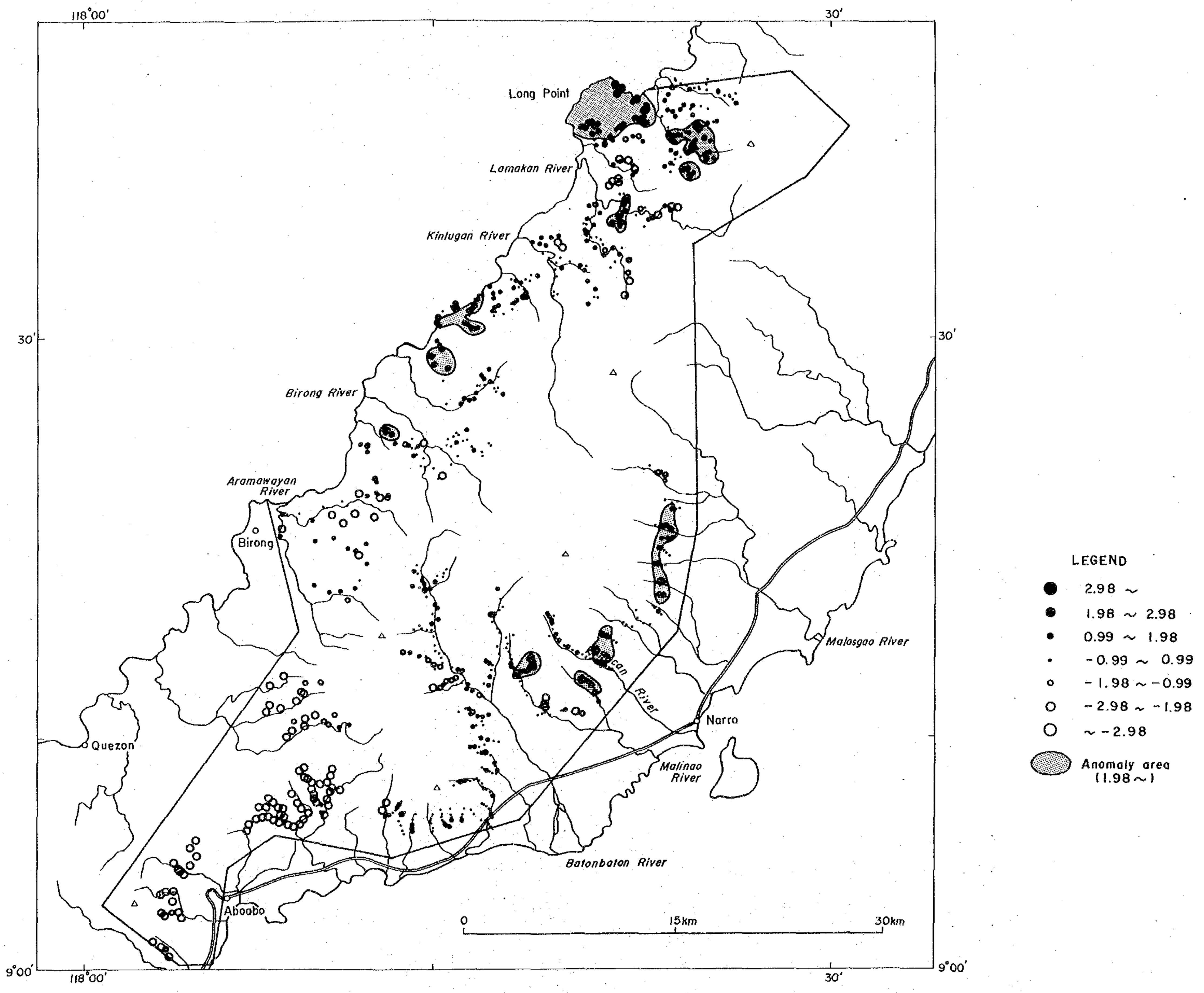

Fig. 52 Scores of principal components analysis in area B (Z1)

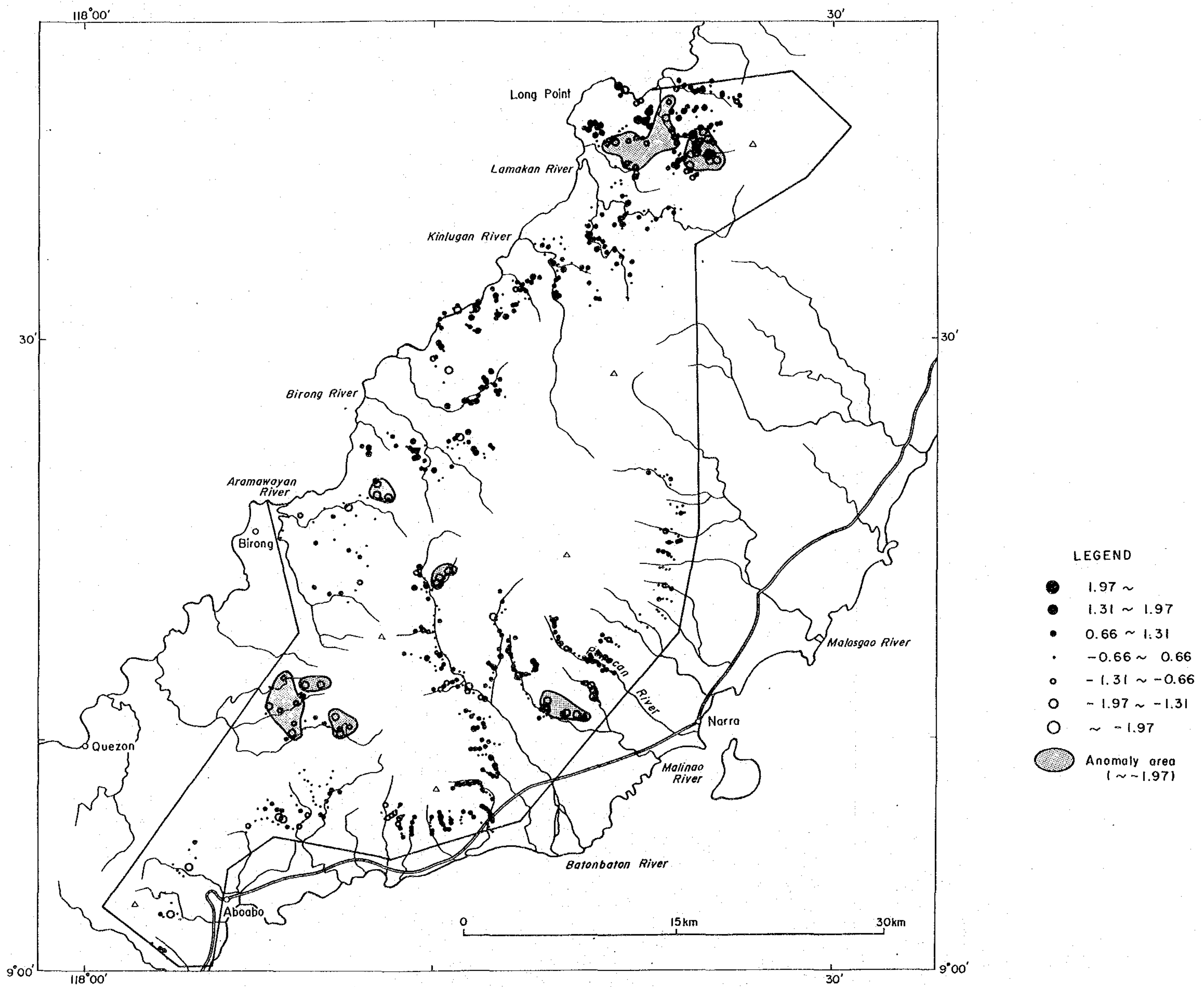

Fig. 53 Scores of principal components analysis in area B (Z2)

2-6-2 Soil geochemistry in detailed survey area B-1

The B-1 geochemical anomaly area is the upper part of Malinao River, located to the west of Narra. This area was followed up with detailed geologic mapping and close spaced soil sampling designed along spurs and ridges.

1) Sampling and chemical analysis

Soil geochemical survey was conducted in combination with geological mapping at the scale of 1:5,000. Sampling method in area B-1 was almost the same with that of B-area.

Soil from B horizon had been taken from opposite banks, and soil samples from each bank were treated and analyzed separately. Same set of elements as B-area were selected as pathfinder elements because of the high possibility of concentration: platinum (Pt), palladium (Pd), gold (Au), nickel (Ni), chromium (Cr), iron (Fe) and cobalt (Co).

The location map of the soil samples is shown in PL. 38. The results of sampling conditions and the analyses are shown in Appendix 23.

2) Data analyses

The method of basic statistical analysis and of principal components analysis were used in this survey.

(i) Statistical analysis

The range, median, mean and standard deviation(σ) are shown in Table 11. Area B-1 is the anomaly area of B-area, so the medians and mean values at all elements are rather higher than the values calculated from A-area and B-area data set.

Histogram and cumulative probability curve of each element are shown in Appendix 24. The class interval of the histogram is half of the standard deviation.

Correlation coefficients between these elements are shown in Table 12. The strong positive correlations of more than +0.5 were recognized with the relations of Pt-Pd, Ni-Cr, Ni-Fe, Ni-Co, Cr-Fe, Cr-Co and Fe-Co, so correlation among Ni-Cr-Fe-Co is strong. The scatter diagrams are shown in Fig. 54.

Table 11 Basic Statistic quantities of soil samples in area B-1

			linear		logarithmic		
element	range	median	mean	std. dev.	mean	10^mean	std. dev.
Pt (ppb)	2.5 - 730	15	24.2	36.3	1.185	15.3	0.408
Pd (ppb)	1 - 290	14	20.3	22.5	1.068	11.7	0.514
Au (ppb)	1 - 316	1	4.7	14.4	0.319	2.1	0.450
Ni (ppm)	34 - 16700	2770	3192.9	2898.7	3.186	1536.0	0.657
Cr (ppm)	100 - 150000	16000	22350.6	21691.0	4.017	10398.5	0.668
Fe(%)	0.6 - 54.0	10.7	14.0	9.9	1.031	10.7	0.329
Co (ppm)	15 - 1990	246	328.0	285.4	2.319	208.2	0.452

(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. 55 to Fig. 61). The contour map and raw values of each element are shown in PL. 40 to PL. 46. These maps show which bank the sample was taken.

Area B-1 is one of the anomaly areas in B-area, therefore we can't apply the same threshold with A-area and B-area to this area. New threshold for area B-1 is considered mean value (m) and standard deviation (σ), and the point of m+1.0σ was adopted as threshold.

On the basis of the above-mentioned thresholds, anomalous values of each element are shown in element content map. The results are as follows:

Pt: The high Pt content area is distributed from gabbro to the transitional zone between gabbro and cumulate dunite occurrences. The basalt area has low Pt content.

Pd: The area of high Pd content is distributed from gabbro area to transitional zone. The high content samples are found sporadically in the peridotite area.

Au: Some anomalous values are sporadically distributed in the area of gabbro, basalt and peridotite.

Ni: The area of high Ni content is distributed from transitional zone to peridotite area. The gabbro and basalt area has low Ni content. The northwest part of Malinao River has unusually high Ni content, and this anomaly area is very broad.

Cr: The area of high Cr content is distributed from transitional zone to peridotite area. The gabbro and basalt area has low Cr content. The belt in peridotite near the transitional zone has unusually high Cr anomaly.

Fe: The distribution of Fe content is very similar with that of Ni. The high Fe area is distributed in the area where transitional zone to peridotite area occurs. Unusually high anomaly is found in the northwest area.

Co: The distribution of Co content is very similar with that of Ni. The high Co area is distributed in the area where transitional zone to peridotite area occurs. Unusually high anomaly is found in the northwest area.

(iii) Principal components analysis

The covariance matrix obtained from standardized ((raw value - mean)/(standard deviation)) data set is equal to correlation coefficients matrix. We have used the correlation matrix as initial matrix for this principal components analysis. The correlation matrix obtained from data set is shown in Table 12.

The eigenvalues above 1.0 are component 1 and 2, and these components explain 77 percent of information. According to the factor loading matrix, elements can be divided into 2 groups. Ni, Cr, Fe and Co have strong positive loading on component 1. Pt, Pd and Au have strong negative loading on component 2.

These results mean that the samples with high scores on component 1 are generally enriched in Ni, Cr, Fe and Co and the sample with negative scores on component 2 are enriched in Pt, Pd and Au compared with the other samples. The scores calculated from weight vector area shown on scores distribution maps (Fig. 62 to Fig. 63). The cumulative probability plots of scores are shown in Appendix 25. The component 1 scores of more than $m+1\sigma$ and the component 2 scores of more than $m+\sigma$ area were picked up as anomalous area.

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. 7) 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.

Table 12 Correlation coefficients of soil samples in area B-1 n=1190

	Pt	Pd	Au	Ni	Cr	Fe	Co
Pt	1.000	0.529	0.078	0.377	0.406	0.249	0.356
Pd	0.529	1.000	0.320	0.025	0.081	-0.072	-0.020
Au	0.078	0.320	1.000	-0.153	-0.076	-0.145	-0.174
Ni	0.377	0.025	-0.153	1.000	0.893	0.836	0.904
Cr	0.406	0.081	-0.076	0.893	1.000	0.770	0.843
Fe	0.249	-0.072	-0.145	0.836	0.770	1.000	0.911
Co	0.356	-0.020	-0.174	0.904	0.843	0.911	1.000

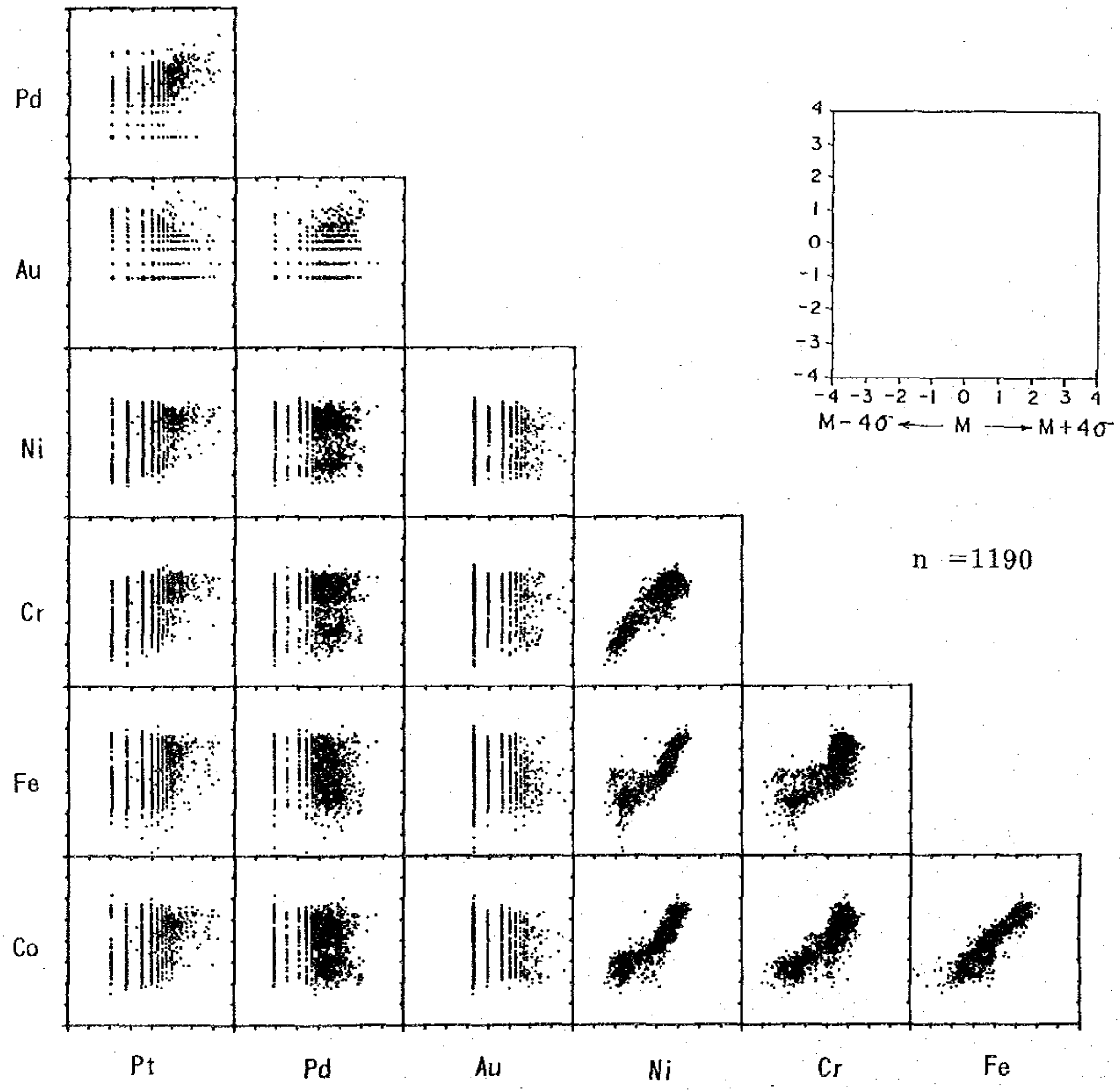

Fig.54 Scatter diagram of soil samples in area B-1

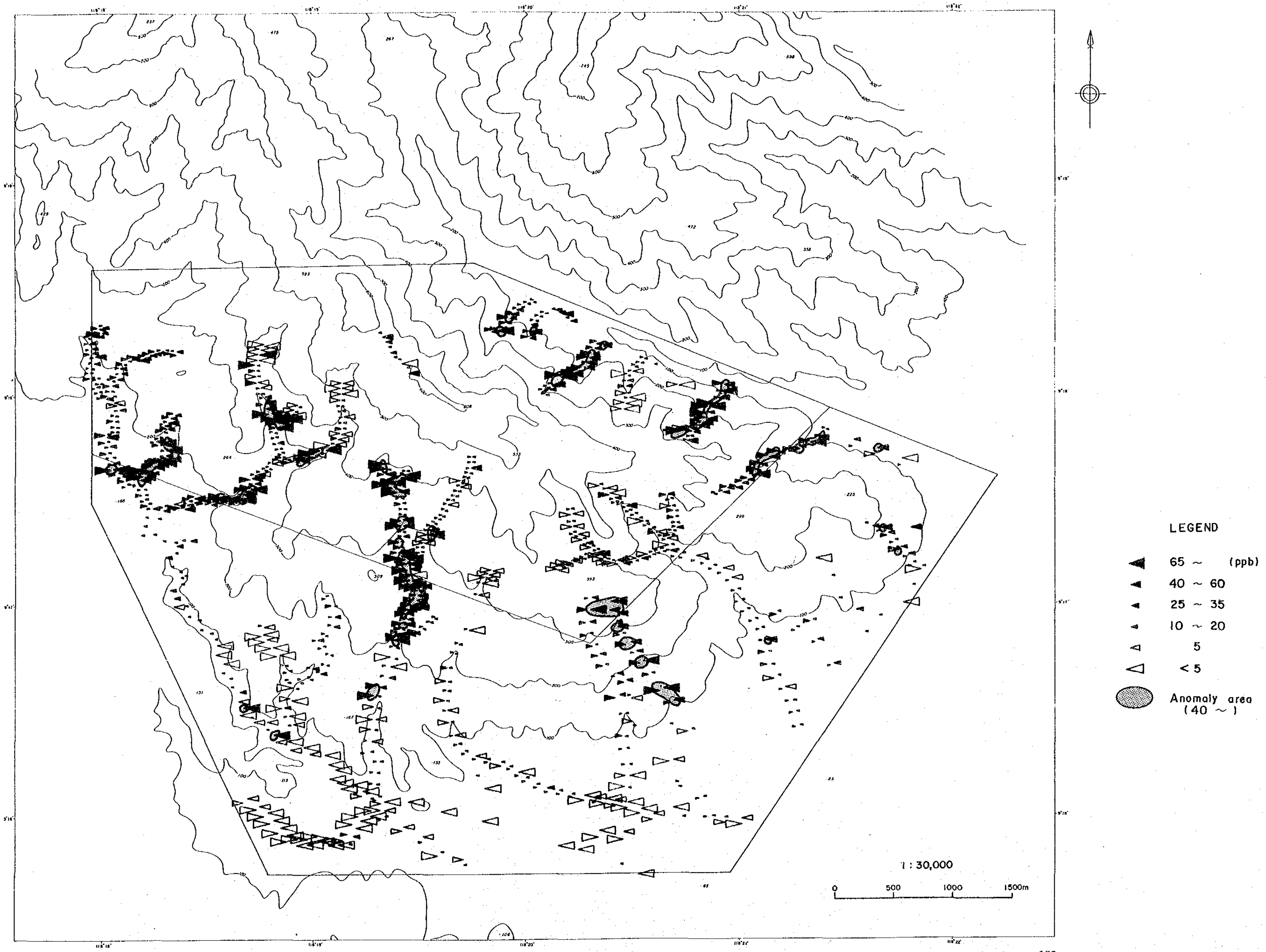

Fig. 55 Pt content of soil samples in area B-1

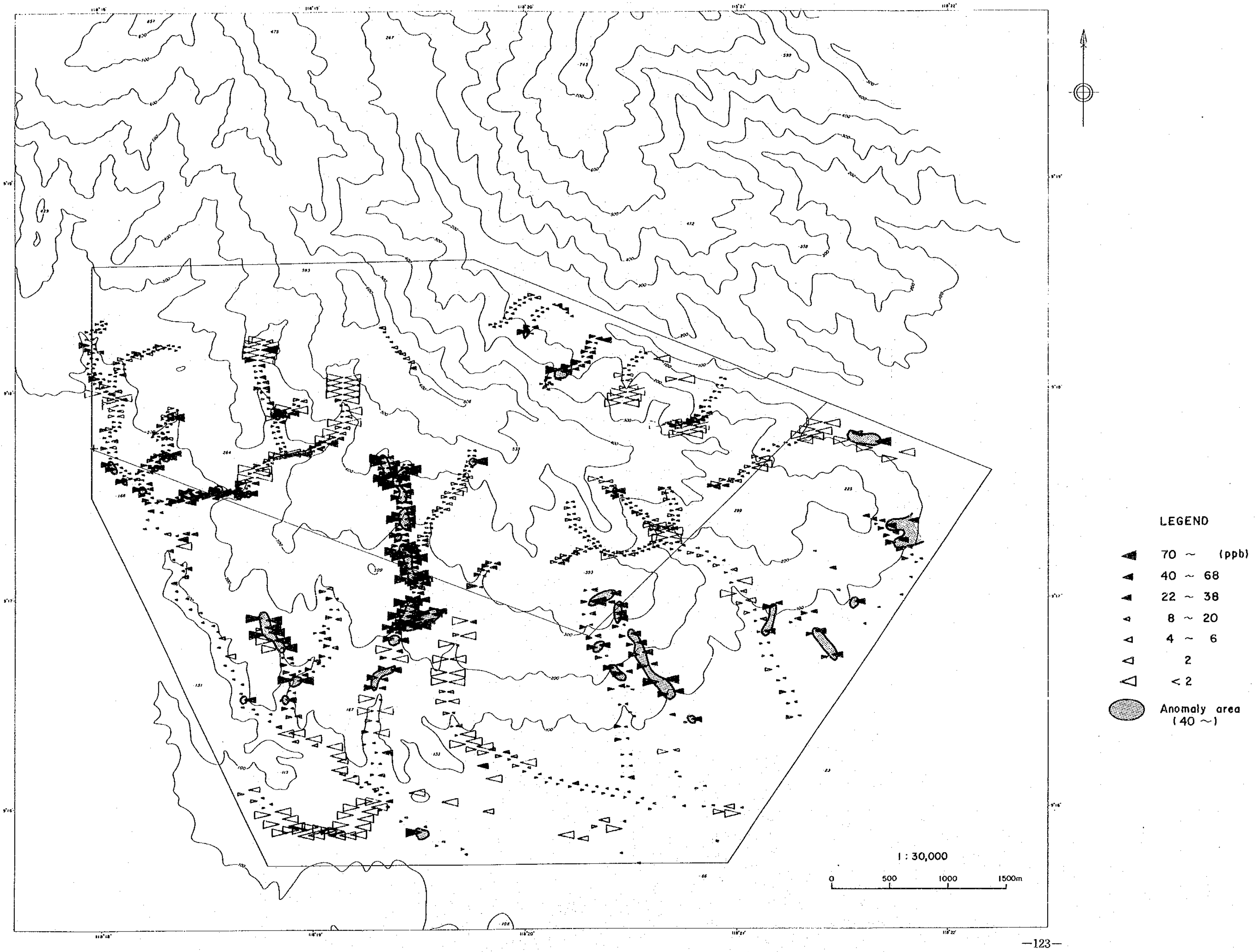

Fig. 56 Pd content of soil samples in area B-1

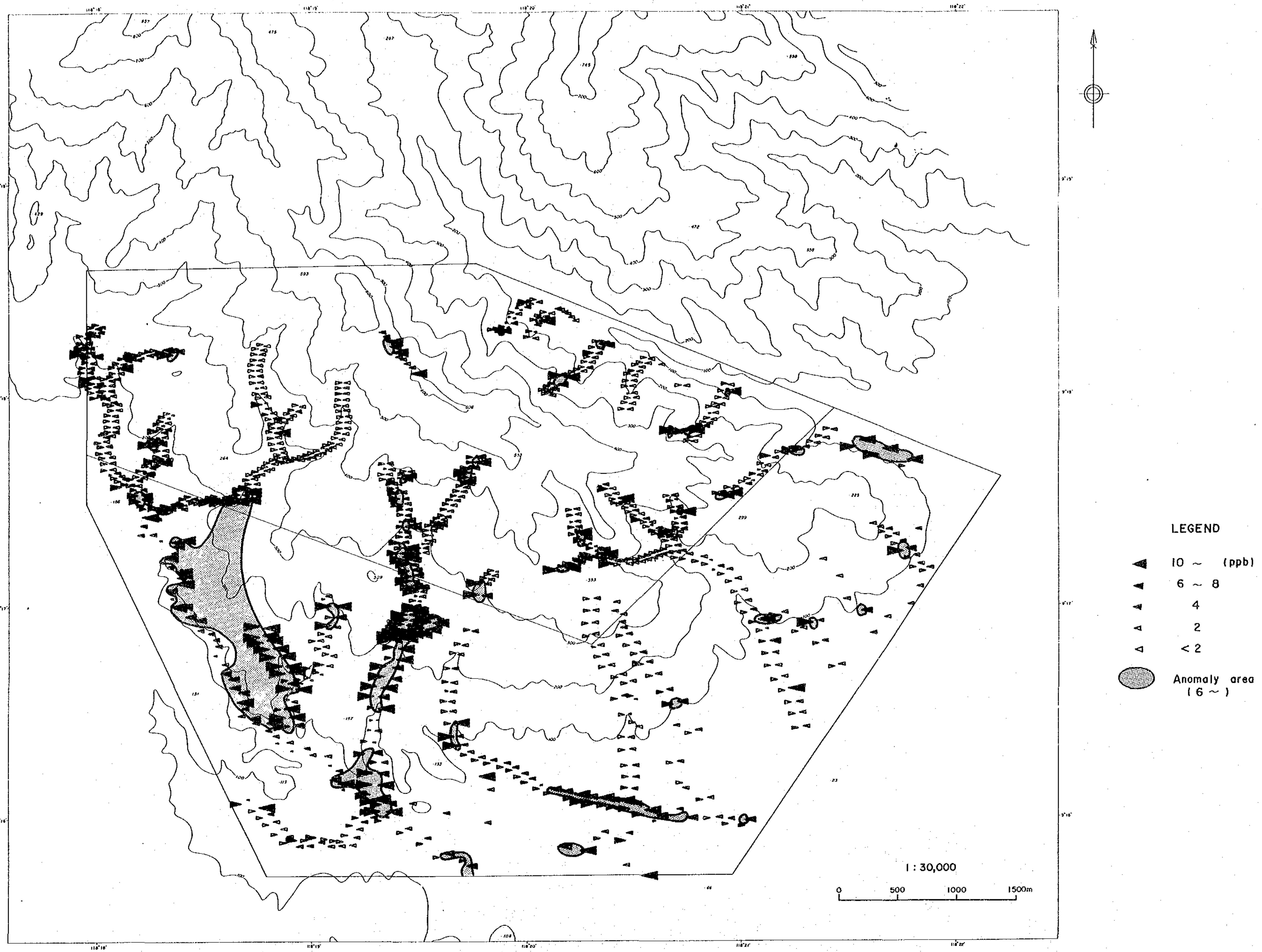

Fig. 57 Au content of soil samples in area B-1

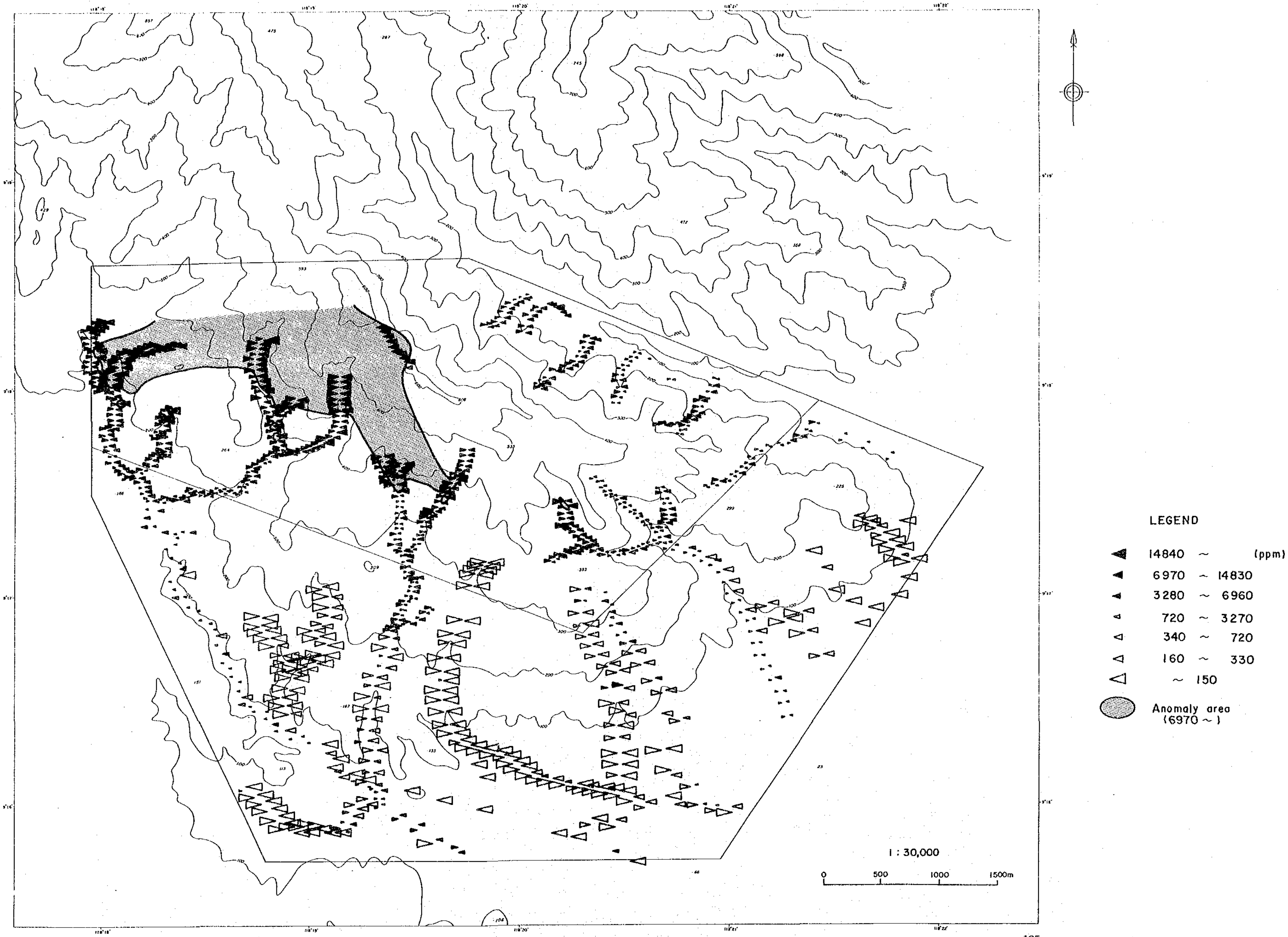

Fig. 58 Ni content of soil samples in area B-1

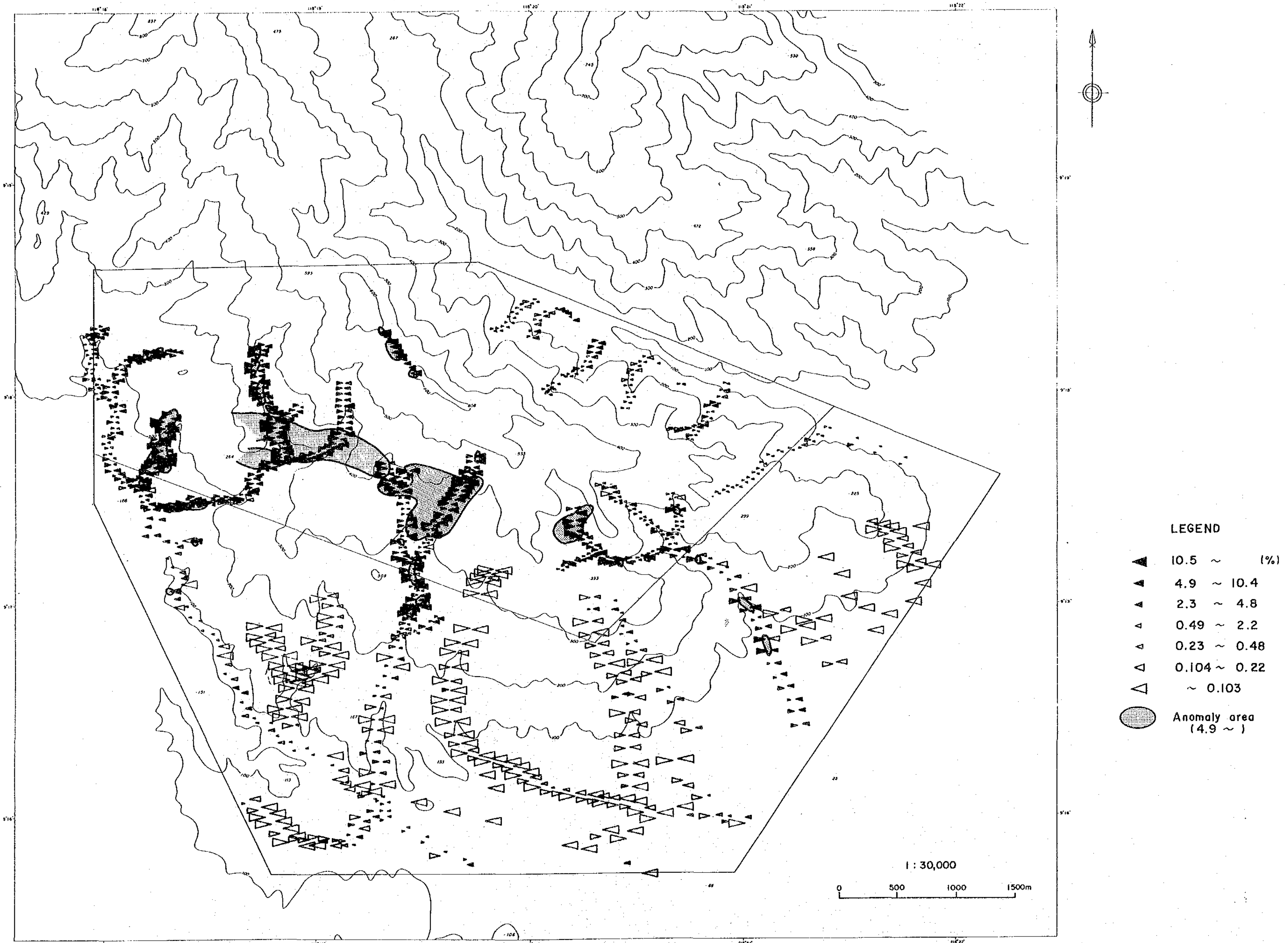

Fig. 59 Cr content of soil samples in area B-1

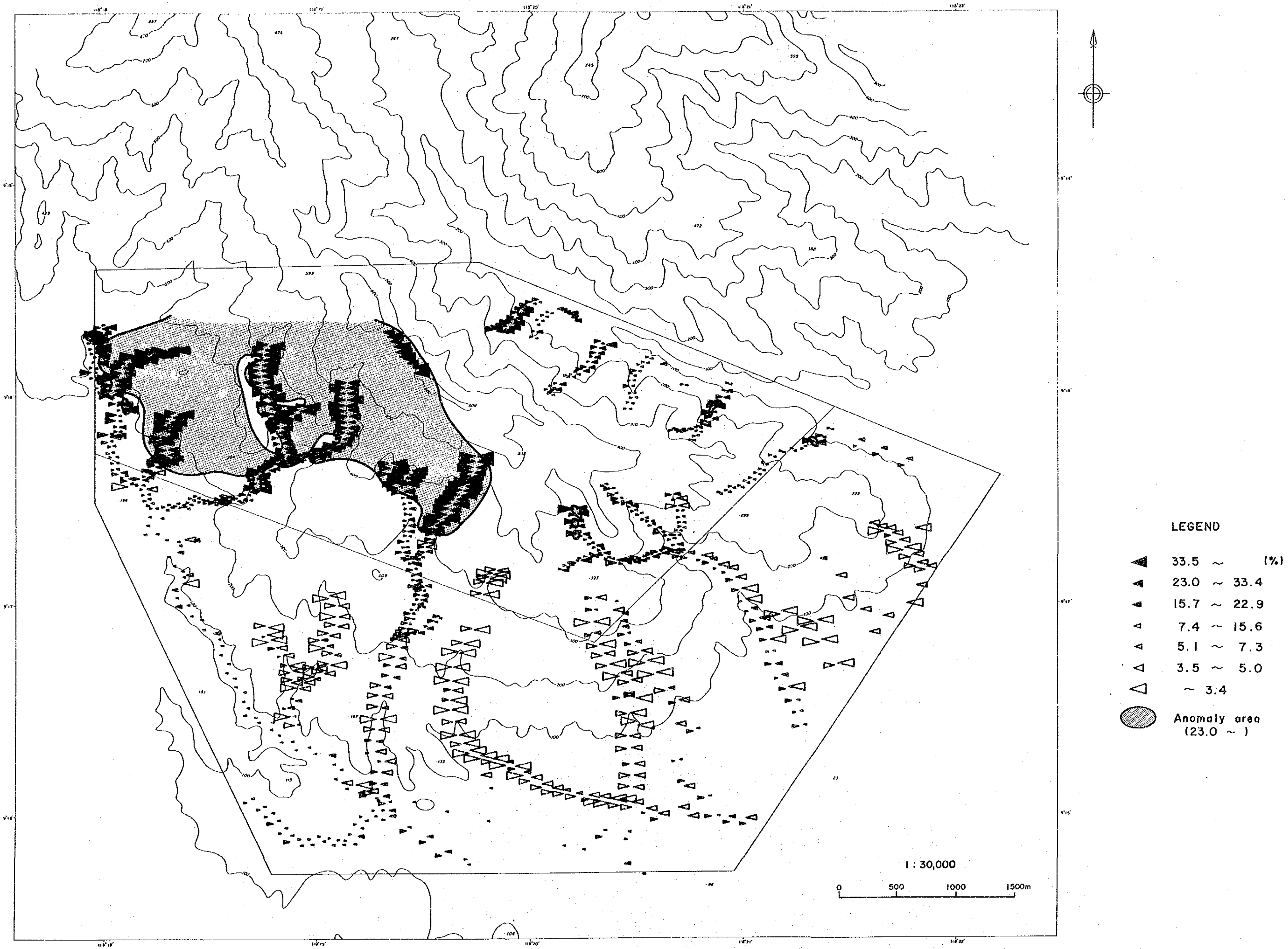

Fig. 60 Fe content of soil samples in area B-1

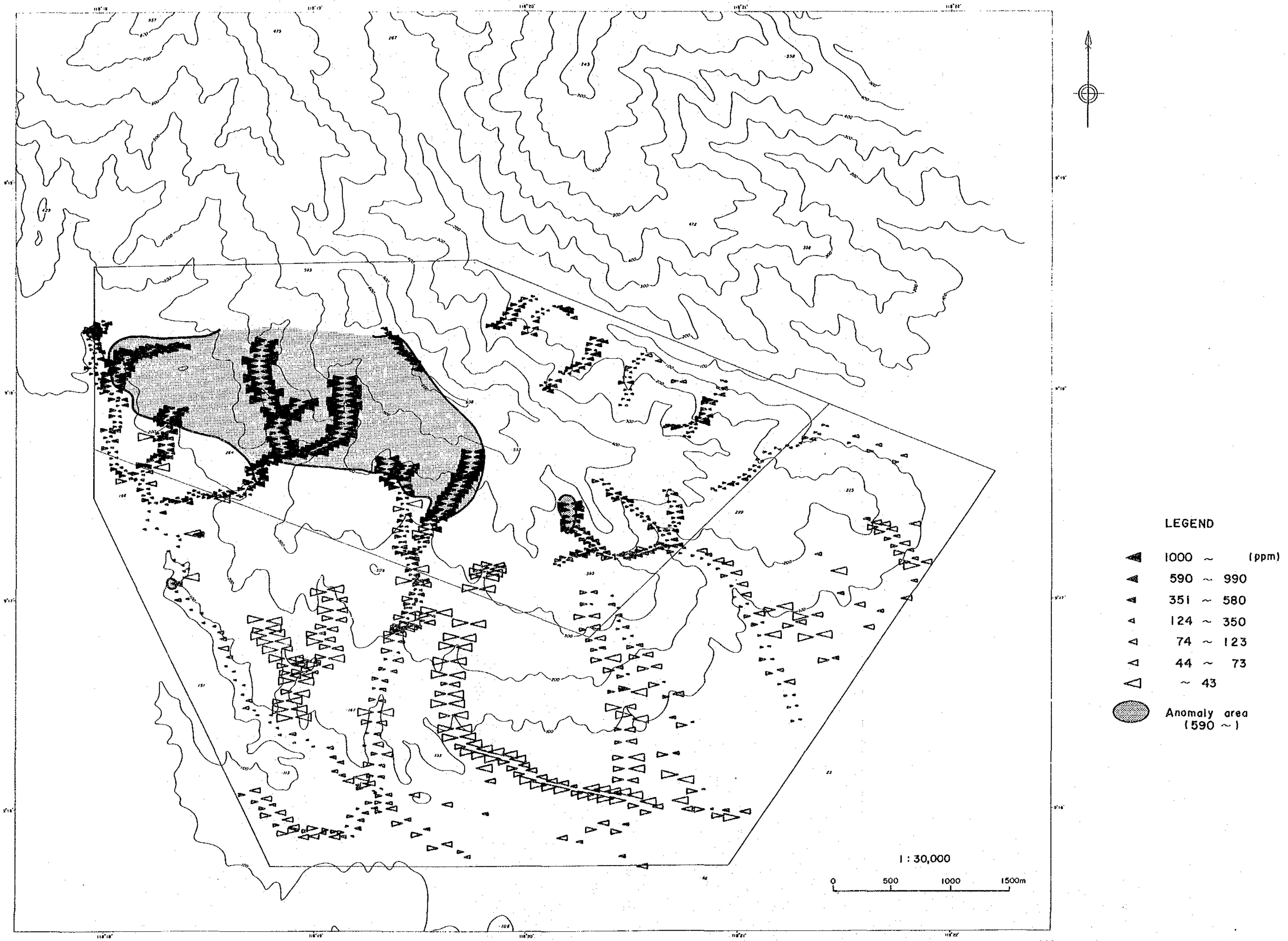

Fig. 61 Co content of soil samples in area B-1

Table 13 Results of principal components analysis in area B-1

COMPONENT	EIGENVALUE	PERCENT	CUMULATIVE
Z-01	3.7823	54.0327	54.0327
Z-02	1.6359	23.3696	77.4023
Z-03	0.8167	11.6677	89.0700
Z-04	0.3716	5.3081	94.3781
Z-05	0.2333	3.3336	97.7117
Z-06	0.0944	1.3486	99.0603
Z-07	0.0658	0.9397	100.0000
TOTAL	7.0000	100	

Factor Loading

	Z-01	Z-02	Z-03	Z-04	Z-05	Z-06	Z-07
Pt	0.4794	-0.6652	-0.3899	-0.4140	0.0632	-0.0092	-0.0147
Pd	0.0777	-0.8831	-0.1955	0.4191	0.0213	0.0015	0.0037
Au	-0.1629	-0.6062	0.7679	-0.1257	0.0125	0.0166	0.0048
Ni	0.9570	0.0570	0.0529	0.0339	-0.1345	0.2201	-0.1022
Cr	0.9264	-0.0306	0.0849	0.0142	-0.3216	-0.1730	0.0143
Fe	0.9080	0.1730	0.1513	0.0812	0.3014	-0.1104	-0.1146
Co	0.9600	0.1099	0.0630	0.0271	0.1281	0.0592	0.2043

Eigen Vector

	Z-01	Z-02	Z-03	Z-04	Z-05	Z-06	Z-07
Pt	0.2465	-0.5201	-0.4314	-0.6792	0.1309	-0.0299	-0.0572
Pd	0.0400	-0.6904	-0.2163	0.6876	0.0440	0.0049	0.0144
Au	-0.0838	-0.4739	0.8497	-0.2062	0.0258	0.0540	0.0186
Ni	0.4921	0.0445	0.0585	0.0556	-0.2784	0.7163	-0.3985
Cr	0.4763	-0.0239	0.0940	0.0233	-0.6657	-0.5630	0.0557
Fe	0.4669	0.1352	0.1674	0.1333	0.6239	-0.3592	-0.4468
Co	0.4936	0.0859	0.0697	0.0445	0.2653	0.1927	0.7966

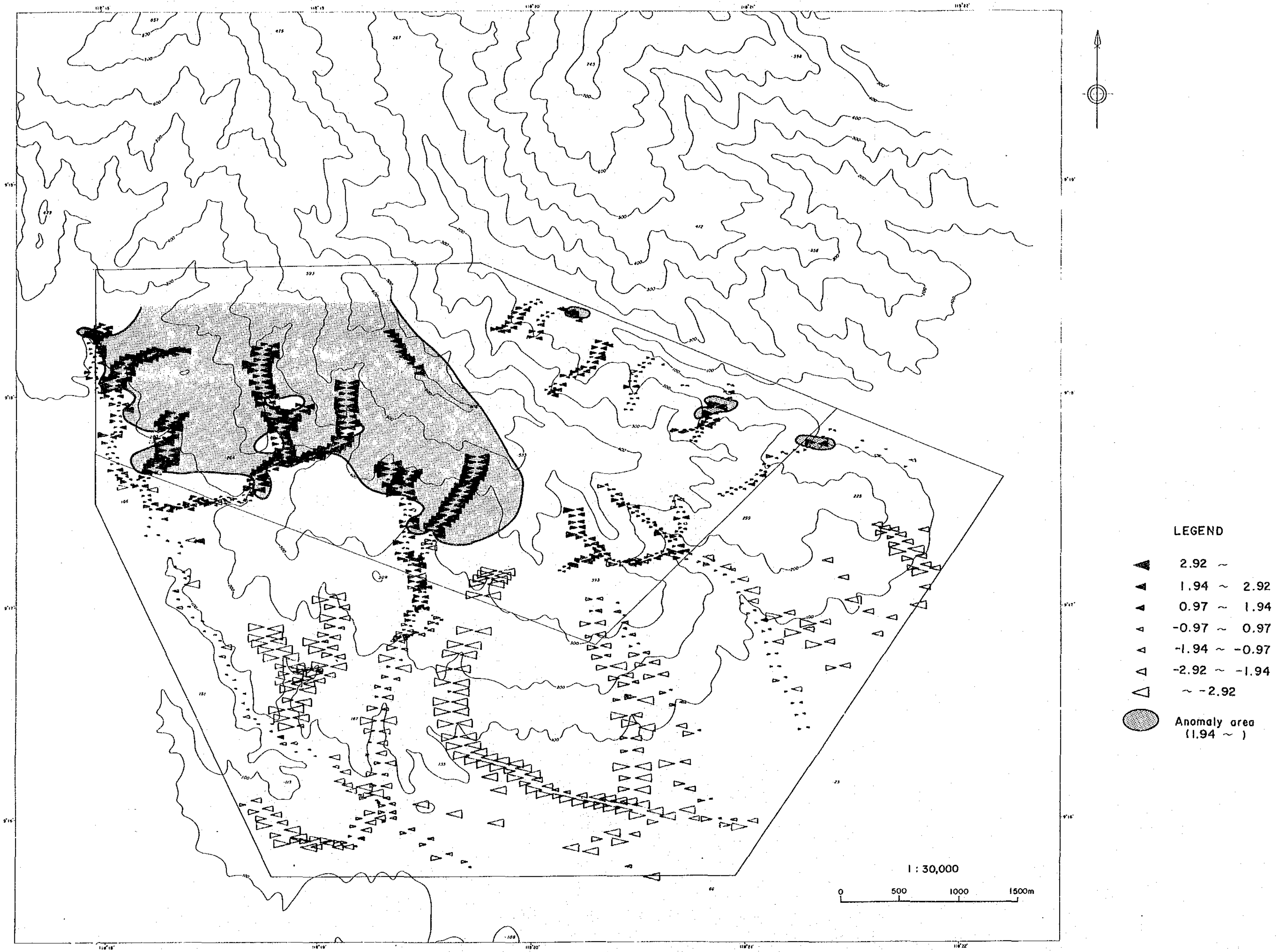

Fig. 62 Scores of principal components analysis in area B-1 (Z1)

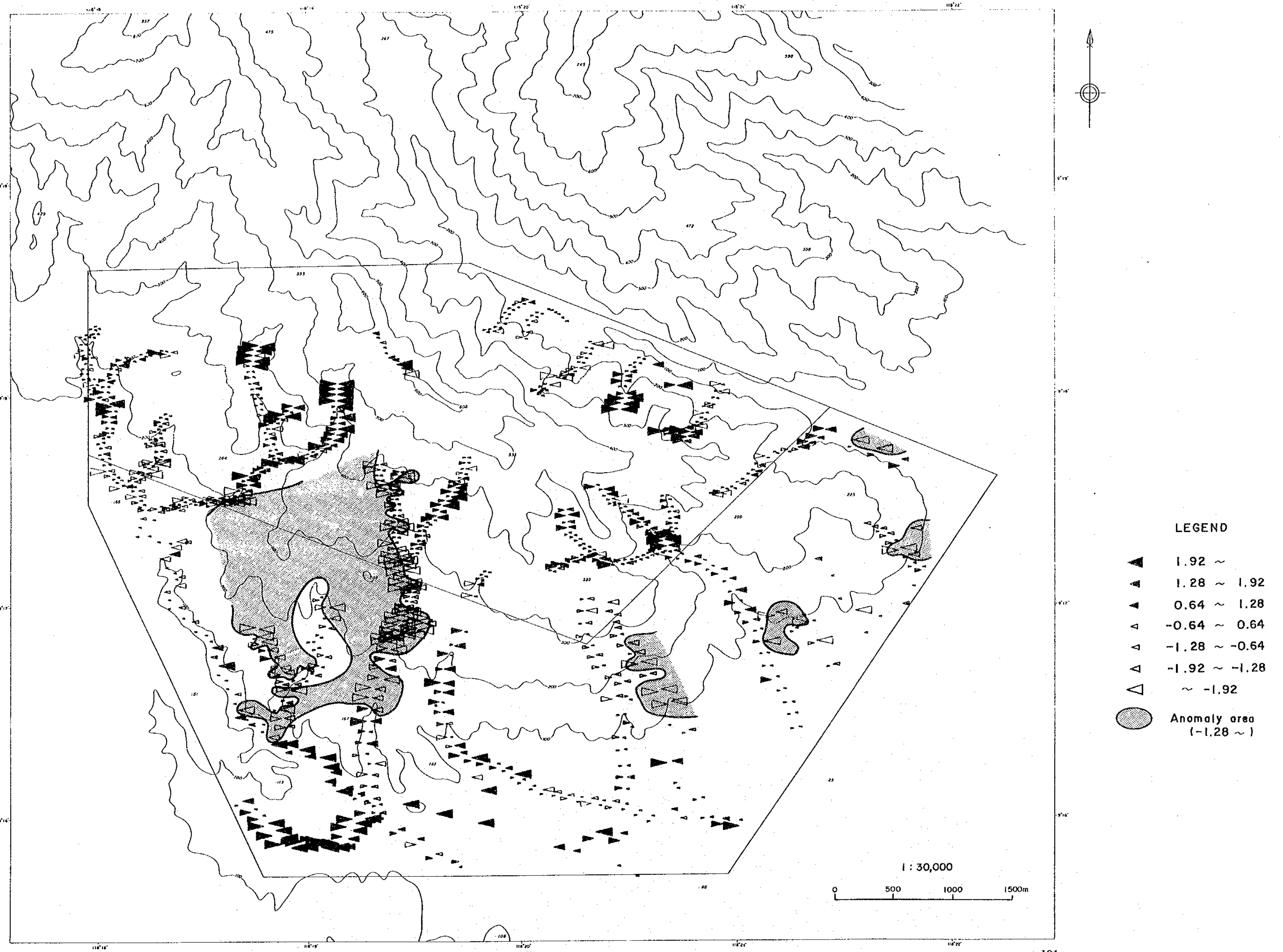

Fig. 63 Scores of principal components analysis in area B-1 (Z2)

2-6-3 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. The results of chemical analysis are shown in Appendix 26. The statistical values are shown in Table 14. 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.

Table 14 Statistic quantities of rock samples in area B and B-1

	Rock type	number	range	median	linear*		logalithmic*		
					mean	std. dev.	mean	10^mean	std. dev.
P t (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
P d (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
A u (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
N i (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
C r (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
F e (%)	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
C o (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.

2-6-4 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.

The results of chemical analysis are shown in Appendix 37.

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.

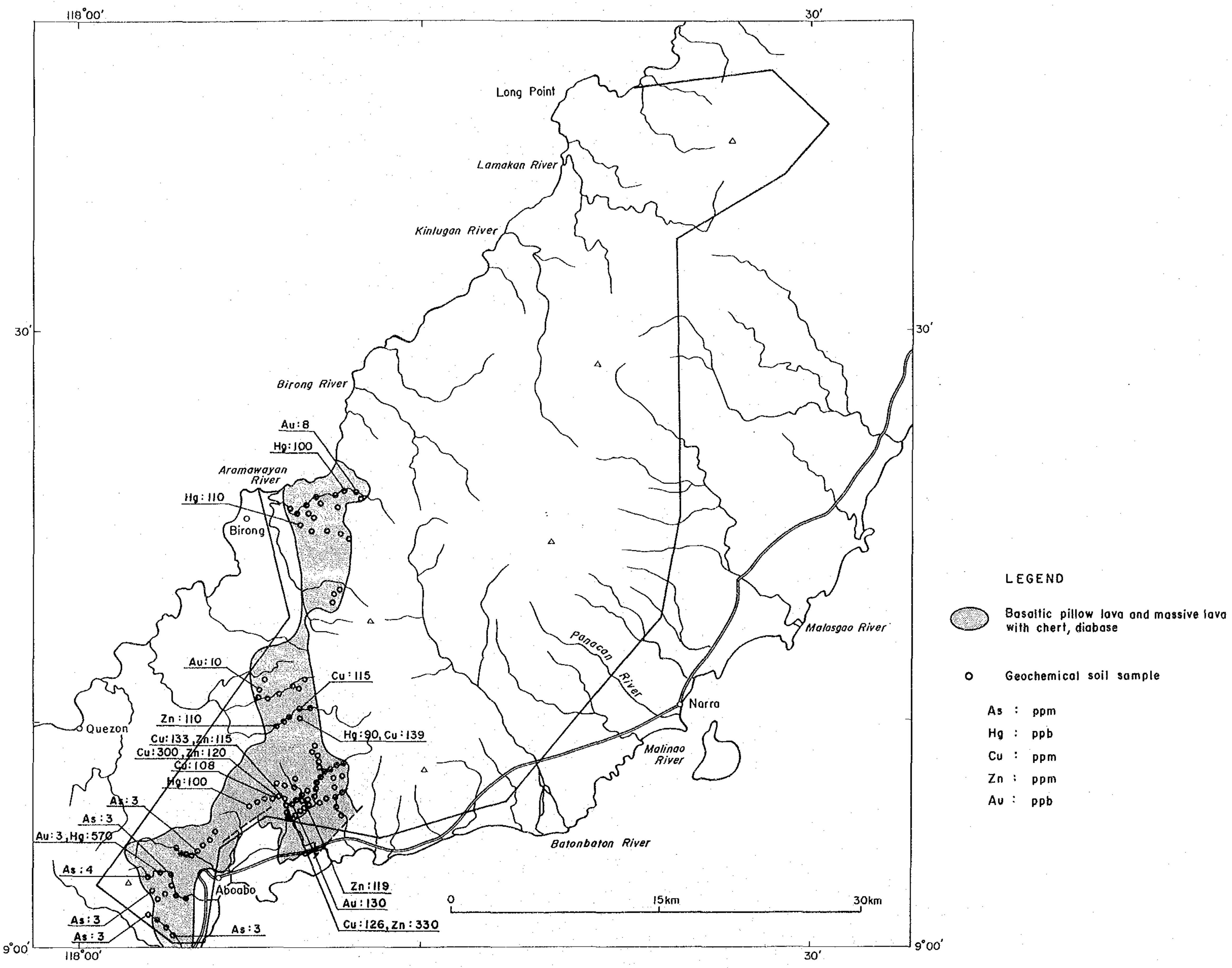

Fig. 64 Element contents of soil samples in basalt area, area B

2-7 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.

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. 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.

Chapter 3 C-area

3-1 Location and transportation

The C-area is situated in the southern part of Central Palawan, southwest of Quezon in the west coast.

A paved road runs from Puerto Princesa to Aboabo through Narra, along the east coast. From Aboabo to Quezon, there is an unpaved road which diverts from the paved road. It is 120 km from Puerto Princesa to Aboabo, and 20 km from Aboabo to Quezon. Bus services are available several times a day from Puerto Princesa to Quezon.

An unpaved road runs from Quezon to Lamacan, in the north end of the C-area.

3-2 Topography and drainage

The backbone range in Central Palawan becomes low at the road that runs from Aboabo to Quezon. From the Pulute Range, located in the southwest of this road, southern Palawan backbone range runs southward. The C-area is situated to the north of the backbone mountains nearby the Pulute Range. The area shows rugged topography.

All the drainage in this area flow toward north from the Pulute Range, and reach into the South China Sea.

3-3 Climate and vegetation

The climate of this area is clearly separated into two seasons, wet and dry, which is characteristic in the tropic areas. The dry season is from December to May, and the wet season is from June to November.

There are shrubs seen in the lowlands in the northern C-area, while in the mountains most of the vegetation is virgin forest that is characteristic in the tropics.

3-4 Survey method

In this survey, 1:10,000 scale topographic maps enlarged from 1:50,000 scale maps have been used. Every outcrop and float along survey routes, which were set up for main stream lines, have been carefully observed. The length of the survey route is 100 km in total. The results of the observations were recorded on the 1:10,000 scale maps. Samples were taken for laboratory studies and geochemical analysis.

The survey has been performed from a subcamp set up at Quezon and using a mobile camp.

3-5 Geology

3-5-1 Outline of geology

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

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.

3-5-2 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

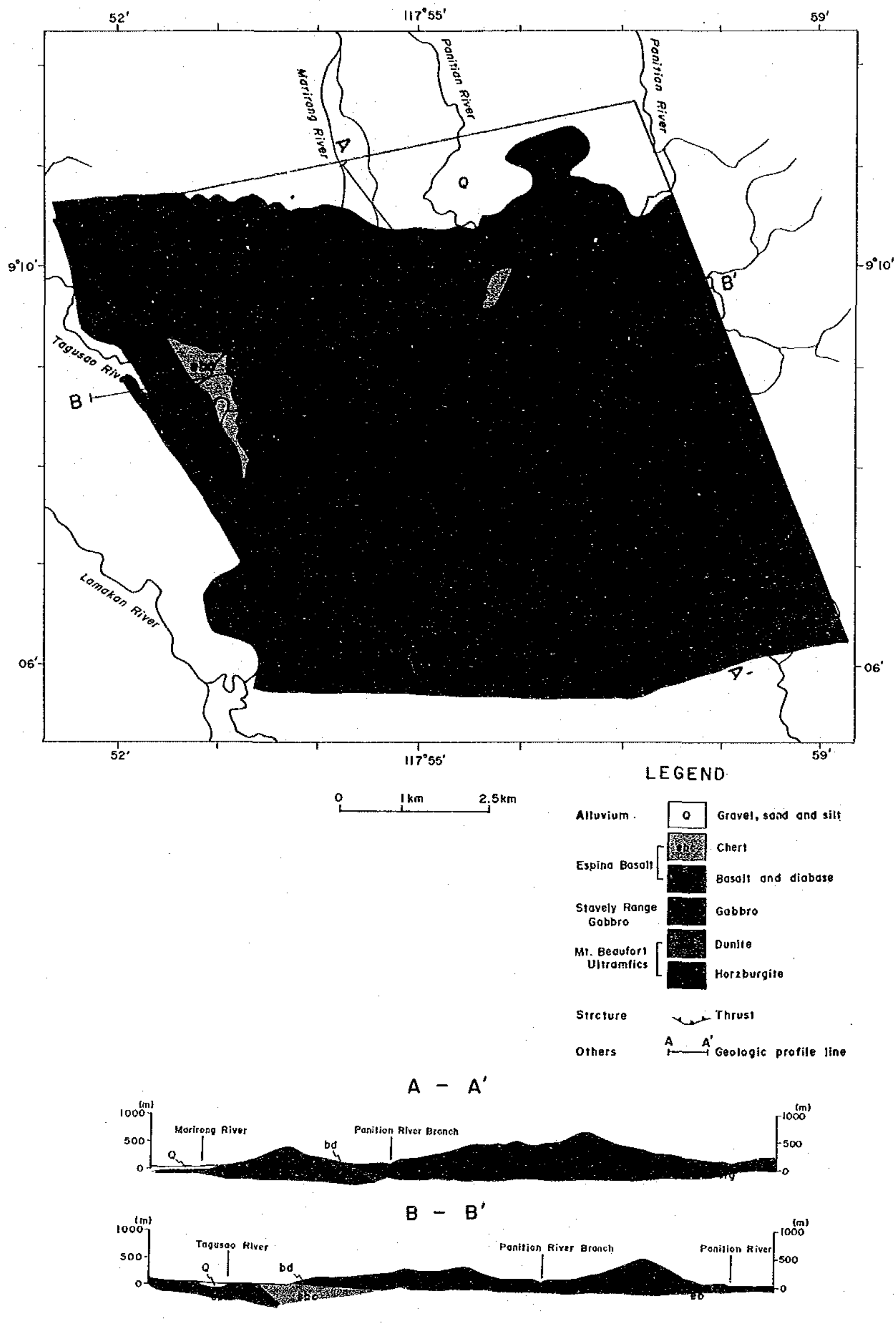

Fig. 65 Geologic map and profile in area C

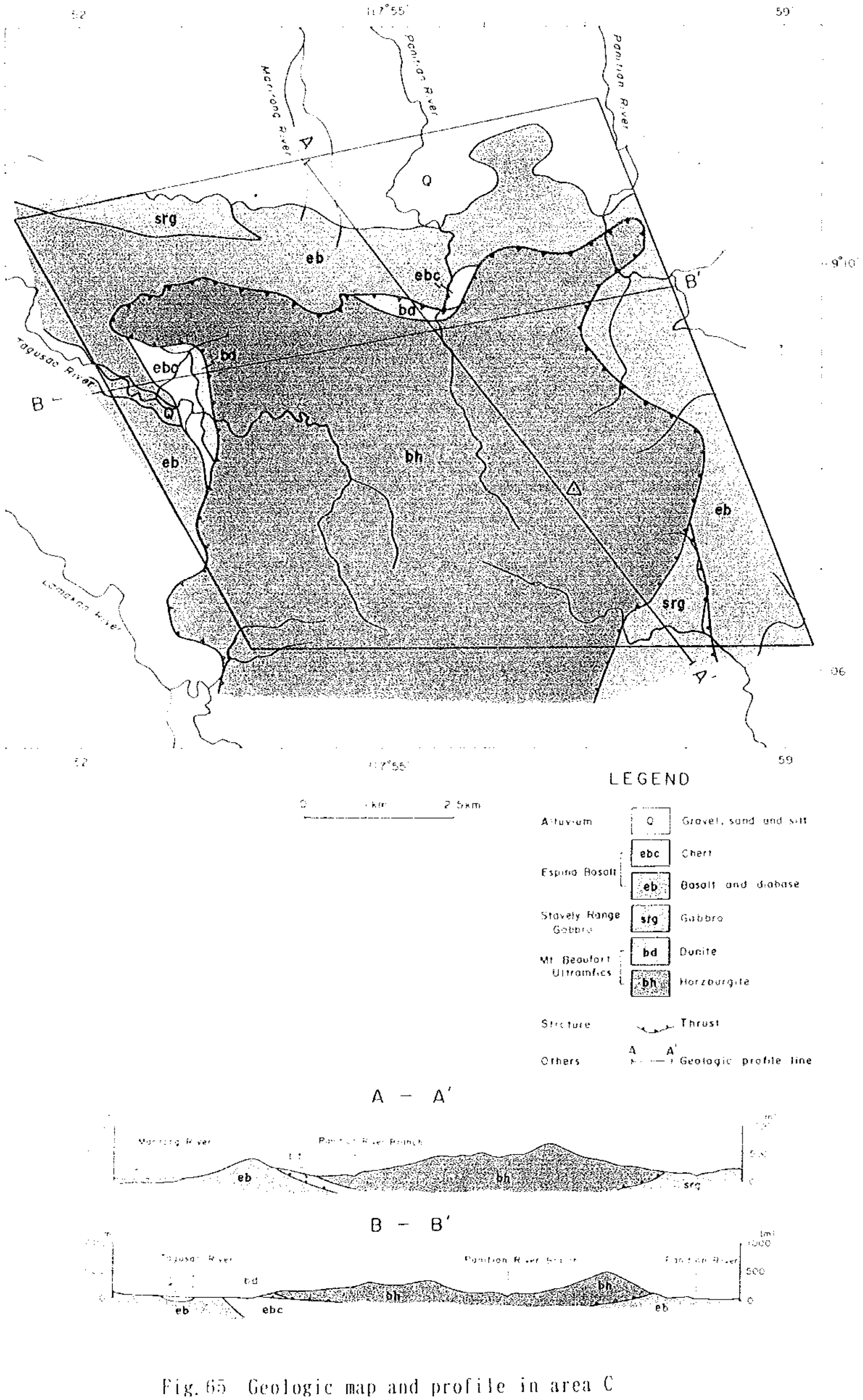

Fig. 65 Geologic map and profile in area C

Age	Geologic Column	Rock Description	Formation/Rock Unit	Mineral Showings
Quaternary	Q	Gravel, sand and silt	Alluvium	
Late Cretaceous	ebc, ebc, 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. 66 Schematic geologic map in area C

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

3-5-3 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.

3-5-4 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..

3-6 Geochemical Survey

3-6-1 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.

Collected soil samples were air-dried and screened with an 80 mesh sieve. About 100 g of -80 mesh fraction of each dried sample was divided into halves. One half was used for chemical analyses in the PETROLAB in Philippines while the other half was used for analyses in Chemex Labs. Ltd. in Canada.

The location map of the soil samples is shown in PL. 52.

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.

The results of sampling conditions and the analyses are shown in Appendix 30.

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 15. The ranges indicate a low content and a very small variation.

Table 15 Basic Statistic quantities of soil samples in area C

			linear		logarithmic		
element	range	median	mean	std. dev.	mean	10^mean	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

Histogram and cumulative probability curve of each element are shown in Appendix 31. The class interval of the histogram is half of the standard deviation.

Correlation coefficients between these elements are shown in Table 16. The strong positive correlation of more than +0.5 is only recognized with the relations of Cu-Zn.

(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. 68 to Fig. 74). The contour map and raw values of each element are shown in PL. 53 to PL. 59. These maps show which bank the sample was taken.

Threshold for C-area is considered as mean value (m) and as standard deviation (σ), and the point of $m+1.0\sigma$ 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 correlation matrix obtained from data set is shown in Table 17.

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. 75 to Fig. 77). The cumulative probability plots of scores are shown in Appendix 32. 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.

3-6-2 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 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.

Table 16 Correlation coefficients of soil samples in area C

n = 209

	Cu	Pb	Zn	Au	As	Sb	Hg
Cu	1.000	0.080	0.479	0.168	0.066	-0.039	-0.119
Pb	0.080	1.000	0.063	-0.120	0.284	0.107	0.096
Zn	0.479	0.063	1.000	-0.099	-0.026	0.044	0.109
Au	0.168	-0.120	-0.099	1.000	-0.033	-0.053	-0.200
As	0.066	0.284	-0.026	-0.033	1.000	0.150	-0.056
Sb	-0.039	0.107	0.044	-0.053	0.150	1.000	0.171
Hg	-0.119	0.096	0.109	-0.200	-0.056	0.171	1.000

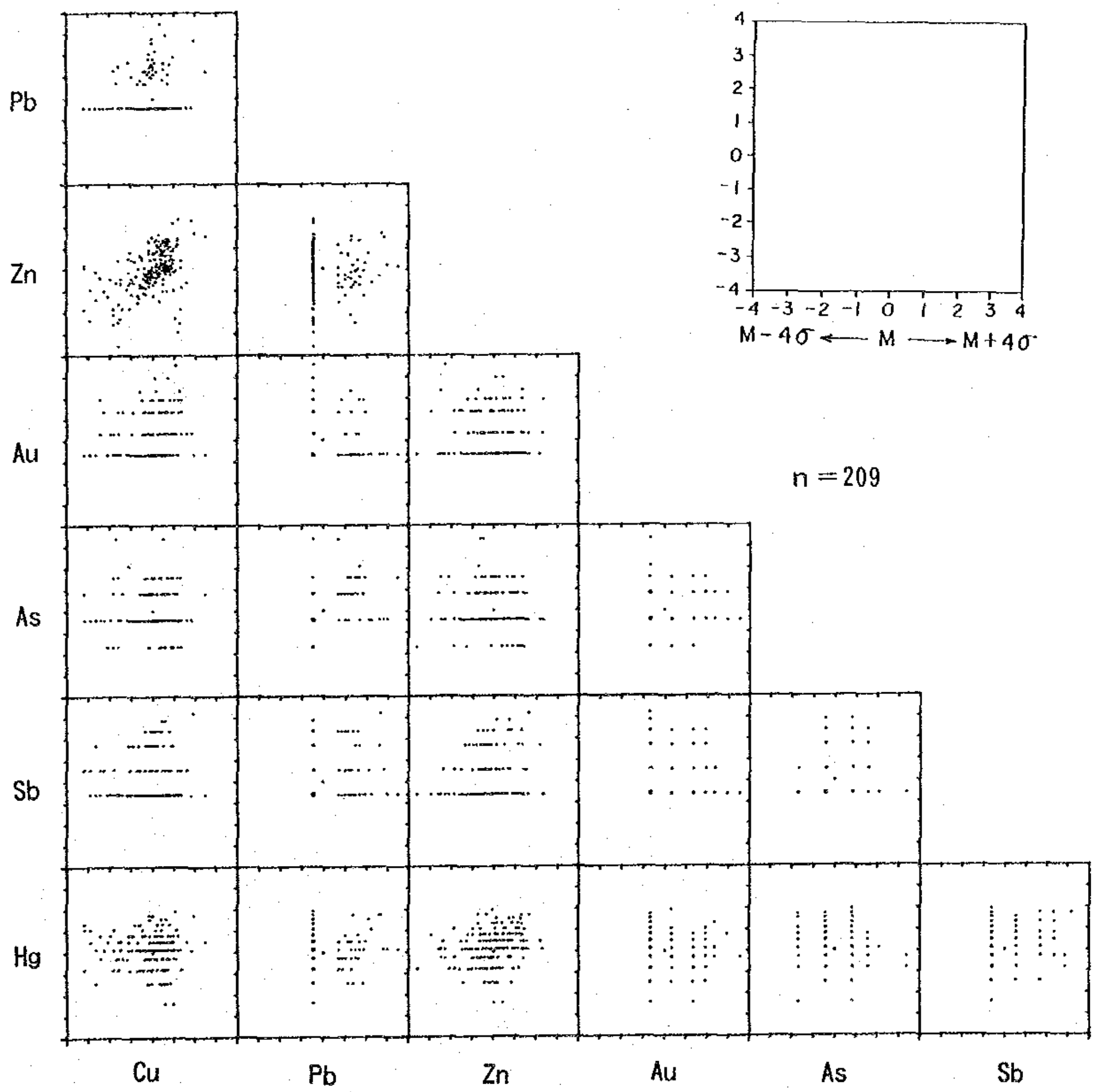

Fig. 67 Scatter diagram of soil samples in area C

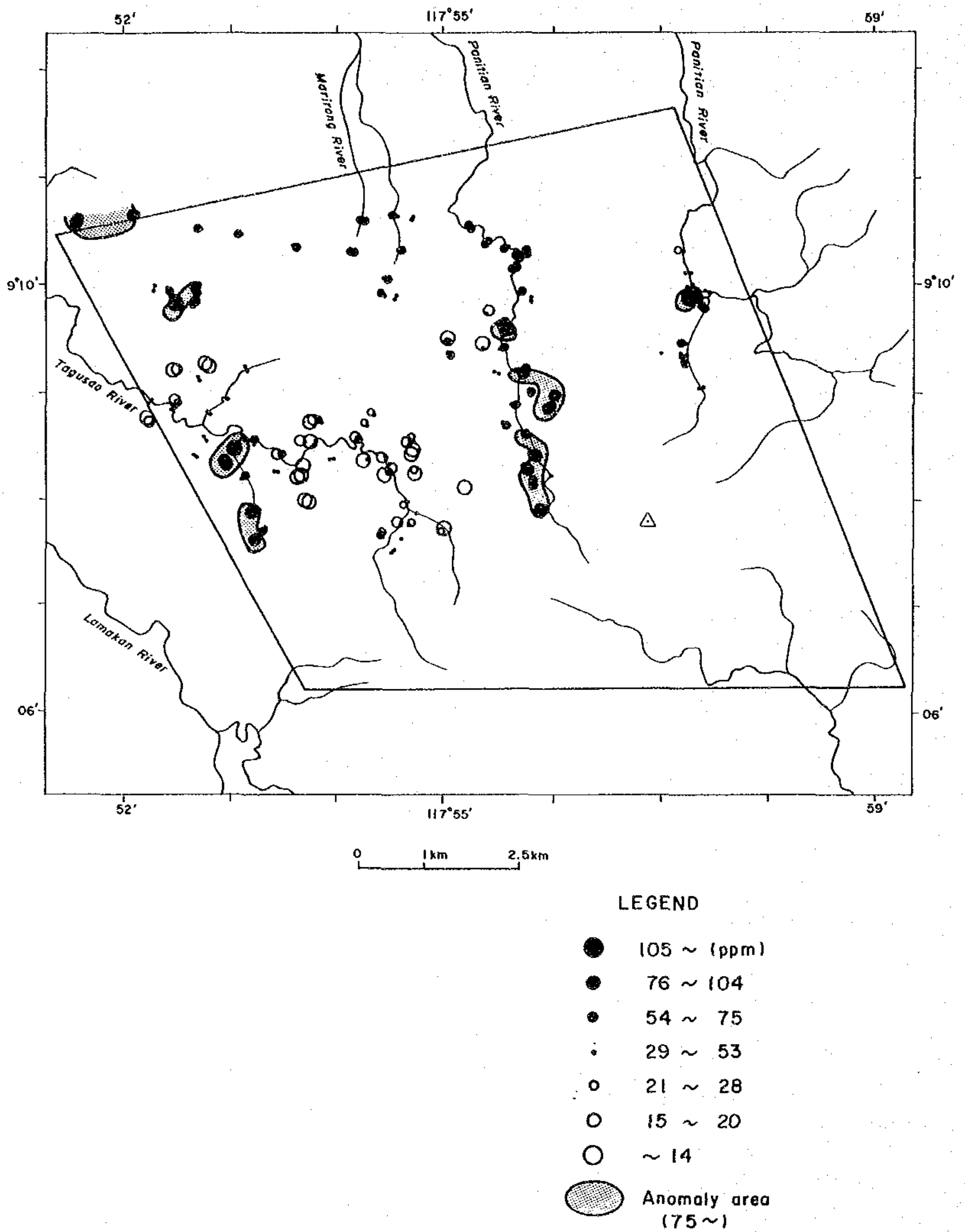

Fig. 68 Cu content of soil samples in area C

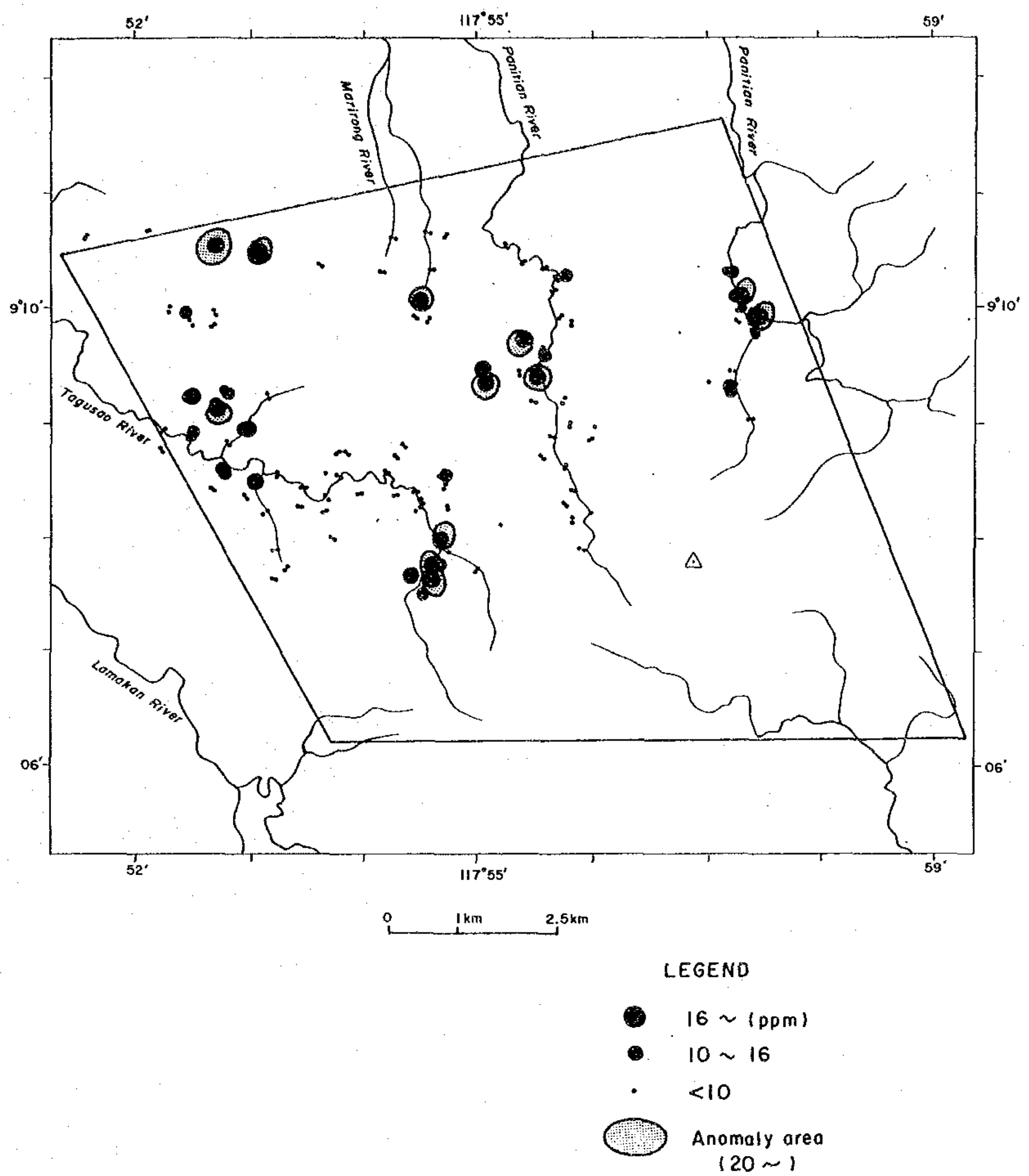

Fig. 69 Pb content of soil samples in area C

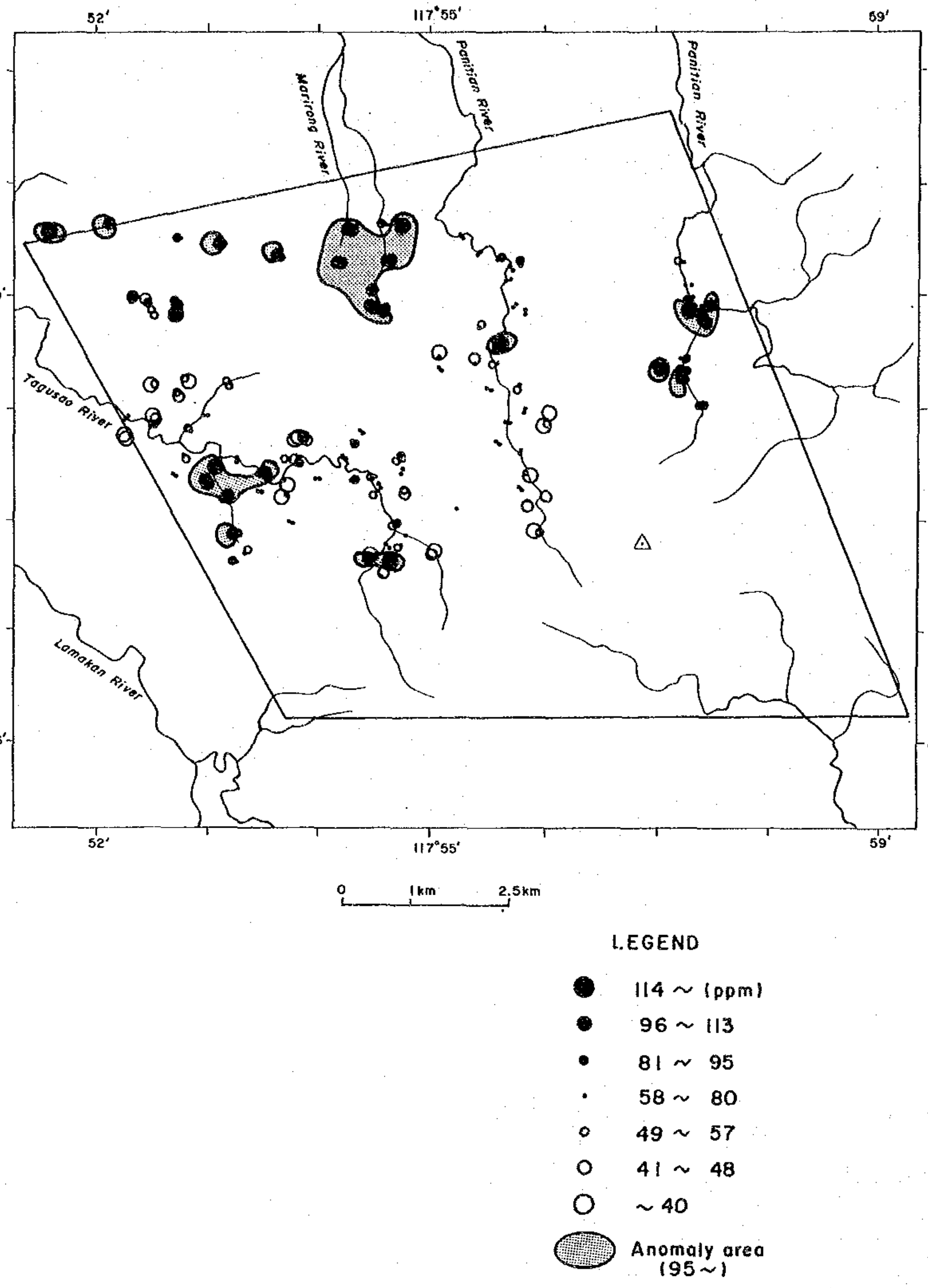

Fig. 70 Zn content of soil samples in area C

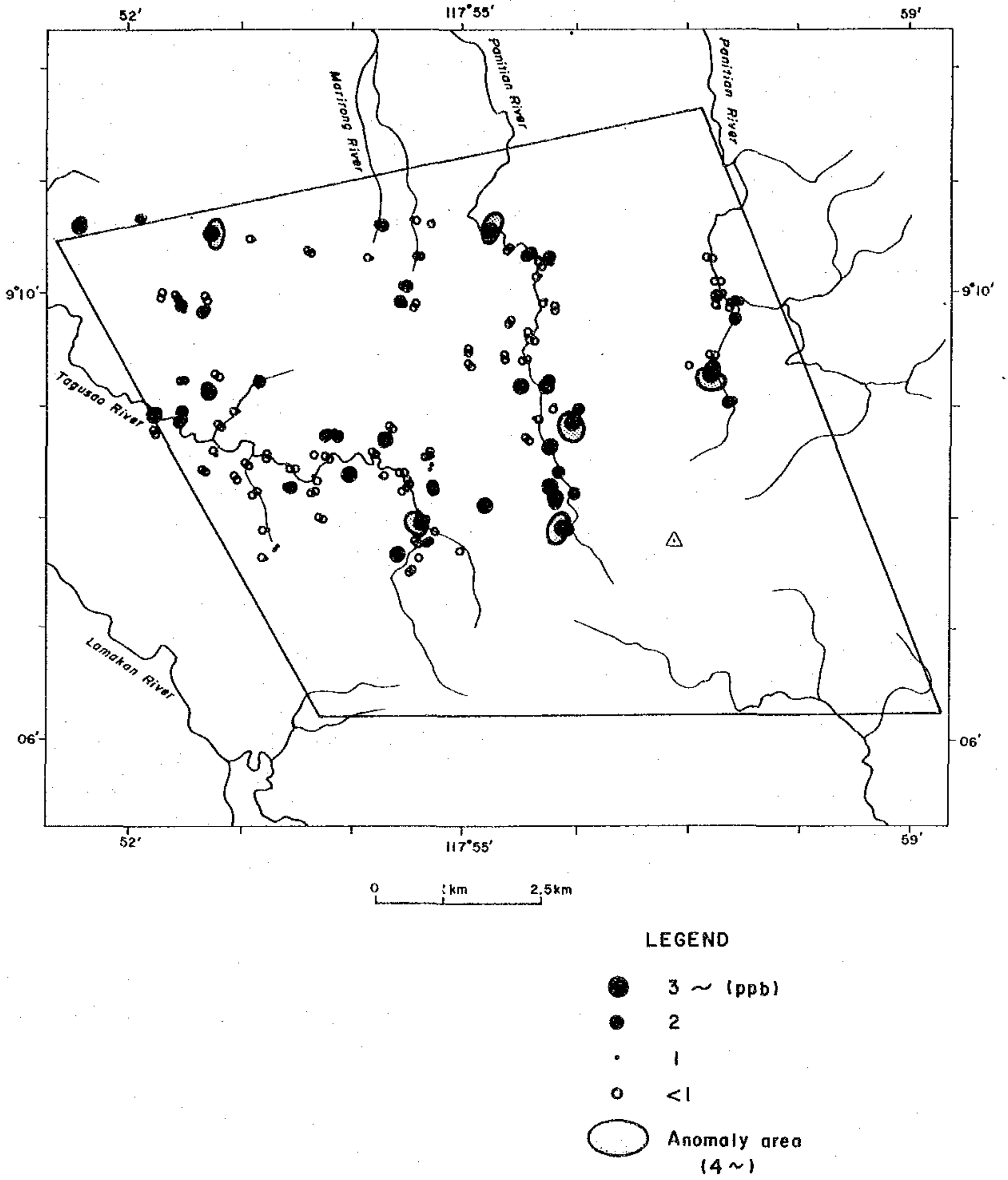

Fig. 71 Au content of soil samples in area C

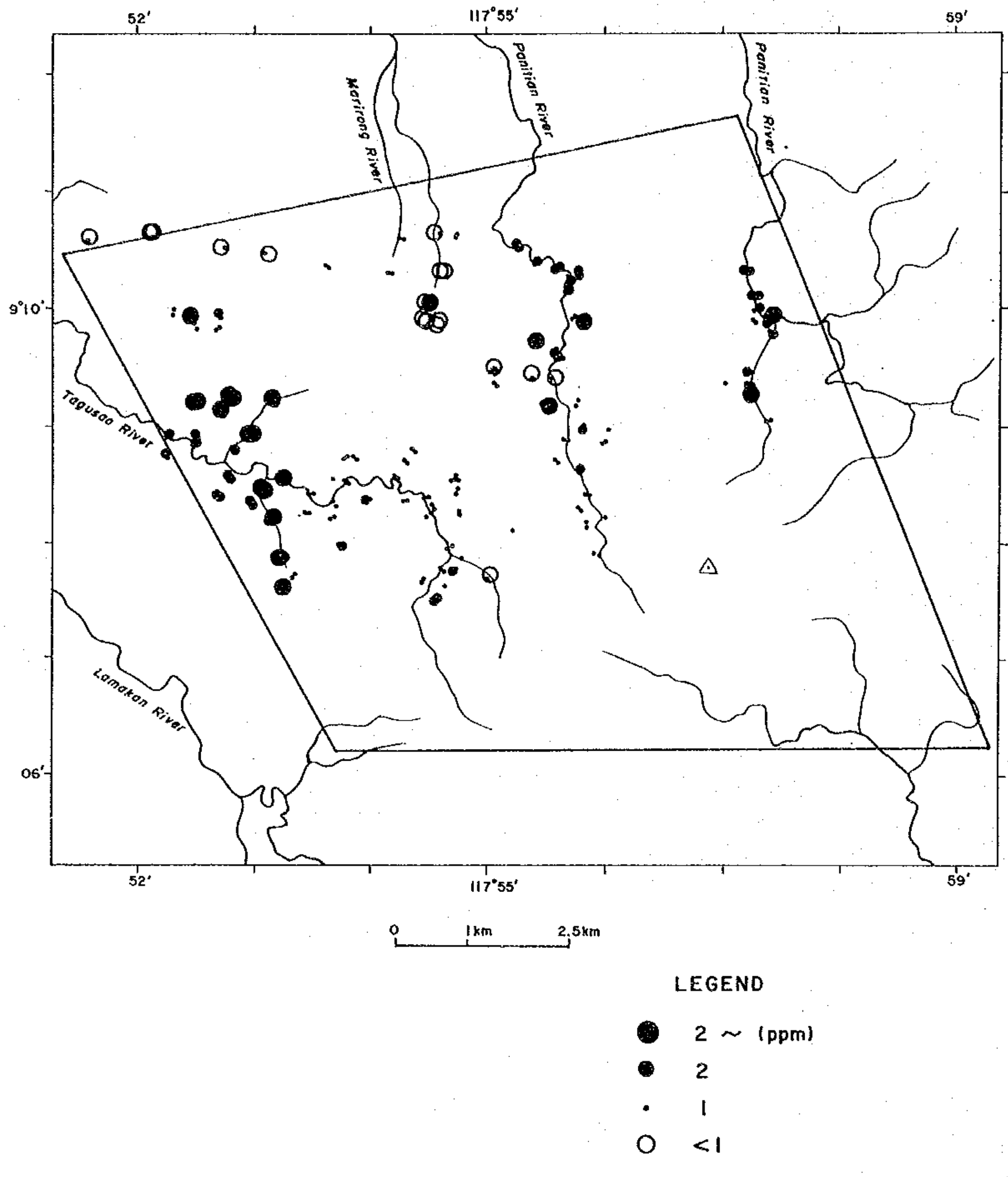

Fig. 72 As content of soil samples in area C

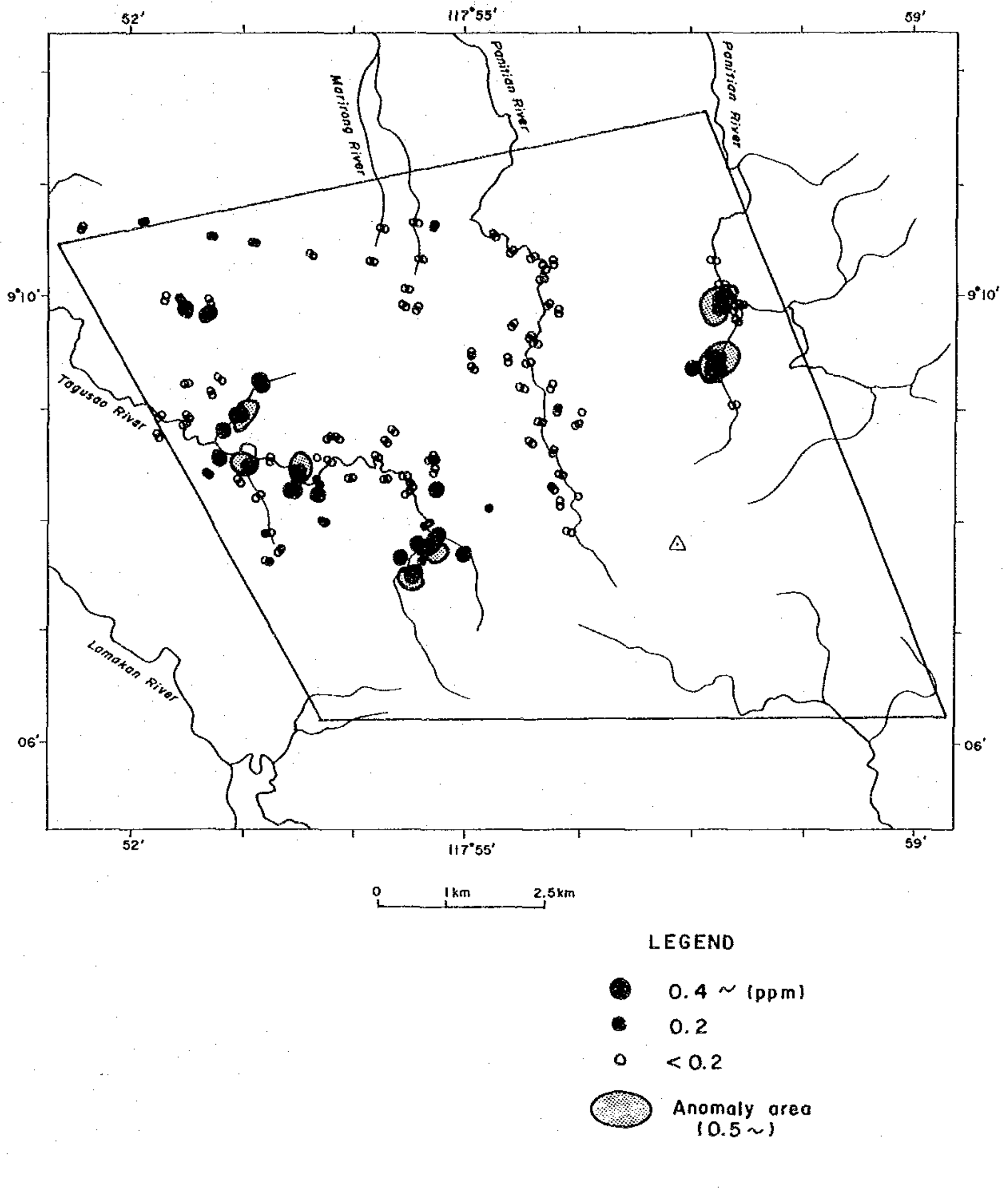

Fig. 73 Sb content of soil samples in area C

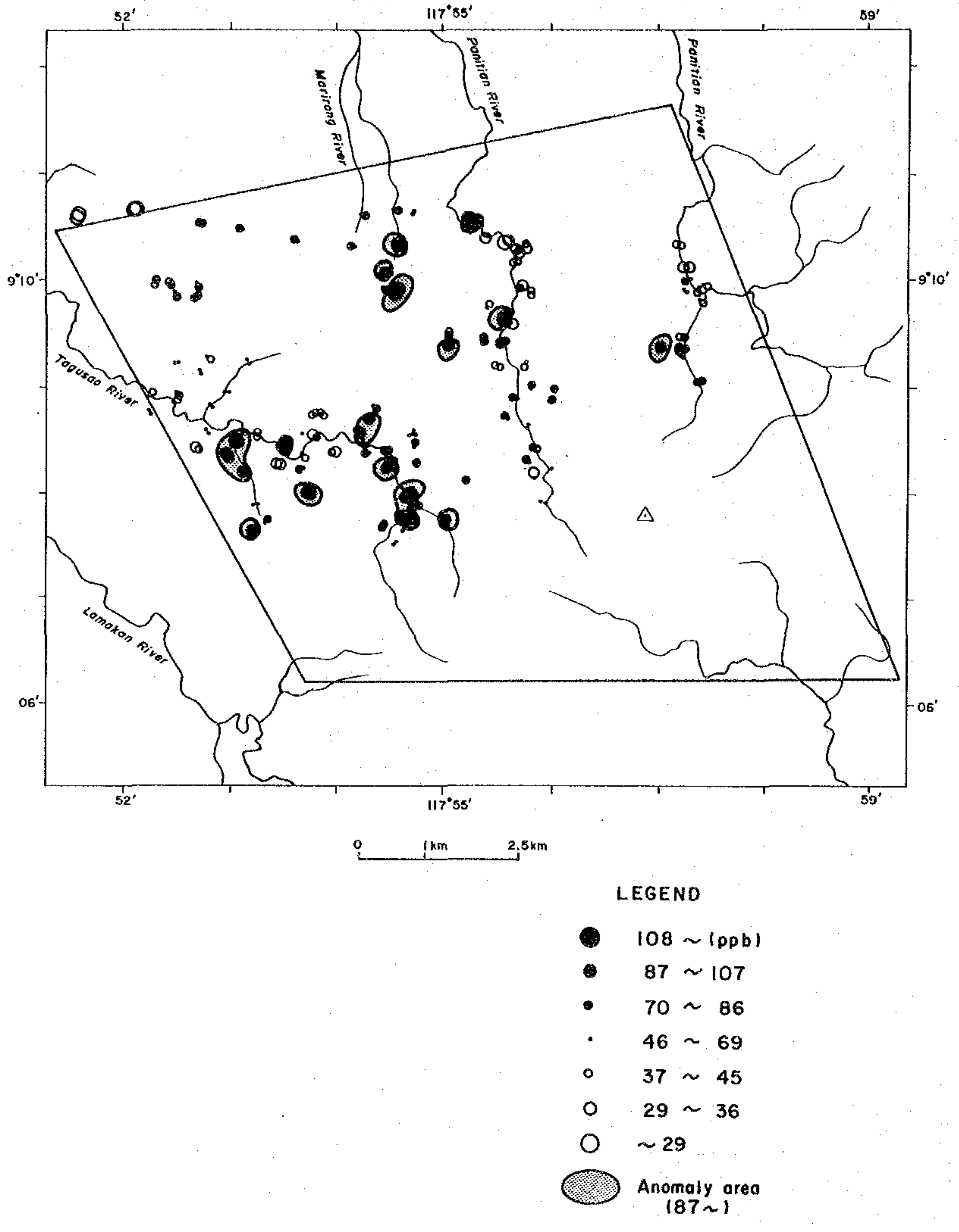

Fig. 74 Hg content of soil samples in area C

Table 17 Results of principal components analysis in area C

COMPONENT	EIGENVALUE	PERCENT	CUMULATIVE
Z-01	<u>1.5388</u>	21.9815	21.9815
Z-02	<u>1.4613</u>	20.8741	42.8556
Z-03	<u>1.2099</u>	17.2822	60.1379
Z-04	0.9444	13.4902	73.6281
Z-05	0.7682	10.9729	84.6009
Z-06	0.6489	9.2689	93.8698
Z-07	0.4291	6.1302	100.0000
TOTAL	7.0000	100	

Factor Loading

	Z-01	Z-02	Z-03	Z-04	Z-05	Z-06	Z-07
Cu	<u>0.6102</u>	<u>-0.6533</u>	-0.0005	0.0373	0.0123	0.0179	-0.4461
Pb	<u>0.5434</u>	0.3315	0.3721	-0.2916	0.4348	-0.4237	0.0489
Zn	<u>0.7012</u>	-0.3704	-0.4159	-0.0249	-0.1271	0.0304	0.4248
Au	-0.2081	<u>-0.5324</u>	0.3735	0.5250	0.4711	0.0697	0.1785
As	0.4071	0.2464	<u>0.6841</u>	-0.0671	-0.1769	0.5163	0.0575
Sb	0.3329	0.4284	0.0601	0.7382	-0.2986	-0.2578	-0.0407
Hg	0.2444	<u>0.5096</u>	<u>-0.5361</u>	0.1798	0.4694	0.3608	-0.1020

Eigen Vector

	Z-01	Z-02	Z-03	Z-04	Z-05	Z-06	Z-07
Cu	0.4919	-0.5405	-0.0005	0.0384	0.0141	0.0223	-0.6810
Pb	0.4380	0.2743	0.3383	-0.3001	0.4961	-0.5260	0.0747
Zn	0.5652	-0.3064	-0.3781	-0.0256	-0.1450	0.0377	0.6485
Au	-0.1677	-0.4404	0.3396	0.5403	0.5375	0.0866	0.2725
As	0.3281	0.2038	0.6219	-0.0690	-0.2019	0.6409	0.0877
Sb	0.2684	0.3544	0.0546	0.7596	-0.3407	-0.3201	-0.0622
Hg	0.1971	0.4215	-0.4874	0.1850	0.5356	0.4479	-0.1557

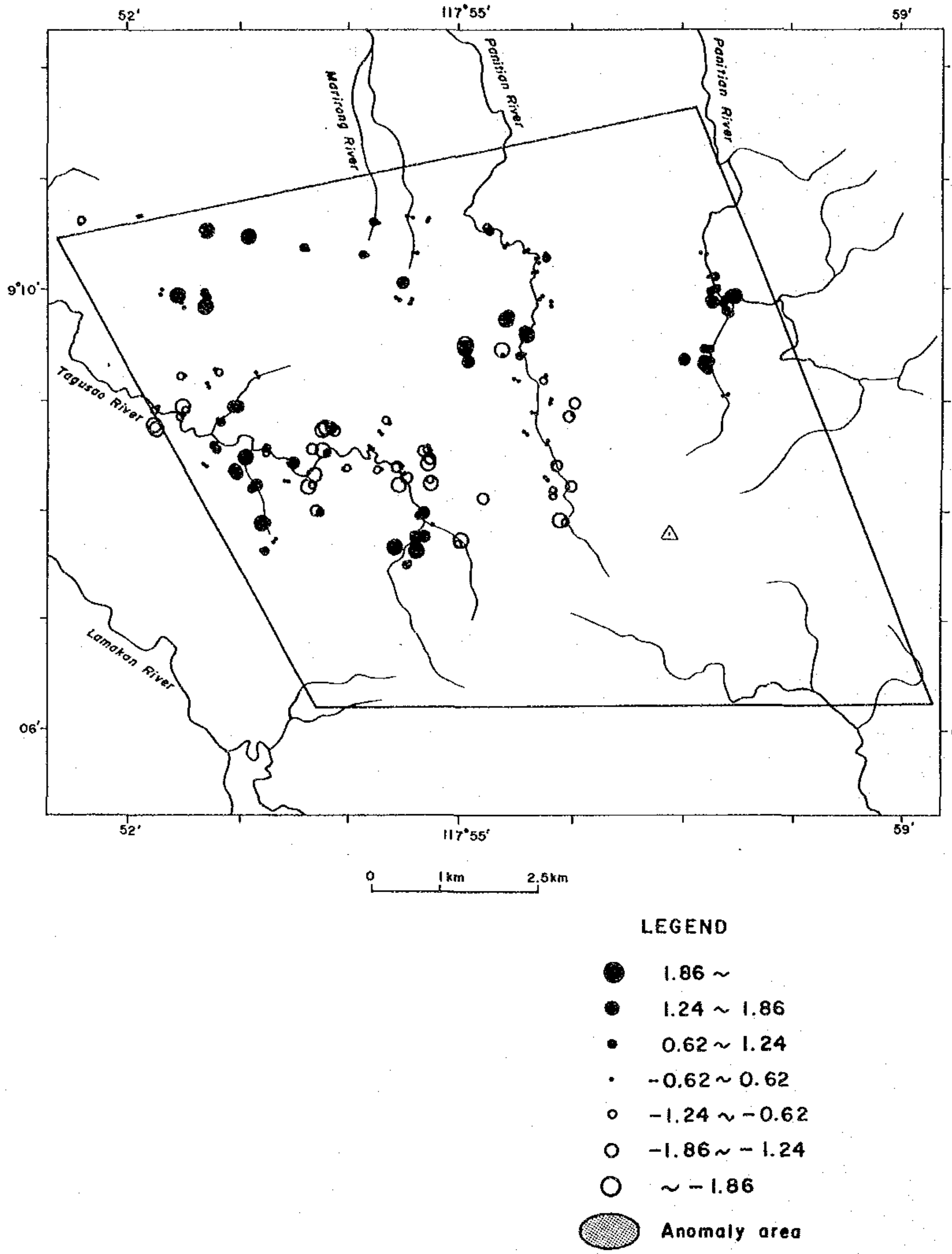

Fig. 75 Scores of principal components analysis in area C (Z1)

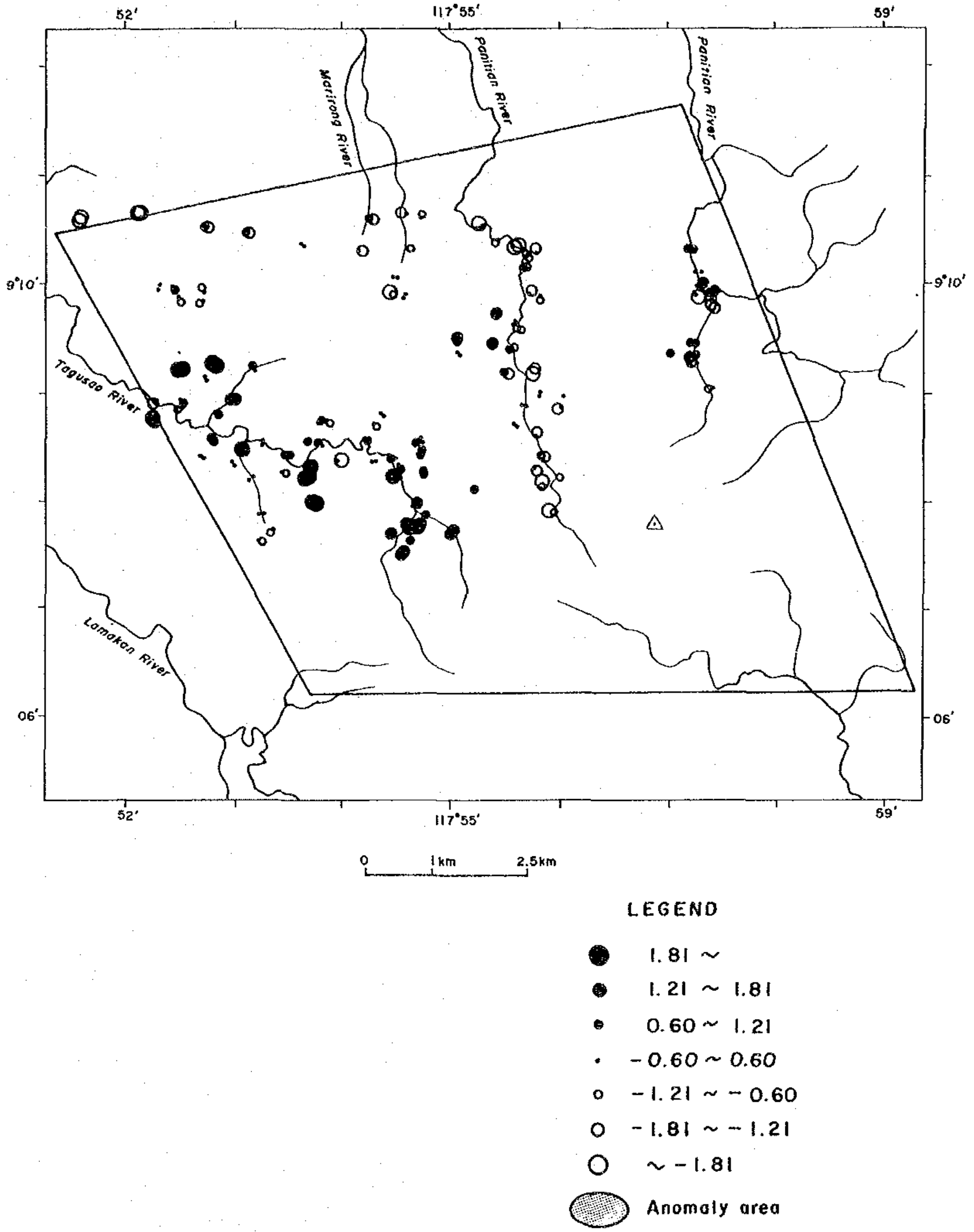

Fig. 76 Scores of principal components analysis in area C (Z2)

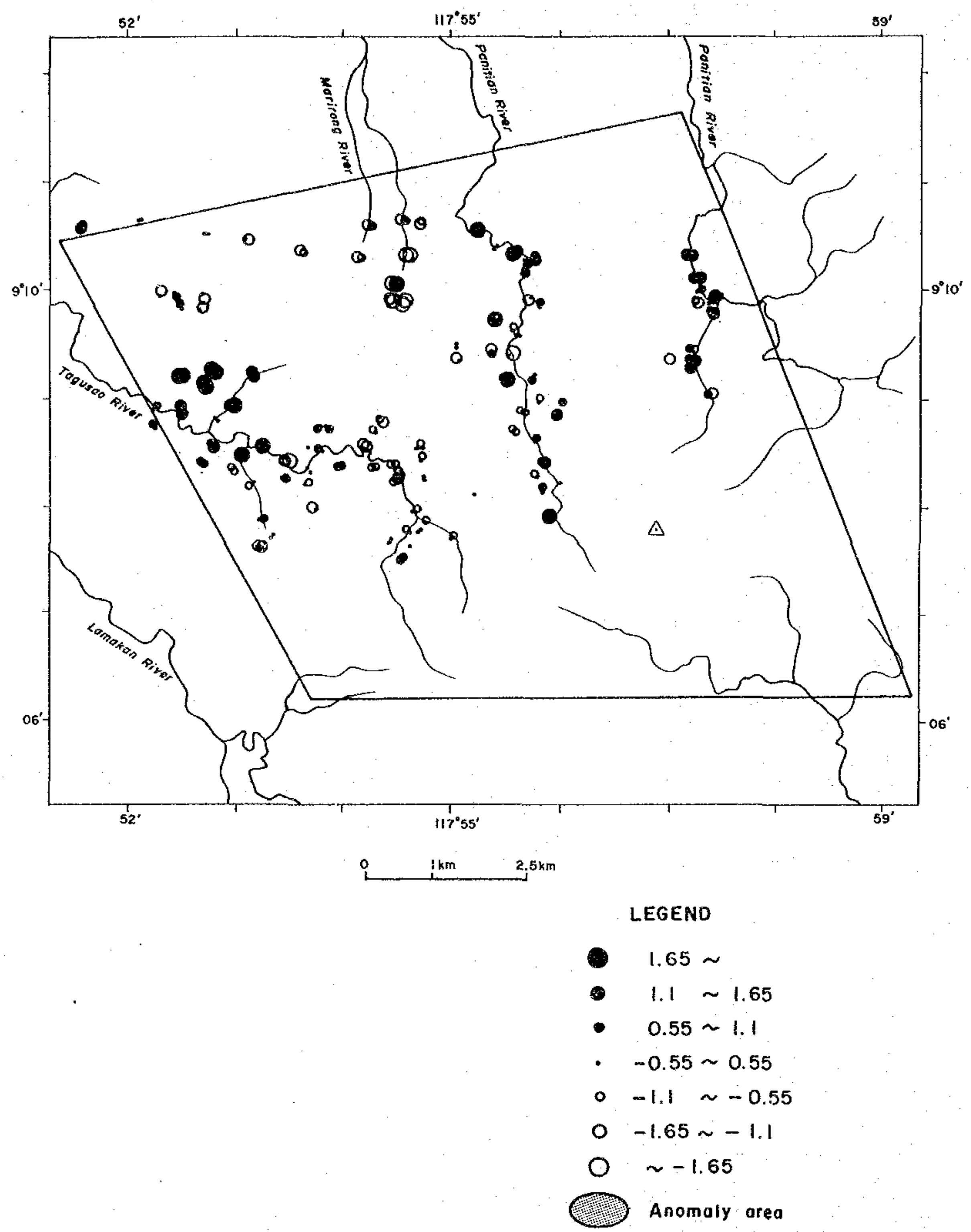

Fig. 77 Scores of principal components analysis in area C (Z3)

3-7 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:

$$QI = Im/Iq \times 100$$

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

Table 18 Result of X-ray diffraction of heavy mineral in soil

Area A

No.	mineral d(Å) / Sample No.	Hb	Opx	Cpx	Cr	Mt	Il	Talc
		8.48	3.17	2.99	2.50	2.51	2.74	9.35
1	AE - 004L				24		24	2
2	AE - 006R	3			55			
3	AE - 008R	6			31			
4	AE - 010R	7			35	26		
5	AE - 012L		29	4	49			
6	AE - 014R	2			40	14		2
7	AE - 016L	8	3	7	45	13		
8	AE - 017L	8	5	9	38	12		
9	AE - 018L	8	2	8	39			
10	AE - 022R		3		43			
11	AE - 024R		10		44			
12	AE - 026L		10		42			
13	AE - 027R		5		44			
14	AE - 028R		6		44	10		
15	AE - 029R		2		48			
16	AE - 030L		5		40			
17	AE - 032L		14		38			
18	AF - 014R	12	3		28	25		13
19	AF - 016R		2		61			
20	AF - 018R	16			32			
21	AF - 019L				52			
22	AF - 021R	1	5		47	10		
23	AF - 026R				75			
24	AF - 028R		23	2	32	11		
25	AF - 029L		19		29	10		
26	AF - 030L		16		37	8		
27	AF - 031R		16		47			
28	AF - 033L		13	6	33			
29	AF - 036L		13		53			

Area B

No.	mineral d(Å) / Sample No.	Hb	Opx	Cpx	Cr	Mt	Il	Talc
		8.48	3.17	2.99	2.50	2.51	2.74	9.35
1	BG - 083L				74			
2	BG - 083R				75			
3	BG - 084R				50			
4	BG - 085R				62			
5	BG - 086R				47			
6	BG - 087L	1		2	63			
7	BG - 088R				59			
8	BG - 089L				61			
9	BH - 039R			2	67			
10	BH - 040L				61			
11	BH - 041L		2	3	71			
12	BH - 042R		1		66			
13	BH - 043R		1		64			
14	BH - 044R				83			
15	BH - 046		2		62			
16	BJ - 029L		2		67			
17	BJ - 030R				48			
18	BJ - 032R		2		60			
19	BJ - 034R		2		52			
20	BK - 055R				65			
21	BK - 063L		2	1	40	32		

Abbreviation
Hb : hornblende, Opx : orthopyroxene,
Cpx : clinopyroxene, Cr : chromite,
Mt : magnetite, Il : ilmenite,
Talc:talc

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 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

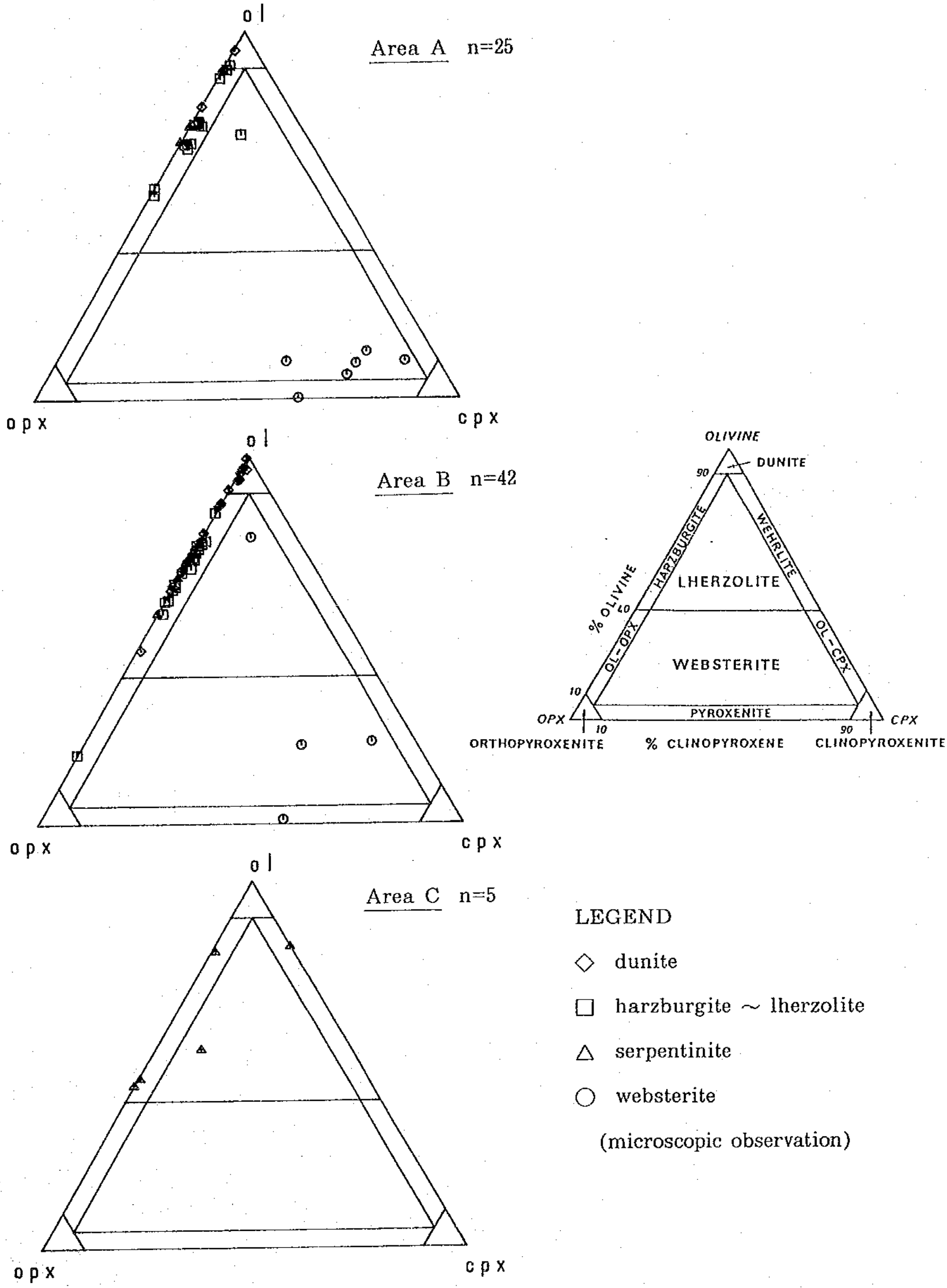

Fig. 78 Classification of ultramafic plutonic rocks, used ICPW Norm results

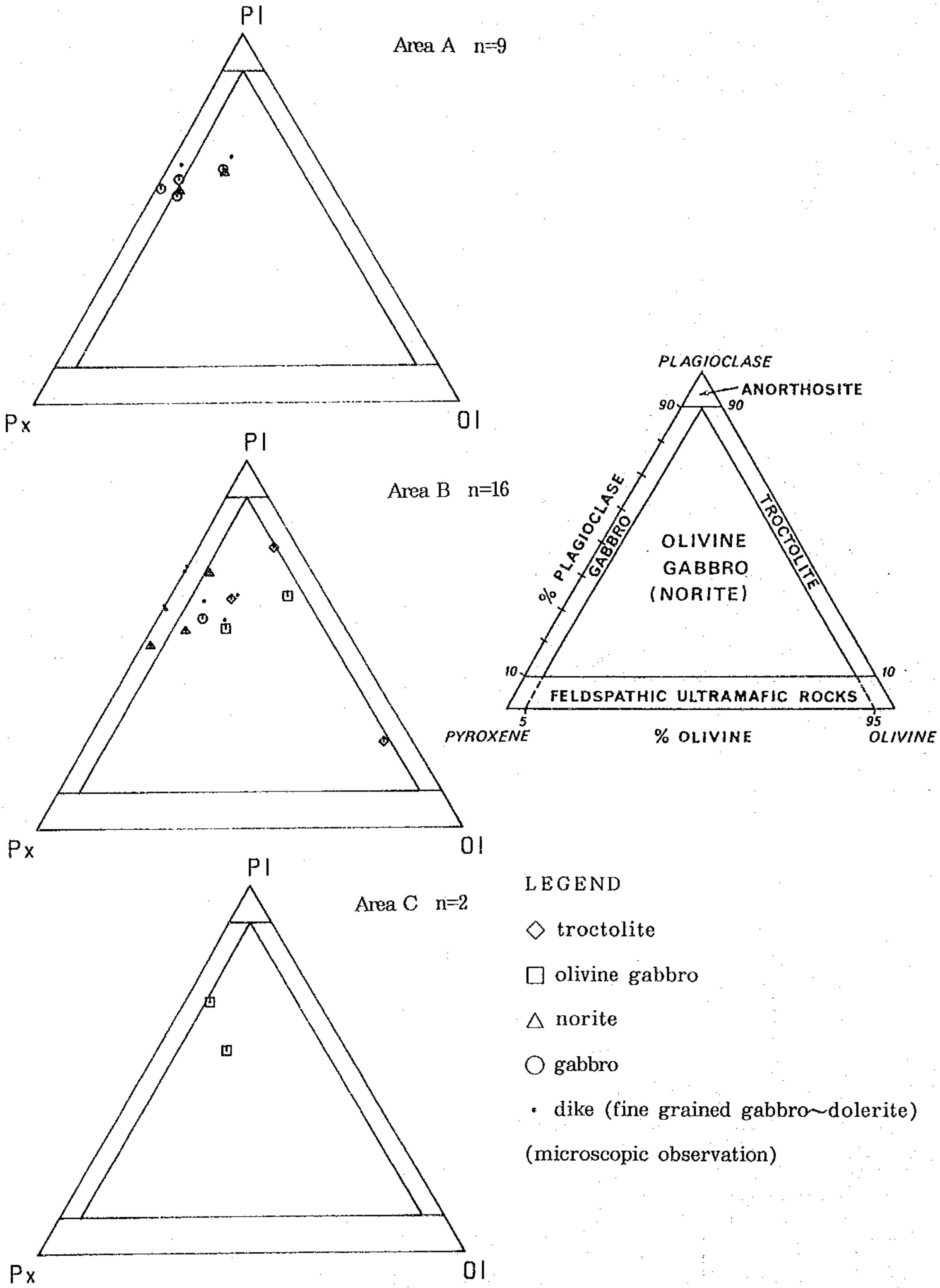

Fig. 79 Classification of mafic plutonic rocks, used ICPW Norm results.

olivine-orthopyroxene line, and these rocks are effectively clinopyroxene free (Fig. 78).

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

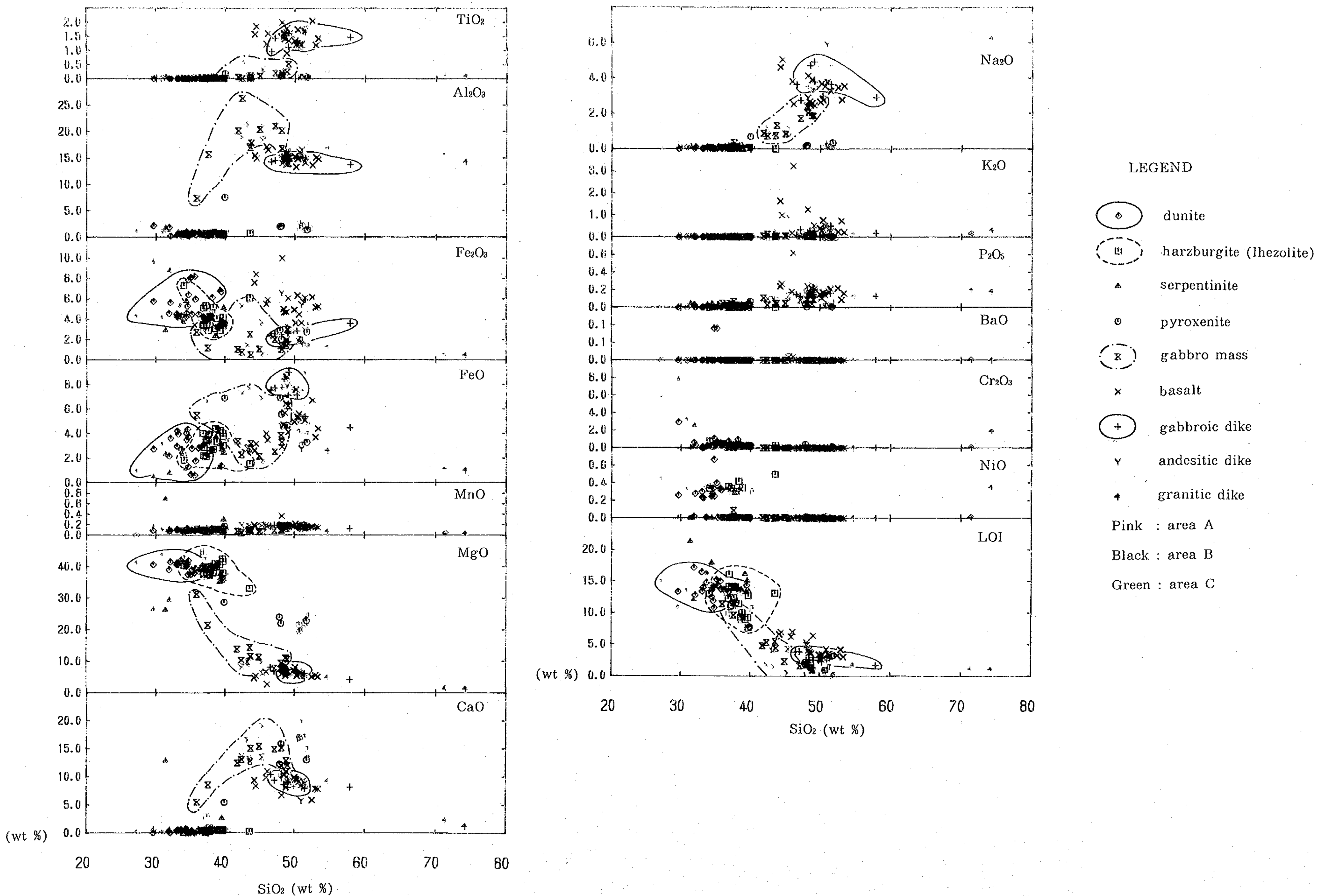

Fig. 80 Variation diagram

4-3 Chemical composition of chromite

The composition of chromite determines directly the grade of ore deposit, and it is also extremely sensitive to bulk composition, mineralogy and petrogenesis of the host rocks.

Chromite was analyzed from 30 chromitite samples taken from mineral showings in this survey. 96 analyses are presented in Appendix 35. There are no apparent chemical zoning, though core and rim of several chromite grains were analyzed.

Chromite series is one series of spinel group. The end-member of chromite is magnesiochromite ($MgCr_2O_4$) and chromite (ferrochromite, $FeCr_2O_4$), and complete solid solution exists between magnesiochromite and chromite (ferrochromite). Natural chromites contain a considerable amount of Al or Fe^{3+} replacing Cr.

The Cr/(Al+Cr) versus Mg/(Mg+Fe*) diagram and Al_2O_3 versus Cr_2O_3 diagram are shown in Fig. 81 (Fe*:total Fe). Usually podiform chromite contains an only small amount of Fe^{3+}, therefore the Cr/(Al+Cr) versus Mg/(Mg+Fe*) diagram shows the variation of the Cr/Al ratio and Mg/Fe^{2+} ratio. The three groups of chromitite orebodies presented in Fig. 81 are classified on the basis of the name of mineral showings.

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 and B-area except area B-1 have Cr/(Al+Cr) ratios of 0.58-0.88.

On the basis of relative geological position in the ophiolite sequence, chromitites of area B-1 is found in transitional zone and cumulate dunite which is in part the cumulous sequence of layered gabbro, and the chromitites of A-area and B-area except area B-1 is found in dunite tectonite which are believed to be dunite pockets in the harzburgite in mantle sequence.

These spatial separation and bimodal compositional distribution of chromite types has been reported in Central Palawan (Rammlmair, 1987) and in Zambales (Leblanc and Violette, 1983). And the chromite composition reflects the degree of melting in the mantle source region (Dick and Bullen, 1984).

For example, in Zambales the Acoje Mine produces metallurgical-grade ore whereas the

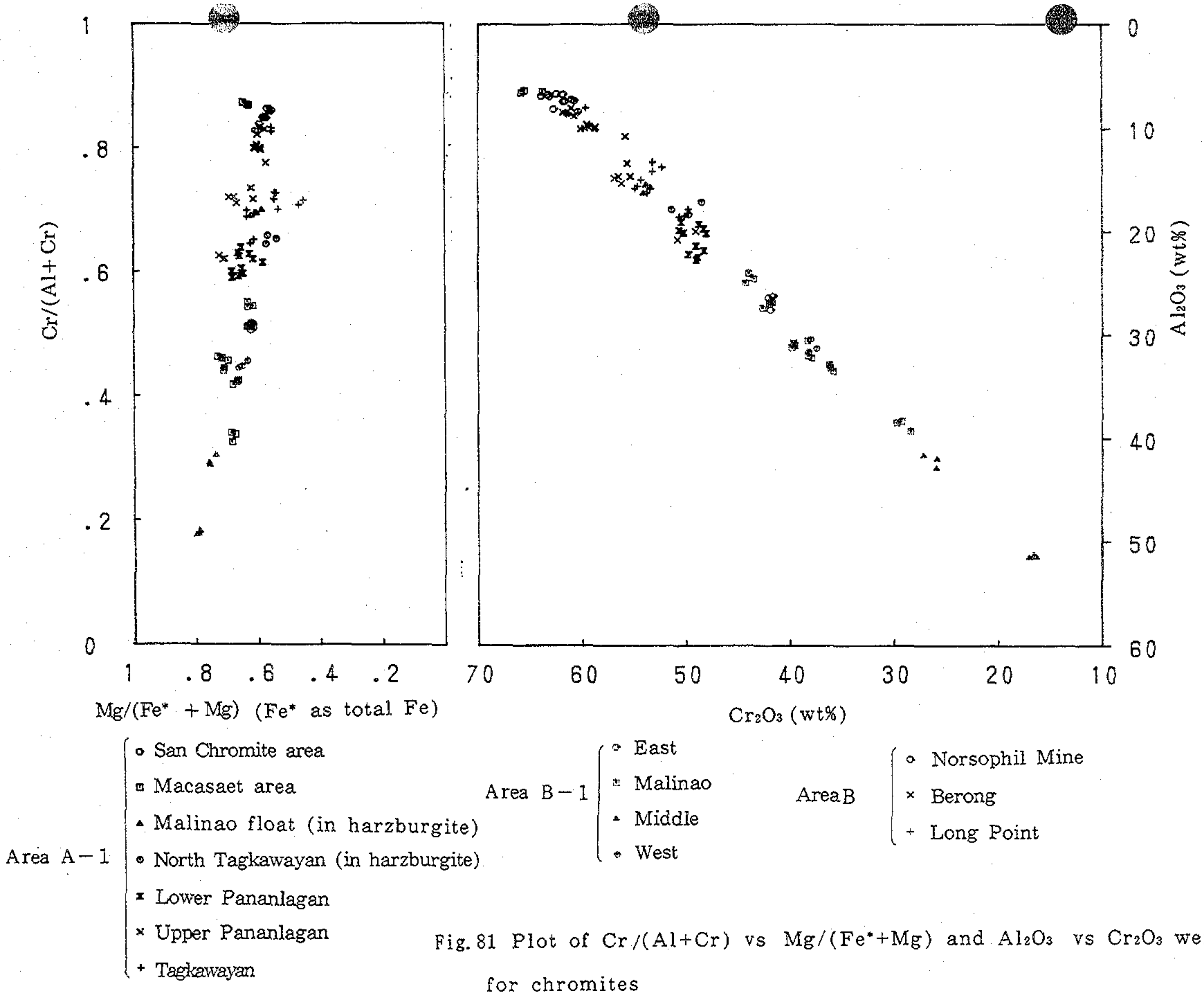

Fig. 81 Plot of Cr/(Al+Cr) vs Mg/(Fe*+Mg) and Al_2O_3 vs Cr_2O_3 weight percent for chromites

Coto district yields refractory-grade ore. The Al rich chromite pods seem to be contained in the peridotite which underlie the gabbroic cumulates whereas the Cr-rich chromite pods are probably related to deeper peridotite.

From this fact it is concluded that the relative position in ophiolite of dunite is very important in the search for chromite ore deposit and also serves as indicator of the probable grade of ore deposits. Al_2O_3 versus Cr_2O_3 diagram indicates that chromite deposits in area B-1 yield refractory chromite and chromite deposits in A-area and B-area except area B-1 produce metallurgical-grade ore. The relation of Norsophil Mine's deposits and mineral showings in area B-1 is of particular interest for chromium research around Norsophil Mine vicinity, because mineral showings in area B-1 is only 3-4 kilometers from Norsophil Mine.

PART III CONCLUSIONS AND RECOMMENDATIONS

Chapter 1 Conclusions

The conclusions of this year's geological and geochemical survey program are as follows.

A-area and area A-1

(1) The A-area is underlain by the Palawan Ophiolite, Kabangan Metamorphics, Tagburos Siltstone, and Sulu Sea Mine Formation.

(2) Mineral occurrences observed in the A-area are of chrome and nickel, and both are restricted in the Mt. Beaufort Ultramafics.

(3) Most of the chromite occurrences are in dunite-tectonite intruded into harzburgite. Principal chromite occurrences have been found by the detailed survey in area A-1, which was selected based on the results of the initial geological and geochemical survey in the A-area. The mineral showings are distributed in the San Chromite area, Macasaet area, Upper Pananlagan, Lower Pananlagan, Tagkawayan, and Tagminatay.

(4) Laterite is distributed in Bacungan, and has a potential for nickel resources.

(5) Evaluation of volume ratios of heavy minerals obtained by panning of soil samples has revealed the following high concentration areas of heavy minerals; the area north of Tagburos, the surrounding area of Bacungan, the northwestern area, and the area along the west coast.

(6) The results of the soil geochemical survey for seven elements, Pt, Pd, Au, Ni, Cr, Fe, and Co, have revealed following the anomalous areas; the area north of Tagburos, the area north to northwest of Bacungan, and the area from the Malinao River to Tagminatay along the west coast.

(7) The results of the above mentioned surveys lead to the selection of following potential areas in the A-area; the area north of Tagburos, the area from the north of Bacungan to the west coast, the area from the Malinao River to Tagminatay.

(8) The detailed survey area A-1, the area from the Malinao River to Tagminatay, was selected from three geochemical anomaly areas which were found by the initial geochemical survey in the A-area. The results of the detailed geological survey clarified occurrences of dunite bodies and mineral showings.

(9) The results of the detailed geochemical survey in area A-1 lead to the selection of following

potential areas for chrome ores; area containing the Pananlagan mineral showings, area from the Tagkawayan mineral showings to the Tagminatay area.

B-area and area B-1

(1) The B-area is underlain by the Palawan Ophiolite, Inagauan Metamorphics, and Panas Formation.

(2) Mineral occurrences observed in the B-area are of chrome and nickel, and they are restricted in the Mt. Beaufort Ultramafics.

(3) Two kinds of chrome occurrences exist in the area. One is associated with cumulate dunite close to layered gabbro, and the other is associated with dunite tectonite in harzburgite. The former is typical in the mineral showings in the basin of the Malinao River, and the latter is typical in the mineral showings within the Norsophil Mine and in the Berong area in the west coast.

(4) The results of interpretation of the chromite components obtained by EPMA analysis have revealed that the chrome grade of the chromite from the transitional zone to the cumulate dunite is lower than those from the dunite tectonite.

(5) Evaluation of volume ratios of heavy minerals obtained by panning from soil samples has revealed the following high concentration areas of heavy minerals; the area within the Norsophil Mine, the upper stream area of the Malasgao River, the basin of the Malinao River, the surrounding area of Long Point, and Berong area.

(6) The results of the soil geochemical survey for seven elements, Pt, Pd, Au, Ni, Cr, Fe, and Co, have revealed that geochemical anomalies are overlapping in the same areas of the heavy mineral anomalies.

(7) The results of the above mentioned surveys lead the selection of following five potential areas in the B-area; the upper stream area of the Malasgao river, the area within the Norsophil Mine, and the upper stream area of the Malinao River, --in the east coast; the surrounding area of the Long Point, and Berong area, --in the west coast.

(8) The detailed survey area B-1, the upper stream area of the Malinao River, was selected from

geochemical anomaly areas which were found by the initial geochemical survey in the B-area. The results of the detailed geological survey revealed the existence of the transitional zones of gabbro and peridotite, and clarified mineral occurrences in dunite bodies.

(9) The results of the detailed geochemical survey in area B-1 lead the selection of the northwestern portion of area B-1 as a promising area for chrome ores.

C-area

(1) Harzburgite is thrust over the Espina Basalt and the Sultan Peak Gabbro in the C-area.

(2) Potential for Cyprus type sulphide ores was previously expected in this area. The survey results, however, indicate that the distribution area of basaltic rocks is small and no mineral indication exists.

(3) No promising area was detected from the geochemical survey.

Chapter 2 Recommendations for Second Year's Survey

The results of this year's survey show that the geochemical anomalies in the area north of Tagburos and the area from the north of Bacungan to the west coast in the A-area, and the upper stream area of the Malasgao River in the east coast in the B-area are favorable for further exploration activities for chrome ores, besides areas A-1 and B-1 where were surveyed this year. Accordingly, It is recommendable to conduct further detailed surveys in those areas to find mineral showings.

The Pananlagan mineral showings and the surrounding area of the Tagkawayan mineral showings in detailed survey area A-1 are significant geochemical anomaly zones, and high potential areas for new ore deposits. Also the geochemical anomaly area in the northwestern portion of the area B-1 is in the chromite disseminated mineralized zone, and a promising area for chromite ores. It is recommendable to conduct an additional pit survey to find new ore bodies in these three areas.

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