PART III bII (MANKADAU) AREA

CHAPTER 1 Geology and Mineralization

1–1 Geology

1–1–1 Stratigraphy

The sedimentary rocks distributed in the survey area are classified into hornfels of unknown age, the Chert-Spilite Formation and the alluvial deposits in an ascending order. Fig. 14, Fig. 15 and Fig. 16 show the geological map, the generalized stratigraphical section and geological columnar section respectively.

The characteristics of each formation are as follows.

(1) Hornfels of Unknown Age

Distribution : The northwestern part of the survey area.

Thickness : more than 200 m

Rock facies : Mainly consists of gray to pale gray, medium to fine-grained massive hornfels derived from sandy rock. The rock is very hard and characterized by sharp fracture. It grades into pale gray quartzite in the southwestern part of the area. It shows a rhythmical alternating beds with interbedded dark gray mudstone in the upper reaches of Sasapan creek. It is locally intercalated with bluish gray massive basalt lava. A pillow structure and amygdaloidal texture are observed in basalt. However, the basalt is not mappable because of too small in size. The hornfels is resistant to the weathering, often forming steep cliffs and water falls.

The characteristics of the typical samples under the microscope are as follows.

Y-29 Hornfels (Sandstone)

Constituents : quartz $\gg$ plagioclase $\gg$ opaque minerals

Microscopic features : It is mainly composed of fine-grained quartz (0.1 ~ 0.2 mm in size) with a few plagioclase and chert. It is arkosic and well sorted. The grained are subangular in shape. The matrix is muddy. Secondary calcite, chlorite and quartz are present.

Stratigraphical Relation : It is generally bordered by thrust with overlying peridotite. In the lower reaches of Sasapan creek, it is unconformably covered by the Chert-Spilite Formation.

(2) Chert-Spilite Formation

Distribution : In the central to the southeastern part of the survey area (surrounding area of the peridotite intrusives)

Thickness : more than 200 m.

Rock facies : The formation is divided into the following three members from its lithologic characteristics.

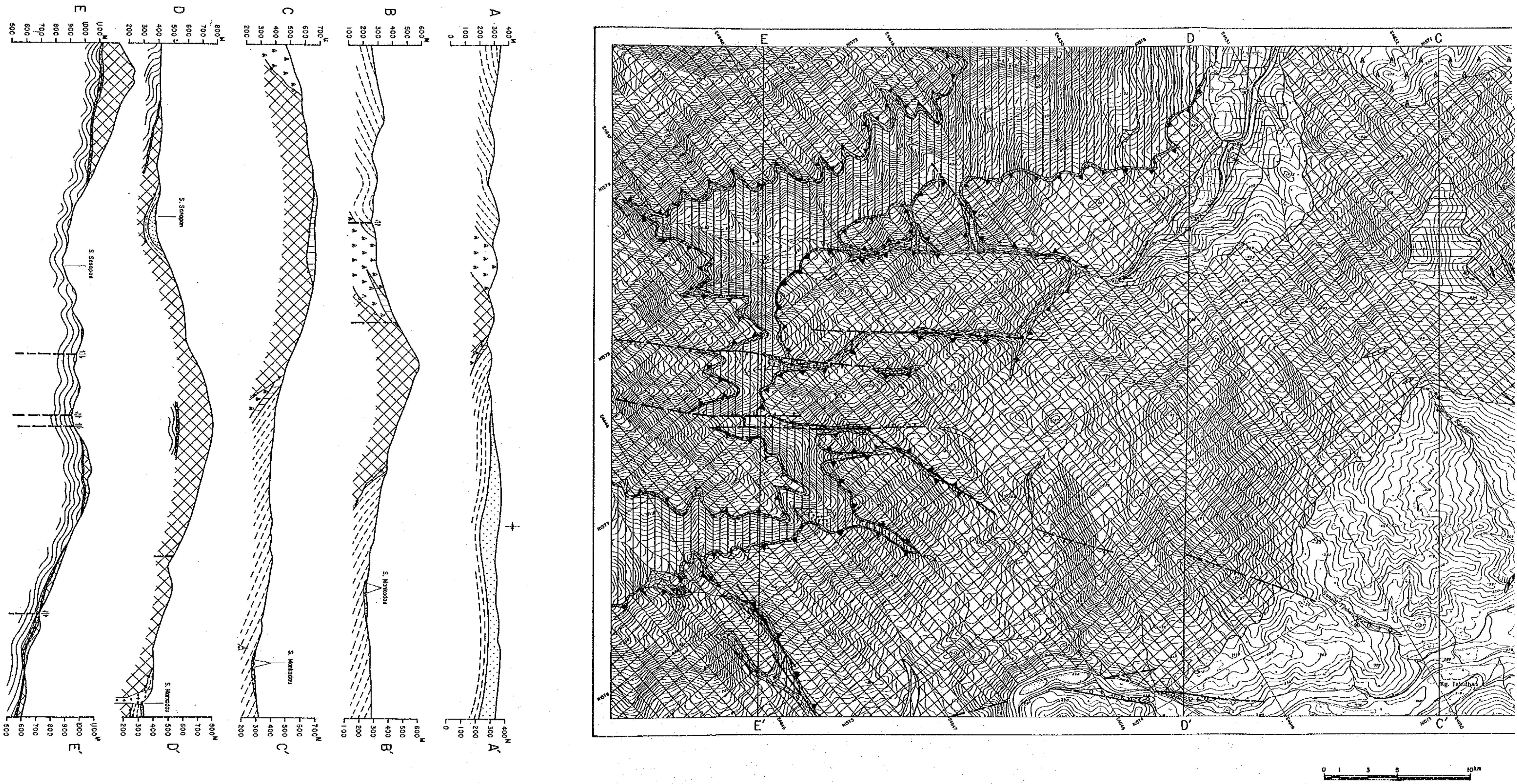
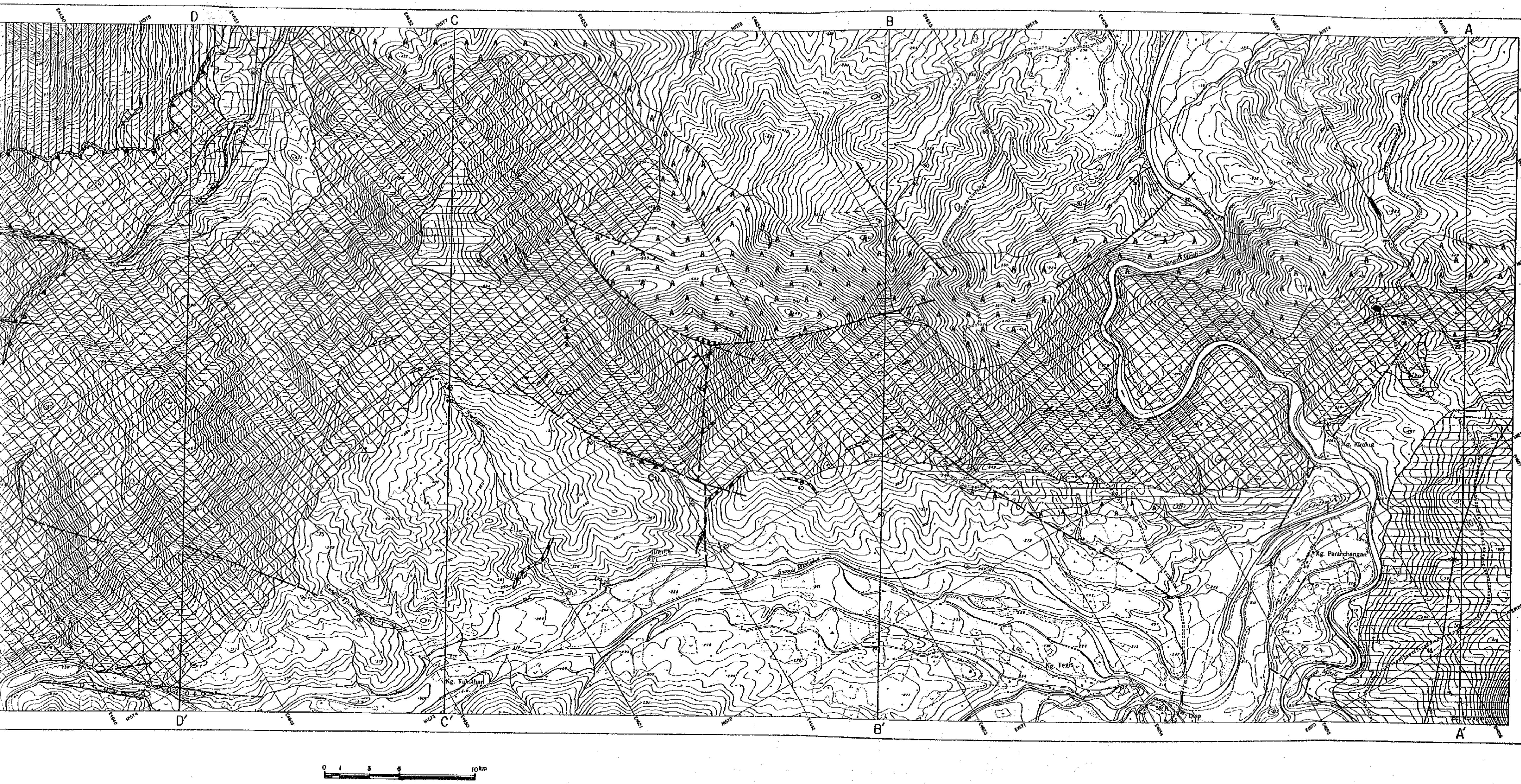


Fig. 14 Geological Map of bII (Mankadau) A



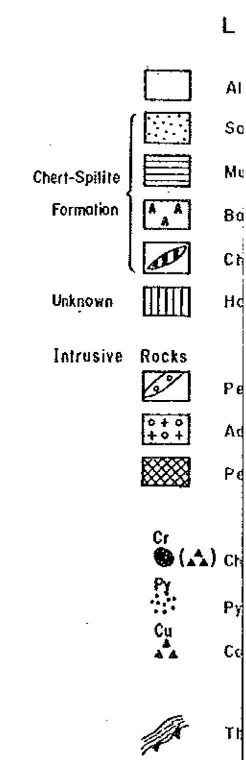
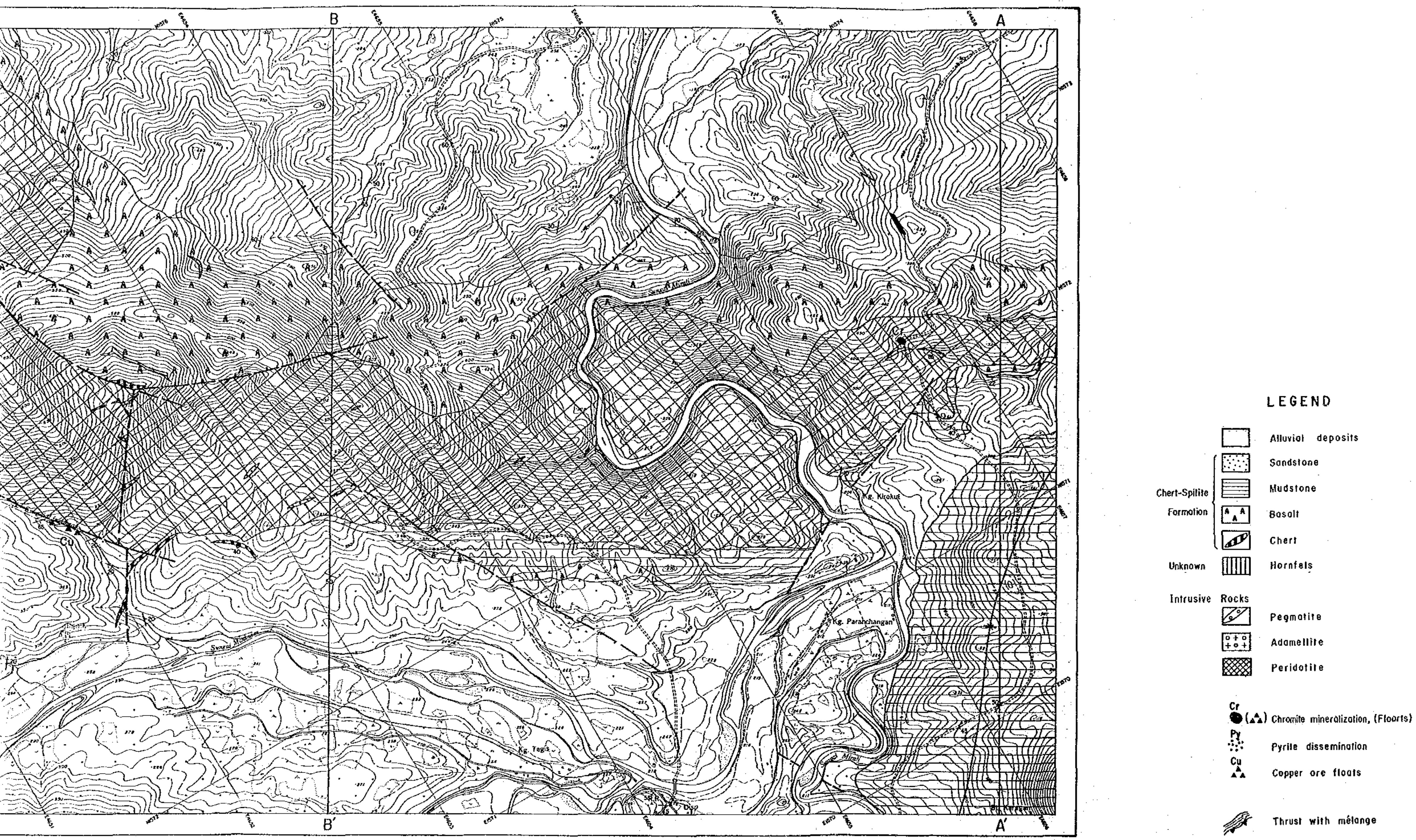


Fig. 14 Geological Map of bII (Mankadau) Area


B
A
B′
A′
Kg. Kirokut
Kg. Parahchangan
LEGEND
Alluvial deposits
Chert-Spilite Formation
Sandstone
Mudstone
Basalt
Chert
Unknown
Hornfels
Intrusive Rocks
Pegmatite
Adamellite
Peridotite
Cr
Chromite mineralization, (Floorts)
Py
Pyrite dissemination
Cu
Copper ore floats
Thrust with mélange

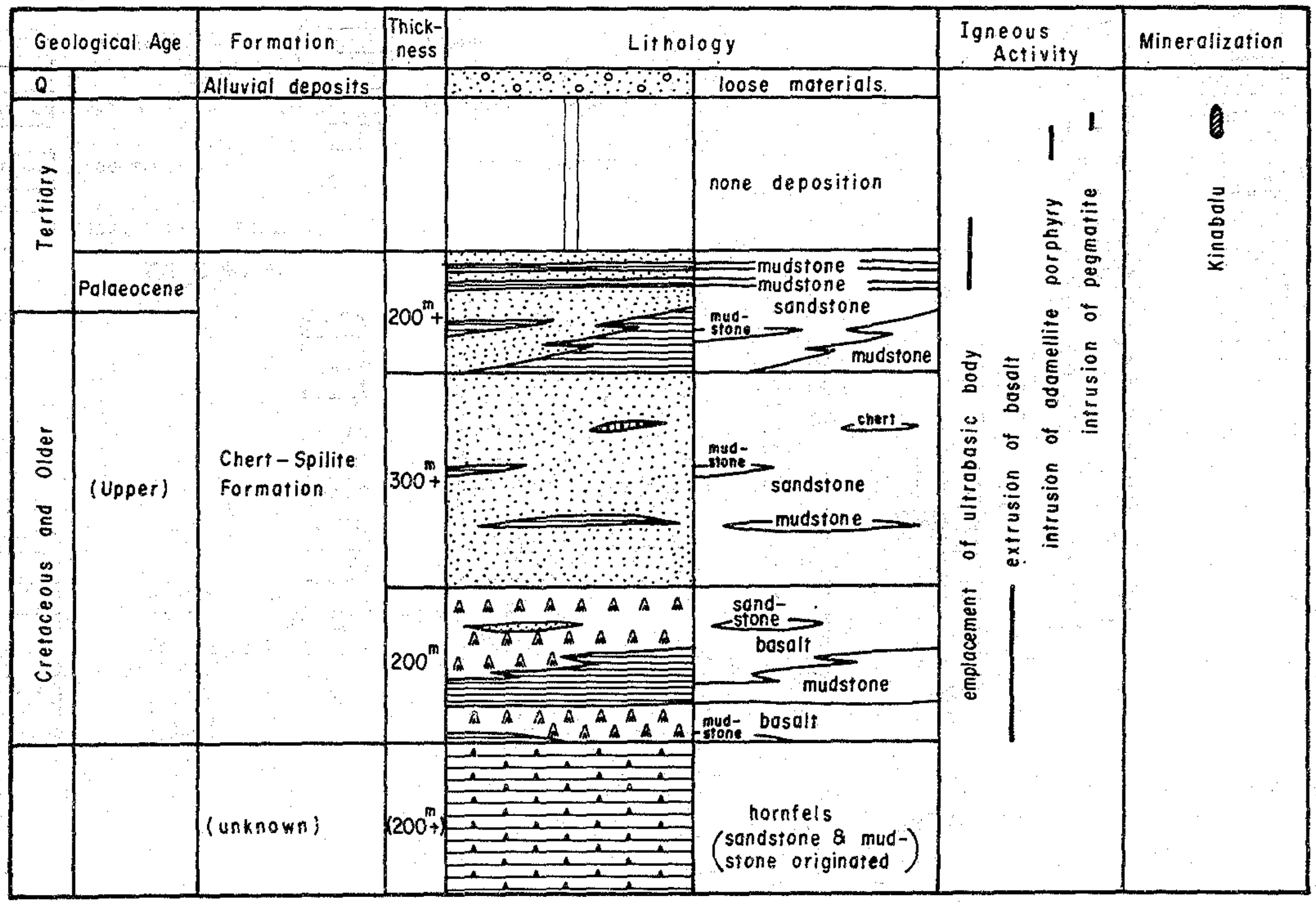


Fig. 15 Generalized Stratigraphic Section of b II (Mankadau) Area

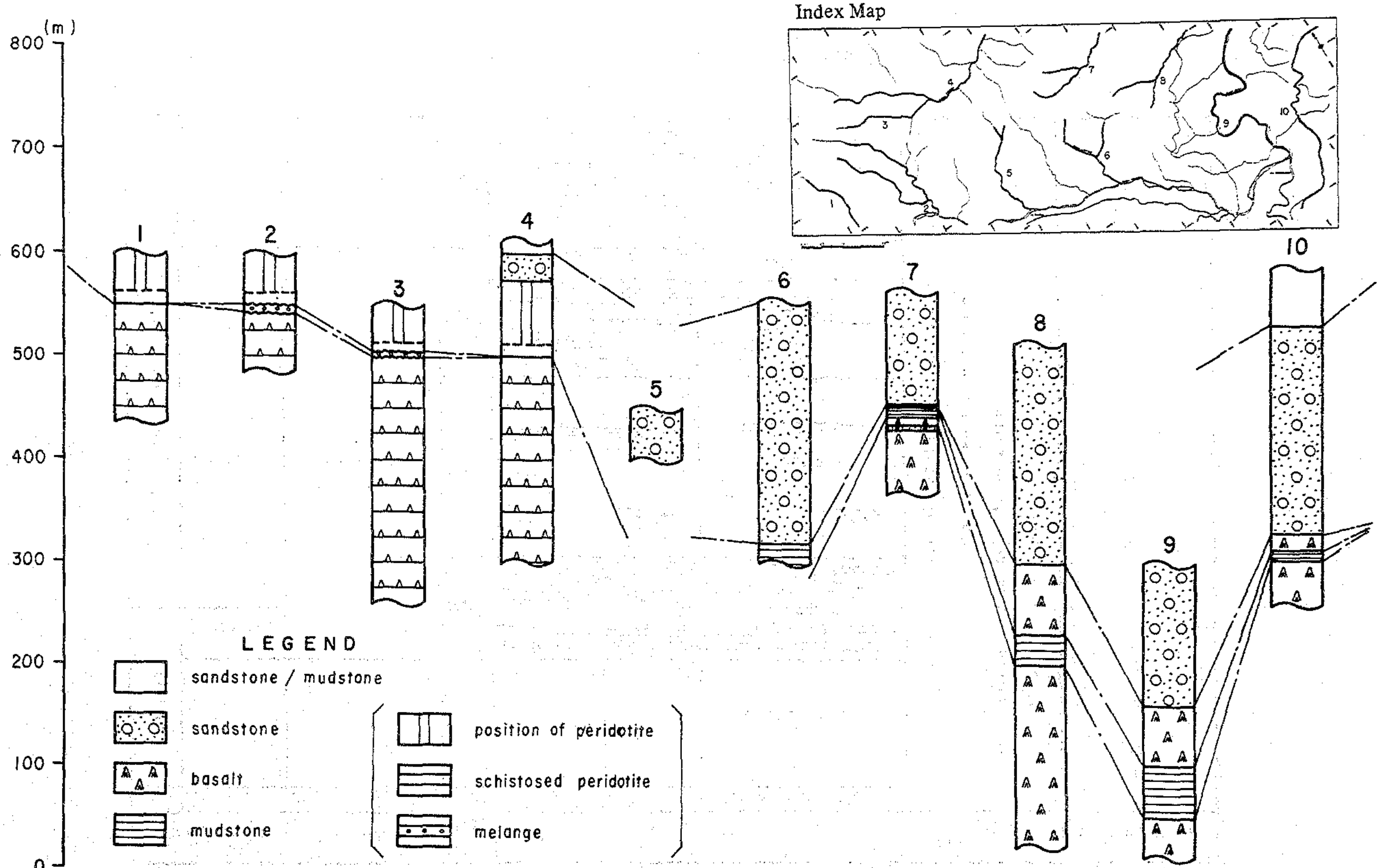


Fig. 16 Geological Columnar Section of bII (Mankadau) Area

(Upper) Alternating beds of sandstone and mudstone

(Middle) Massive sandstone

(Lower) Spilitic basalt lava

(i) Spilitic Basalt Lava

It is harmoniously distributed with the peridotite which extends in the central to the southeastern part of the survey area, especially widely on the northern side of the intrusive. It directly covers the peridotite in the central part of the area. The thickness is assumed to reach up to about 200 m.

The member mainly consists of spilitic basalt lava, partly interbedded with brownish grey or greenish grey mudstone, grey sandstone and reddish brown chert.

The spilitic basalt lava is greenish grey in general, sometimes brownish grey in color. A pillow structure is common, accompanied with small quantities of hyaloclastite. The rock shows an intersertal texture, in which two milimetres long prismatic laths of plagioclase are observed. An amygdaloidal texture is commonly observed and the amygdaloids are filled with calcite or zeolite. The rock locally grades into massive coarse-grained facies of dolerite. The intercalated mudstone is mainly distributed on the southern side of the peridotite intrusive in the eastern part of the area, and it distributes stratigraphically in the horizon of the bottom of spilitic basalt lava. The rock is weakly bedded, interbedded with lenses of sandstone and shale. Further it is intercalated with sandstone and chert, both of which form thin layers with about 10 metres in thickness. The rock facies of the sandstone resembles the massive sandstone in the upper sequence, to be mentioned later, and it is medium to fine-grained, massive and hard, containing "concretion" of the same source. Chert is well bedded and hard, and characterized by sharp fracture and abundant radiolaria.

The characteristics of the samples under the microscope are as follows.

Y-06 Basalt

Texture : Subophitic

Phenocrysts : plagioclase > augite

Microscopic features : Plasmatic crystals of plagiocase are enveloped in the xenocrysts of augite. Plagioclase is partially replaced by clinozoisite. Quartz and pyrite occur as the secondary minerals.

Y-32 Radiolarian Chert

Microscopic features : Many spherulites (0.1 ~ 1 mm in size) replaced by quartz or chalcedony are embeded in a cryptocrystalline matrix. Some quartz or calcedony veins (0.2 ~ 1 mm) cut the spherulites. A very few opaque minerals are present.

(ii) Massive Sandstone

The rock is widely distributed near the spilitic basalt, and also in the lower reaches of Sasapan creek. The thickness reaches up to more than several hundred metres, and varies greatly in places.

The sandstone is grey to dark grey, medium to fine-grained, hard and compact rock, is poor in facies change. It often contains the concretion disseminated by pyrite of one centimetre, almost spherical sandy to silty concretion rarely reaching up to two metres in diameter. A sole mark is also observed on the weathered surface of the rock. Breccias of basalt are rarely contained at the bottom of the sandstone, suggesting that it would occupy the upper sequence of spilitic basalt lava. The sandstone is intercalated with thin layers of dark grey, a little soft mudstone and reddish brown, well bedded chert. It yields no fossile in general.

The characteristics of the typical samples under the microscope is as follows.

Y-03 Fine-grained Sandstone

Constituents : quartz > chert, K-feldspar, opaque minerals > zircon

Microscopic features : It is mainly composed of quartz grains (less than 0.2 mm in size) with some fragments of chert, plagioclase. It is arkosic and poorly sorted. The grains are subangular in shape. The matrix is muddy and a little amount in volume. Secondary minerals are sericite, montmorillonite and calcite.

(iii) Alternating Beds of Sandstone and Mudstone

It is distributed at the eastern end and in the lower reaches of Sasapan creek in the survey area and spreads widely toward the outside of the survey area. The thickness seems to be more than 200 meters.

The member is rich in mudstone in the lower part and predominant in sandstone in the upper part. The former is distributed at the eastern end of the survey area. It is dark grey to black, hard and compact rock, often forming alternating beds of dark grey sandstone and shale. It is well bedded as compared with massive sandstone in the lower part. The latter is distributed in the lower reaches of the Sasapan creek, and it is grey, hard and compact rock, showing rhythmical alternation beds of dark grey mudstone with laminae and small amount of shale, with repetition of the banding of 10 to 30 cm wide.

No fossile was discovered from any layer of the formation.

Stratigraphic Relationship : The three members mentioned above are conformable each other and these are in the relation of interfinger in places. The formation unconformably covers the underlying rocks.

In the Phase I report, the sedimentary rocks distributed in the 4 km² survey area of this phase were tentatively correlated to the Trusmadi Formation, however the writers pointed out that they may rather belong to the Chert-Spilite Formation.

According to the results of Phase II survey which covered a more wider area i.e., 50 km², especially judging from the wide occurrence of spilite lava and chert, it can be concluded that the sedimentary rocks in the area are to be correlated to those of the Chert-Spilite Formation instead of the Trusmadi Formation.

(3) Quaternary Sediments

The sediments are distributed in the valley of the Mankadau River and the Mirali River, consisting of unconsolidated sand and gravel. These sediments form the river terrace and the flood plain in topography. The gravels are made up of various rocks including adamellite and adamellite porphyry which form the Kinabalu mountain.

1–1–2 Intrusive Rocks

The intrusive rocks distributed in the area consist of adamellite porphyry and pegmatite. These are considered to have intruded at the last stage of a series of the adamellite plutonism which forms the Kinabalu mountain (last stage of Neogene igneous activity). It is assumed that the peridotite has intruded before late Cretaceous.

(1) Adamellite Porphyry

Distribution : Northwest of Kg. Takuthan.

The rock shows a form of dike intruded along the fault, extending west-northwesterly.

Rock facies : The rock is characterized by large crystals of potash feldspar of two centimetres across, and shows a porphyritic texture. The phenocrysts consist of potash feldspar, hornblende, plagioclase and biotite. A matrix is holocrystalline, consisting of fine-grained quartz and potash feldspar. The joint is often prevalent at the exposures, which obliquely intersects the direction of extension of rock body.

The characteristic of the typical sample under the microscope is as follows.

Y-10 Adamellite Porphyry

Texture : Holocrystalline, porphyrytic

Phenocrysts: plagioclase > K-feldspar > quartz, biotite, hornblende, augite > opaque minerals

Microscopic features : Euhedral plagioclase and K-feldspar are partially replaced by sericite and calcite. Biotite and hornblende are altered to chlorite, and augite, to tremolite and chlorite. A groundonass consists of tinny crystals (0.1 ~ 1 mm in size) of the same mineral assemblage as phenocrysts, and is slightly replaced by chlorite.

(2) Pegmatite

Distribution : The rock is mainly distributed in the peridotite mass in the central part of the survey area. It generally trends east to west and dips vertically. The length of extension on the surface is not clear but it is assumed to reach up to 200 m. The width of the dikes varys, with a maximum width of 30 m.

Rock facies : It is generally leucocratic, equigranular and holocrystalline, mainly consisting of quartz and plagioclase, accompanied by small quantities of hornblende and biotite. Resistance to weathering is very high. Quartz and plagioclase are a few centimetres in size, but large crystals more than 10 centimetres long are also observed. Hornblende and biotite show a euhedral to subhedral form and tend to be unevenly distributed unlike quartz and plagioclase.

(3) Peridotite

Distribution : The rock is widely distributed in the survey area extending northwest, and thins out at the eastern end of the area. In the western part of the area, the distribution is limited to the shallow part of subsurface because it rests on the underlying rocks by the thrust.

Rock facies : The rock is generally melanocratic and lustrous, and contains olivine with a small quantity of rhombic pyroxene, corresponding to harzburgite in composition. The occurrence of small lenticular dunite was confirmed in the vicinity of the Paranchangan chromite deposit. However, the original texture has not remained because of strong serpentinization. Brecciation can be observed everywhere, and platy or fibrous talc is found. The intensity of brecciation varys from place to place, with an irregular distribution.

In the western part of the survey area, the mélange which has formed by the thrust movement of the peridotite is distributed, and the schistosity is observed in the peridotite immediately above the mélange. It contains subangular to subround pebbles of peridotite and hornfels in a muddy to sandy matrix. The size of the pebbles is various, raning from one metre to several metres. The thickness reaches up to 10 m. The mélange is considered to be the tectonic mélange formed by the tectonic movement.

The peridotite with distinct schistosity is distributed in harmonious with the mélange, containing the blocks of the same source. The peridotite with schistosity grades into the massive one.

The result of microscopic observation of the typical samples is described in the following.

Y-05b Dunite

Texture : equigranular

Constituent mineals : olivine ≫ plagioclase > opaque minerals.

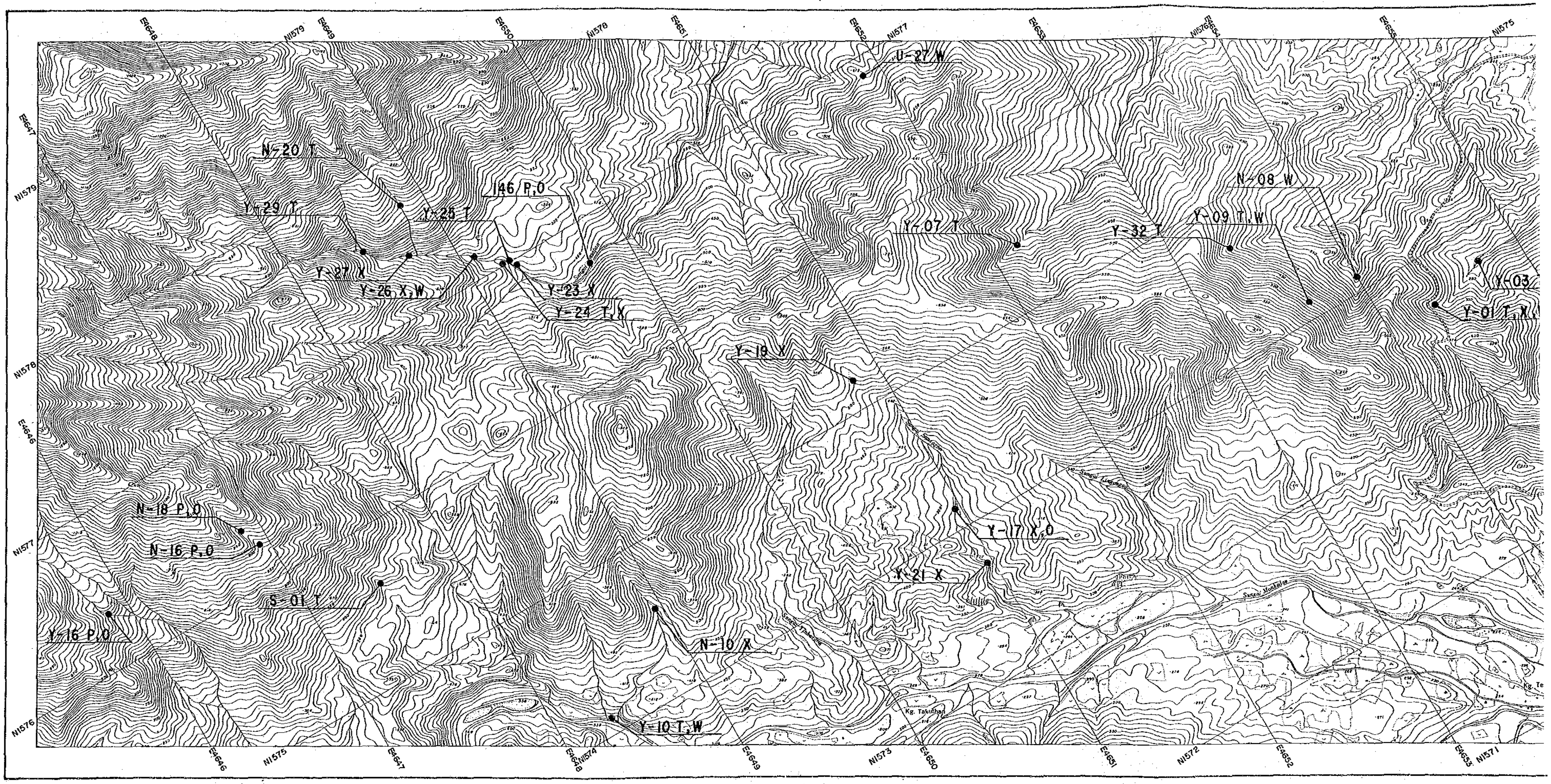


Fig. 17 Location Map of Rock Samples in bII (Mankadau) Area

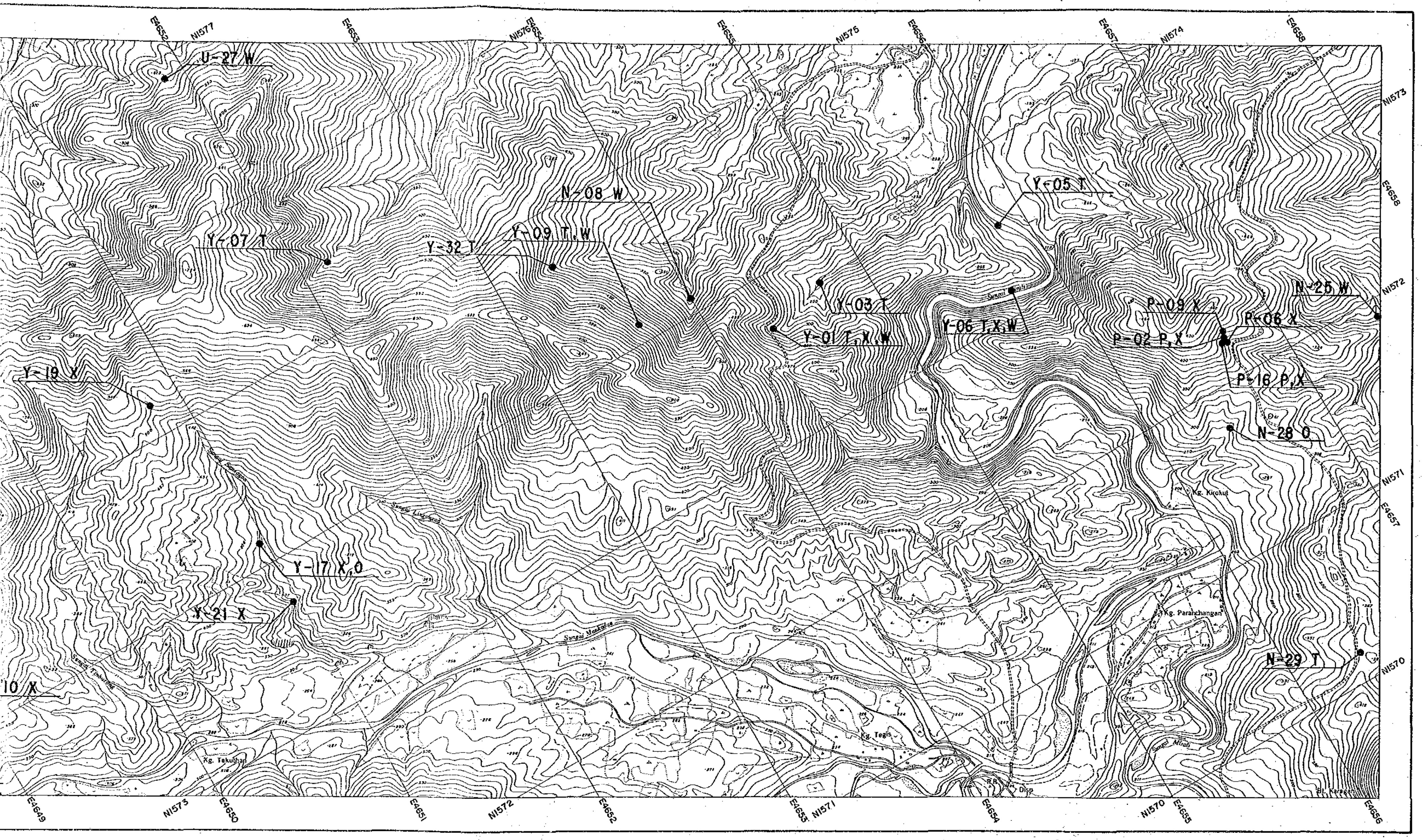


Fig. 17 Location Map of Rock Samples in b II (Mankadau) Area

LEGEND

●	S-01	Sampling location and sample number
	T	Thin section
	P	Polished section
	X	X-ray diffractive analysis
	O	Chemical analysis of ore
	W	Chemical analysis of whole rock

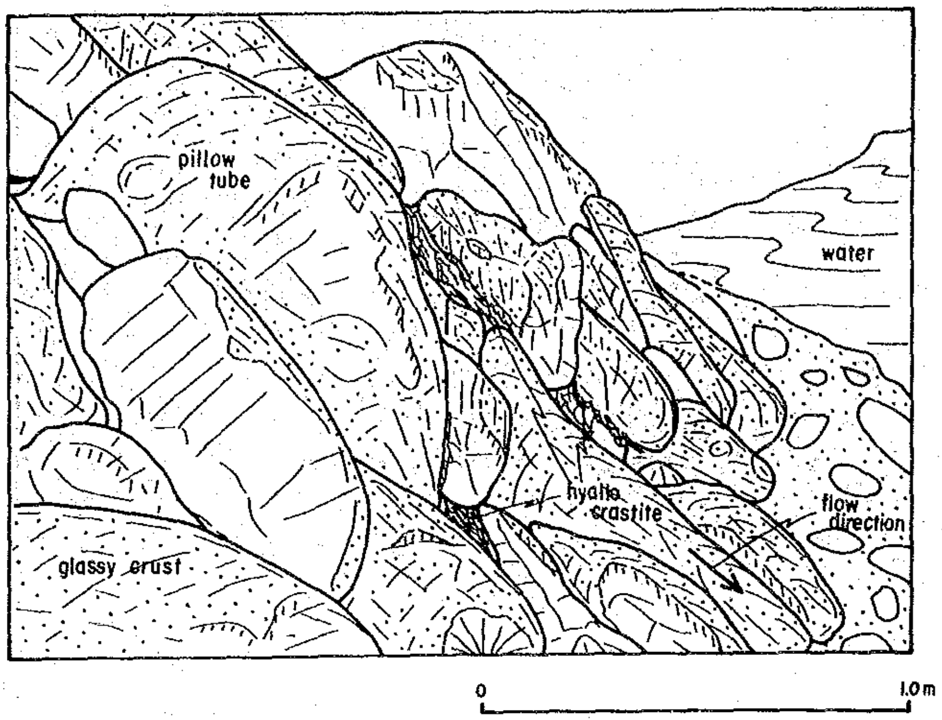


Fig. 18 Geological Sketch showing a Pillow Structure in Basalt in the Mirali River

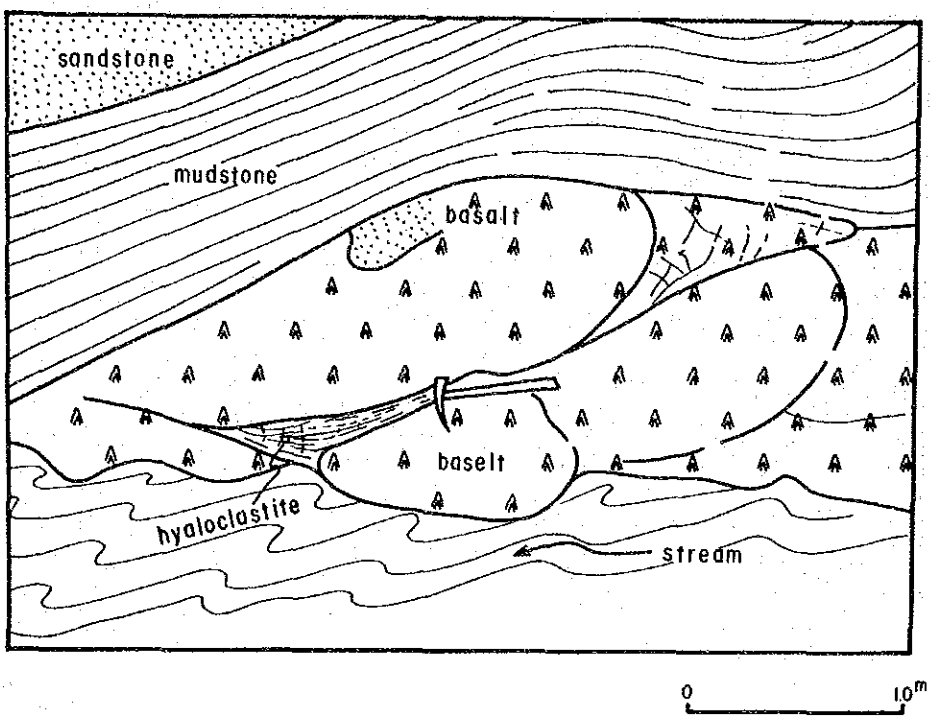
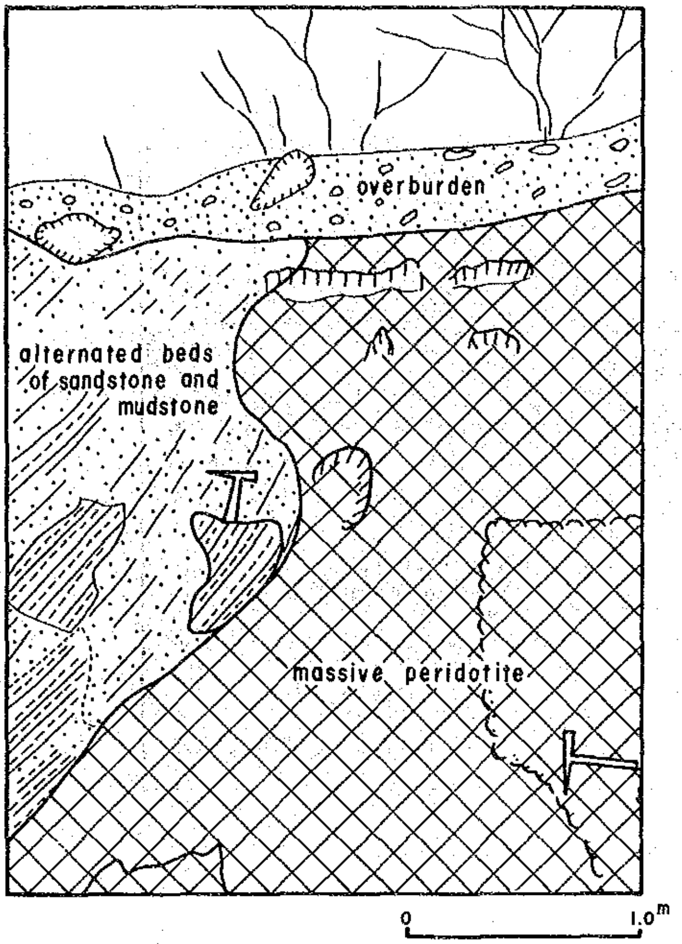
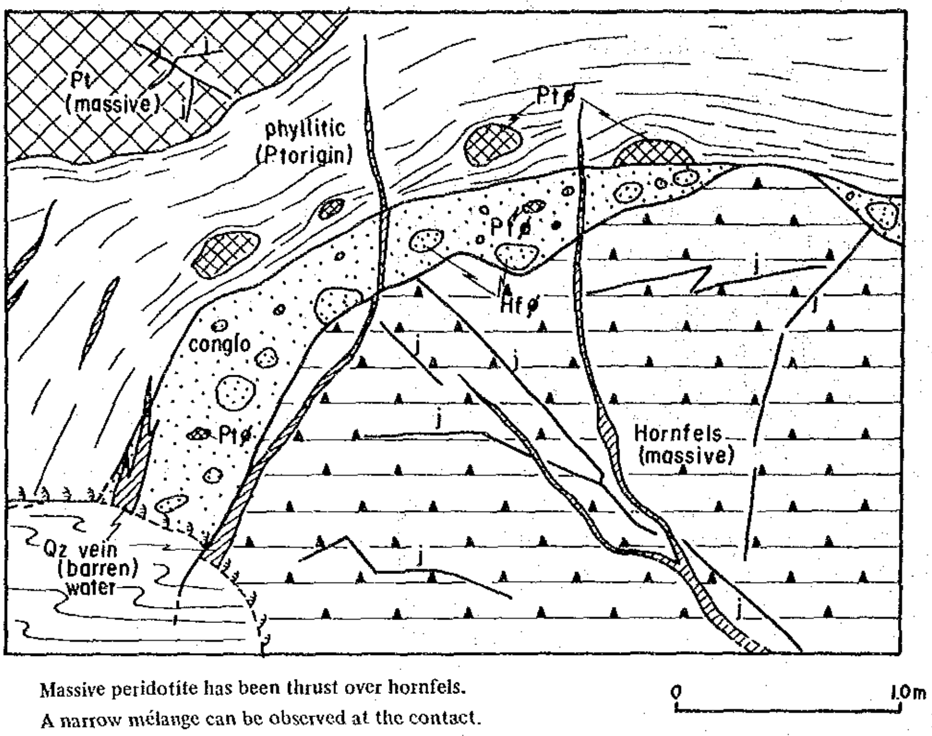


Fig. 19 Geological Sketch showing the Relationship between Basalt Lava and Clastic Rocks in Eastern Area



The Trusmadi Formation unconformably overlies peridotite

Fig. 20 Geological Sketch Showing Unconformity between Peridotite and Chert-Spilite Formation in Paranchangan Area



Massive peridotite has been thrust over hornfels.
A narrow mélange can be observed at the contact.

Fig. 21 Geological Sketch showing Métange at the Contact between Peridotite and Hornfels

Microscopic features : Alteration is so strong that original minerals are hardly recognizable. Olivine, 1 ~ 2 mm in size, is thoroughly replaced by serpentine and calcite. Plagioclase is also replaced by calcite. Many opaque minerals occur along the rim of colored minerals.

Y-25 Mélange

Fragments : sandstone > mudstone > serpentine • harzburgite • opaque minerals

Microscopic feature : Fragments of various rocks and minerals are embeded in a muddy matrix.

Location of the tested samples and sketchs showing geological relationship are shown in Figs. 17, 18, 19, 20 and 21.

1–1–3 Chemical Composition of Basalt

The seven basalt samples collected from the Mankadau area were analysed and the chemical analytical values and the normative minerals of these samples are shown in Table 8.

The values of Al_2O_3 are high and the values of K_2O are low in all samples, which show similar values to those of basalt of an oceanic crust type.

Fig. 22 shows the various diagrams on which the chemical analytical values of the basalt, collected in Phase I and Phse II, were plotted.

Firstly, Fig (1) the diagram of SiO_2 – $Na_2O + K_2O$, shows that the values of all samples fall within the field of alkalic basalt or near the boundary between alkalic and non-alkalic basalts.

Secondarily, Fig (2) the diagram of SiO_2 - FeO*/MaO, (where FeO* is the total FeO value recalculated as FeO) shows that each sample belongs to the thoreiite series.

Lastly, Fig (3) is the diagram of TiO_2 - FeO*/MgO, showing the field of basalt associated with the ophiolite sequence in the world. The basalt in the Mankadau area can be plotted around the center of the field, except for Y-26.

From the facts as stated above, the basalt in the Mankadau area belongs to the tholeiite series from its chemical composition and it is likely to be distinguished to an extrusive rock in the ophiolite sequence or the similar one related to the sequence.

Regarding Y-26 sample, it could be the rock which has been considerably altered, having a clear evidence of both abundant of CaO and ignition-loss.

1–1–4 Geological Structure

The most important structure in the survey area is the thrust which controls the bottom phase of the peridotite intrusive. It is clear at least that the peridotite distributed in the western part of

Table 8 Chemical Composition of Basalt in bII (Mankadau) Area

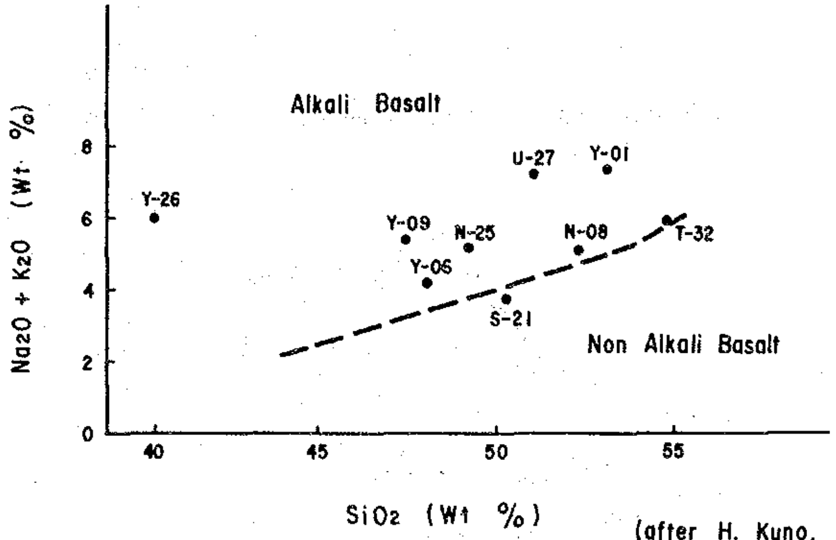
(1) Chemical Composition

Sample No.	N-08	N-25	U-27	Y-01	Y-06	Y-09	Y-26
SiO_2	52.31	49.26	51.07	53.10	48.04	47.46	40.41
TiO_2	0.77	1.23	0.88	0.81	0.91	1.36	1.47
Al_2O_3	15.52	14.74	16.10	16.77	16.69	15.39	10.61
Fe_2O_3	8.12	9.47	7.14	6.85	6.82	8.27	10.16
FeO	2.81	4.43	1.47	1.88	5.36	5.22	5.87
MnO	0.32	0.17	0.09	0.10	0.13	0.14	0.38
MgO	6.32	6.71	4.14	5.23	7.66	8.25	4.96
CaO	5.16	8.30	7.28	4.63	9.86	7.37	13.01
Na_2O	4.54	4.11	5.27	5.90	3.29	4.54	4.80
K_2O	0.60	1.09	1.93	1.53	0.91	1.02	1.23
P_2O_5	0.08	0.17	0.19	0.28	0.12	0.22	0.77
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H_2O^+	5.25	3.01	5.27	4.17	3.67	4.78	10.26
H_2O^-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	101.81	102.70	100.84	101.26	103.47	104.03	103.94

(2) Normative mineral

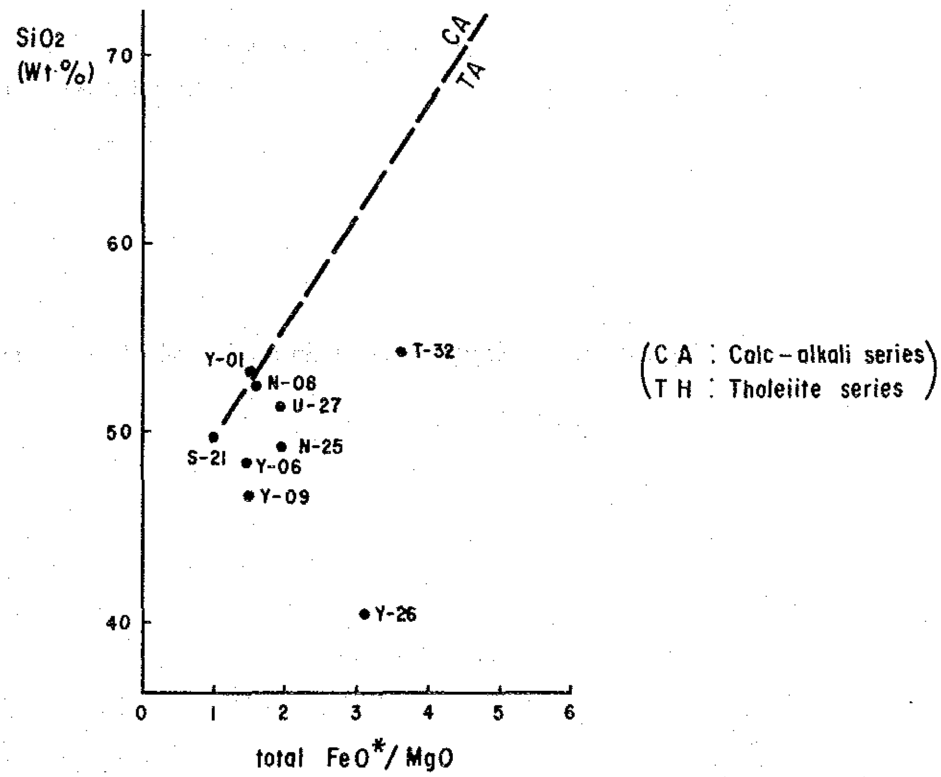
Sample No.	N-08	N-25	U-26	Y-01	Y-06	Y-09	Y-26
q	4.40	0.00	0.00	0.00	0.00	0.00	0.00
c	0.00	0.00	0.00	0.00	0.00	0.00	0.00
or	3.55	6.44	11.41	9.04	5.38	6.03	7.27
ab	38.42	34.78	44.59	49.92	27.84	32.81	40.62
an	20.20	18.55	14.57	14.76	28.08	18.60	3.77
ne	0.00	0.00	0.00	0.00	0.00	3.04	0.00
ac	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ns	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ks	0.00	0.00	0.00	0.00	0.00	0.00	0.00
wo	0.00	0.00	*0.00	0.00	0.00	0.00	*8.40
diwo	2.05	8.99	*8.48	2.67	8.38	6.91	*14.88
dien	1.77	7.77	*7.33	2.31	6.48	5.80	*12.35
difs	0.00	0.00	*0.00	0.00	1.00	0.22	*0.66
hyen	13.97	3.98	0.00	1.94	1.22	0.00	0.00
hyfs	0.00	0.00	0.00	0.00	0.19	0.00	0.00
olfo	0.00	3.48	0.00	6.15	7.97	10.33	0.00
olfa	0.00	0.00	0.00	0.00	1.36	0.43	0.00
mt	7.87	11.27	2.48	4.04	9.89	11.99	14.73
hm	2.69	1.70	5.43	4.07	0.00	0.00	0.00
il	1.46	2.34	1.67	1.54	1.73	2.58	2.79
tn	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pf	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ap	0.19	0.39	0.44	0.65	0.28	0.51	1.78
cc	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	96.56	99.69	96.41	97.08	99.80	99.25	107.26

(1) Na_2O+K_2O–SiO_2 Diagram



(after H. Kuno, 1966)

(2) SiO_2–Total FeO/MgO Diagram



(after A. Miyashiro, 1975)

(3) TiO_2 –Total FeO/MgO Diagram

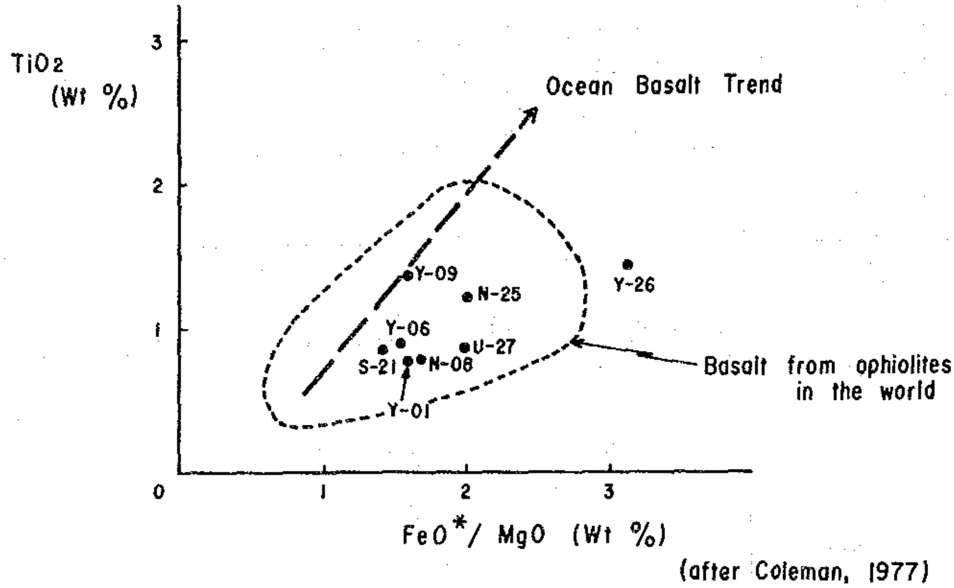


Fig. 22 Chemical Composition of Basalt in b II (Mankadau) Area

the area does not continue to the deeper level due to the thrust movement.

While the Chert-Spilite Formation distributed in the upper sequence is unconformable with the peridotite, it is distributed harmoniously. Therefore, it has become highly possible that the sequence in the area corresponds to the ophiolite sequence consisting of peridotite, spilitic basalt and sedimentary rocks in an ascending order.

The fault found in the area consists of a NW-SE system and oblique systems such as N-S, NE-SW and ENE-WSW systems. Among them, the NW-SE system is most prominent, which control the distribution of the peridotite and provided the field of intrusion of adamellite porphyry in the neighborhood of Kg. Takuthan. Furthermore, the Mankandou River which flows in the southern part of the area is also controlled by fault. Other systems are not considered to control the major structure, only affecting the local structure.

As the folding structure of the area is very complicated, the detail has not been made clear. However, from the regional point of view, an anticlinal structure is recognized, in which peridotite extending northwesterly forms the core.

Local anticlinal structures oblique to the anticlinal structure are observed at the southeastern end of the area and the Sasapan creek area.

It is likely that the thrust movement was completed before late Cretaceous, and faulting and folding took place associated with the thrust. It is understood that the following structural movement would continued to the Kinabalu plutonism which is represented by the faults of NW-SE system controlling the fault structure of the area.

1–2 Mineralization

1–2–1 Alteration

The alteration found in the area consists of spilitization in basalt lava, serpentinization in peridotite and silicification in hornfels observed in the western part of the area.

Spilitization is commonly observed in basalt lava distributed in the area. The basalt lava is presumed to belong primarily to tholeiitic series of non-alkali basalt and is characterized by albitization of calcareous plagioclase. Under the microscope, serpentinization of olivine, epidotization of pyroxene and other secondary minerals such as zeolite, calcite and chlorite are observed.

Serpentinization is common in peridotite distributed in the central part of the survey area extending northwesterly. Serpentine consists mainly of antigorite and chrysotile, being pale green to dark green. Locally, abundant talc is present.

Silicification is found in hornfels in the western part of the area and is recognized partially in peridotite positioned in the upper sequence of hornfels. A number of quartz veins are distributed along with this silicification, sometimes reaching up to 30 centimetres wide. However, the distribution of quartz veins is irregular and no ore mineral can be recognized.

1–2–2 Mineralization

Regarding the mineralization in the survey area, pyrite dissemination in hornfels in the western part of the area and chromite deposit in Paranchangan of the eastern area were confirmed this year, except for the floats of the massive sulfide copper ore scattered along the Lingangaa creek and the chromite floats distributed in the uppermost reaches of the creek, both of which were surveyed in Phase I.

(1) Pyrite Dissemination

The dissemination is found in the hornfels below the peridotite mass bordered by the thrust. Fig. 14 shows their location. The mineralized zone is accompanied with strong silicification (quartz veins of various sizes). The bleaching associated with the mineralization is locally observed.

The intensity of the pyrite dissemination is weak and no ore minerals were detected in the quartz vein.

The ore minerals found in the dissemination in hornfels consist mainly of pyrite, accompanied by small quantities of pyrrhotite and sphalerite.

The result of microscopic observation of the typical samples is as follows.

<u>N-16 Pyrite-chalcopyrite dissemination</u>

Constituent minerals : pyrite > chalcopyrite > magnetite > pyrrhotite > valleriite

Microscopic features : Very fine-grained chalcopyrite and pyrrhotite are included in a little amount of pyrite (0.1 ~ 0.15 mm in size). A very few fibrous valleriite are also present.

The assay result is as follows.

Sample No.	Location	Au(g/r)	Cu (%)	Pb (%)	Zn (%)	Mo (%)	Hg (%)
N–16	Mankadau R.	<0.07	<0.01	<0.01	0.01	<0.001	<0.001
N–18	do	<0.07	<0.01	<0.01	<0.01	<0.001	<0.001

(2) Paranchangan Chromite Deposit

The ore deposit is located on the gentle southern slope of a hill at about 400 metres ASL, about 1.5 kilometres north-northeast of Kg Paranchangan. A new road extends along the site from Kg. Paliu.

The deposit was discovered by R.R. Pilz in 1910. In 1957, Collenette P. conducted pitting, trenching and geochemical survey, and reported the details. The report states that the deposit shows a small lenticular shape, though somewhat irregular, and that the volume to the depth of 2.1 metres (7 feet) below the surface is calculated to be 114.5 m^3 (150 yd^3), which vertically extends toward the depth (see Fig. 23).

A detailed geological survey was carried out this year over the area of 100 m x 60 m surrounding the deposit. The result of survey is shown in Fig. 24.

The site is situated at the eastern end of a peridotite mass which has an unconformable contact with the massive sandstone, putting spilitic basalt lava between them on the north and mudstone on the south. A dunite lense is observed in peridotite extending N45°W which dips approximately 65° toward the south.

According to the Collenette report, the deposit seems to be distributed in the southern part of the area shown in Fig. 24. However, no outcrop could be found out so far other than the chromite ore floats and wastes excavated by pitting and trenching in the past, being scattered on the surface. The ore floats are several centimetres to several tens sentimetres in size, and found in abundance in the southern part of the area and in the southern adjacent area as shown in the figure 24. In the surrounding area, weathered, leached and massive low-grade chromite disseminated zone is distributed over the area of 100 metres north to south and 40 metres east to west.

The ore is black, compact and hard, mainly consisting of chromite with a small quantity of serpentine and chlorite. Although the texture is cataclastic, it is coarse-grained in general, reaching up to 5 milimetres in grain size. On the other hand, the low-grade ore distribited in the surrounding area is the dissemination bearing a small quantity of chromite in peridotite, and the fine chromite streaks seems to be of primary chromite removed from elsewhere, can be observed.

The characteristics of typical samples under the microscope are as follows.

P-16 Chromite

Constituent minerals : chromite

Microscopic features : The ore consists of an aggregate of a little rounded euhedral chromite with 3 to 4 mm in size. Many mechanical joints can be observed. No other accessory ore minerals.

The assay result of ore is as follows. The location of samples in shown in Fig. 24.

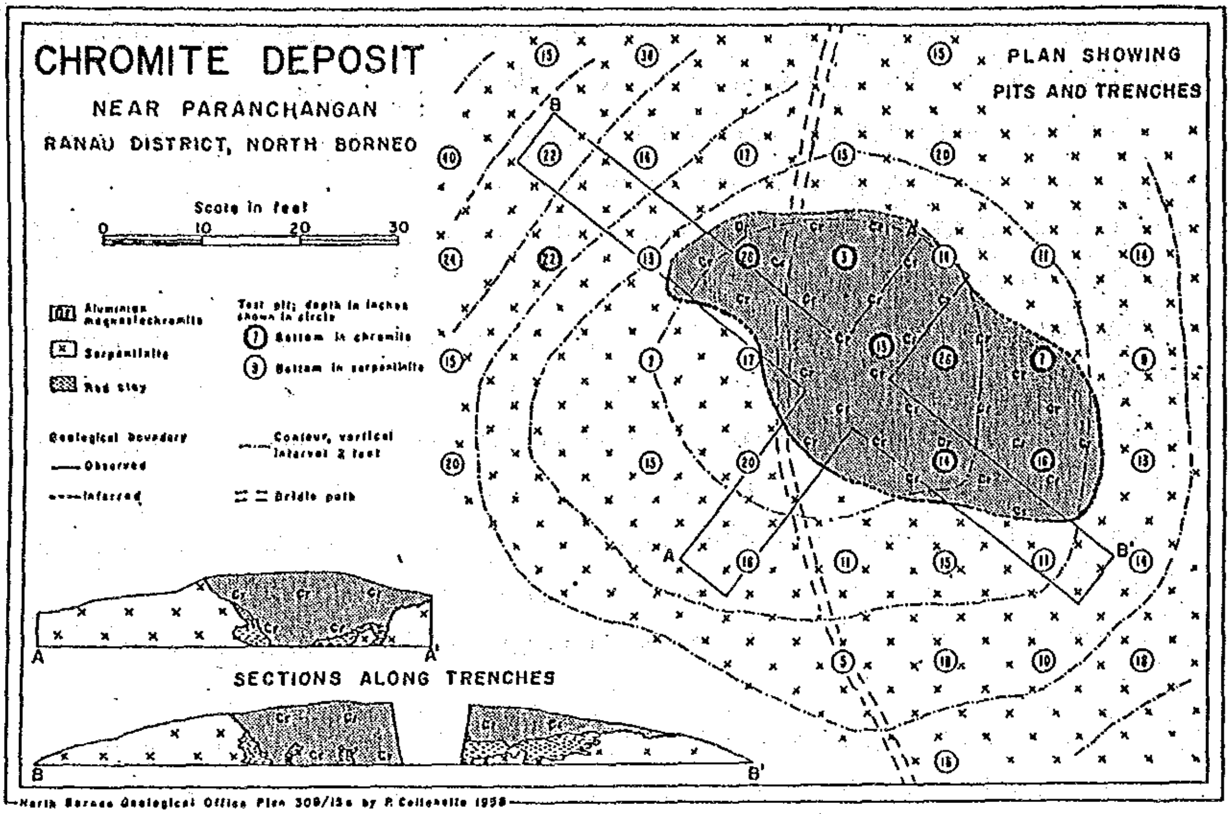


Fig. 23 Map Showing Chromite Ore Distribution in Paranchangan Area

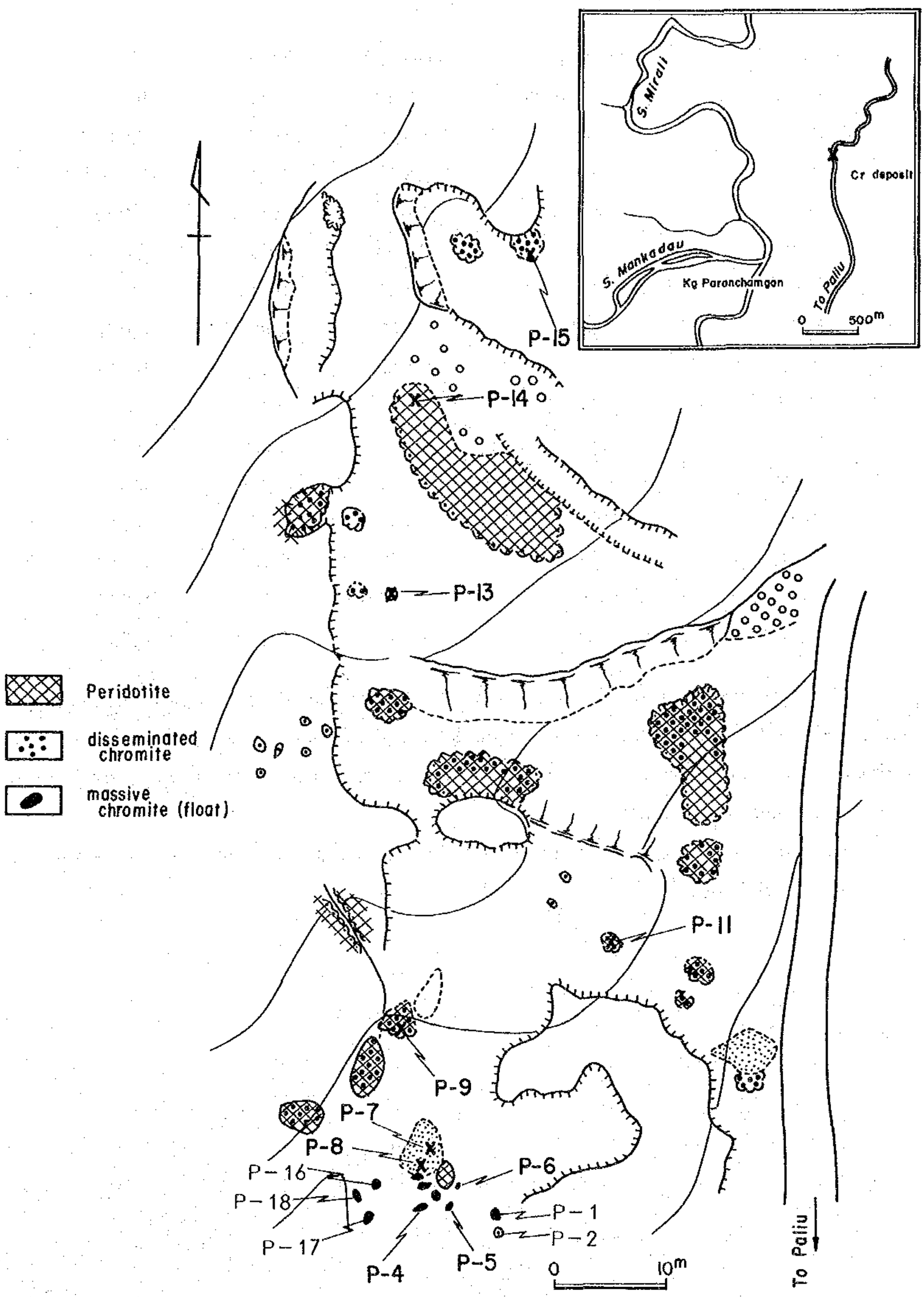


Fig. 24 Sketch Showing Chromite Mineralization in Paranchangan Area

Sample No.	Location	Cr_2O_3 (%)	Ni (%)	Co (%)
P–01	Paranchangan	28.80	0.12	0.016
P–02	do	0.86	0.22	0.012
P–04	do	28.20	0.12	0.014
P–05	do	29.40	0.14	0.020
P–06	do	30.20	0.12	0.017
P–07	do	2.63	0.91	0.083
P–08	do	2.87	0.89	0.071
P–09	do	1.66	0.22	0.013
P–11	do	1.63	0.25	0.013
P–13	do	0.64	0.23	0.013
P–14	do	0.51	0.28	0.013
P–15	do	0.45	0.22	0.012
P–16	do	31.40	0.16	0.019
P–17	do	31.90	0.15	0.020
P–18	do	29.80	0.15	0.025

From the above mentioned result, it is to say that the deposit is related with dunite found in peridotite, however the shape can not be delineated at present stage. The low-grade ore is irregularly distributed on the footwall side of the dunite, which is considered to reach up to several tens metres in thickness.

The nature of the ore resembles to the floats discovered at the uppermost reaches of the Lingangaa creek in Phase I.

CHAPTER 2 Geochemical Survey by Soil

2–1 Method of Survey

The geochemical survey was conducted in parallel with the geological survey, and the soil samples were collected at the every point considered to be of the possible occurrence of ore deposit (spot sampling). The density of sampling was increased in the terrain of basalt lava in which a possibility of ore occurrence is considered high and in the terrain of hornfels in the western part of the area where pyrite dissemination was discovered by geological survey of this Phase. Map 4-2 shows the location of samples.

The samples were collected from the B horizon at the points not to be affected by river, and full attention was paid not to be mixed up with the A and C horizons, especially the humus soil on the surface.

The samples were sieved after drying by natural seasoning, and the silty soil under 80 mesh was taken for chemical analysis. The number of sample collected was 235.

2–2 Method of Analysis

The samples prepared in the camp were sent to the Geological Survey of Malaysia, Sabah and analyzed by the atomic absorption method for five elements such as Au, Cu, Pb, Zn and Mo.

The detection limits of each element are 0.03 ppm in Au and 1 ppm in Cu, Pb, Zn and Mo.

2–3 Method of Analysis

2–3–1 Single-Variate Analysis

Since there is significant differences in the metal content of the rocks distributed in the survey area as the result of analysis in Phase I, it is desirable to investigate by dividing into each rock facies. But the analysis was performed in one group in this year without dividing into each rock facies, because of small number of samples collected, such as 289.

Fig. 25 shows the histogram of each element. According to the figure, in spite of Cu and Zn showing the normal distribution, Au and Pb show the bimodal distribution, and Mo does not show any regularity.

The cumulative frequency curve (Fig. 26) shows that Cu, Pb and Zn are approximately on a straight line, and Au is on a curve close to the straight line although it is dispersed to some extent. Only Mo is exception. Therefore, the threshold value $\overline{X} + 2t$ was adopted, which correspond to about 2.5 per cent of the whole population and is generally used for the analytical procedure in the geochemical survey.

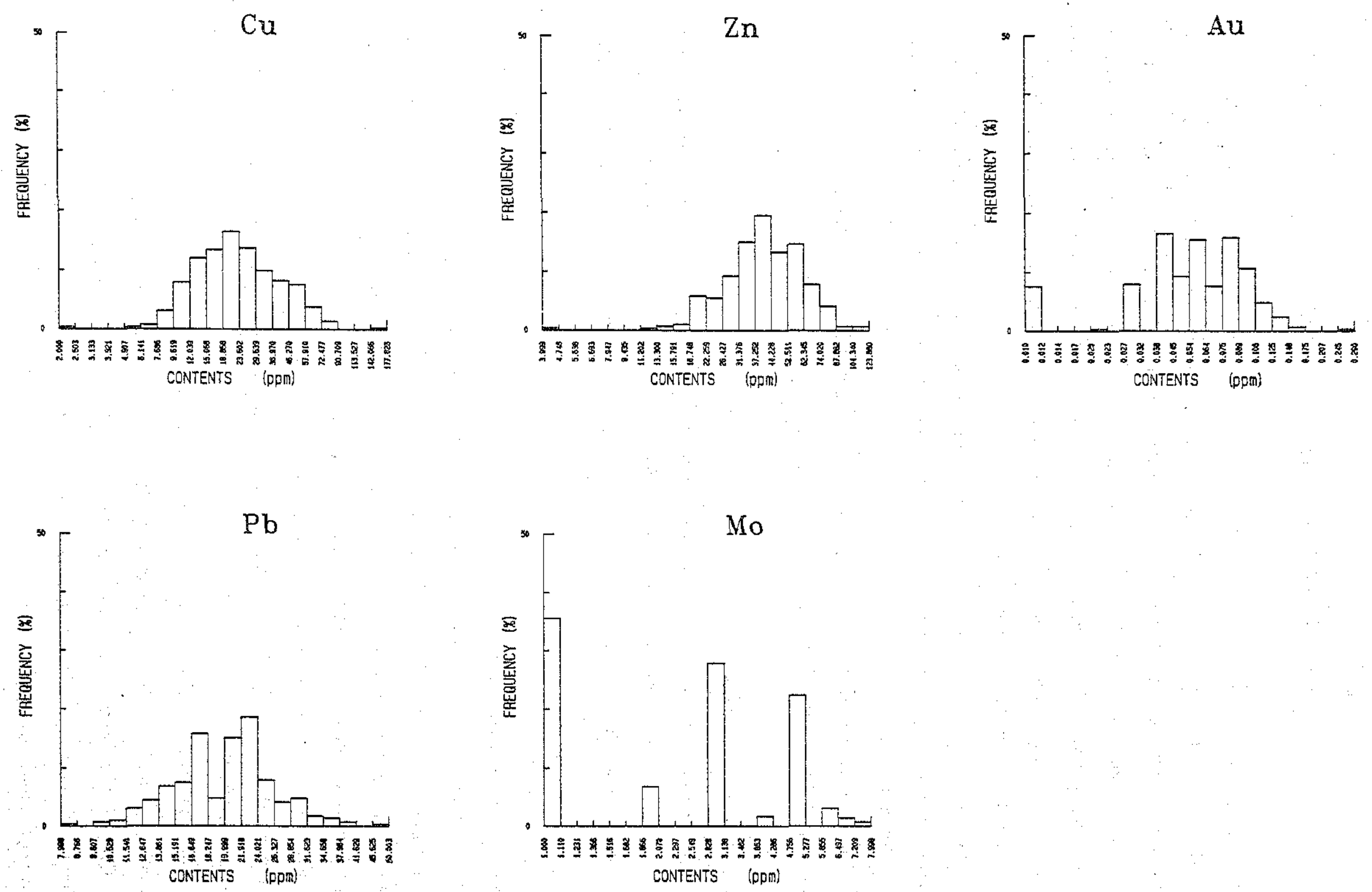


Fig. 25 Histograms for Soil Samples in b II (Mankadau) Area

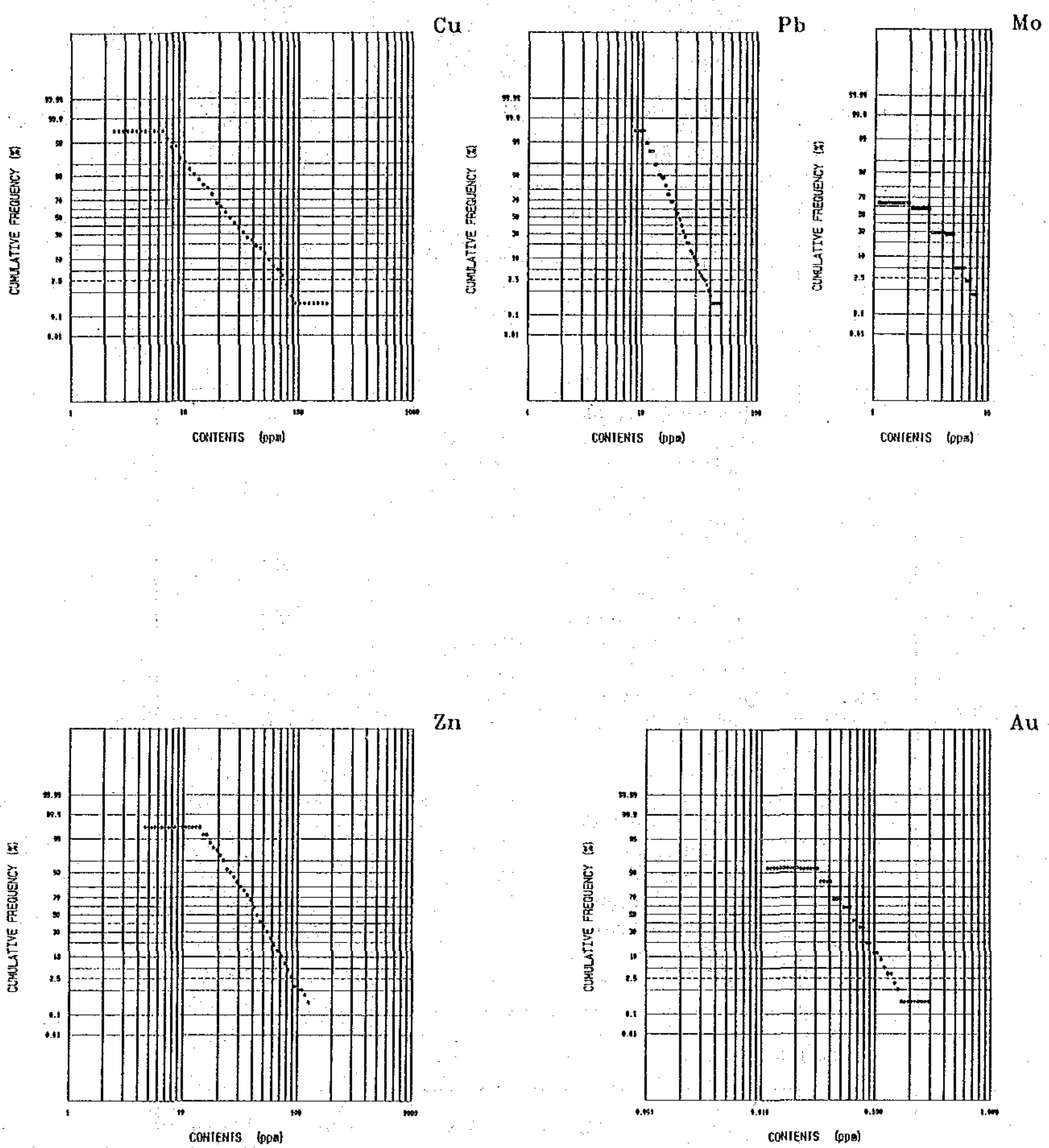


Fig. 26 Cumulative Frequency Curves for Soil Samples in b II (Mankadau) Area

Table 9 Statistic Values for Soil Samples in b II (Mankadau) Area

Cu (ppm)	Number of samples		289
	Maximum value	(Vmax)	178
	Minimum value	(Vmin)	2
	Geometric mean	($\bar{x}$)	23.0
	Standard deviation	(t)	0.249
	$10^{\log\bar{x}+t}$		41
	$10^{\log\bar{x}+2t}$		72
Pb (ppm)	Number of samples		289
	Maximum value	(Vmax)	50
	Minimum value	(Vmin)	8
	Geometric mean	($\bar{x}$)	19.9
	Standard deviation	(t)	0.119
	$10^{\log\bar{x}+t}$		26
	$10^{\log\bar{x}+2t}$		34
Zn (ppm)	Number of samples		289
	Maximum value	(Vmax)	124
	Minimum value	(Vmin)	4
	Geometric mean	($\bar{x}$)	40.8
	Standard deviation	(t)	0.179
	$10^{\log\bar{x}+t}$		62
	$10^{\log\bar{x}+2t}$		93
Mo (ppm)	Number of samples		289
	Maximum value	(Vmax)	8
	Minimum value	(Vmin)	1
	Geometric mean	($\bar{x}$)	2.3
	Standard deviation	(t)	0.297
	$10^{\log\bar{x}+t}$		5
	$10^{\log\bar{x}+2t}$		9
Au (ppm)	Number of samples		289
	Maximum value	(Vmax)	0.29
	Minimum value	(Vmin)	0.01
	Geometric mean	($\bar{x}$)	0.54
	Standard deviation	(t)	0.272
	$10^{\log\bar{x}+t}$		0.10
	$10^{\log\bar{x}+2t}$		0.19

Correlation Matrix

	Cu	Pb	Zn	Mo	Au
Cu	1.000				
Pb	.075	1.000			
Zn	.734	.021	1.000		
Mo	.037	.200	.047	1.000	
Au	.062	.178	.066	.074	1.000

For the analysis, although it was necessary to utilize the assay data of Phase I, those values were interpolated using the values estimated from the trend of distribution of metal content, because 29 samples have not been chemically analyzed for Au and Mo.

Beside $\overline{X} + 2t$, the values of $\overline{X} + 0.5t$, $\overline{X} + 1.0t$ and $\overline{X} + 1.5t$ were supplementarily used for metal content distribution map, and were drawn the equicontent lines using computor (Maps 4-1 and 4-2). Table 9 shows these statistic values and correlation factor between the elements.

2–3–2 Factor Analysis

The factor analysis is a method to set up a small number of theoretical variates (factor) from many variates and to indicate, by factor score, to what extent each sample maintains these factors.

In the case of the geochemical data, it is expected that some of these factors generally indicate some kind of the mineralization and the rock facies and it is thought that the factor score would tell the intensity of mineralization of each sample.

The above mentioned procedure is treated by the varimax method using computer.

2–4 Result of Analysis

2–4–1 Distribution of Elements

The distribution of each of five elements such as gold, copper, lead, zinc and molybdenum is indicated on the 1 : 25,000 geological map (Map 4-1, 4-2).

The distributions and characteristics of the elements are as follows:

(1) Gold

A high content of gold, no corresponding to the geology, is distributed (on the high slope) in the eastern area, eventhough no distinct characteristic point can be detected.

(2) Copper

It has a tendency that the copper content is high in spilitic basalt lava and relatively high value is obtained in peridotite which distributes in the eastern area. A limited anomaly has been detected in hornfels which is distributed in the western area.

No dominant anomalies were confirmed in the area, where many floats of massive sulphide copper ore scatter along the upper reaches of the Lingangaa creek so far, as well as those has not been obtained in Phase I.

(3) Lead

The lead distribution tends to increase in sedimentary rock and decrease in basalt lava and peridotite, and it shows high value exceeding $\overline{X} + 2t$ (= 64 ppm) in the hornfels occurring in the western area.

(4) Zinc

It shows high values in peridotite and in basalt, and the pattern of distribution is similar to the pattern of copper. In the area of sedimentary rock, the value is very low. It is clear that the copper variation coinsides with the difference of rock facies.

(5) Molybdenum

No prominent tendency of the distribution is found as relatively low content. However, a little difference may be distinguished locally as a value of 6 ppm detected in the western area.

No high value is distributed in the surrounding area of adamellite-porphyry intruded in the western area.

2–4–2 Factor Analysis

As the result of the factor analysis, the factor-1 (Cu-Zn), the factor-2 (Pb-Mo) and the factor-3 (Au-Pb) have been detected (Table 10).

Table 10 Result of Factor Analysis

Factor Loading

	factor-1	factor-2	factor-3
Cu	.845	.059	.128
Pb	.004	.345	.321
Zn	.852	.038	.091
Mo	.011	.446	.100
Au	.016	.089	.420

Factor Contribution

factor	contribution
1	1.4398
2	.3308
3	.3143

Communarity

Cu	.7340
Pb	.2225
Zn	.7349
Mo	.2089
Au	.1847

(1) Factor-1

Tie factor loading shows a high value of Cu : 0.845, Zn : 0.852. Because of the high correlation coefficient between copper and zinc, it may be the factor explaining the close relationship between these elements.

The samples showing the high factor score in plus are abundantly distributed in the basalt lava of the eastern area and the high score in minus are abundant in the hornfels of the western area. There are some possibilities that it is the factor characterizing the occurrence in basalt lava and hornfels, as confirmed by the analysis for the single element of each copper or zinc. Since the geochemical anomalies of the stream sediments by the United Nation program and the weakly pyrite disseminated zone by Phase II survey are detected in the area of hornfels and peridotite zone distributed in the western area, some effects of the mineralization can be considered.

Regarding the group of high factor score in minus concentrating around Paranchangan area, it has been delivered from the high contamination caused by the present artificial development.

(2) Factor-2

It shows rather high factor loading of lead and molybdenum. There are some correlation between lead and molybdenum from the analysis of single element. The ratio of the factor contribution is 0.33, a lower value than that of factor-1. The factor scores are generally low and the samples which have high factor scores only scatter in the peridotite of the central and the western areas.

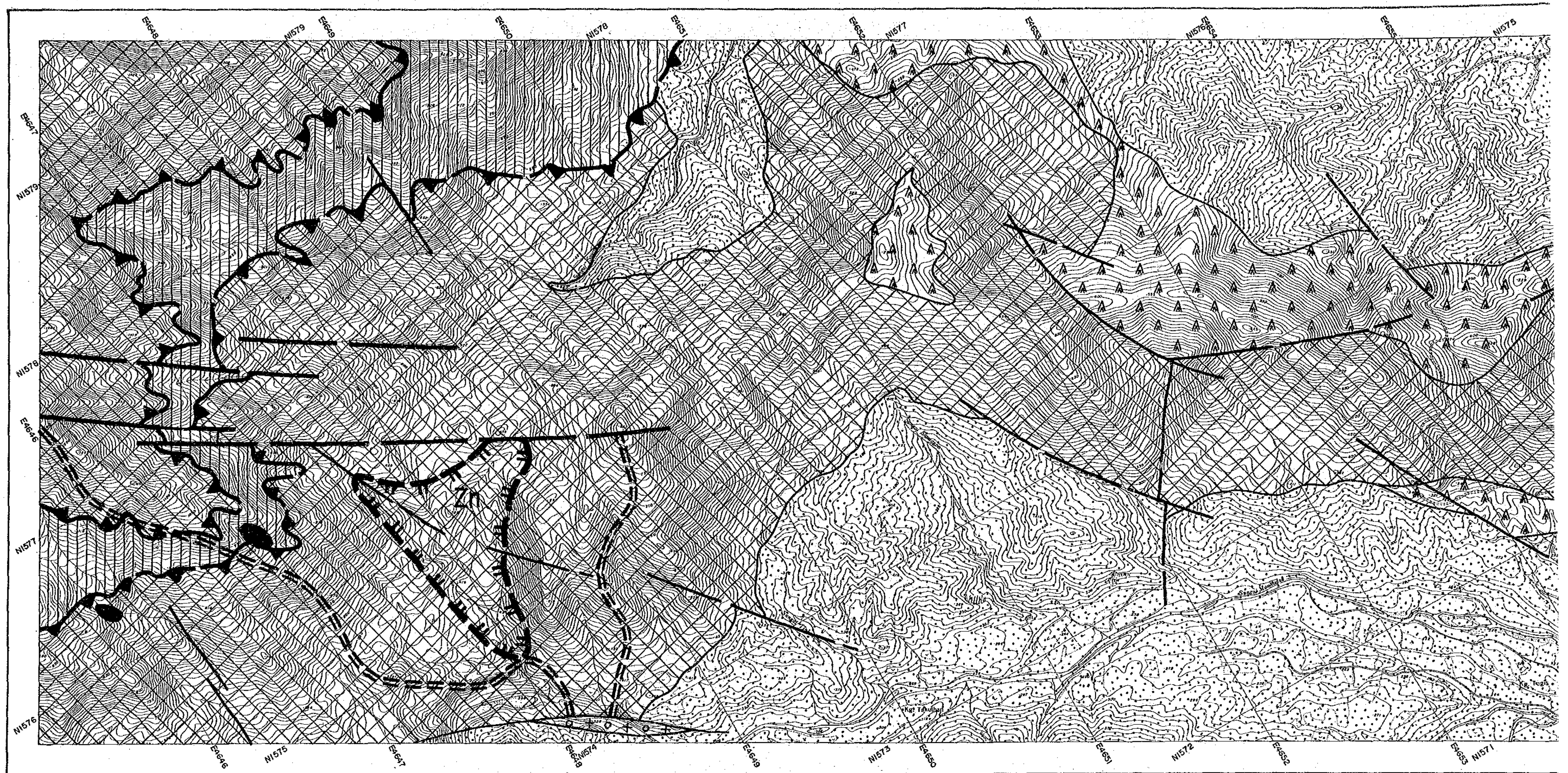
(3) Factor-3

The factor characterizing the relation of gold and lead, shows the similar factor contribution to factor-2. The factor scores are generally low and the samples which have high factor score scatter in the basalt lava of the central area.

As stated above, no independent factor representing the mineralization has been drawn out so far. Factor-1 is the one reflected the rock facies, moreover it is distributing into the peridotite and the hornfels zones which have originally less contents.

Therefore, it is assumed that the partial samples of high factor scores contain some factor indicating the mineralization eventhough it is very weak.

In and around the Lingangaa creek, no high factor scores were obtained in any combination of the factor. It is to say that the zone of weak pyritization in western part of the area which has a high Cu-Zn factor score, has no direct relationship with the secondary massive sulphide ore floats, since they have few zinc content.



LEGEND

- Sandstone
- Basalt
- Hornfels
- Adamellite porphyry
- Peridotite
- Pyrite dissemination

Geochemical anomalies

- Zn West Germany anamalous zone
- Phase II anomalous zone

Fig. 27 Geochemical Interpretation Map of bII (Mankadau) Area

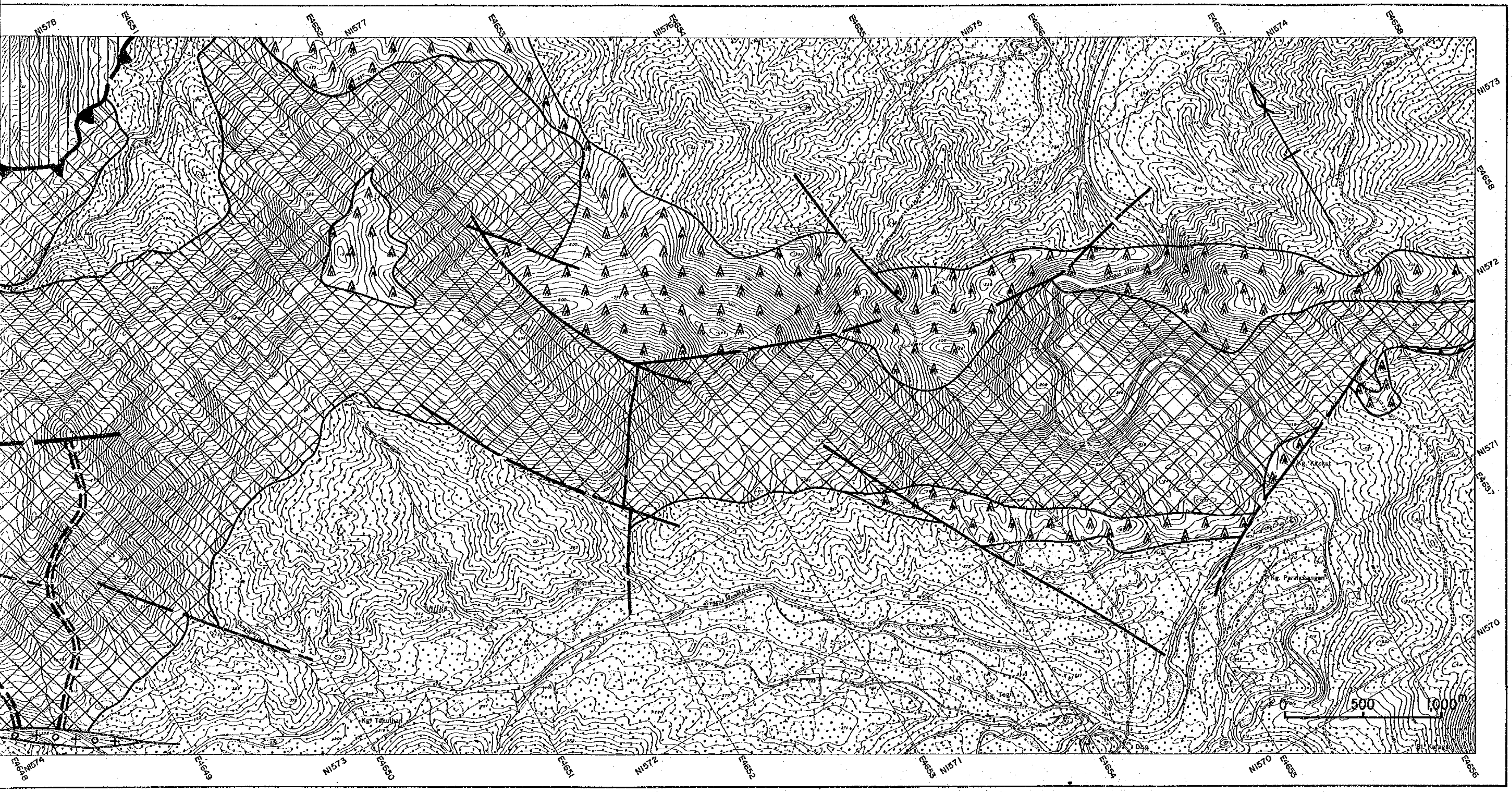


Fig. 27 Geochemical Interpretation Map of b II (Mankadau) Area