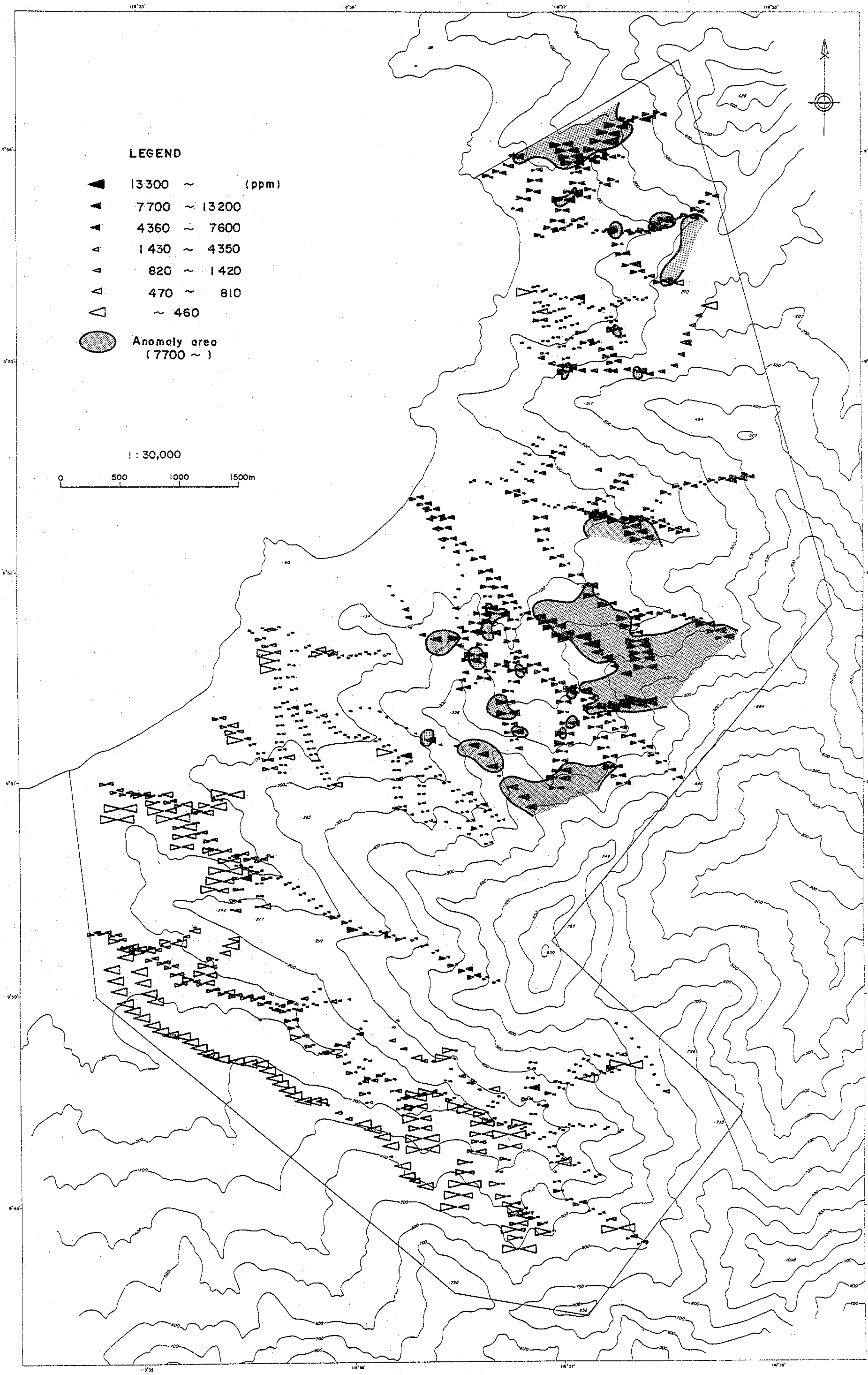


Fig.21 Ni content of soil samples in area A-1

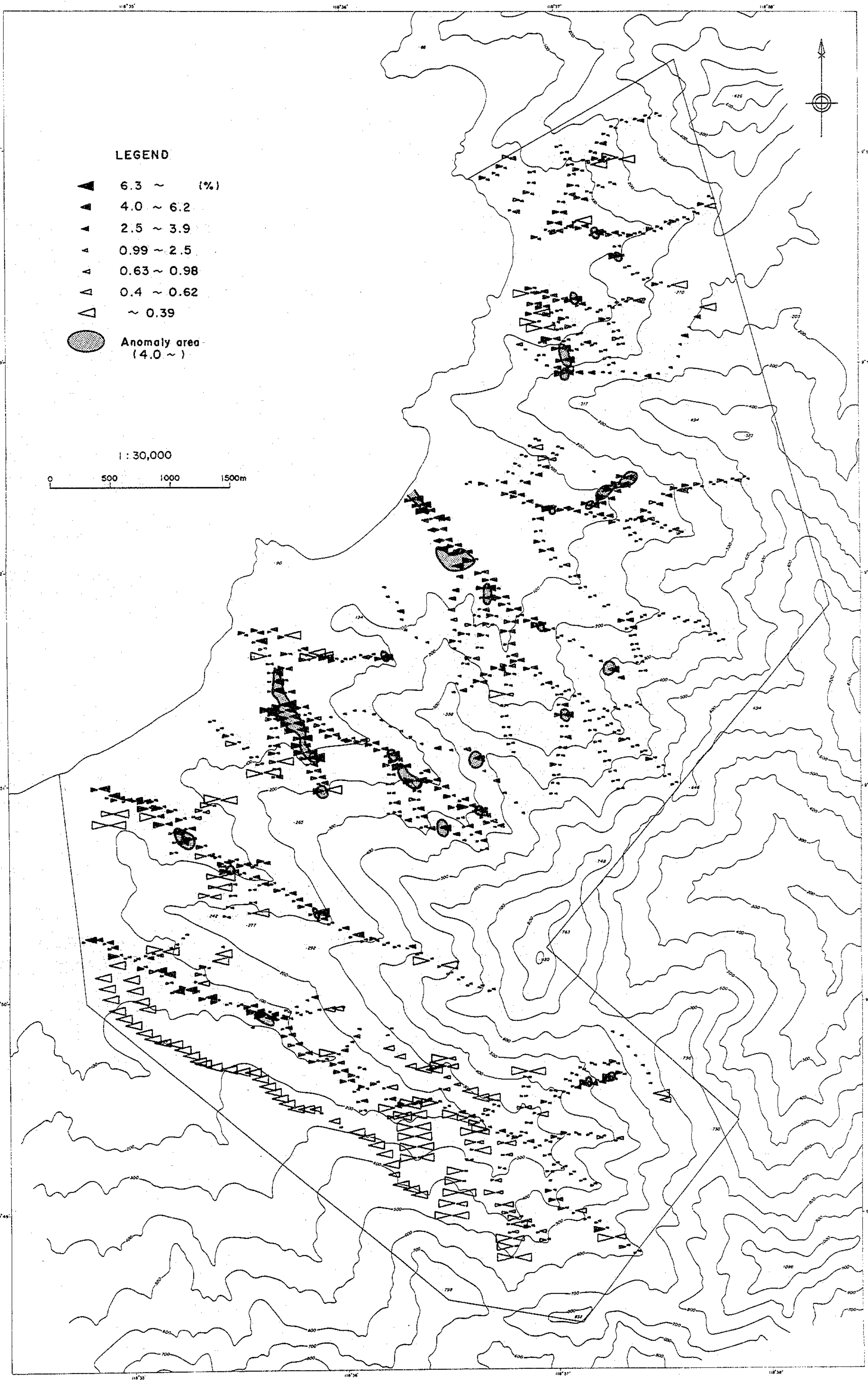


Fig.22 Cr content of soil samples in area A-1

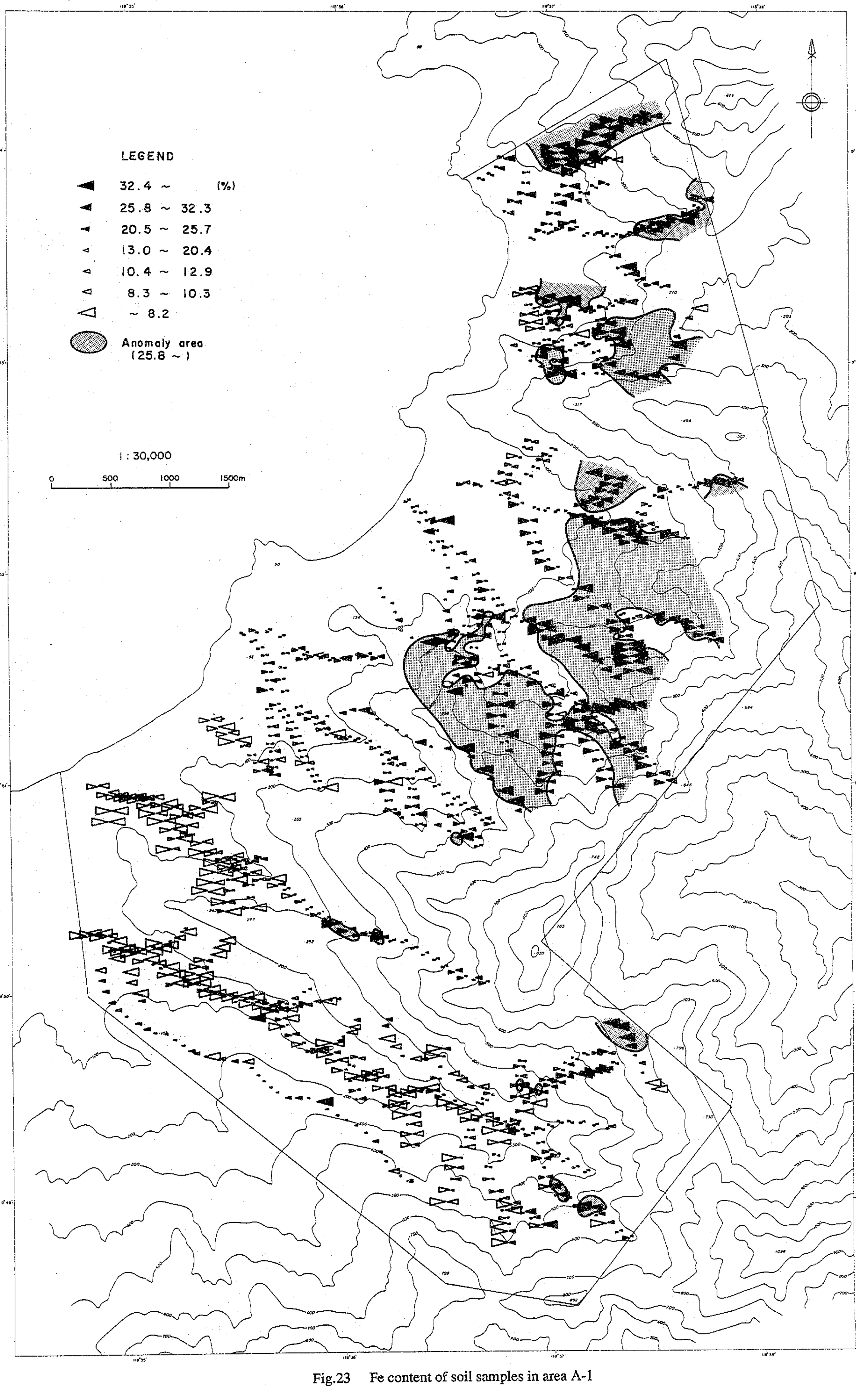


Fig.23 Fe content of soil samples in area A-1

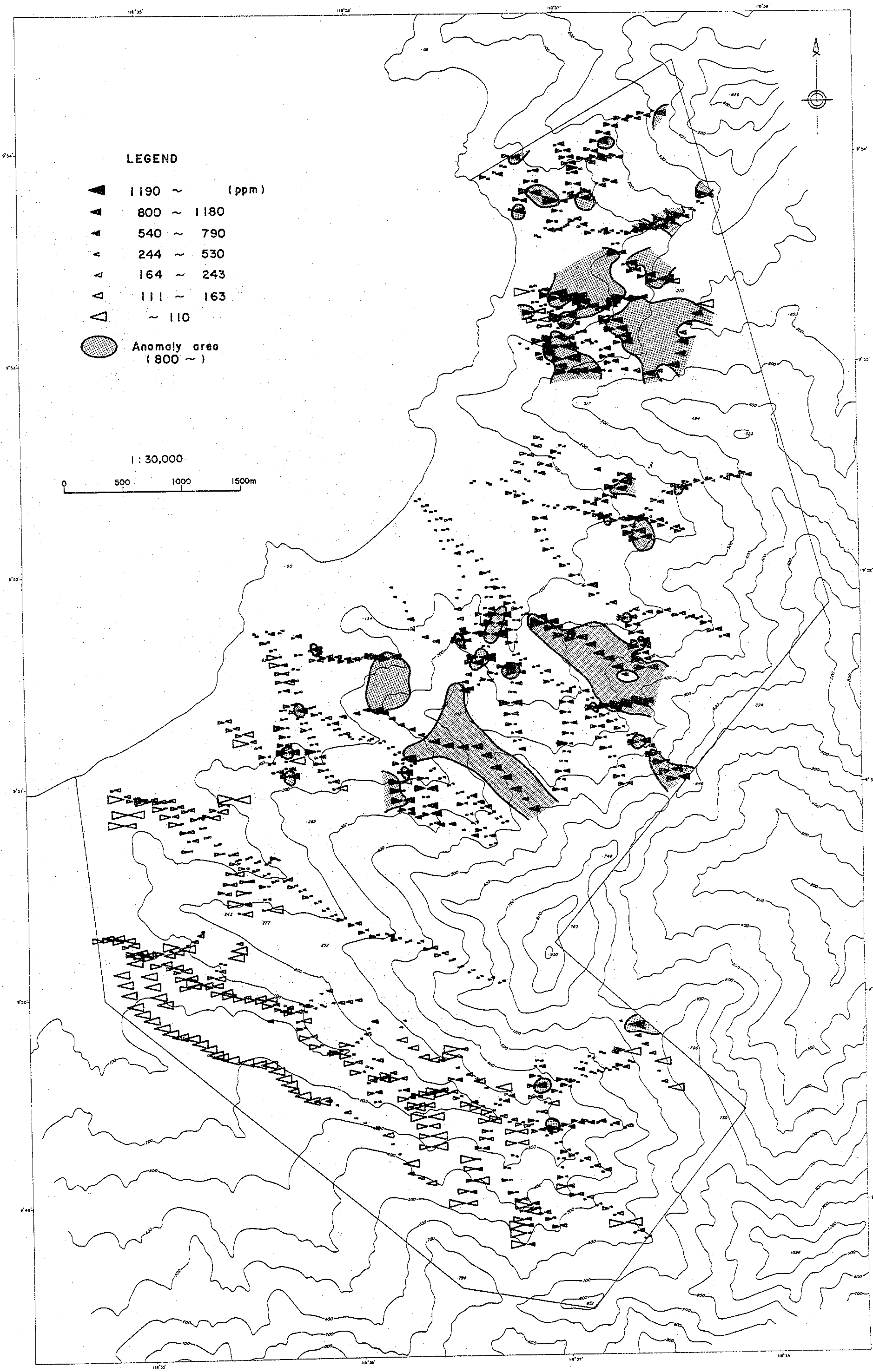


Fig.24 Co content of soil samples in area A-1

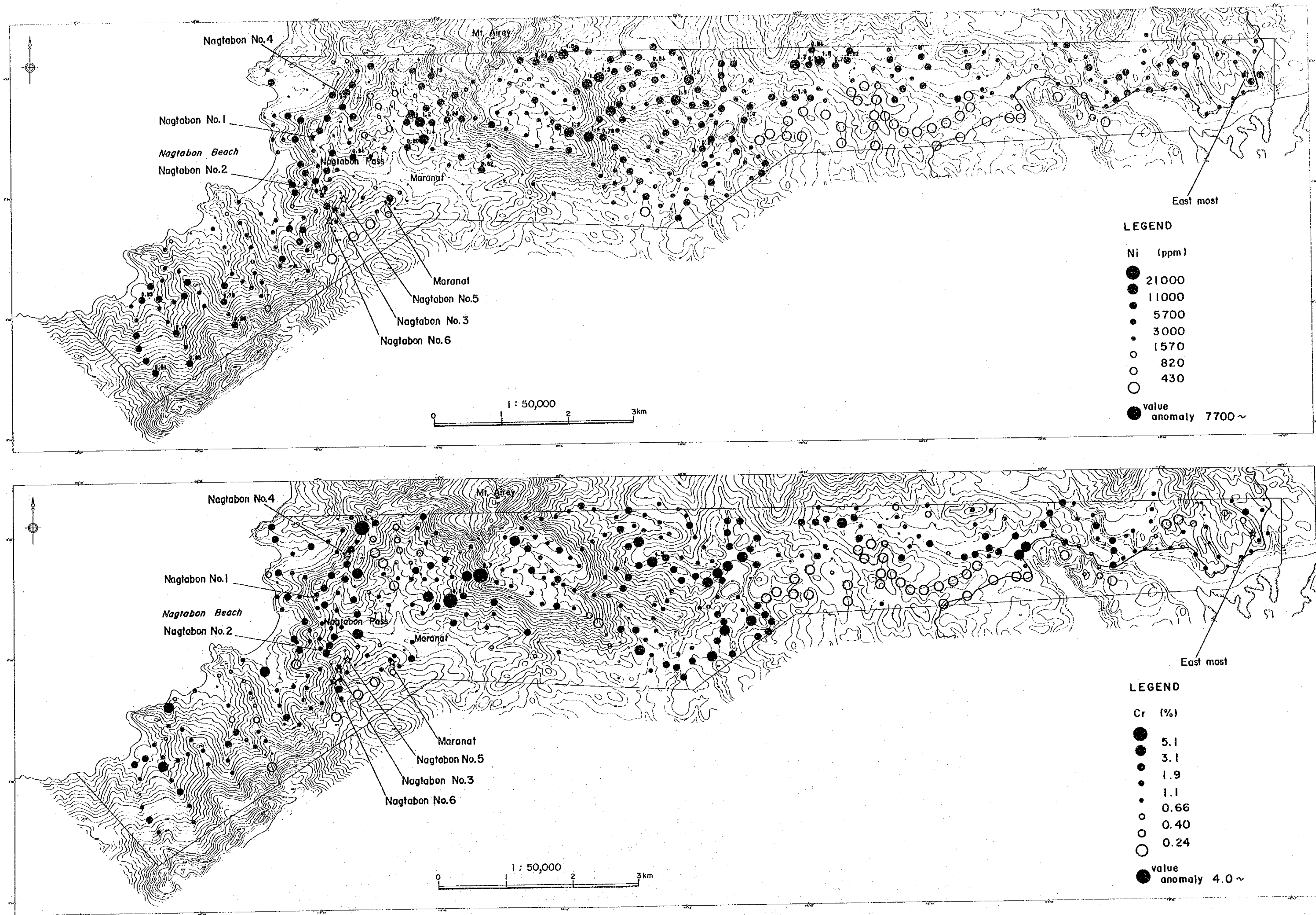
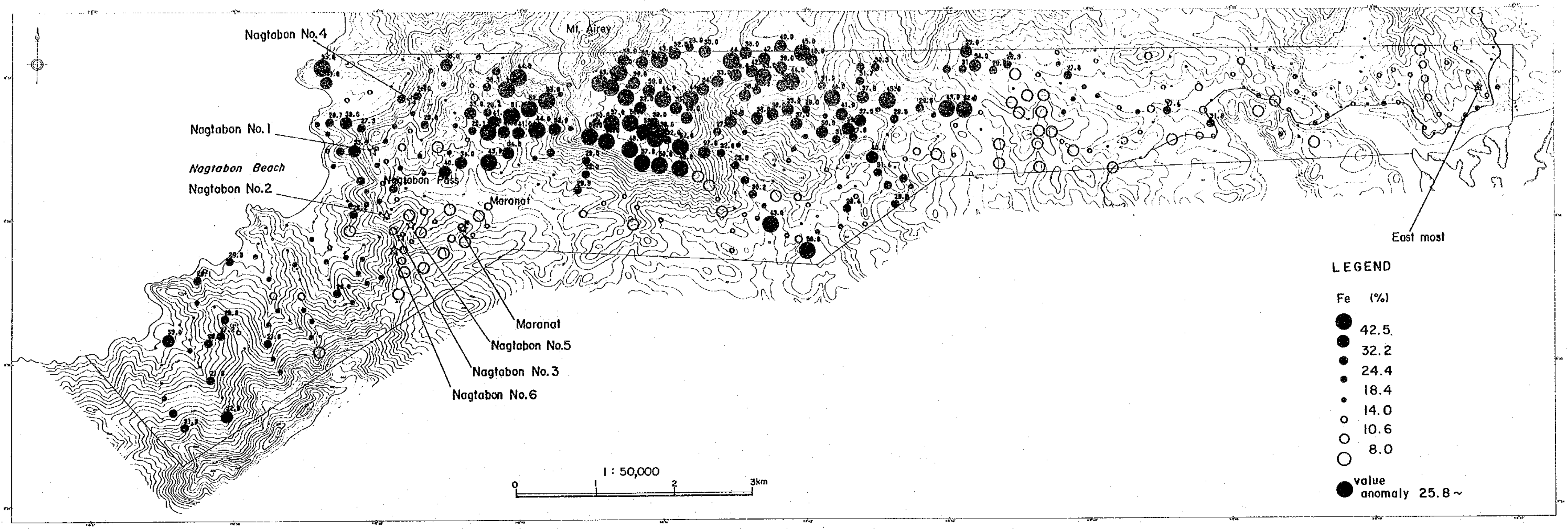


Fig.25 Ni and Cr content of soil samples in area A-2



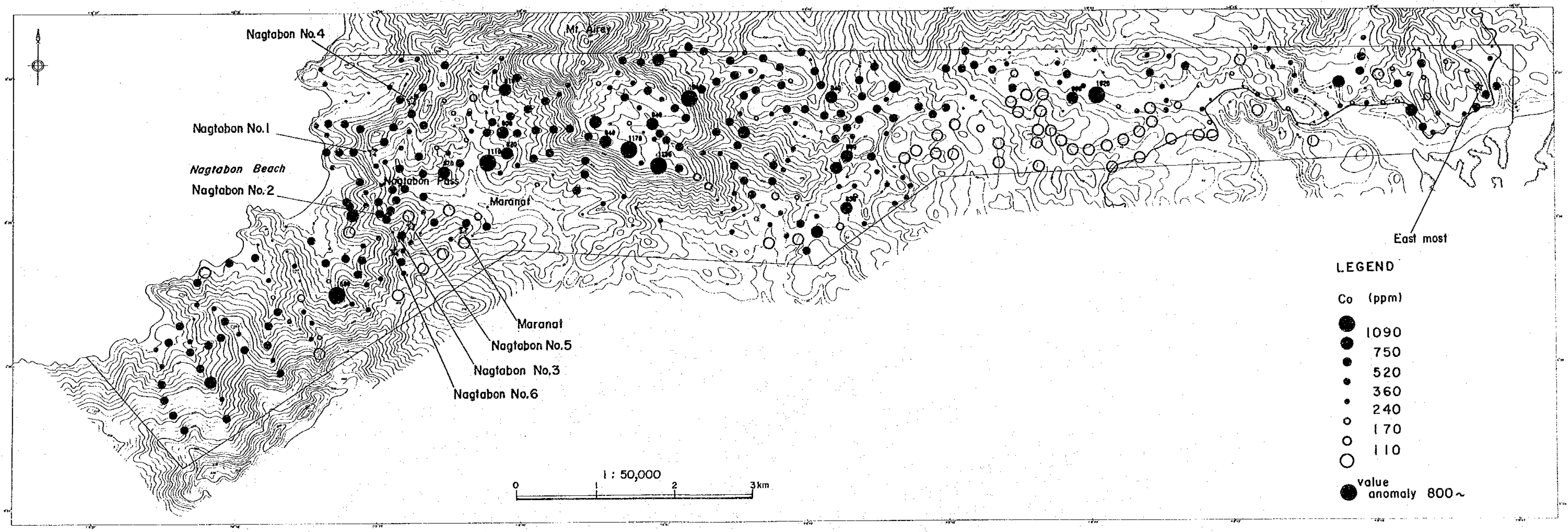


Fig.26 Fe and Co content of soil samples in area A-2

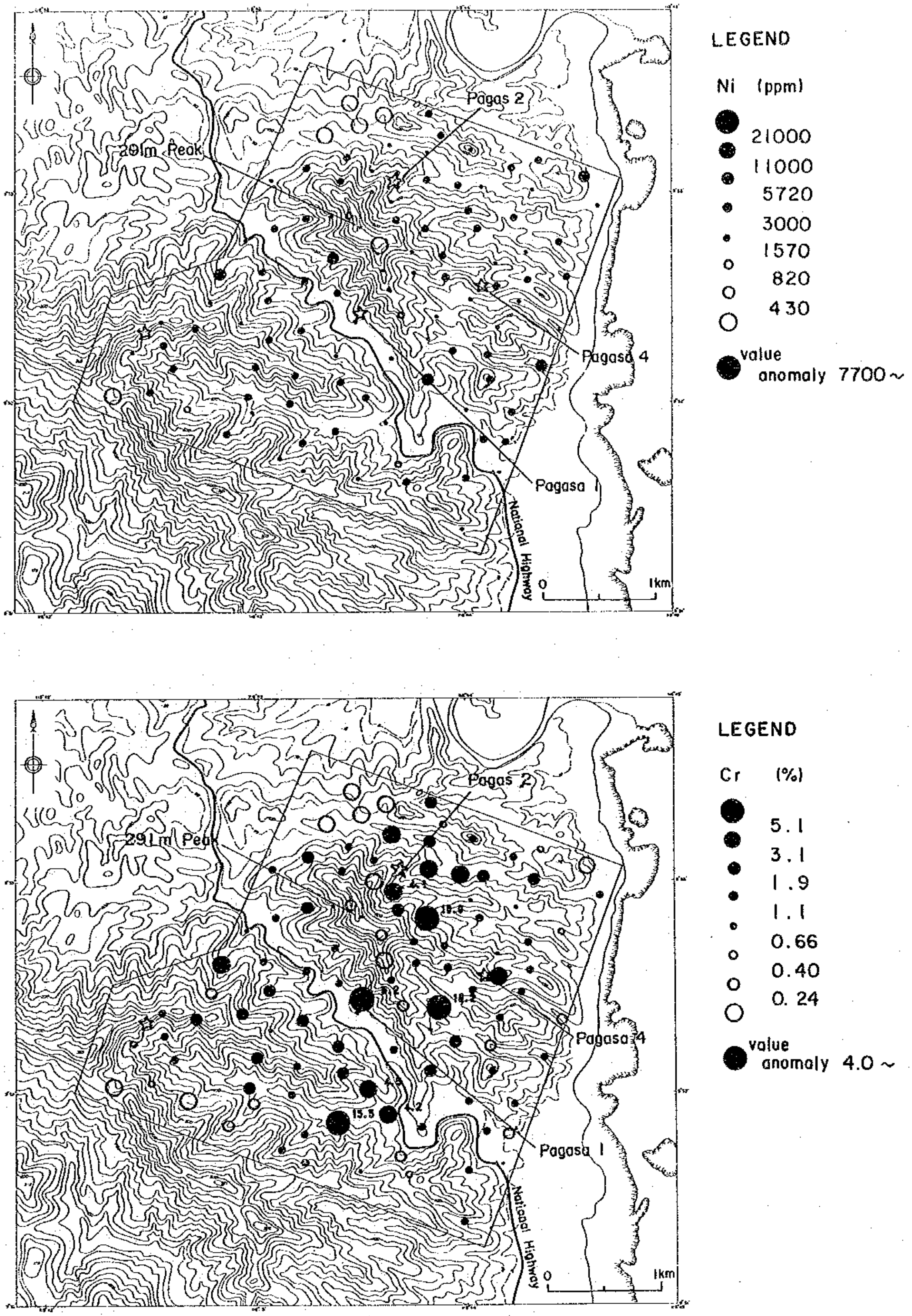
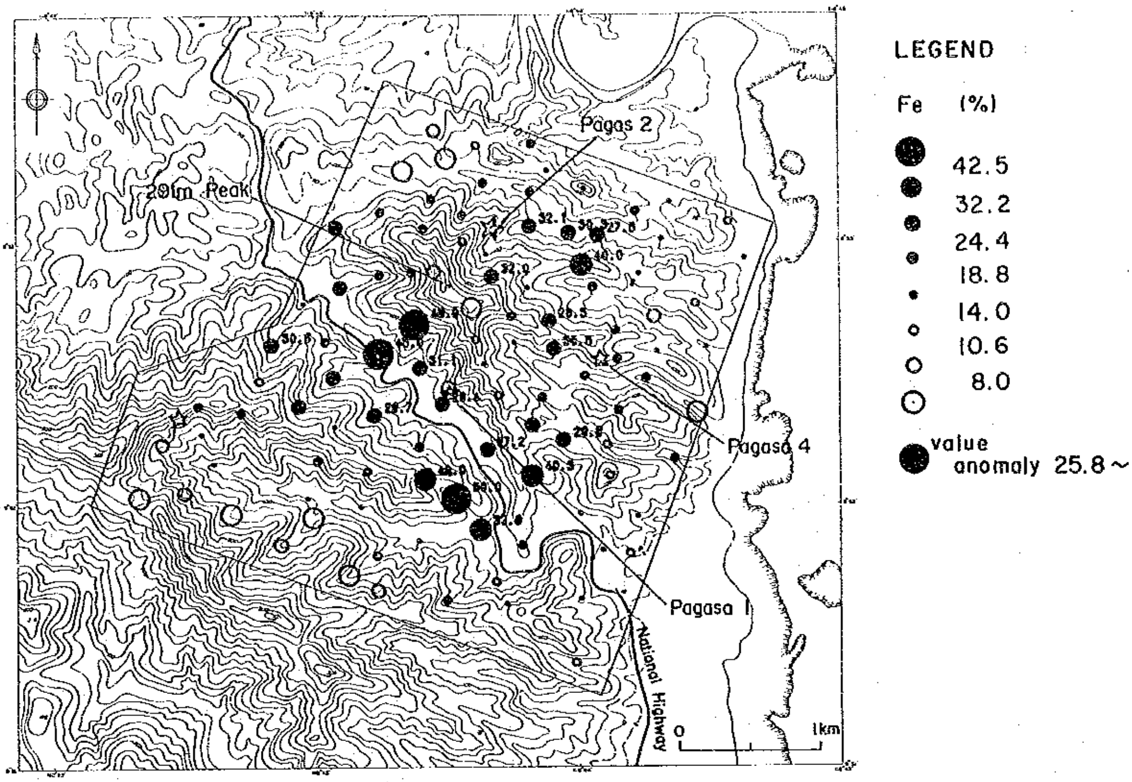


Fig.27 Ni and Cr content of soil samples in area A-3



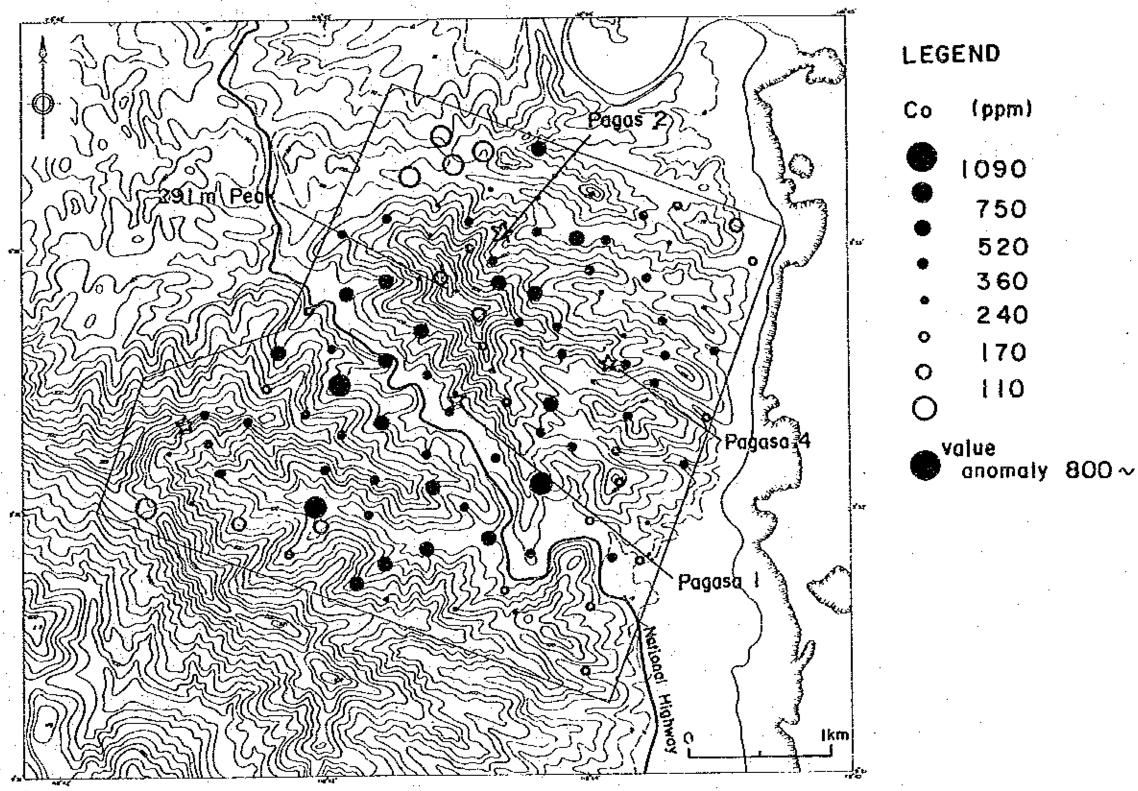


Fig.28 Fe and Co content of soil samples in area A-3

1-2-4 Rock geochemistry

Many kinds of rocks are exposed in this area. Chemical analysis was conducted to check the differences in metal of concentration in the different kinds of rocks presenting in this area. The same elements with that of soil geochemical survey are analyzed for rock geochemistry. The number of rock samples is 123. The results of chemical analysis are shown in Appendix 13. The statistical values are shown in Table 6. These data are divided into seven groups by rock types.

A: Basalt and basaltic pyroclastics
B: Gabbroic rocks, porphyritic rocks and pegmatite
C: Harzburgite and lherzolite
D: dunite
E: Massive chromite ore
F: Pyroxenite
G: Metamorphics

Peridotite and pyroxenite have relatively high content of Pt and Pd, while others have very little Pt and Pd. The content of Au is usually very low except for some specimen from harzburgite.

Peridotites have high content of Ni and Cr, more than 1,000 ppm. Whereas other rock types contain very little Ni and Cr, less than 100 ppm. Peridotite contains twice the amount of Co compared with the other rock types.

In the peridotites, dunites have higher content of Ni and Cr than harzburgite and lherzolite. This may be due to the fact that chromite deposits of both the massive and banded types occur in the peridotite mainly within dunite bodies.

Values of Cr and Fe in peridotite are much lower than those obtained from the soil surveys but with a few exceptions. They simply suggest of the superficial concentration of chromite and iron-oxide in soils.

Table 6 Statistic quantities of rock samples in A-area and area A-1

	Rock type	number	range	median	linear* mean	linear* std. dev.	logalithmic* mean	logalithmic* 10^mean	logalithmic* std. dev.
Pt (ppb)	basalt	n=1	<5	-	-	-	-	-	-
	gabbroic	n=9	<5 - 10	<5	3.6	2.4	0.498	3.1	0.201
	harzburgite	n=51	<5 - 80	<5	9.1	14.8	0.682	4.8	0.413
	dunite	n=57	<5 - 75	<5	6.7	11.0	0.610	4.1	0.351
	chromitite	n=1	<5	-	-	-	-	-	-
	pyroxenite	n=2	<5 - 45	-	23.8	21.3	1.026	10.6	0.628
	metamorphics	n=2	<5 - 5	-	3.8	1.3	0.548	3.5	0.151
Pd (ppb)	basalt	n=1	<2	-	-	-	-	-	-
	gabbroic	n=9	<2 - 4	<2	1.3	0.9	0.067	1.2	0.189
	harzburgite	n=51	<2 - 120	2	9.1	21.2	0.444	2.8	0.557
	dunite	n=57	<2 - 82	<2	5.2	11.7	0.351	2.2	0.473
	chromitite	n=1	<2	-	-	-	-	-	-
	pyroxenite	n=2	2 - 36	-	19.0	17.0	0.929	8.5	0.628
	metamorphics	n=2	<2 - 2	-	1.5	0.5	0.151	1.4	0.151
Au (ppb)	basalt	n=1	<2	-	-	-	-	-	-
	gabbroic	n=9	<2 - 4	<2	1.4	1.0	0.100	1.3	0.201
	harzburgite	n=51	<2 - 42	<2	2.3	6.0	0.100	1.3	0.307
	dunite	n=57	<2 - 6	<2	1.3	1.1	0.059	1.1	0.183
	chromitite	n=1	<2	-	-	-	-	-	-
	pyroxenite	n=2	<2 - <2	-	1.0	0.0	0.000	1.0	0.000
	metamorphics	n=2	<2 - <2	-	1.0	0.0	0.000	1.0	0.000
Ni (ppm)	basalt	n=1	70	-	-	-	-	-	-
	gabbroic	n=9	3 - 2620	60	316.2	814.9	1.412	25.8	0.871
	harzburgite	n=51	40 - 2910	2240	1852.5	820.5	3.139	1377.3	0.461
	dunite	n=57	820 - 3430	2470	2241.9	664.6	3.328	2129.8	0.146
	chromitite	n=1	500	-	-	-	-	-	-
	pyroxenite	n=2	160 - 1750	-	955.0	795.0	2.724	529.2	0.519
	metamorphics	n=2	50 - 130	-	90.0	40.0	1.906	80.6	0.207
Cr (ppm)	basalt	n=1	<100	-	-	-	-	-	-
	gabbroic	n=9	<100 - 1700	<100	255.6	512.3	1.975	94.4	0.485
	harzburgite	n=51	<100 - 17000	1700	2168.4	2827.3	3.159	1443.5	0.404
	dunite	n=57	500 - 54000	2400	4978.9	9008.9	3.444	2778.6	0.383
	chromitite	n=1	148000	-	-	-	-	-	-
	pyroxenite	n=2	<100 - 2000	-	1025.0	975.0	2.500	316.2	0.801
	metamorphics	n=2	<100 - 200	-	125.0	75.0	2.000	100.0	0.301
Fe (%)	basalt	n=1	5.7	-	-	-	-	-	-
	gabbroic	n=9	0.3 - 4.2	2.3	1.7	1.5	0.014	1.0	0.461
	harzburgite	n=51	1.2 - 7.0	4.3	4.1	1.0	0.591	3.9	0.144
	dunite	n=57	1.8 - 8.2	4.5	4.8	1.1	0.669	4.7	0.102
	chromitite	n=1	0.5	-	-	-	-	-	-
	pyroxenite	n=2	1.4 - 4.3	-	2.9	1.5	0.390	2.5	0.244
	metamorphics	n=2	0.8 - 3.2	-	2.0	1.2	0.190	1.5	0.315
Co (ppm)	basalt	n=1	48	-	-	-	-	-	-
	gabbroic	n=9	14 - 63	55	44.2	17.0	1.602	39.9	0.213
	harzburgite	n=51	29 - 281	93	91.8	35.2	1.936	86.3	0.154
	dunite	n=57	39 - 137	91	90.4	21.4	1.943	87.7	0.109
	chromitite	n=1	125	-	-	-	-	-	-
	pyroxenite	n=2	46 - 97	-	71.5	25.5	1.825	66.8	0.162
	metamorphics	n=2	2 - 380	-	191.0	189.0	1.440	27.6	1.139

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

1-3 Test pitting survey in detailed survey area A-1

The follow-up work with test pitting survey was carried out in the area selected last year by the detailed geological survey and geochemical prospecting in area A-1 and B-1 (Fig. 6).

Two hundreds and four test pits were sunk by hand to reach to basement rock. Soil samples were collected from bottom of pit and upper 1m from the bottom in each pit.

1-3-1 Pananlagan area

The objectives of test pitting survey in Pananlagan area are as follows;

1. To confirm the extension of massive chromite ore body in lower Pananlagan
2. To make clear the anomaly along the branch of the Pananlagan River
3. To confirm the extension and discovery of chromite ore body in upper Pananlagan

1) Confirmation of lower Pananlagan massive chromite ore body

Small scale minings were operated by Sulu Sea Mines Corp. in this area. Massive and disseminated types' ore bodies 50 cm wide, strike N80°W and dip 60° to 80°W, occur in the weathered and brecciated dunite. The test pitting survey was operated at 2 sites (PB047 and PB048) to confirm the extension of ore bodies (Fig.29), but extension was not recognized here.

2) Anomaly along the branch of the Pananlagan River

A remarkable geochemical anomaly was detected last year by soil geochemical prospecting. Test pits were sunk at 4 sites to make clear this anomaly. Every pit reached to basement rock of harzburgite, and no mineralization was recognized. Chromium content of harzburgite is very low, 0.2 to 0.4 %. This area is alluvial fan formed by many small streams running from eastern slope, therefore this geochemical anomaly may be regarded as false anomaly due to secondary concentration of chromite.

3) Confirmation of chromite ore deposits in upper Pananlagan area

Two old workings are recognized in the north slope of Pananlagan River. Test pits were sunk at 46 sites setting on 5 survey lines in the direction of northeast that cross general trend of dunite around the mineral showings. The spacing between survey lines was 100 meters, and the interval between pits 25 meters. Location of test pits and geology were shown in Fig. 30.

A disseminated type ore extending in the E-W direction crops out 10 meters long in the lower old working. Channel samples of 2.0 meters wide and 2.5 meters wide from this outcrop show 30.30 % and 50.70 % Cr_2O_3. This ore continues to PA051, 10 meters apart from outcrop. Another chromite band was discovered in the pit PA015, and this band is inferred to parallel with this ore body. The analysis of this chromite band shows 18.10 % Cr_2O_3.

Another old working is rather large 50 x 200 meters in scale. Though no outcrop of chromite ore was recognized in this working, residents said that massive chromite ores were mined in this old working before, but this outcrop was buried now. Several tons of massive chromite ore are stocked near the working. An outcrop of massive chromite ore was newly discovered 100 meters apart from the working, and the scale of outcrop is more than 7 meters

long and 2 meters wide. The analysis of channel sample 1 meter wide shows 49.00% Cr_2O_3.

Dunite containing chromite is widely recognized in upper Pananlagan area, but they show low chromite content.

1-3-2 Tagkawayan area

A remarkable chromium anomaly was detected and two chromite disseminated zones about 3 meters wide were discovered last year by Phase 1 follow-up survey along the north branch of the Tagkawayan River, and fifty test pits were sunk in this survey. Five survey lines were set in the N-S direction considering the general trend of dunite striking N70°E to E-W, dipping 60° to 70°N. The spacing between lines was 100 meter, and pit interval 25 meters. Location of pits and geology are shown in Fig. 31.

A small working was found when the survey lines were cut, where several tons of massive chromite ore were stocked. The analysis of the ore from this stock shows 35.30 % Cr_2O_3. Another small stock of massive chromite ore is found near TG030 pit. It is inferred that small scale of prospecting was conducted before. Many floats of massive chromite ore are also scattered along small branch.

Though it was thought that this area promised to chromite deposit because of the existence of many mineral showings, the dunite in this area contains chromite little and no chromite disseminated portions and bands.

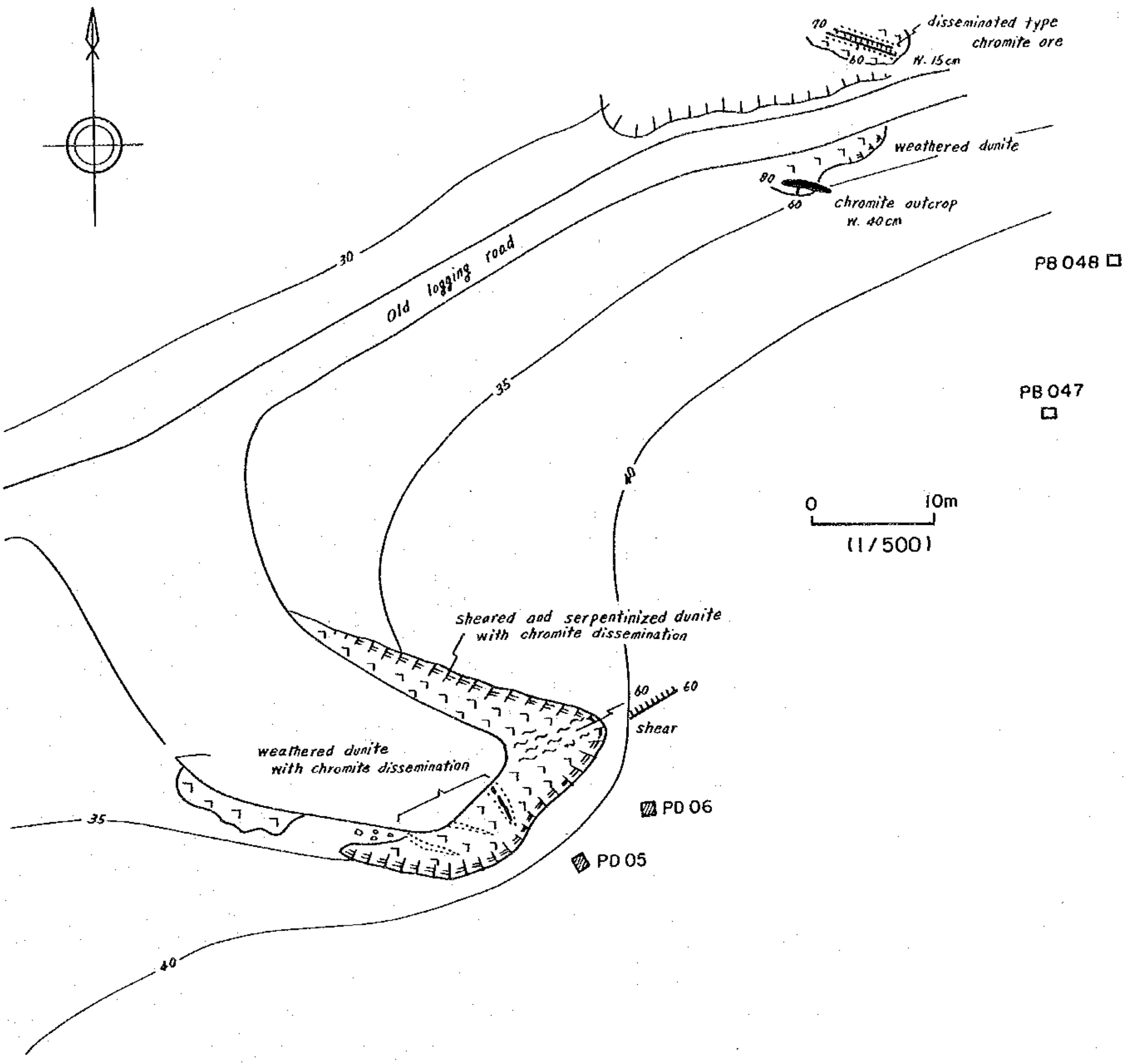


Fig.29 Location of test pits in Lower Pananlagan area

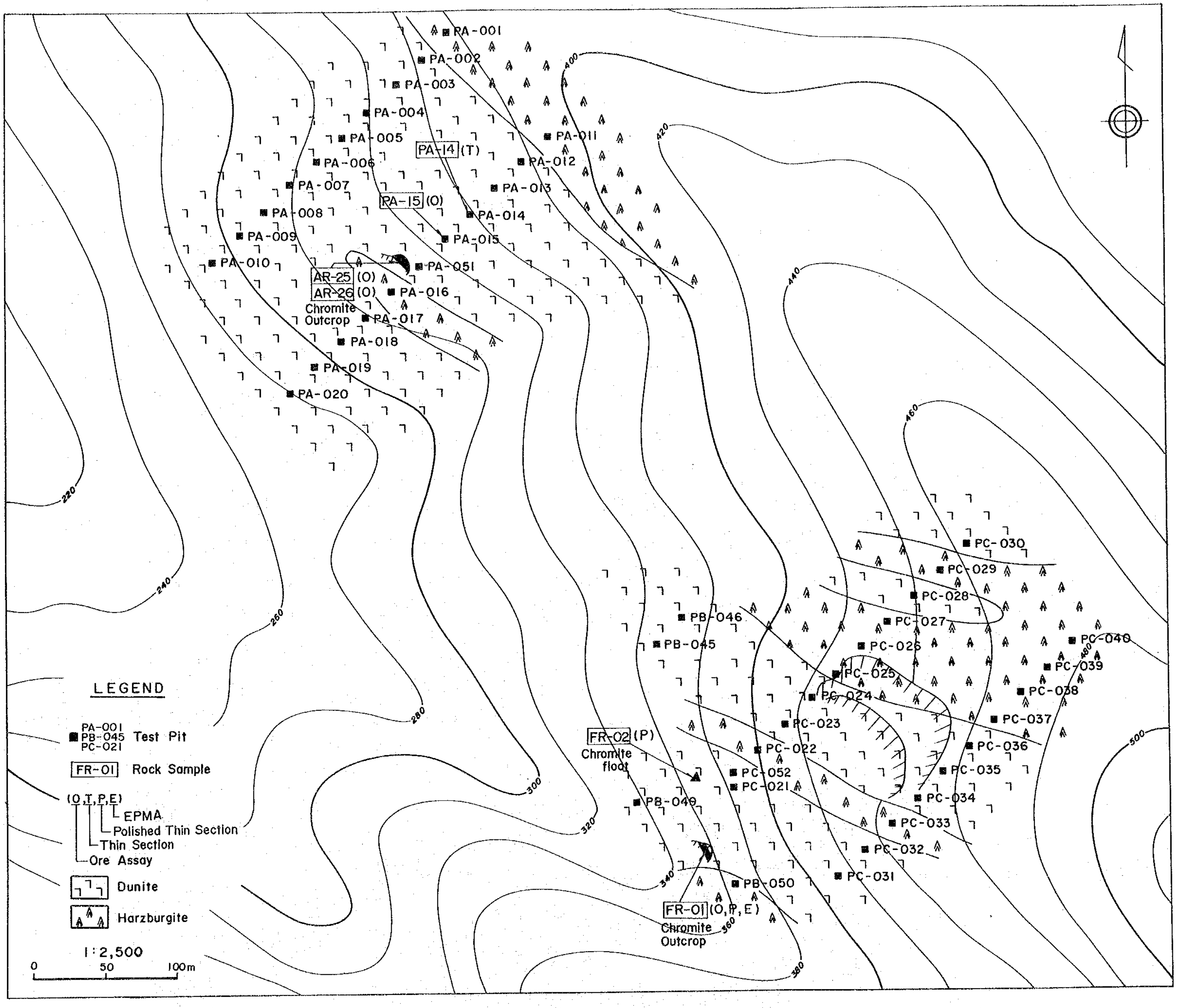


Fig.30 Geology and location of test pits in Upper Pananlagan area

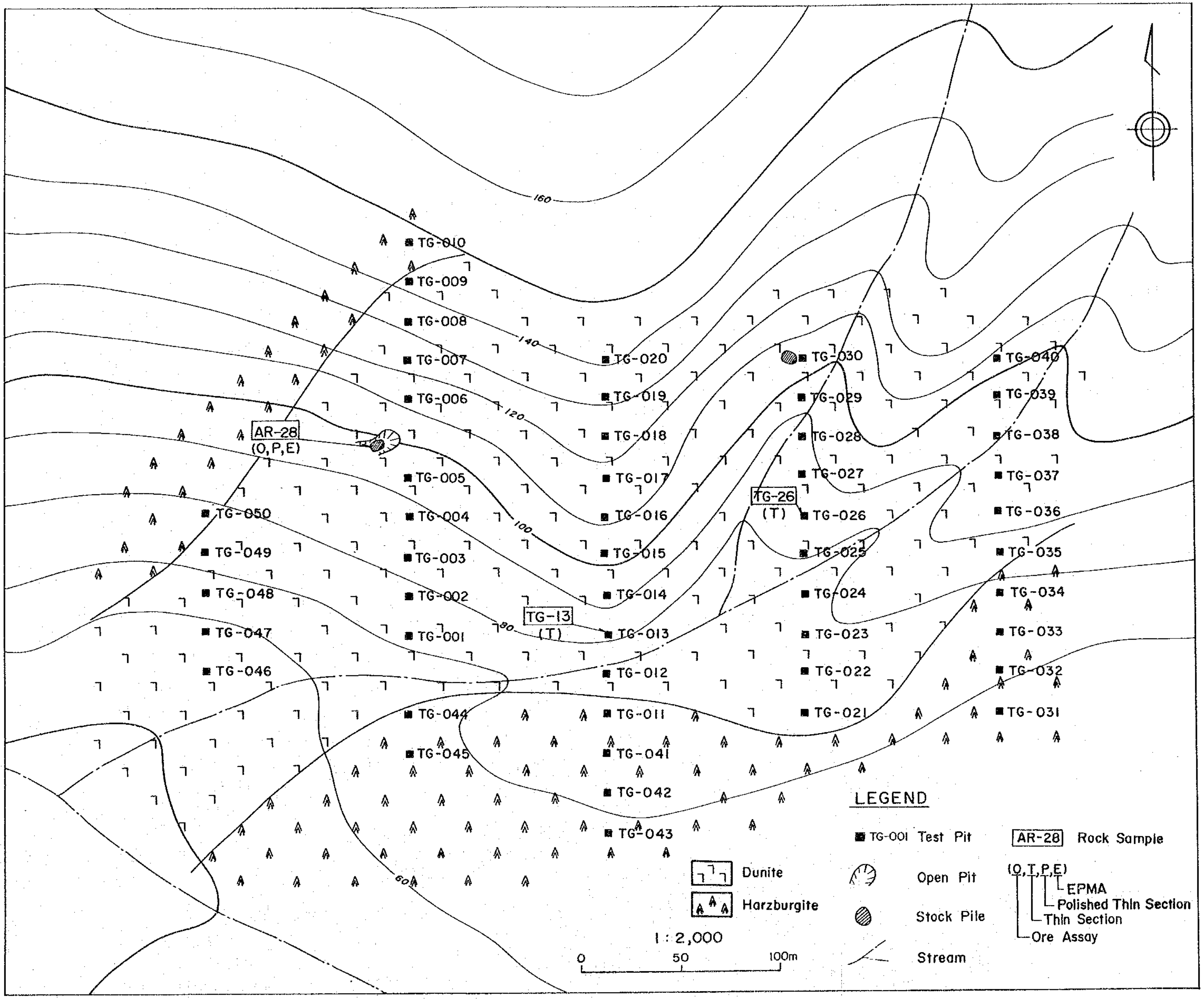


Fig.31 Geology and location of test pits in Tagkawayan area

1-4 Discussion

1) A-area

The project area is underlain by the Palawan Ophiolite, the Kabangan Metamorphics (UNDP,1985), the Tagburos Siltstone, and the Sulu Sea Mine Formation. The Palawan Ophiolite is distributed in a large area, and consists of the Mt. Beaufort Ultramafics, the San Vicente Gabbro, the Stavely Range Gabbro, and the Maranat Pillow Basalt (UNDP,1985) from the bottom. Each formation has been sheared by thrust faults during the ophiolite thrust movement, and imbricated as presently seen. In the field the uppermost lithology, which is the Mt. Beaufort Ultramafics, overlies other formations as a nappe. The Bacungan Window and the Iratag Window have been formed by the erosion of the Mt. Beaufort Ultramafics.

The most important mineral occurrences in the area are the chrome and the nickel, which are hosted by the Mt. Beaufort Ultramafics. The observed outcrops of chromitites are small in scale, only several meters wide, consisting of lenses, pods, or disseminated seams. Most of these were found as the results of the detailed geological and geochemical surveys in area A-1,A-2 and A-3 which were selected based on the results of the initial geochemical survey in the A-area. Most of the chromite showings are in dunite tectonite, which intruded as diapir-like bodies into harzburgite. Some occurrences are in harzburgite too, however these are of small scale and quite few. It is possible to say that the distribution of dunite bodies controls the location of chromite occurrences.

Nickel laterite has been formed by weathering of peridotites in this area. Laterite occurrences, in which iron hydroxide have concentrated on the surface, are distributed in the Bacungan area in the northern part and the basin of the Tagkawayan River in the west coast. The depth of the lateritic layers in the Bacungan area is very deep, therefore most of the test pits digged in the area up to a depth of 5 meters did not reach altered peridotite zones, in which nickel is concentrated. Some test pits at Tagkawayan area along the west coast have revealed nickel occurrences, but the area is poor in laterite due to steep topography. The important factors for forming nickel-laterite zones area the topography and the level of groundwater, which give strong influences to weathering processes, than nickel contents of host rocks.

In the geochemical survey in the A-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 delineate promising areas promptly 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, relating to chromium, and the other is a group of Pt, Pd, and Au relating to precious metals. Interpretation of the geochemical anomalies of the both groups lead the extraction of three potential areas;the area from the Malinao River to Tagminatay in the west coast(detailed survey area A-1),the area from north of Bacungan to the west coast(detailed survey area A-2),and the area north of Tagburos.

Main purpose of geochemical prospecting is to delineated the high potential area for chromite deposits. Soil geochemistry generally reflects the character of lithological basement, because soil is derived from these rocks by weathering. The test pitting survey was clarified that chromite tends to concentrate in residual laterite, thereby soil geochemical survey of chromium could be delineated the potential area more sensitively than rock geochemical survey. Nevertheless the geochemical anomaly area for chromite deposit could not be extracted from this

soil geochemical survey

Soil geochemical exploration of chromite is effective in the following two cases.

1. Regional exploration to delineate the potential areas

2. Grid prospecting (grid interval; from several meters to several ten meters) to identify the anomaly areas derived directly from ore deposits.

The geochemical prospecting last year in A, B and C area belongs to first case, and many mineral showings were recognized by detailed survey in the extracted anomaly areas.

2) Detailed survey area A-1

The main chromite occurrences were found through the detailed survey of area A-1, which as selected based on the results of the initial geological and geochemical survey in A-area. Area A-1 is mainly underlain by the harzburgite of the Mt. Beaufort Ultramafics, and most of the chrome occurrences are in dunite tectonite, which intruded as diapir-like bodies into harzburgite. These are in the San Chromite area, Macasaet area, Upper Pananlagan, Lower Pananlagan, Tagkawayan, and Tagminatay. The observed occurrences are small in scale, and as lenses with several meters width, as pods, or as disseminated seams. Tagminatay. As a result of the geochemical survey done in area A-1, the two groups of assayed elements, relating to chromium and precious metals respectively, show geochemically different behavior. However the following two areas show some overlap of anomalies of these two groups, and are judged as promising areas for further exploration activities; i.e. the area containing the Pananlagan mineral showings and the area from the Tagkawayan mineral showings to Tagminatay.

Phase 1 survey has revealed that the in-situ soil geochemical survey was effective to delineate chromite deposits' areas. However, some mineral showings did not show any geochemical anomalies in spite of its formation under the same environment, like the case of the Macasaet occurrences. This case probably shows that in some cases chromium contents are rather less in areas around ore deposits due to strong mineral concentration into ore bodies from high chromium content host rock areas.

3) Detailed survey area A-2

The chromite deposits occur in dunite bodies of Mt. Beaufort Ultramafics. The rather large scale of dunite bodies are distributed in the southwest slope of Mt. Airey and the vicinity of Nagtabon Pass. Small diapir-like dunite bodies ranging in width from several ten centimeters to several meters are also found at all over the area. Among them, the one around Nagtabon Pass has the highest potential for chromite deposits, because many chromite deposits and mineral showings of both the massive and disseminated types occur in this dunite body. These deposits are named Nagtabon No. 1 to No. 6. The Nagtabon No. 1 deposit is rather large among these deposits,though it consists mainly of disseminated ore. Though the subsurface occurrence is not clear, as far as disseminated ore is concerned, this deposit can be estimated the volume about 2,000 tons as chromite by presuming the extension of ore body 10 meters downward and 24 % of chromite content.

Area A-2 was extracted as one of the chromium anomaly areas by the Phase 1 regional geochemical prospecting , and many chromite showings are discovered by this survey. In this area chromite grains are not observed only in dunite around ore deposits but also in dunite and harzburgite apart from deposits. This means that the chromite deposit does not always have clear

geochemical halo in this area. In this case it is needed to detect the anomaly concerning directly with ore deposits itself. The geochemical anomaly area was not extracted by this prospect because the chromite deposits in this area are generally very small.

4) Detailed survey area A-3

Same as area A-2, area A-3 mainly consists of Mt. Beaufort Ultramafics. San Vicente Gabbro is distributed in west and north of the area being thrust by the Mt. Beaufort Ultramafics. The Mt. Beaufort Ultramafics comprises of harzburgite, dunite and pyroxenite. Dunite tectonite is distributed around the 291m peak at the high elevation part in the central portion of the area. The main chromite deposits occur in this dunite. These deposits were explored by private company, Country Mineral Resources Corporation, during later half of 1970's. Since the name of claim was "Pagasa", they named the possible areas Pagasa 1 to Pagasa 5. Mining and exploration might have been operated in Pagasa 1, 2 and 4. Among these, Pagasa 1 deposit is rather large in scale. Many outcrops of massive and disseminated chromite ores occur in Pagasa 1, and mineralized area covers more than 150 x 150 meters. On the basis of assumptions of the 150 x 150 meters promising area, the extension of deposit 10 meter downward, 20 to 30 % ore existence and 30% of chromite content, it may be inferred that the volume of chromite is 40 to 60 thousand tons. Pagasa 2 and 4 deposits is smaller than Pagasa 1 deposit It appears from the soil geochemical survey that chromite deposit is only potential in this area, because nickel and cobalt content are low in soil. The dunite tectonite in area A-3 is distributed in high elevation to the east of national highway. Since almost all chromite deposits occur in dunite tectonites in Palawan, the dunite tectonite has a potential for chromite ore. Because of this, it can be stated that the areas of high chromium content in soil within this dunite body are delineated as high potential area for chromite deposits; thereby the areas around Pagasa 1 and south of Pagasa 2 are promising areas for chromite deposits.

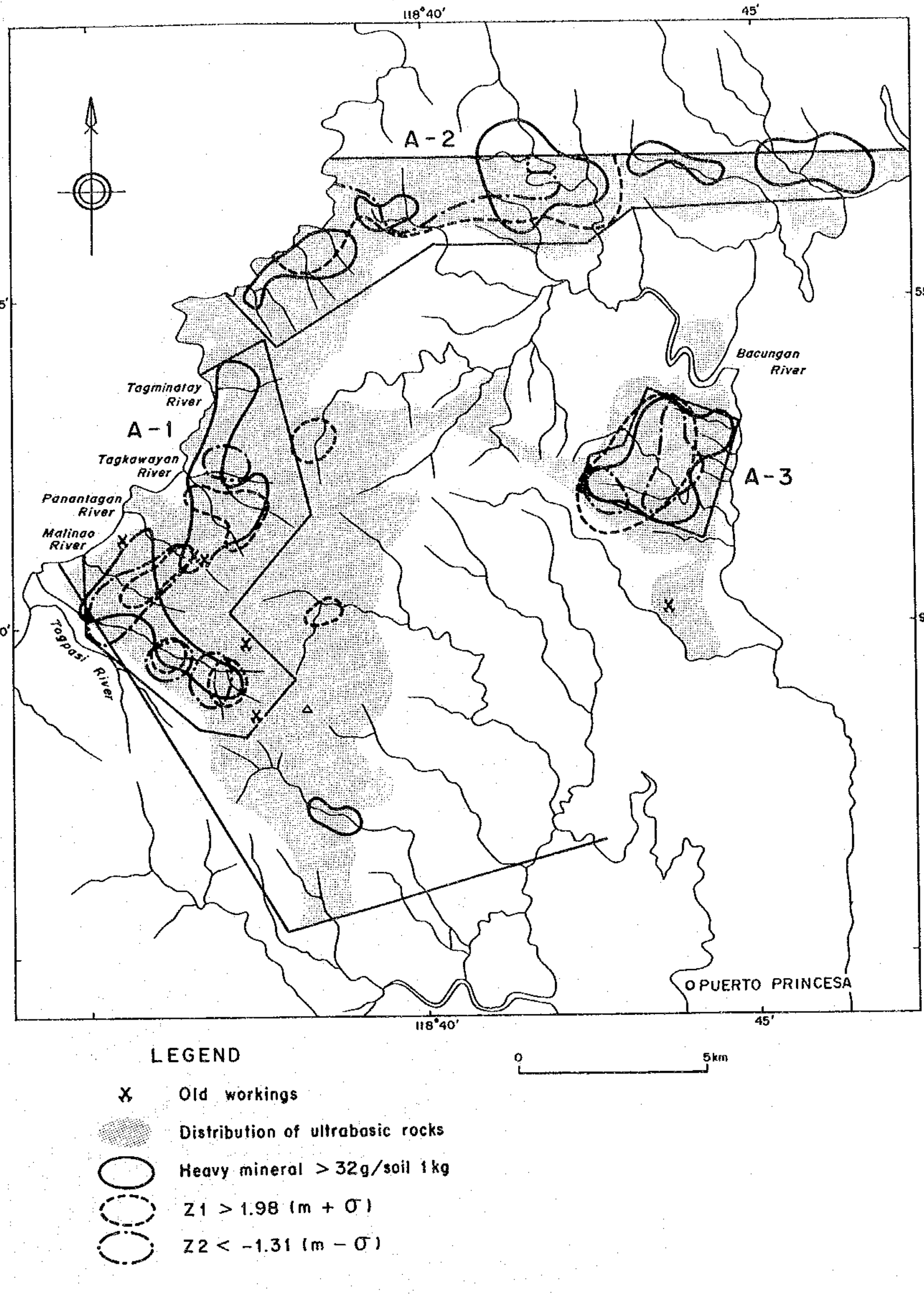


Fig.32 Interpretation map of A-area

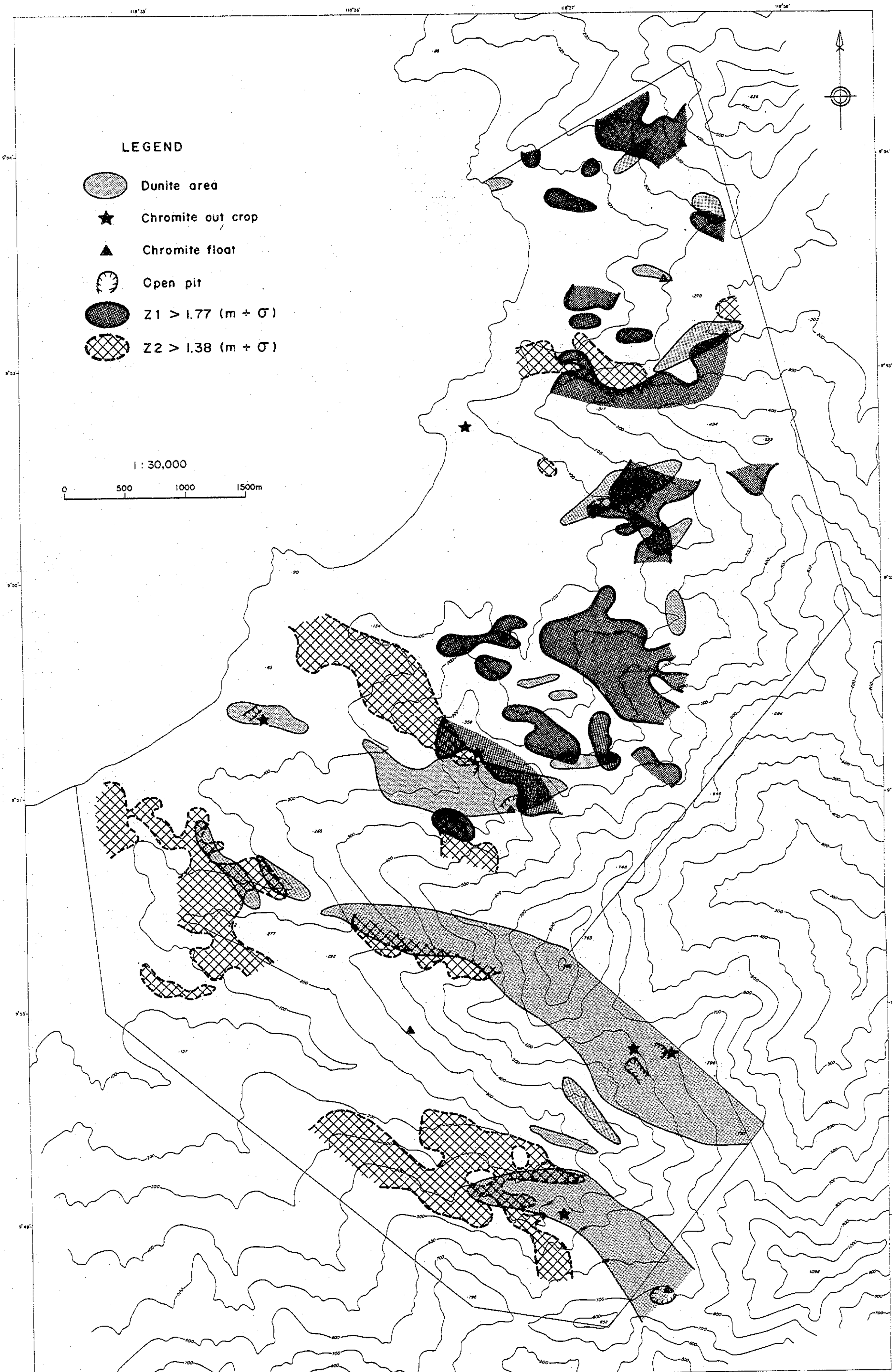


Fig.33 Interpretation map of area A-1

Fig.34 Interpretation map of area A-2

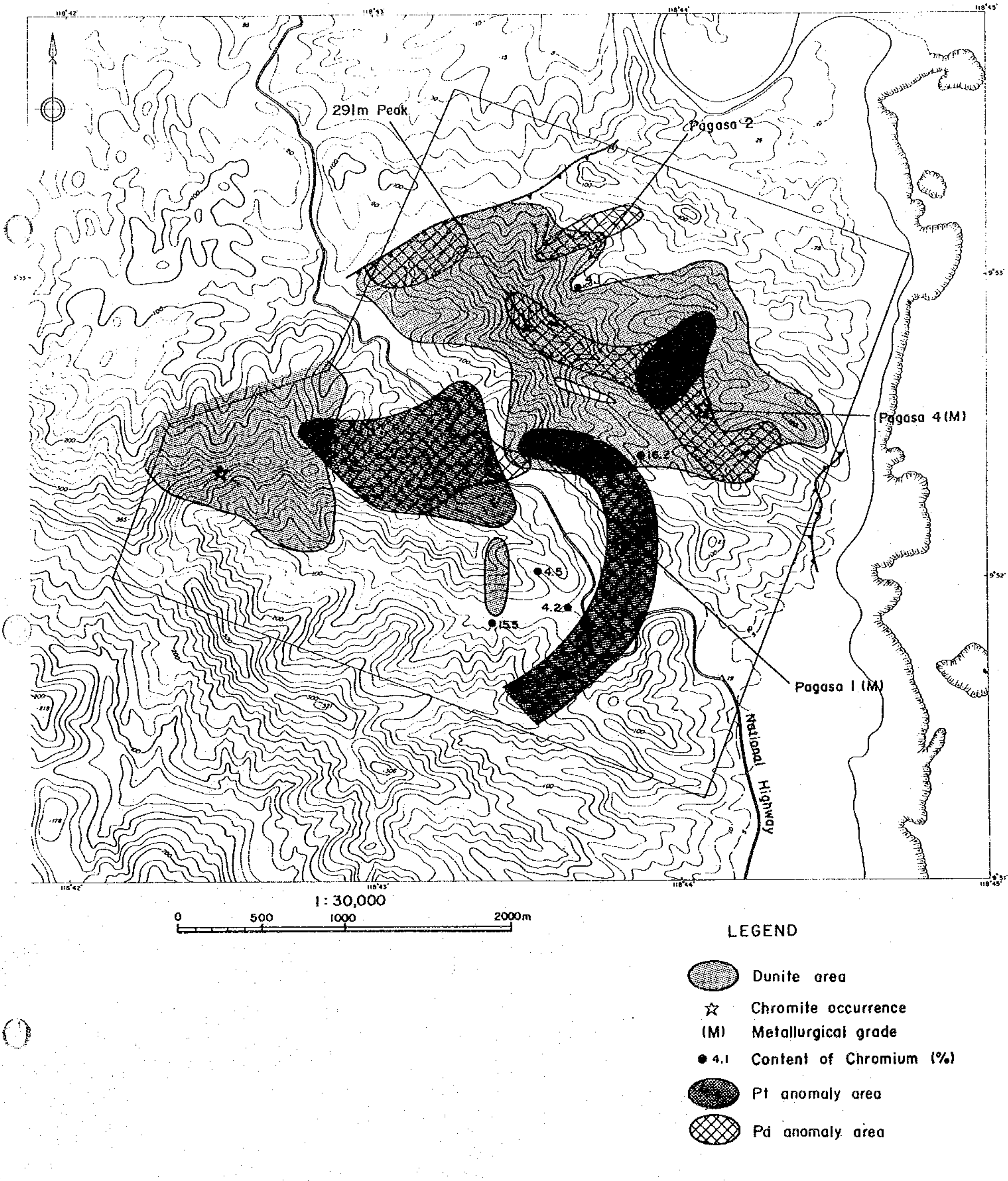


Fig.35 Interpretation map of area A-3

Chapter 2 B-area and detailed survey area B-1

2-1 Geology

2-1-1 Outline of Geology

The B-area is underlain by the Panas Formation of Eocene age, the Palawan Ophiolite which is thrust over the Panas Formation during late Eocene time, and unconformably overlying the Ransang Formation, the Isugod Formation, the Alfonso XIII Formation, and the Iwahig Formation of Miocene to Pliocene age, and alluvium.

The Panas Formation consists of siliceous shale, phyllitic shale, siliceous sandstone, and chert. It is distributed in the surrounding area of Berong and south of Moorsom Point in the west coast, and the upstream areas of the Malasgao River and Panacan River as windows in small scale.

The Palawan Ophiolite is dominant in the B-area, and is composed of harzburgite and dunite of the Mt. Beaufort Ultramafics, layered gabbro of the Sultan Peak Gabbro, and diabase and basalt of the Espina Basalt.

The Inagauan Metamorphics, consisting of quartz-mica schist, green schist, and amphibolite. They are believed to have formed due to dynamic metamorphism along the thrust fault during the thrusting and emplacement of the ophiolite sheet.

The Ransang Formation and later formations are distributed in the lowland areas of the east and west coasts, overlying the Palawan Ophiolite.

The thrust fault between the Panas Formation and Palawan Ophiolite are almost horizontal in the angle. A left lateral, high angle fault exists in the central B-area, which trends south to west. The geological structure is different in the eastern side and western side of this fault. The ophiolite in the eastern side trends WNW to ESE and dips SSW, while the ophiolite in the western side trends NNW to SSE and dips SW.

The detailed survey area B-1 is underlain by the Mt. Beaufort Ultramafics, the Sultan Peak Gabbro, and the Espina Basalt. The Iwahig Formation is distributed in the lowland areas of the eastern area, overlying these rocks.

2-1-2 Detailed geology

1) *Panas Formation*

The Panas Formation is distributed in the upper part of the Inagauan River --in the northeastern B-area, the area around Berong River and the vicinity of Tagbolante River --in the west coast. This Formation consists of siliceous shale, phyllitic shale, siliceous sandstone, and chert. The siliceous shale and chert are pink, red, brown, and dark gray, and have distinct stratification. The phyllite is greenish gray, and accompanied by quarts veinlets. The sandstone is grayish green, and hard, compact, fine grained equi-granular rock. It have been slightly metamorphosed. The metamorphic grade tends to increase near the Inagauan Metamorphics.

This Formation strikes N-S to N30°E, and dips 50° to 80°NE. Judging from the nannofossil and foraminifera yielded here, it is reported as of Eocene age.

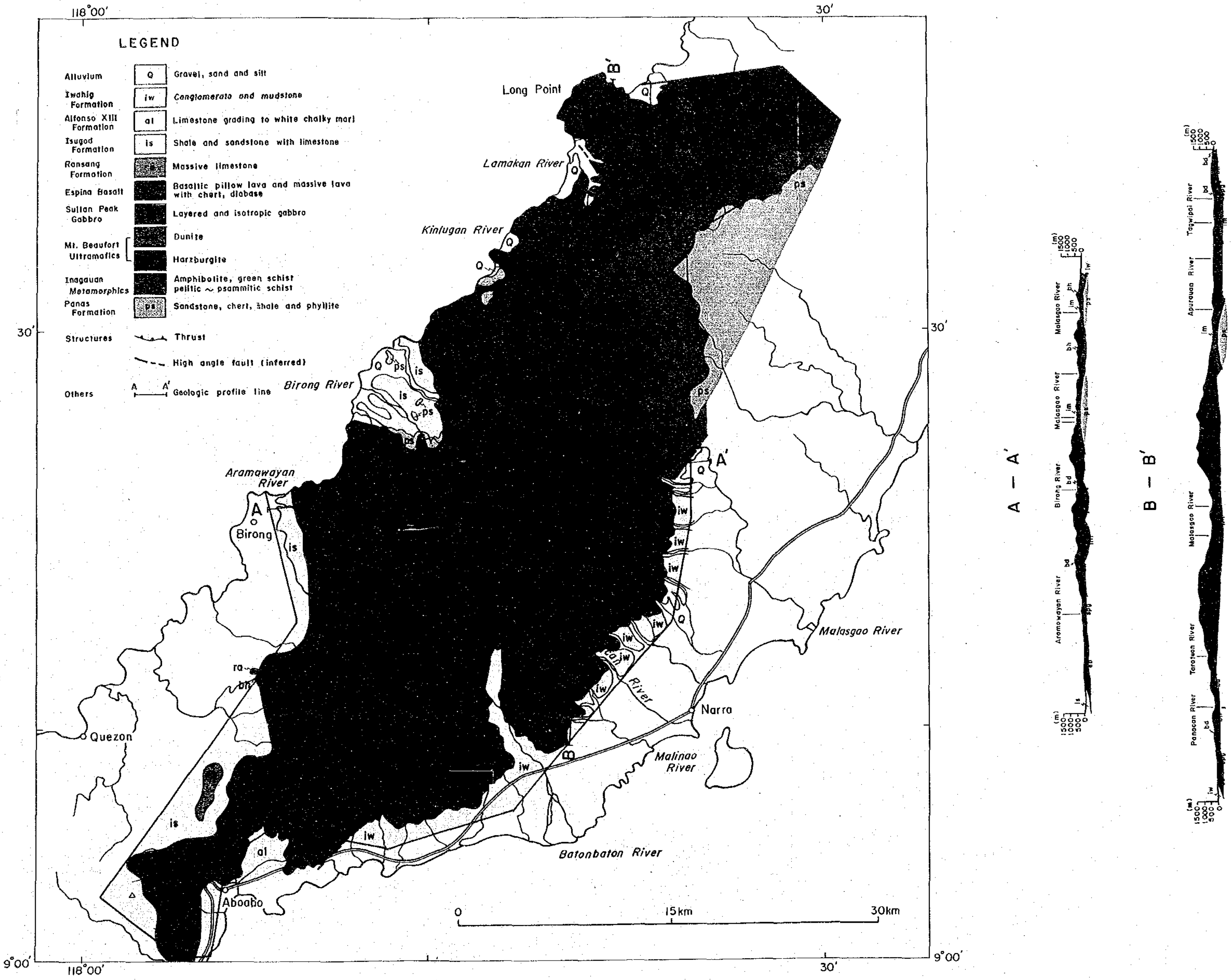


Fig.36 Geologic map and profile in B-area

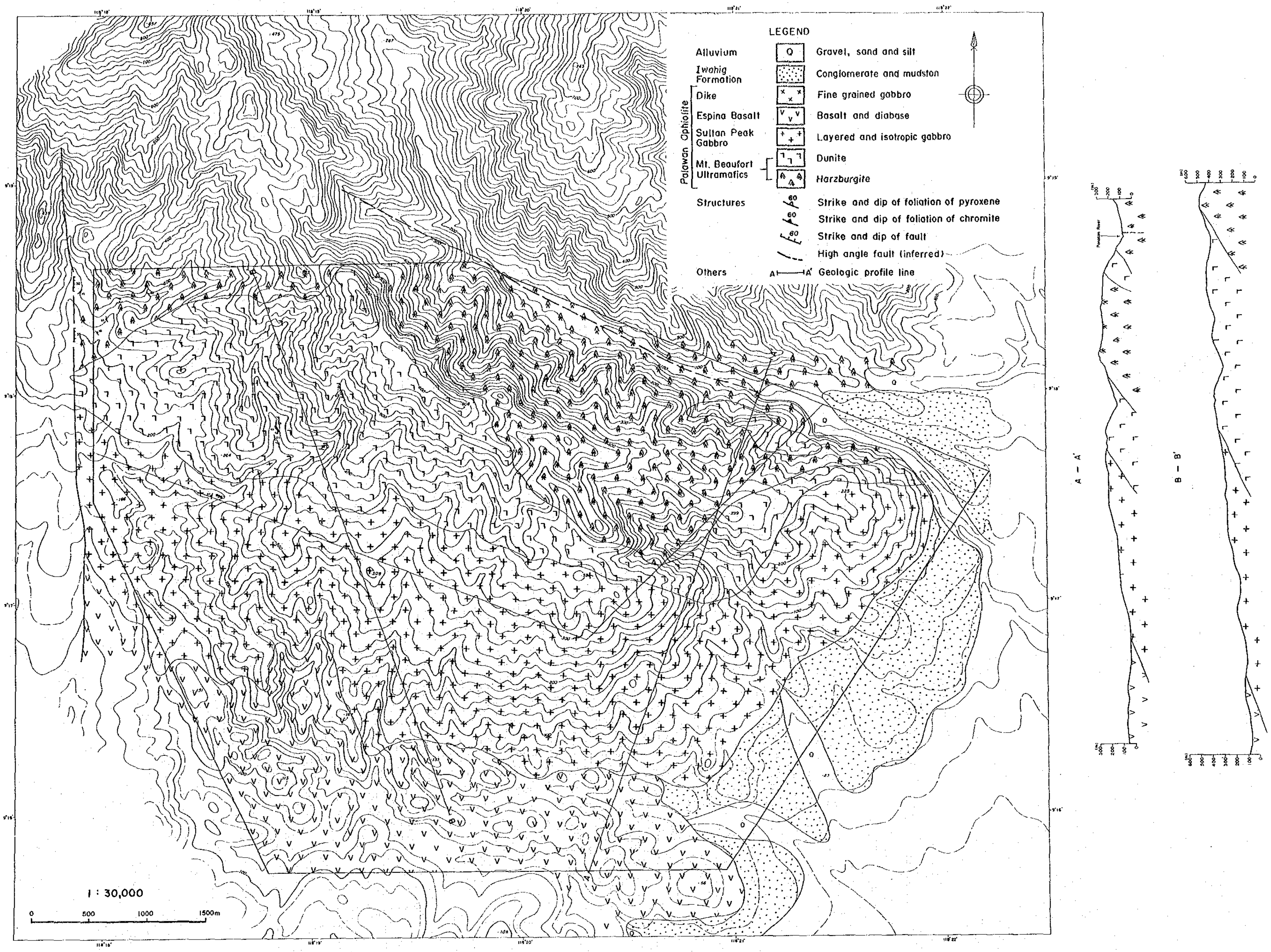


Fig.37 Geologic map and profile in area B-1

2) Inagauan Metamorphics

The Inagauan Metamorphics is distributed in the northeastern B-area and the area underlain by the Panas Formation around Berong on the west coast. They overlie on the Panas Formation, and consist of quartz-mica schist, quartz schist, green schist, and amphibolite.

The quartz-mica schist and quartz schist are distributed in three areas: 1) the upstream area of the Inagauan River, 2) the mid and upstream area of the Malasgao River in the northeastern B-area, 3) in the hills around Berong on the west coast. They are pale gray to pale pink, and mainly consist of quartz and plagioclase, which are 0.1mm to 0.5mm in size, being accompanied by muscovite. They have intense schistosities and microfoldings, and trend N-S, dip 60°SE near Berong on the west coast. Those in the northeastern area of the Malasgao River has a schistosity trending N-S, dipping 25°NW. The results of the K-Ar dating of the quartz-mica schist indicates 45.6 ± 6.8 Ma (JICA and MMAJ, 1989).

Green schist and amphibolite are distributed in the following areas; the uppermost-stream area of the Inagauan River and the upstream area of the Malasgao River in the northeastern B-area, and the border zone between the hills and mountains around Berong in the west coast. The green schist is pale blue to bluish gray, and having been undergone intense shearing. Amphibolite is bluish gray. They show banded structure consisting of amphibole rich parts and feldspar rich parts. Quartz veinlets, in some places, are observed along the schistosity of the green schist and amphibolite.

Around Berong, these rocks commonly show schistosities of NE-NNE to SW-SSW dipping 30° to 80°SE, in some cases 50°NW. It is presumed that there exists microfoldings with a axis trending NE-NNE to SW-SSW. In the area along the Malasgao River, microfoldings trend NNW to SSE and dip 60°NW. The result of the K-Ar dating of the amphibole from the upstream area of the Malasgao River indicates 37.2 ± 1.9 Ma (JICA and MMAJ, 1987).

3) Mt. Beaufort Ultramafics

The Mt. Beaufort Ultramafics are dominantly distributed in the central to northern B-area, and consist mainly of harzburgite accompanied by dunite in some places.

Fresh harzburgite is greenish gray, but weathered parts are pale brown. It consists mainly of olivine, several millimeters in size, accompanied with orthopyroxene. Both minerals have undergone serpentinization. The harzburgite commonly hosts for chromite.

Dunite consists of olivine, 4mm to 5mm large, and have undergone serpentinization in part or in the most of part. It can be divided into two kinds; 1) dunite of the cumulate member, being directly overlain by the gabbro, 2) dunite tectonite, which intruded into the harzburgite as diapir-like bodies.

The cumulate dunite is greenish gray in fresh parts, while pale brown in weathered parts. The transitional zones with overlying gabbro and troctolite exist in some places, which show banded structure of both rock units. The dunite has undergone serpentinization, and is accompanied with a small amount of chromite.

The dunite tectonite is also accompanied with chromite. The direction of chromite seams and lenses seems to be arranged in the same direction of a dunite tectonite bodies's trend. in a layer or lens. The chromium deposit in the Norsophil Mine is contained in the diapir-like bodies of dunite tectonite.

The cumulate dunite is distributed in the area northwest of Narra in the central part of the east

coast, and the area southeast of Berong in the central part of the west coast.

The cumulate dunite in the northwest of Narra trends WNW to ESE, approximately 6km long and 100m to 200m thick, and dips 20° to 30°SW. The cumulate dunite in the southeast of Berong trends NW-NNW to SE-SSE, approximately 200m to 300m thick, and dips 20° to 30°SW.

The dunite tectonites are commonly small scale with 1m to 2m in width. Some dunite bodies are rather large, one of the largest dunite tectonite body one which contains the Norsophil Deposit trends WNW to ESE, approximately 4km long, 1km wide. Judging from the shape of the other small scale diapir-like dunite bodies, it probably dips at a deep angle towards the northeast. The diapir-like dunite bodies commonly appears to cut the foliation of the harzburgite.

The foliation of harzburgite formed by the orthopyroxene are observed. Its orientation differs in parts of the B-area. It trends NNW to SSE and E to W dipping to the south in the basin of the Tagbolante River in the central area of the east coast and on the west coast. In the northern west coast, it trends NEN to SWS and dips south in some cases. In the east coast side, it trends commonly NE to SW and NW to SE, and dips north, but in some cases dips south.

Judging from the structure and its distribution area of the cumulate dunite, it is assumed that the Mt. Beaufort Ultramafics generally trend NW to SE, and dip gently to the southwest. Accordingly, the southwestern side is of upper, and the northeastern side is of lower.

The Mt. Beaufort Ultramafics is thrust over the Panas Formation. In between these two, the Inagauan Metamorphics exist as metamorphic sheets. On the upper part of the Malasgao River, the Mt. Beaufort Ultramafics near the metamorphic rocks have undergone shearing and mylonitization.

4) Sultan Peak Gabbro

The Sultan Peak Gabbro is distributed in the area centered by Sultan Peak situated in the southern B-area as a large scale intrusive mass, covering the eastern and western sides of the backbone mountains. It is also distributed to the west of Narra in the east coast, to the south of Berong and around Long Point in the west coast.

The rocks are pale greenish gray, medium grained gabbro to olivine gabbro, and mainly consist of plagioclase and clinopyroxene, accompanied with olivine in some cases. The plagioclase is usually fresh, but sometimes has altered to prehnite. The olivine has almost completely altered to serpentine.

This rock is characterized by a clear banded structure of white and dark parts. The gabbro situated near Berong, however, does not show any banded structure.

A gabbro body located in detailed survey area B-1 trends N50°W, and dips 80°SW.

In area B-1, a troctolite layer underlies normal gabbro. Under the troctolite layer, a transitional zone and the cumulate dunite lies as cumulous phase of the Sultan Peak Gabbro.

5) Espina Basalt

The Espina Basalt is extensively distributed in the southern B-area, extending to the north up to the south of Berong on the west coast. It is also distributed in the areas to the south of Long Point in the west coast and to the northwest of Narra in the east coast.

It consists of basaltic pillow lava and diabase.

The basaltic pillow lava is gray to pale gray, and its pillow structure is clear. The size of the pillow ranges from 0.4m to 1.0m. Massive basalt is also observed. Boulders of red chert are

found in the distribution area of the basalt. It is assumed that the chert is intercalated by the basaltic pillow lava.

The diabase is gray to pale gray, and shows the ophitic texture. It has undergone silicification in some cases. The basaltic pillow lava trends N30°W, and dips 40° west. The diabase dikes trend N20°W-N45°W, dips southwest.

6) Ransang Formation

The Ransang Formation is distributed in the small area on the west foot of the backbone mountains in the southern B-area.

It consists of micritic limestone containing a large amount of microfossils. It is said to be of Early Miocene age, and a part of it is correlated to the St.Paul Limestone of northern Palawan.

7) Isugod Formation

The Isugod Formation is distributed in lowland area around Berong on the west coast and the southwestern area. It mainly consists of shale and sandstone, accompanied with limestone.

8) Alfonso X III Formation

The Alfonso XIII Formation unconformably overlies the Espina Basalt near Aboabo in the southern B-area. It consists of coarse grained to muddy limestone and microcrystalline coral limestone. Judging from the nannofossil and foraminifera, it is probably of Late Miocene age.

9) Iwahig Formation

The Iwahig Formation conformably overlies the Inagauan Metamorphics and the Palawan Ophiolite in the lowland areas on the east coast of the B-area. It mainly consists of conglomerate and mudstone, accompanied with limestone in some places.

2-1-3 Geological structure

The geological structure of the B-area are ascribed to the emplacement of the ophiolite, which is believed to have generated during Late Cretaceous time and have thrust over the Panas Formation during the Eocene. The main features of the structure in this area are thrust fault, high angle fault, and folding.

1) Thrust fault

It is presumed that two thrust faults exist in the B-area. One is on the bottom of the Mt. Beaufort Ultramafics, and the other is on the boundary between the green schist and amphibolite unit and quartz-mica schist and quartz schist unit of the Inagauan Metamorphics. Around the former, the harzburgite and dunite on the hanging wall side have undergone intense shearing and serpentinization, resulted mylonitization in some places. As for the latter, it has two different features. To the south of Berong, it borders the green schist/amphibolite and quartz-mica schist/quartz schist. In the Upper part of the Malasgao River and further north, it borders the Mt. Beaufort Ultramafics and quartz-mica schist/quartz schist. This means that the two thrust faults are situated between the Mt.Beaufort Ultramafics and Panas Formation. It lacks the green schist/amphibole facies in some places. The texture of the Mt. Beaufort Ultramafics generally

trend NE to SW and dip southwest, therefore it is oblique to the general trend of the thrust faults.

The quartz-mica schist has been dated as 44.8 to 46.3 ± 6.8 Ma. It may be inferred that the thrust movement occurred in the Middle Eocene.

2) High angle fault

A high angle fault runs from the middle of the Batanbatan River in the central-southern area along the east coast in the B-area to the upstream area of the Tagbolante River on the west coast. This fault cut the Mt. Beaufort Ultramafics, and accompanies a sheared zone with 2m wide, in where intense serpentinization occurred. The fault trends N to S, and appears to be a left lateral fault on the geological map.

Other small scale faults exist in the middle of the Batanbatan River and along the Panacan River on the east coast, and the surrounding area of Berong and near Long Point on the west coast.

3) Folding structure

Folding structure exists in the area to the south of Berong, where the Inagauan Metamorphics are distributed. It shows repeatedly synclines and anticlines, and the general trend of the axes is NNE to SSW.

A lineation of orthopyroxene and other minerals exists in the Mt.Beaufort Ultramafics, but its orientation and dip varies area by area. It is assumed that there are folding structure in the banded structures, but details are not yet revealed.

2-1-4 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.38)

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(Fig.39).

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-1

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 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

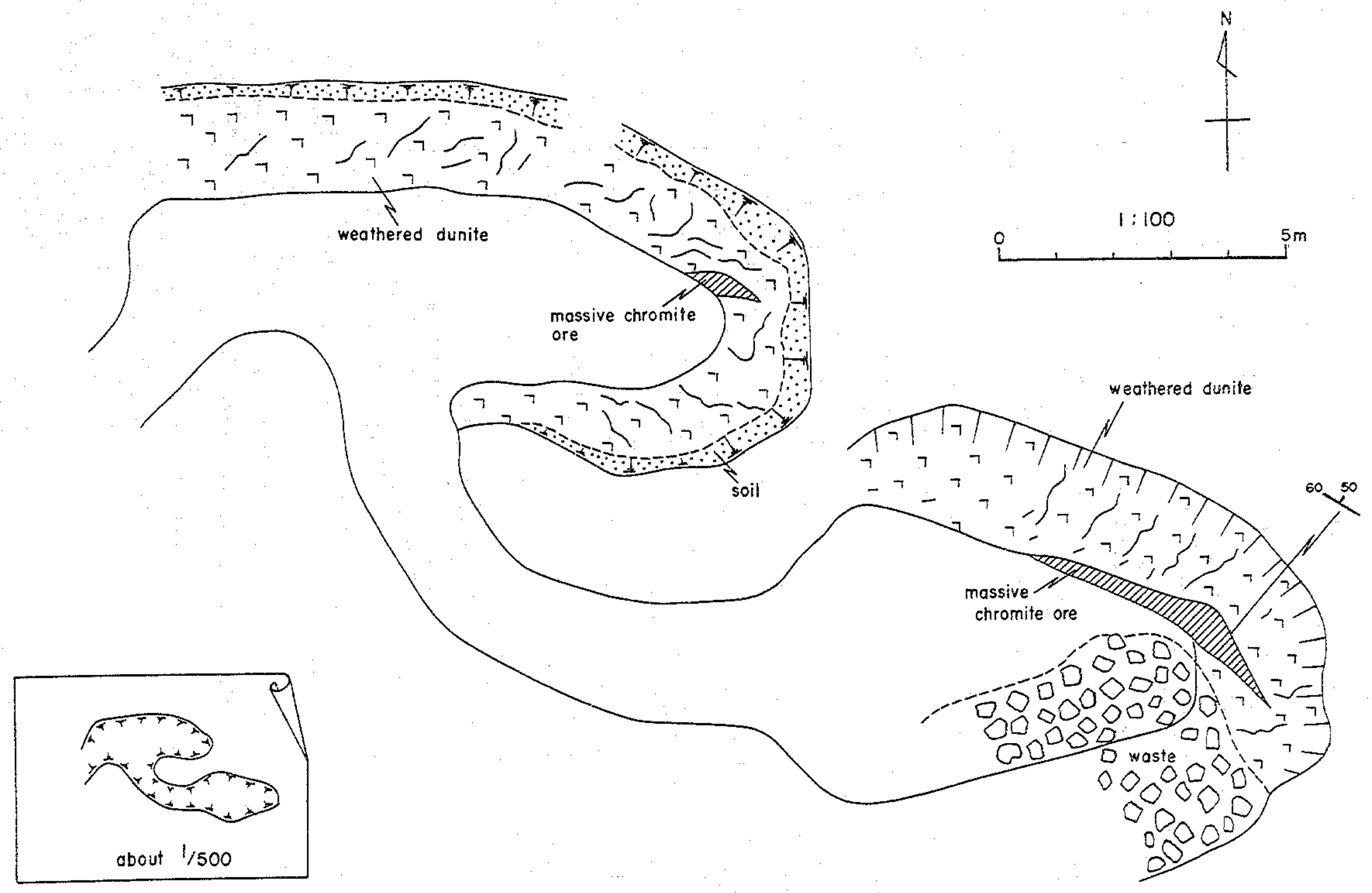


Fig.38 Taytay chromitite outcrop in Long Point area

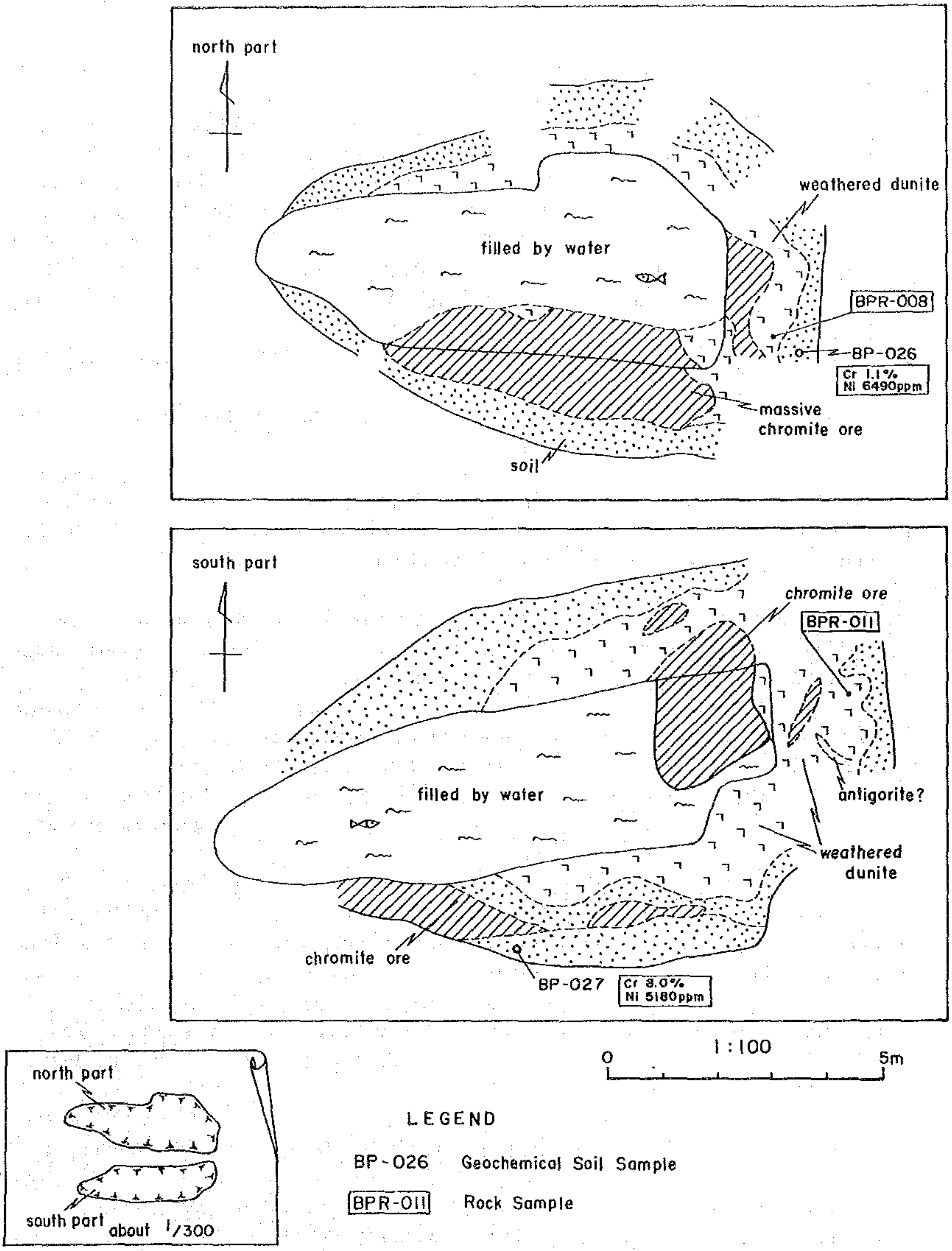


Fig.39 Chromitite outcrop to the north of Berong area

600ppb in test pit PK04.

6) East part of the detailed survey area B-1

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.

2-2 Geochemical Survey

2-2-1 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.

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.

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 1-2-1.

(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. 40 to Fig. 43).

On the basis of the aforementioned thresholds (Chapter 1-2-1), anomalous values of each element are shown in element content map. The results are as follows:

Heavy mineral sand in soil(Fig.44): 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.

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 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

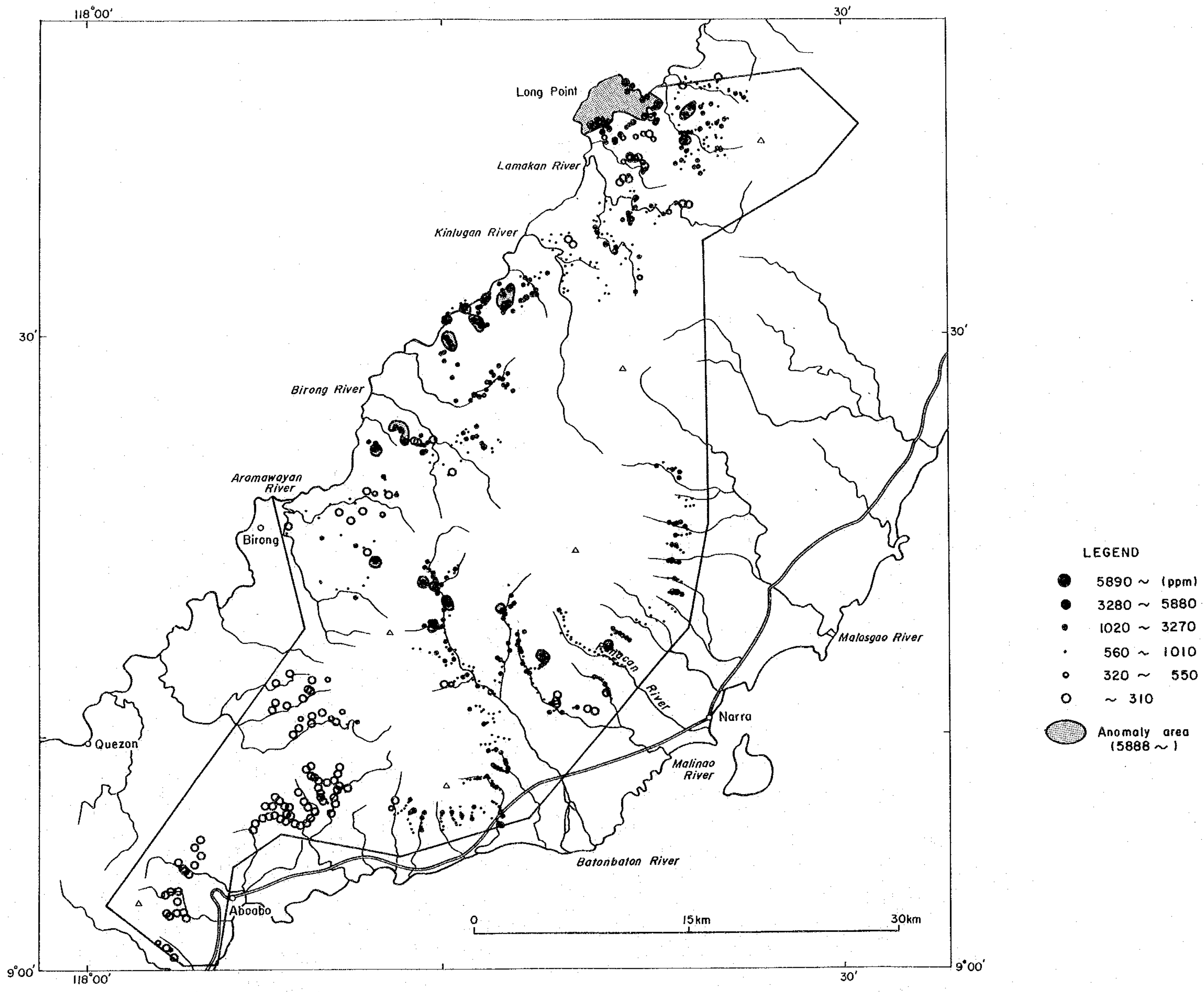


Fig.40 Ni content of soil samples in B-area

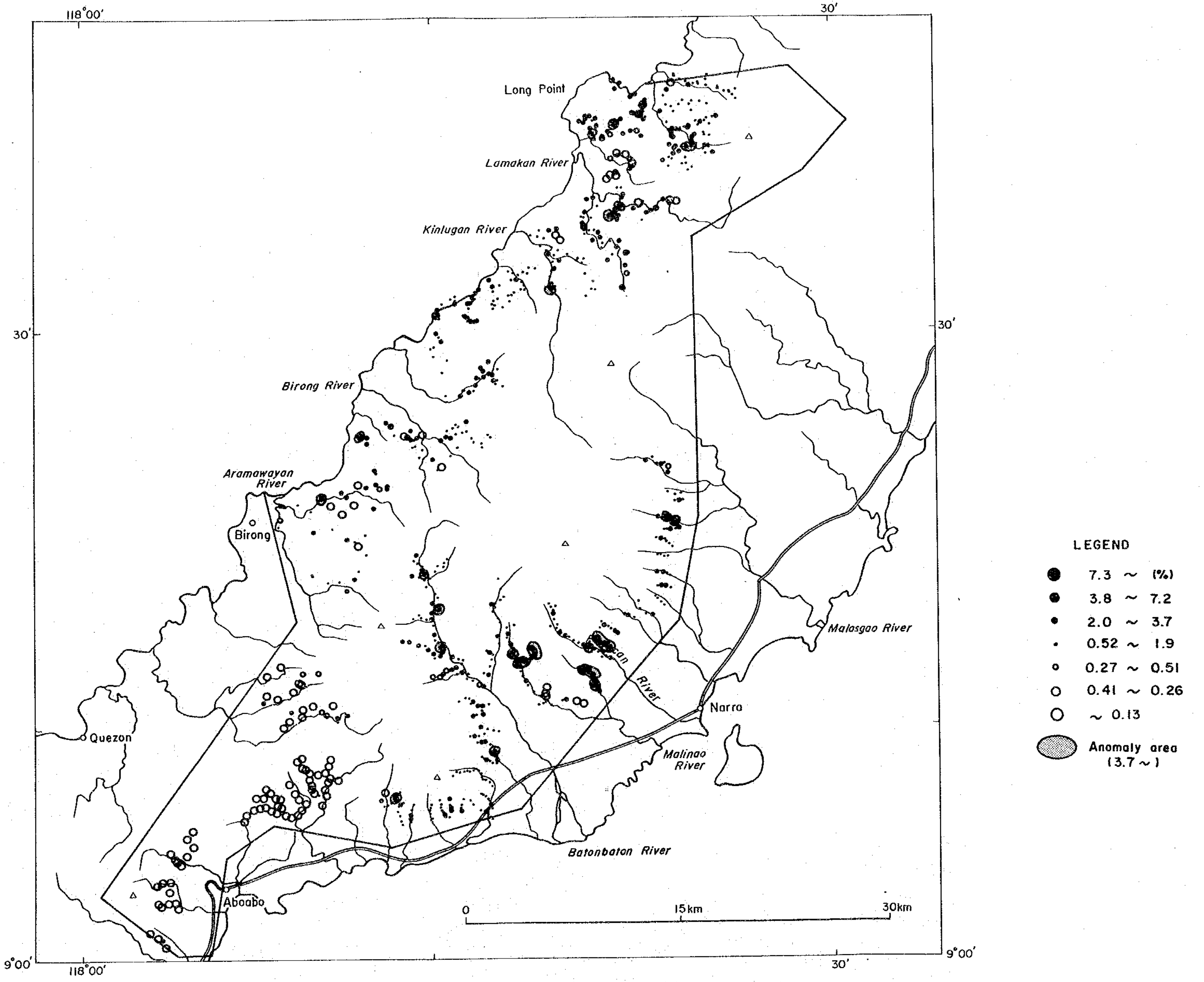


Fig.41 Cr content of soil samples in B-area

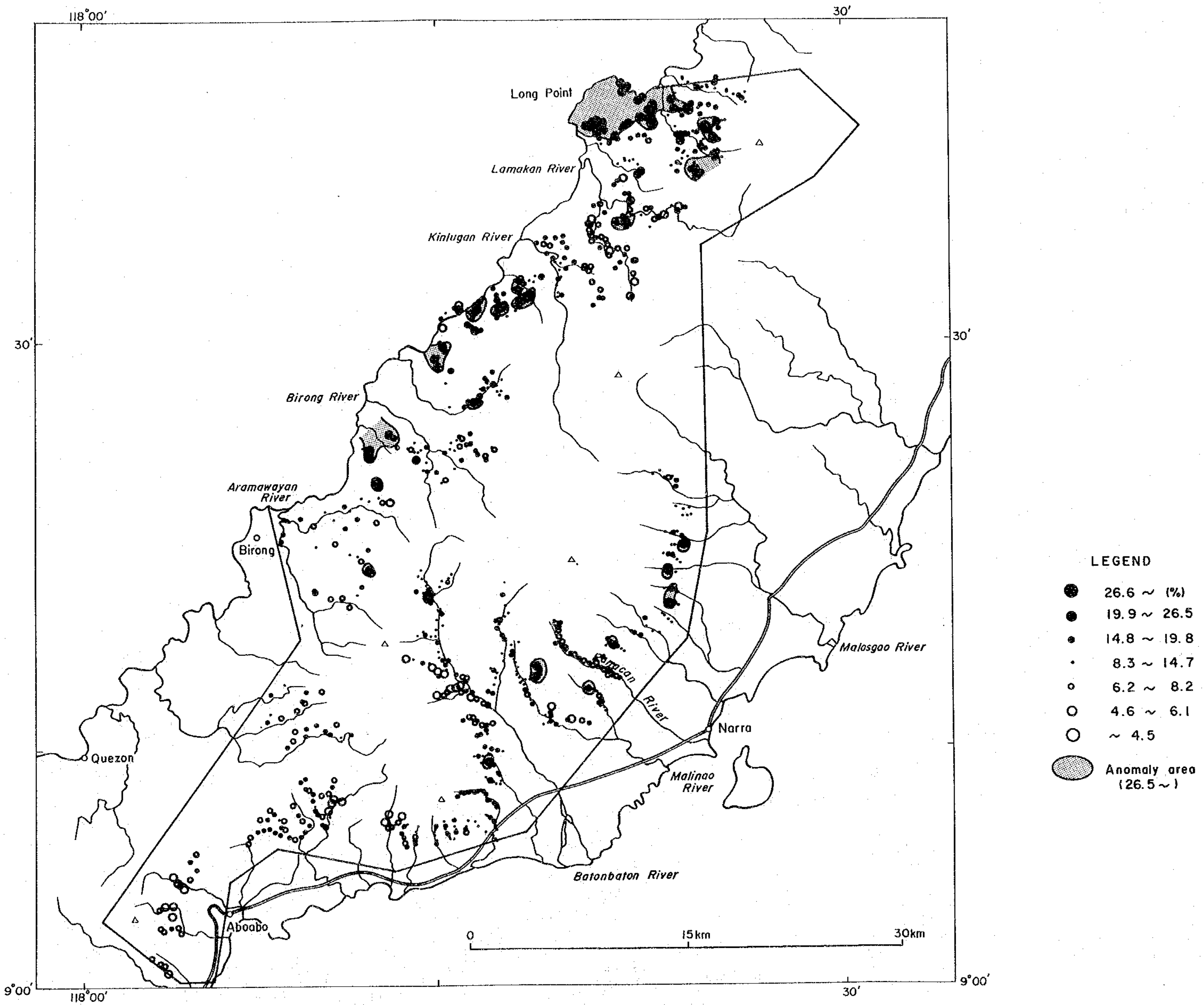


Fig.42 Fe content of soil samples in B-area

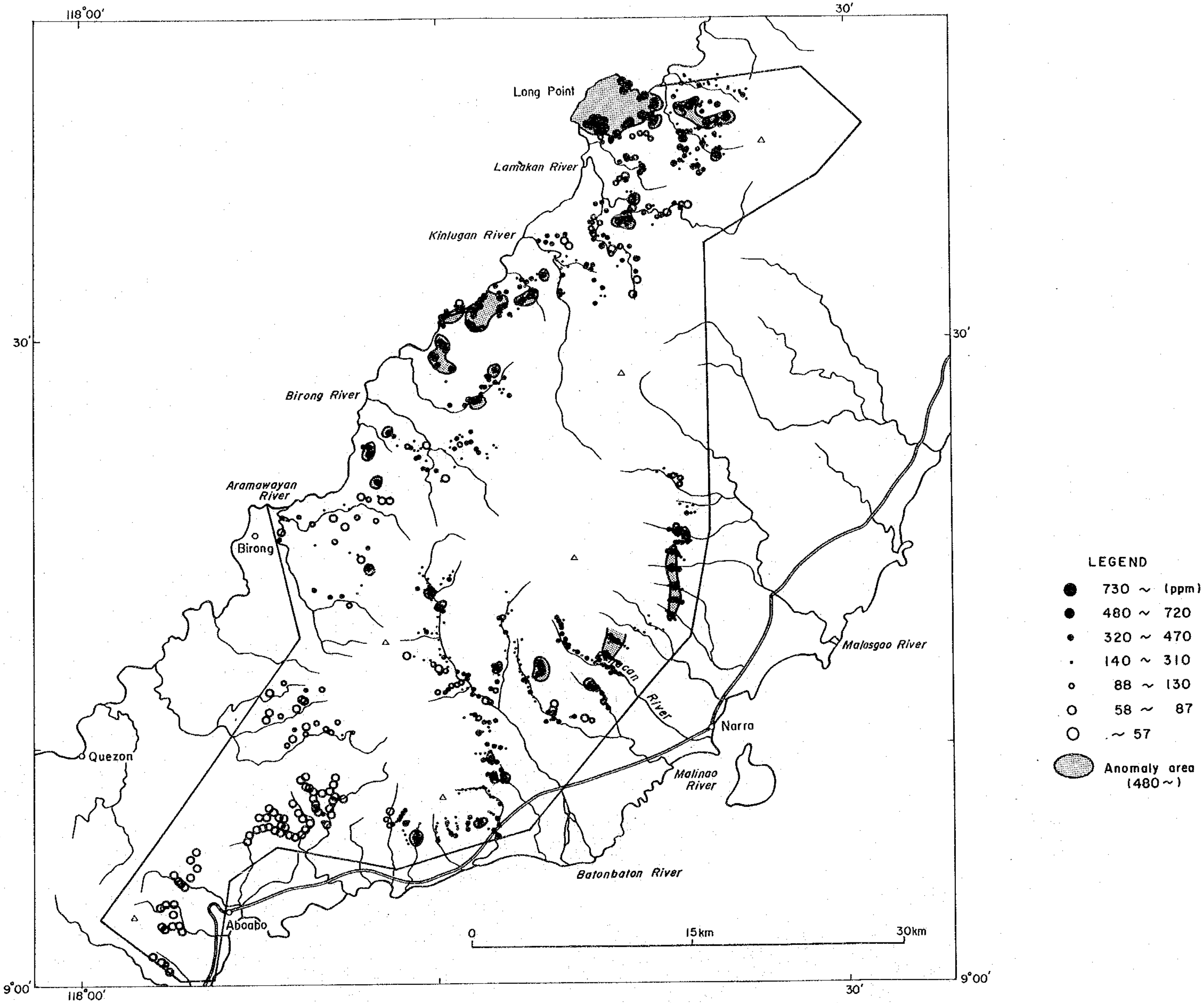


Fig.43 Co content of soil samples in B-area

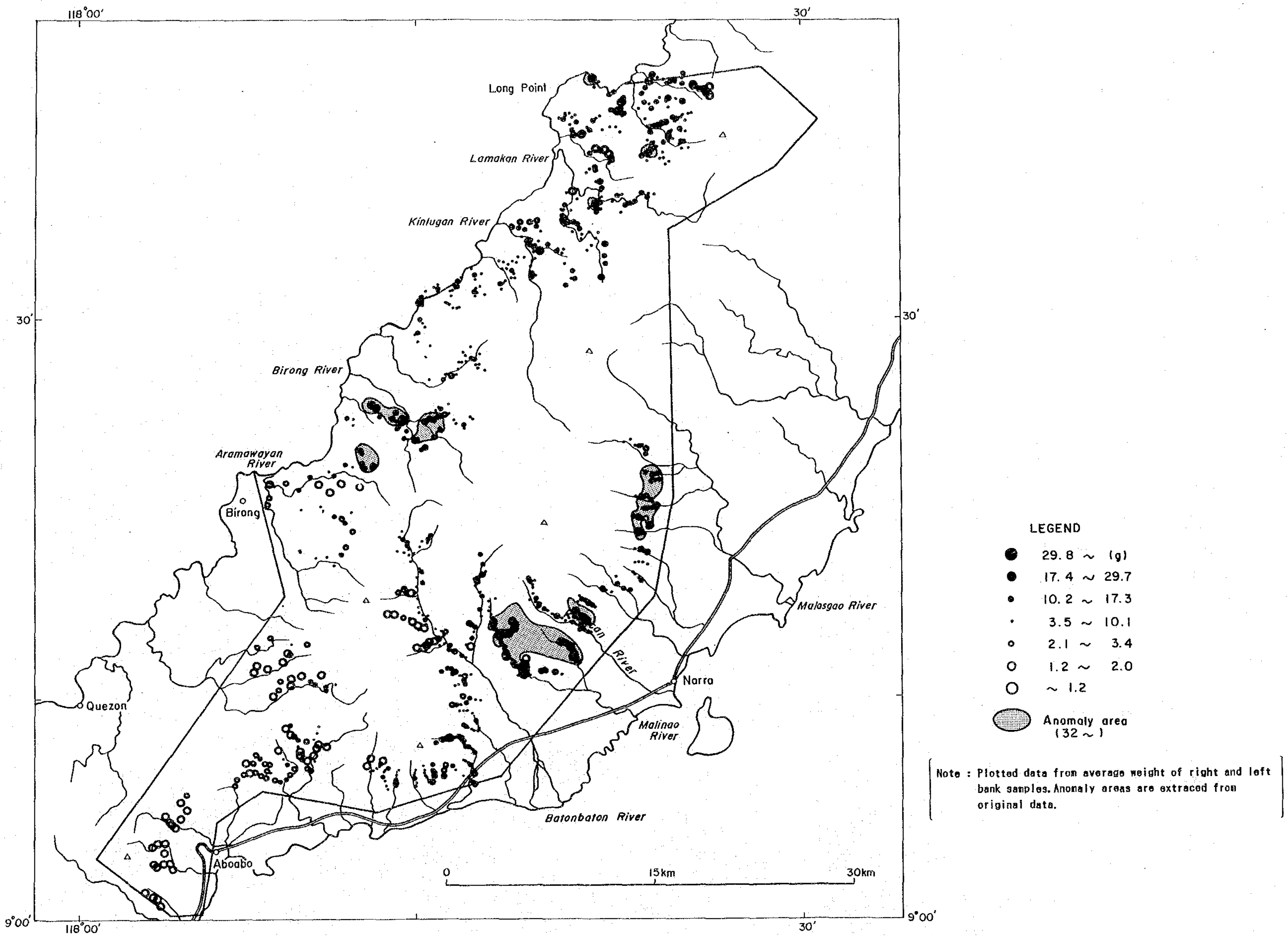


Fig.44 Heavy mineral content of soil samples in B-area

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

2-2-2 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.

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 7. 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.

Table 7 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).

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:

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

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

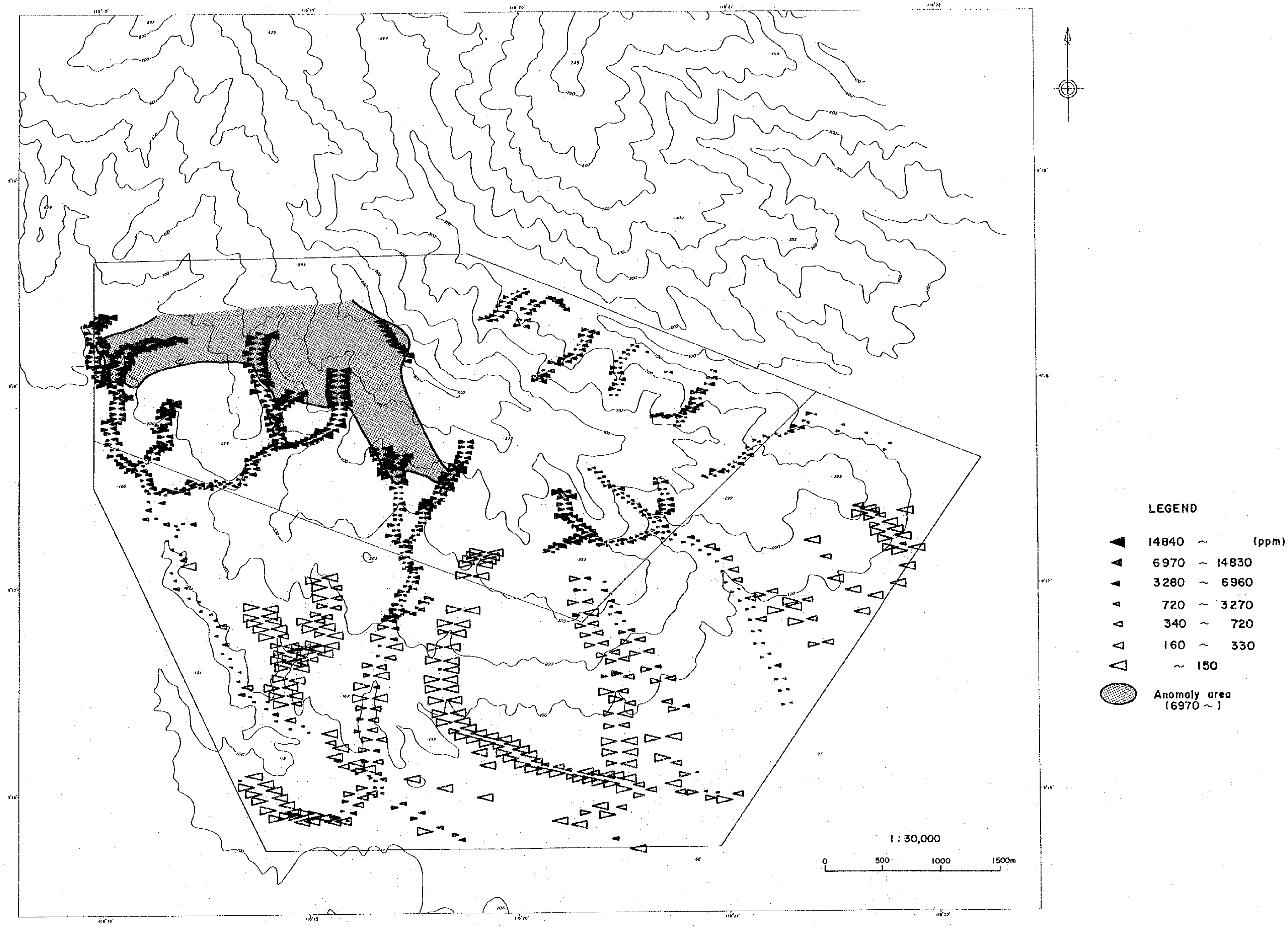


Fig.45 Ni content of soil samples in area B-1

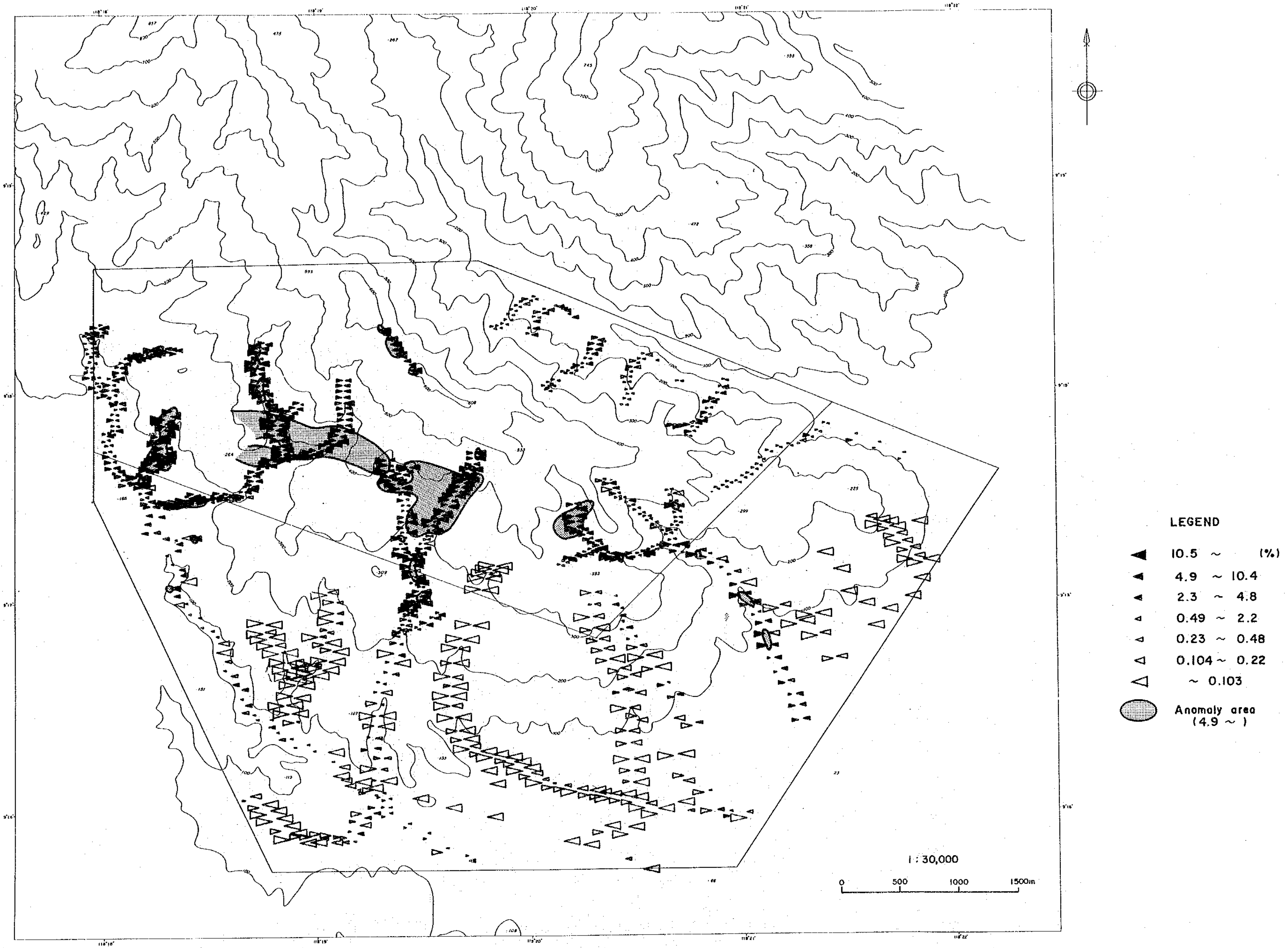


Fig.46 Cr content of soil samples in area B-1