REPORT ON THE COOPERATIVE MINERAL EXPLORATION IN THE KERIO VALLEY DEVELOPMENT AUTHORITY AREA REPUBLIC OF KENYA

CONSOLIDATED REPORT

MARCH 1988

METAL MINING AGENCY OF JAPAN

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

At the request of the Government of the Republic of Kenya, the Japanese Government planned and carried out a geological survey concerning mineral exploration to examine the possibility of the existence of mineral resources in the Kerio Valley Development Authority Area located in the northwestern part of Kenya. The Japan International Cooperation Agency was entrusted with the execution of the general plan. The Japan International Cooperation Agency in turn entrusted the execution of this survey to the Metal Mining Agency of Japan since this survey was essentially a professional survey of geology and mineral resources.

The survey was conducted for three years from fiscal 1983 to 1985 and accomplished as schedule with the cooperation of the Kenya Government, particularly the Kerio Valley Development Authority and Mines and Geological Department of the Ministry of Environment and Natural Resources.

This report is the compilation of the results of the whole survey during these three years.

Lastly, we would like to express our heartfelt gratitude to the members concerned of the Government of the Republic of Kenya, the Ministry of Foreign Affairs of Japan, the Ministry of International Trade and Industry of Japan and the Embassy of Japan in Kenya, and to all those who extended their kind cooperation to us in executing the above-mentioned survey.

December, 1985

Keisuke Arita
President,
Japan International Cooperation Agency

Masayuki Nishiie
President,
Metal Mining Agency of Japan

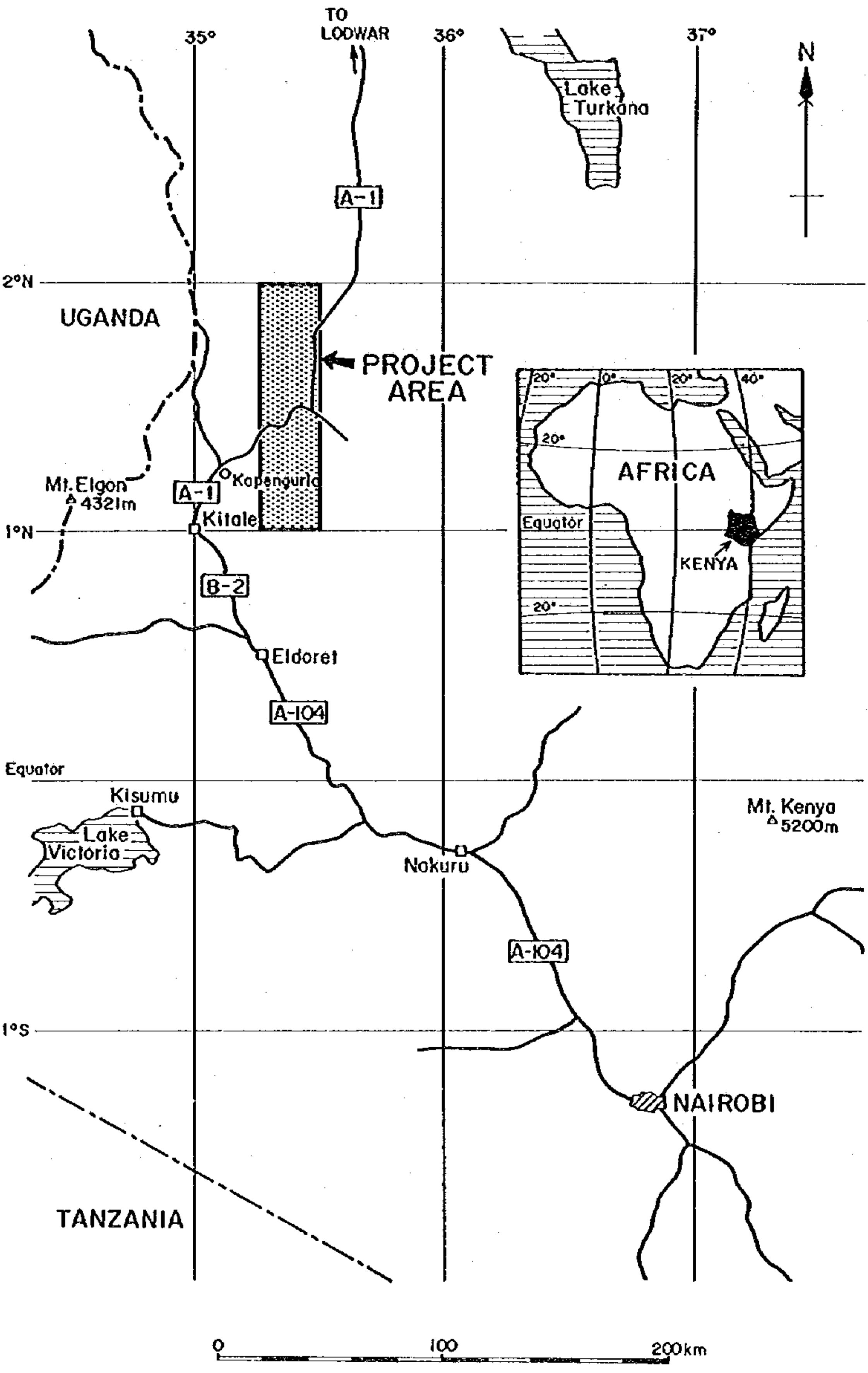

Fig. 1 Location Map of the Project Area

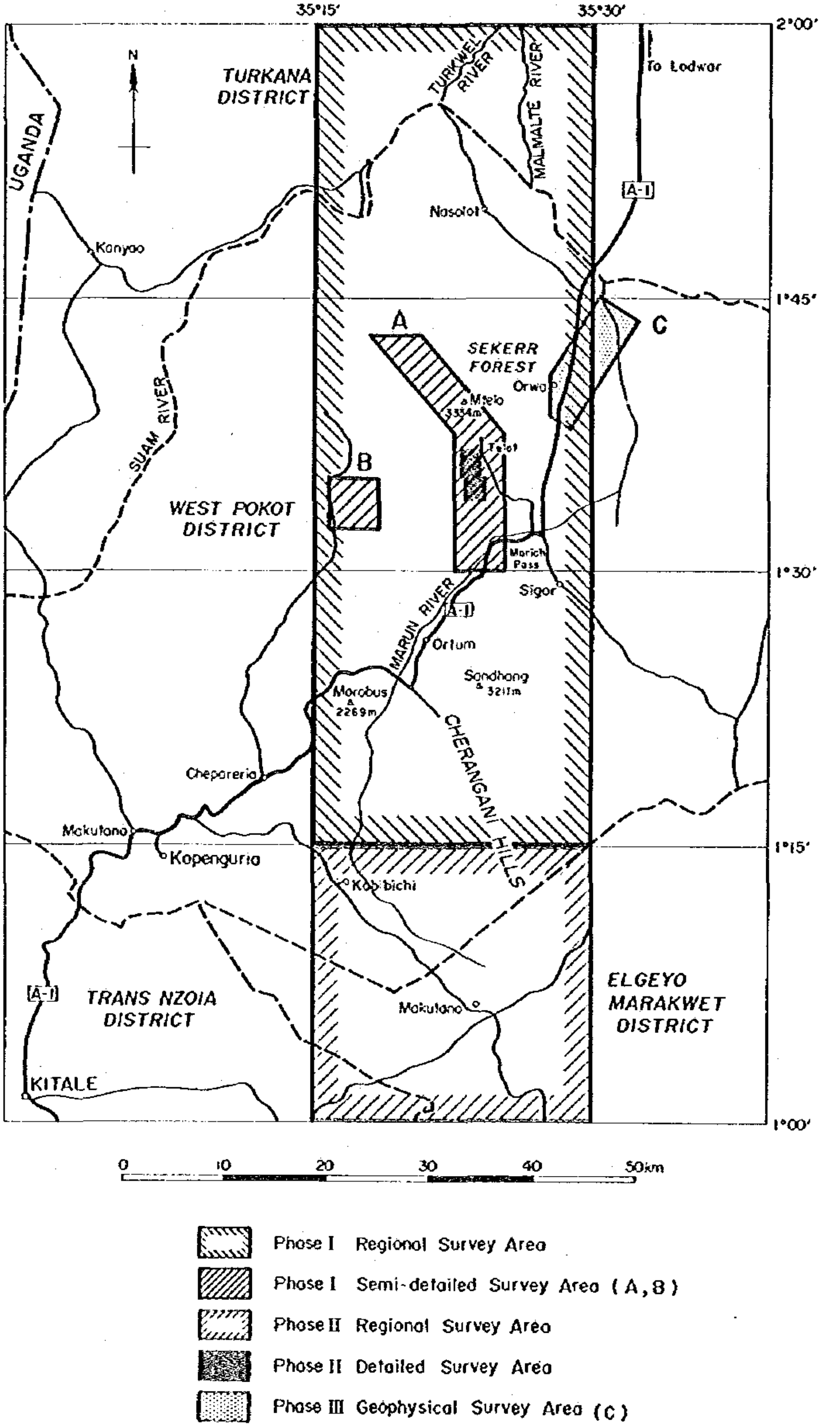

Fig. 2 Location Map of the Surveyed Area

ABSTRACT

The cooperative mineral exploration project in the Kerio Valley Development Authority Area was conducted in the Area of 3,070 km^2 for three years from 1983 to 1985.

The purpose of the project was to extract target areas having potential mineral resources by studying the relationship between geological structure and mineralization.

For this purpose, regional, semi-detailed and detailed surveys of both geology and geochemistry were operated and also the ground geophysical survey was carried out in the area which was extracted from the result of the airborne geophysical survey conducted by Mines and Geological Department.

From these exploration works, the geology and mineralization of chromium, nickel and gold deposits at Telot were made clear and the deposits have turned out to be too small in scale or too low in grade to be exploited at present economic conditions.

Gold deposits of alluvial and eluvial origin and other mineral showings such as copper, molybdenum and so on were also judged to be unsuitable as objects for large scale mining operation.

The survey results for each area are summerized as follows:

(1) Regional Survey Area

Geology of the Area consists of Mozambique metamorphic rocks and intrusive rocks. The former is divided into five formations and is controlled by the group of overturned folds showing remarkable north-northwesterly to northerly trend. The latter ranges from granitic to ultrabasic in composition and has close genetic relation with those mineralization of gold, chromium, nickel etc.

During this survey, several mineral showings of placer gold, copper, and molybdenum were found, but all they are small in scale.

From geochemical survey, anomalous zones of Au were detected at several places reflecting the known placer gold deposits well. Among them, the anomalous zone at Kamngeyon is remarkable. Several weak anomalous zones for Cr, Cu, Zn and F were also detected, but they are too small in scale to be potential ore deposits.

Considering these results, the mineralization of metal in the area is generally weak except gold, so it is thought that the targets of exploration should be limited mainly for gold.

(2) Semi-detailed Survey Area A, Detailed Survey Area

The geological structure of the area is controlled by the Endogh-Telot overturned syncline trending N-S direction. Along the axial zone of the syncline, many faults and fractures are developed and intrusion of serpentinites and gabbros are observed.

The Telot serpentinite body occurring in the central part of the area extends for about 2.5 km northwards with a width of about 1 km showing an elliptical form. Chromium, nickel and gold deposits occur in the body.

The chromium deposit is composed of two podiform chromite bodies in echelon, and ore reserve of a single body is estimated to be several thousands tons. The ore reserves calculated by the previous survey are 8,400 tons in total proved and probable reserves together with the grade of 48 percent of Cr_2O_3. The deposit is high in chromium grade and suitable for open pit mining, but scanty in ore reserves. The possibility of occurrence of more ore bodies in the shallow places from the surface is estimated to be very negative judging from both of the geological and geochemical surveys.

The nickel deposit is composed of four sizable mineralized zones of garnierite formed by weathering and residual processes.

The calculation of ore reserves conducted by the Department of Mines and Geology of Kenya (presently Mines and Geological Department) gives about five million tons (about one percent in nickel content) of probable ore reserves and about fourteen million tons (0.7 percent in nickel grade) of possible ore reserves, which are considered to be reasonable on the basis of the result of survey of this phase. However, in the nickel ore deposits of this kind elsewhere in the world (for example, in New Caledonia), the ore reserves are several tens million tons with nickel grade of two to three percent, and the ores with more than two percent are mined and shipped.

The Telot nickel deposit is low in nickel grade and scanty in ore reserves. Moreover, the deposits are situated far away from the coast for shipment and infrastructure conditions need to be improved. Therefore, it does not appear to warrant further exploration work.

The eluvial gold deposit occurs in the silicified zone extending for two kilometers towards north with a width of 350 meters in the E-W direction, in the central zone of Telot serpentinite body. The body is almost consistent with the geochemical anomalous zone of gold. The gold mineralization appears to be closely associated with chalcedonic quartz veins. The results of analyses of silicified rocks confirm this association.

The gold content in the high grade parts of the deposit is estimated to be approximately 1 g/ton, and the estimation lead us to a conclusion that the deposit could not be operated by a systematic mining method. However, it is expected that the area to the south of the present min-

ing site, currently being mined by hand by the local residents would be the next mining site for them. Because, in the area silicified zone and the geochemical anomalous zone are overlapping. Geochemical anomalous zones of Cr, Ni, Au were also detected in the Telot serpentinite body but no other remarkable anomalous zones reflecting potential mineralization were found in the area.

(3) Semi-detailed Survey Area B

Geology of the area is composed mainly of biotite gneisses, hornblende gneisses and quartzites accompanied with a lot of pegmatites. Genesis of the pegmatites in the area is estimated as a result of partial melting of pelitic metamorphic rocks and not due to intrusion of granitic rocks judging from their occurrences. These pegmatites comprise quartz, plagioclase, microcline and minor amounts of biotite and muscovite but are barren of any useful metal elements. No anomalous value of Nb, Ta, Sn, W, Li and F were also detected by geochemical survey. No further exploration work will be recommended for the area.

(4) C Area

Geology of the area is composed of foliated granites of the basement zonally distributed at the western end of the area and Quaternary alluvial formation which is extensively distributed over the most part of the area.

Northeastern trend of the geologic structure, clearly observed by the distribution of gravitational anomalies is conspicuous and the fault structure steeply dipping southwestward is observed on the western side of the area. This might indicate the fault at the western end of the Rift Valley.

A boat-shaped basin structure with increasing depth toward the southwest is assumed at the central part of the survey area. The bottom of the basin is estimated to be at about two hundred and fifty meters below the surface.

The rock masses detected by the aeromagnetic survey seem to form two series of magnetic anomalies in the northern part and a series in the southern part. It is highly possible that the magnetic rock mass in the northern part would be serpentinites from the results of measurement of magnetic susceptibility etc. The central part of the mass seems to have a width of about one kilometer and to occur at the place deeper than 250 meters from the surface.

The magnetic rock mass in the southern part is small in scale and it is assumed that the depth is great or the rock is of low magnetic susceptibility.

If the rock mass in the northern part is serpentinites, the occurrence of chromite deposit could be expected. However, taking into consideration the scale of the rock mass and the size and

the grade of the known ore deposit occurring in the Telot serpentinite mass, it is likely that the deposit comprises small podiform chromite bodies and exploration work to find out sufficient ore reserves to warrant economic operation would be pretty difficult. Moreover, taking account that the rock mass lies beneath the soft and thick alluvial formation and the Weiwei River with plenty water flows at the central part of the mass, the exploitation of the deposit would be pretty high in cost.

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1–1 Outline of the Survey

1–1–1 Purpose of the Survey

The purpose of the Mineral Exploration in the Kerio Valley Development Authority Area is to extract target areas worth for potential mineral resources by studying the relationship between geological structure and mineralization.

1–1–2 Contents of the Survey

The survey was conducted for three years from fiscal 1983 to 1985. The survey of the Phase I (1983) and Phase II (1984) comprises geological and geochemical survey in the regional, the semi-detailed and the detailed survey area. The Phase III (1985) survey is a geophysical one composed of ground magnetic and gravity survey. Field and laboratory works carried out are shown in Table 1–1.

1–1–3 Organization of the Survey Team

The members who partitiated in the survey are shown in Table 1–2 and 1–3.

Table 1-1 Outline of the Field Survey and Laboratory Work in Phase I-III

Phase	Phase 1 (1983)	Phase 2 (1984)	Phase 3 (1985)
Period in Kenya	Oct. 7 – Dec. 31, 1983	Jul. 13 – Sept. 23 (1984)	Jun. 28 – Sept. 15 (1985)
Geological, Geochemical Survey			
Regional Survey (km^2)	2,300 km^2	770 km^2	
Semi-detailed Survey (km^2)	145 km^2 Area A: 120 km^2 Area B: 25 km^2		
Detailed Survey (km^2)		10 km^2	
Geophysical Survey			60 km^2
Laboratory Work: Geochemical Samples (Analysis)			
Stream Sediment	1,552 Au, Cu, Pb, Zn, F, Cr (Regional Survey Area)	709 Au, Cu, Zn, F, Cr (Regional Survey Area)	
Soil	256 { 206 Cr, Ni, Co, V, Pt (Area A); 50 Nb, Ta, Li, Sn, W, F (Area B) }	607 Au, Ni, Cr (Detailed Survey Area)	
Ore Samples (Analysis)	10 Au, Ag (Regional Survey Area) 20 Cr, Ni, Co, Cu, Pt, V, Fe, Al (Area A) 10 Nb, Ta, Sn, W, Li, F, U (Area B)	70 (Detailed Survey Area) { 50 Ni, Co, Cr, Fe, SiO_2, MgO; 20 Au, Ag }	
Rock Samples			
Whole Rock Analysis	12 (13 elements)	5 (13 elements)	
X-ray Diffraction	11	11	
Thin Section	63	30	
Polished Section	13	10	
Susceptibility			50
Density			50

Table 1–2 Member List of Planning and Negotiating Mission in Phase I–III

	Japanese Member		Kenyan Member	
Phase I (1983)	Toshio Sakasegawa	Metal Mining Agency of Japan	H.K.A. Rotich	Kerio Valley Development Authority
	Ken Nakayama	ditto	A.M. Ngumi	ditto
	Yoshitaka Hosoi	ditto	C.Y.O. Owayo	Mines and Geological Department
	Hideyuki Ueda	ditto		
	Yosuke Suzuki	ditto (Nairobi Representative)	J.K. Wachira	ditto
	Takayoshi Hagio	Embassy of Japan		
	Susumu Yanai	Japan International Cooperation Agency, Nairobi		
	Toshiichi Nagashima	ditto		
	Hayao Takenaka	ditto		
Phase II (1984)	Shoichiro Yoshimura	Ministry of International Trade and Industry	H.K.A. Rotich	Kerio Valley Development Authority
	Toshio Sakasegawa	Metal Mining Agency of Japan	S.K. Tubei	ditto
	Ken Nakayama	ditto	A.M. Ngumi	ditto
	Yasuhisa Yamamoto	ditto	C.Y.O. Owayo	Mines and Geological Department
	Takashi Kamiki	ditto	J.K. Wachira	ditto
	Yoshiyuki Kita	ditto	F.G. Theuri	ditto
	Yosuke Suzuki	ditto (Nairobi Representative)		
	Osamu Nakano	Embassy of Japan		
	Susumu Yanai	Japan International Cooperation Agency, Nairobi		
	Toshikazu Nagashima	ditto		
	Hayao Takenaka	ditto		
Phase III (1985)	Toshio Sakasegawa	Metal Mining Agency of Japan	S.K. Tubei	Kerio Valley Development Authority
	Yasuhisa Yamamoto	ditto	A.M. Ngumi	ditto
	Yoshiyuki Kita	ditto	C.Y.O. Owayo	Mines and Geological Department
	Yosuke Suzuki	Nairobi Representative	F.G. Theuri	ditto
	Osamu Nakano	Embassy of Japan		
	Noboru Akahoshi	Japan International Cooperation Agency,		
	Akira Takahashi	ditto (Nairobi)		
	Norio shimomura	ditto (Nairobi)		
	Mitsuru Suemori	ditto (Nairobi)		

Table 1–3 Member List of Survey Team in Phase I–III

	Japanese Member			Kenyan Member		
Phase I (1983)	Kinsuke Uchida	Leader	Metal Mining Agency of Japan	A.M. Ngumi	Leader	Kerio Valley Development Authority
	Haruo Watanabe	Member	ditto	K.L.A. Sogomo	Member	Mines and Geological Department
	Masahiro Hase	ditto	ditto	K.H. Ndugu	ditto	ditto
	Akira Takigawa	ditto	ditto	A.O. Odawa	ditto	ditto
Phase II (1984)	Haruo Watanabe	Leader	Metal Mining Agency of Japan	A.M. Ngumi	Leader	Kerio Valley Development Authority
	Kotaro Tonoda	Member	ditto	K.L.A. Sogomo	Member	Mines and Geological Department
	Akira Takigawa	ditto	ditto	K.H. Ndugu	ditto	ditto
				A.O. Odawa	ditto	ditto
Phase III (1985)	Haruo Watanabe	Leader	Metal Mining Agency of Japan	A.M. Ngumi	Leader	Kerio Valley Development Authority
	Motoharu Takagi	Member	ditto	M.C. Lilako	Member	ditto
	Seiji Tsuchida	ditto	ditto	J.J. Maneno	ditto	Mines and Geological Department
				W.F. Muthigani	ditto	ditto
				G.M. Kavuthi	ditto	ditto

1–2 Outline of the Survey Area

1–2–1 General

The Republic of Kenya is located in the central part of East Africa and occupies a total area of 582,644 km^2. Its population is about 17.86 million in 1982, and its capital is situated in Nairobi. In 1963, Kenya achieved independence from the United Kingdom and after that Kenya has been keeping stable situation in political and economical status.

Gross national product of Kenya in 1981 reached to the amount of $7,300 millions and is estimated to be $420 per head.

Agriculture is the main industry of the country and occupies about 33 percent of the gross product. Other industries include processing of agricultural products, chemical products, plastics, oil products, textiles etc.

Mining products are rather small in quantity, and soda ash from Magadi Lake, fluorite from Elgeyo Maraquet district and limestone for cement material are just noticeable.

Exported goods are coffee (35%), petrochemicals (17%), black tea (12%), vegetable raw materials (5%) and leather good (3%), etc.

National language of Kenya is Kiswahili and official language is English. Kiswahili and English are widely spoken in the urban areas, but in the rulal parts vernacular is spoken.

The currency of the country is the Kenyan shilling and the exchange rate for U.S. dollars was 17.1 K.S. per 1 dollar as on 24th September, 1985. Foreign currencies can be exchanged in general bank in both cases of cash or traveler's check.

1–2–2 Location and Communication

The survey area is spread over mainly West Pokot and Turkana districts and partly Elgeyo Marakwet and Trans Nzoia districts in Rift Valley province, and is bounded by N1°00'–2°00' latitude and E35°15'–35°30' longitude forming a rectangle, which covers 3,070 km^2 (Fig. 1). The area, on the other hand, is included in the Kerio Valley Development Authority Area which is defined by the drainage basin of the Turkana Lake, northmost of Kenya. The name of the Authority is derived from the Kerio Valley which is the most prominent in the basin, and the area includes the northern Kenyan Rift Valley.

Access from Nairobi, the capital city of Kenya, up to Ortum which is located in the centre of the area, the paved national highway A-101 and A-1 which is a part of Pan-African road and cuts the central and northeast part of the area are available. It is about six hours ride by car with the distance of about five hundred kilometers.

As concerns the other roads, in the central and north parts of the area, there are only unpaved mountain roads for lorry or four wheel drive car, and the transportation is very inconvenient. The south part of the area, on the contrary, is easy of access because it is agricultural land and pasture in highlands.

1–2–3 Physiographical Features

The surveyed area is situated in the highland which is underlain by metamorphics and intrusives of the Precambrian orogenic belt. The crustal movement started in Miocence and volcanism related with the activity affected most to form the topography of the area.

The African Rift Valley which traverse the east side of Africa diverges into two rifts in East Africa, the East Rift and the West Rift, and the former passes the northeast part of the area.

The area is divided into two topographical units by the escarpment facing east on to the East Rift Valley. The northeast part of the area, which belongs to the Rift valley, is semi-desert or bushland with the altitude from 700 m to 1,000 m above sea level. The main part of the area, which is separated from the former by the steep escarpment with the altitude difference of 1,000 m, forms mountainous region extending in N-S or NNW-SSE, roughly parallel to the geological structure of the area. The mountainous region is composed of Cherangani Hills in the south part and Sekerr massif in the north part. The Cherangani Hills (2,600 m–3,300 m) forms highlands composed of grasslands and forests, which are believed to be the remnants of a peneplain in the geological age. The Sekerr massif, on the other hand, forms rapid mountains rising from 1,200 m to 3,334 m at Mt. Mtero, the highest peak in the area.

The drainage system of the area is divided into the Turkana Lake drainage in the central and north parts of the area and the Victoria Lake drainage in the south. The Turkena Lake drainage comprises two systems, that of Turkwel-Suam in the north and the Marun-Malmalte system in the south. These drainages to a great extent follow the structure of Mozambique Belt Rocks and are thus "subsequent". The Victoria Lake drainage flows toward the Victoria Lake in southwest direction from the watershed in the south of the Cherangani Hills.

1–2–4 Climate and Vegetation

The survey area is situated in the mountainous region along the Equator in the East African tableland, and partly includes the semi-desert zone of the Rift Valley.

The climate shows an Equator-type annual variation, and rainy seasons and dry seasons come twice for each year, and it is divided into warm dry season from December to March, heavy rainy season from March to June, cool dry season from June to September, and light rainy season from September to November.

The climate ranges from that of semi-desert or bushland in the Rift Valley to mountainous zone in the Sekerr and highland zone in the Cherangani Hills. This reflect an altitude variation of over 2,500 meters.

In the semi-desert zone of the Rift Valley, temperature goes up nearly 35°C in day-time and comes down to below 10°C at night. The annual rainfall is between 300 mm to 800 mm. Thorny plants and cactuses are sparsely observed in the area.

In the Sekerr area, the climate includes that of semi-desert near the Rift Valley and moderate highland in the central of the mountains and the temperature goes up nearly to 25°C to 33° C in day-time and descends below 5°C at night although it is quite variable owing to the height. The annual rainfall ranges from 600 mm to 1,200 mm. Vegetational type in the area can be divided into copse composed of acasia and thorn, grassland with shrub and dense rain-forest.

In the highland at Cherangani Hills, the climate is rainy forest type and it is considerably cool. Although no record of temperature throughout the year, the temperature in August to September in 1984 at Kabibich, altitude 2,600 meters from sea level, was 5°C minimum and 22°C maximum. The annual rainfall is assumed to be more than 2,000 milimeters judging from the mode of vegetation. Vegetation of this area is characterized by bamboo forests at lower area and sparse cedar forests in higher area set out flat grassy table land.

1–3 Previous Geological Works

Publications by Government about the geology and mineral occurrences in Kenya are as follows.

(1) Du Bois, C.G.B (1966): Minerals of Kenya. Bull. Geol. Surv. Kenya No. 8

(2) Pulfrey, W. and Walsh J. (1969): The geology and mineral resources of Kenya. Bull. Geol. Surv. Kenya No. 9

Geological Map and Mineral Map in Kenya are the followings.

(1) Geological Map of Kenya (1962, scale 1 : 3,000,000)

(2) Mineral Map of Kenya (1962, scale 1 : 3,000,000)

Geological survey and mineral exploration in the project area have been operated since before the independence of Kenya mainly by the Geological Survey and those results have been published as official geological reports mainly such as quadrangle geological maps of 1:125,000 in scale and attached texts. The north half of the area is covered by "Geology of the Sekerr Area" by McCall (1964) and the south half by "Geology of the Kitale-Cherangani Hills Area" by Miller (1956). They deal in considerable detail with the geology and minerals occurring in the area.

In addition to these works, mineral exploration works in limited areas for chromium-nickel deposits, placer gold deposits and some copper showings have been done in the area. Among them, exploration works were most concentrated on the chromium and nickel deposits which occur in the Telot serpentinite body.

The deposits were first discovered in 1956. Since then, New Consolidated Gold Field Ltd. of South Africa carried out exploration works by 1958. After that, survey works were conducted by the Geological Survey of Kenya in 1959, by Mines and Geology in 1964, by Department of Mines and Geology in 1967 to 1968. Moreover, a Japanese consortium operated the exploration composed mainly of drilling works. The outline and conclusion of these works are summerized in Table 2-16.

On the other hand, Mines and Geological Department conducted airbone geophysical survey including air-borne magnetic and radiometric survey in the Kerio Valley Development Authority Area through the aid by European Community. One of the target areas extracted from the results of the air-bone magnetic survey was selected for the area of ground geophysical survey in Phase III.

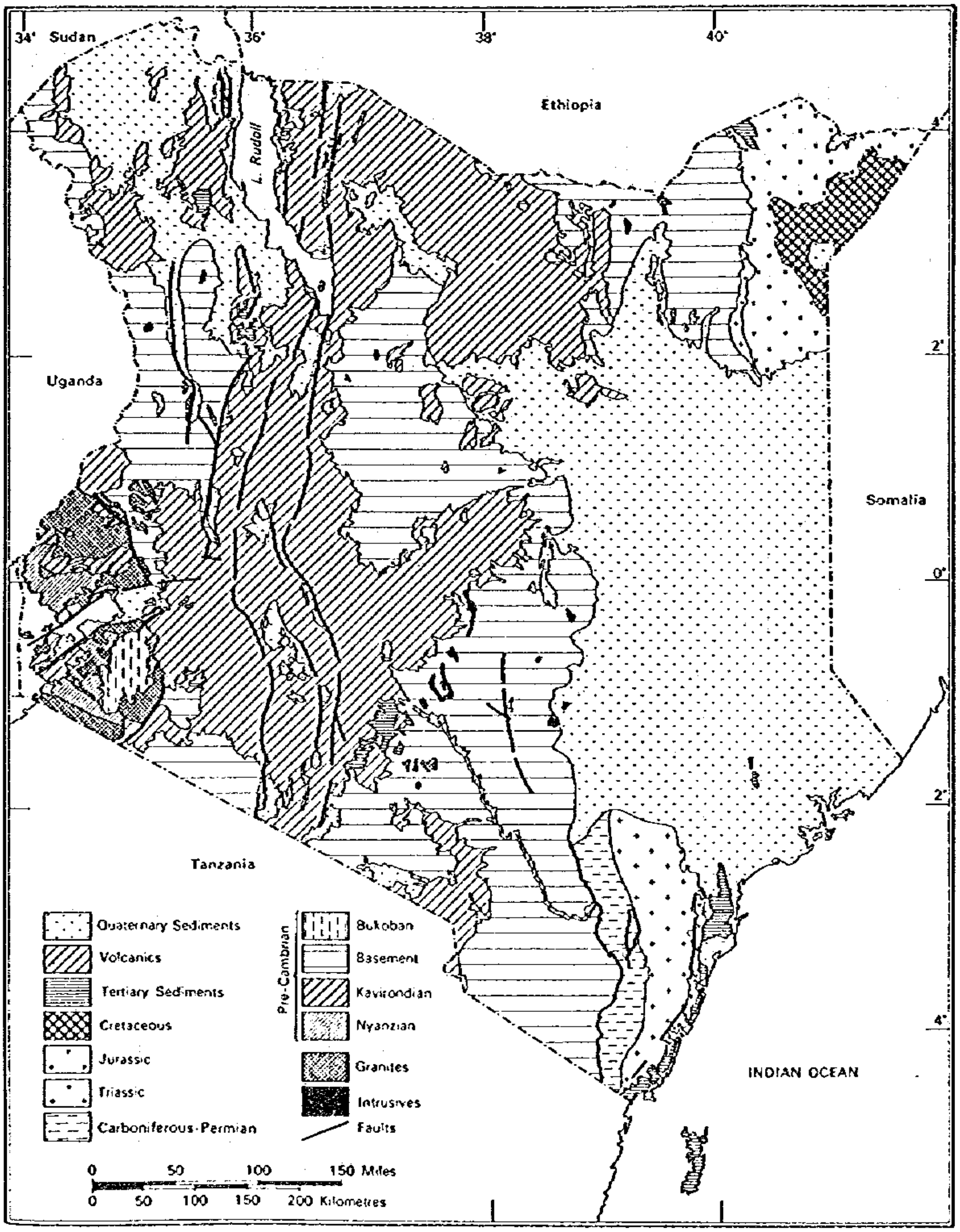


Fig. 1-1 Simplified Geological Map of Kenya

(*After* Mines and Geological Department, 1969)

Table 1-1 Geological Succession and Economic Minerals, Kenya (after Pulfrey et al., 1969)

Geological Age	Representatives: Bedded Rocks	Representatives: Intrusive Rocks	Approximate age in millions of years	Associated Economic Minerals*
RECENT	Soils, alluvials, beach sands, Magadi soda lake, hot-spring deposits.		up to 1/40	TRONA, SALT, kaolin, brickearths, clays, sand, manganese, gypsum, guano, mineral pigments, meerschaum, (alum, diamonds, rubies, sapphires, ilmenite, monazite, rutile, zircon, nitre).
PLEISTOCENE	Raised coral reef and sandstones at the coast. Rift Valley and other inland sediments, some volcanic rocks of the Highlands and North-Eastern and Eastern Provinces.		up to 2	LIMESTONE, DIATOMITE, GYPSUM, pumice, pozzolana, bentonitic clays, manganese, kaolin, (sulphur, cement-stones).
TERTIARY	Coastal sediments. Volcanic rocks of the Highlands, western and northern Kenya. Inland Miocene.	Alkaline syenites, ijolites, etc. of volcanic centres such as Mt. Kenya, Ruri, etc. Carbonatites of south-western Kenya.	2-25	LIMESTONES, CARBON DIOXIDE, BUILDING-STONE, ROADSTONE and BALLAST, bentonitic clays, pozzolana, lead, barytes, fluorite (zinc, cinnabar, nepheline, apatite, pyrochlore, monazite, wollastonite).
CRETACEOUS	Coastal sediments and sediments of north-east Kenya.	Ijolites and alkaline syenites of Jombo at the coast and east Kitui. Alkaline dykes at the Coast and in east Kitui. Carbonatite at Mrima (Coast).	60-120	Manganese, pyrochlore, rare earth minerals.
JURASSIC	Coastal sediments and sediments of north-east Kenya		120-150	LIMESTONES, SHALES (for cement and ceramics), gypsum, ballast.
TRIASSIC / PERMIAN / CARBONIFEROUS? } KARROO	Sediments of the coast hinterland. Sediments of north-east Kenya(?).		150-250	Ballast.
PRECAMBRIAN	*Kisii Series* (Bukoban System)—Sediments and volcanics of south-western Kenya.	Dolerites.	600	SOAPSTONE, gold, (cassiterite).
	Embu series—Metamorphosed sediments, central Kenya.		?	
	Ablun Series—Metamorphosed sediments, north-east Kenya.		?	
		Pegmatites in the Basement System.	500-600	Mica, piezo-electric quartz, samarskite, columbite, beryl, felspar, (amblygonite, bismuth, ilmenorutile, amazonite, zinc spinel, fluorspar, rare earth minerals).
		Gabbros of western Kenya; dunites.	?	Chromite, garnierite, magnesite, vermiculite, corundum sapphire, (olivine).
	Basement System—Gneisses and schists.	Norites and allied rocks, minor peridotites, pyroxenites and granites.	600+	LIMESTONES, MARBLE, WOLLASTONITE, kyanite, asbestos, magnesite, dolomitic limestones, garnet, rutile, ilmenite, sillimanite.
	Kavirondian System—sediments and volcanics of south-western Kenya.	Granites, syenites, dolerites etc.	2,200	GOLD, silver, (molybdenite).
	Nyanzian System—Sediments and volcanics of south-western Kenya.	Granites, epidiorites, etc.	2,200+	GOLD, COPPER, zinc, silver, pyrite, (cobalt, scheelite, arsenic, fluorite).

*Minerals and rocks that are of notable economic importance in Kenya are indicated in capitals, less important minerals (which are not all being worked at present) in lower case letters and minerals known but not yet worked by parentheses.

CHAPTER 2 SURVEY RESULTS

2–1 Regional Survey Area

Regional Survey Area covers 3,070 square kilometers, and among them an area of 2,300 square kilometers of the north part was surveyed in Phase I and 770 square kilometers of the south part in Phase II.

The area is mainly situated in the block mountains on the west of Kenyan Rift Valley and is underlain by Pre-Cambrian metamorphic rocks of basic valcanic rocks and sedimentary rocks in origin which are intruded by granitic rocks and basic to ultrabasic rocks. Mineralization of metals related with these igneous activities has been expected in the area.

Chromium and nickel deposits occurring serpentinites, small placer gold deposits being operated in several localities and mica deposits operated in the past are known in the area, and several small copper showings have also been reported in the area.

Geological mapping and geochemical exploration were carried out in the area and the results are as follows.

2–1–1 Geology

(1) Outline of Geology

The metamorphic rocks distributed in the Mozambique Orogenic Belt running northerly through the eastern part of the African Continent have been named the basement rocks in Kenya and called the "Basement System". Later, although it became clear that the Nyanzian System and the Kavirondian System distributed in the surrounding area of the Lake Victoria in the western part of Kenya were older than the Basement System, the name "Basement System" has been adopted as it was.

During the first year survey programme, the metamorphic rocks in the Mozambique belt were called the Basement System, which was divided from the apparent lower sequence toward the upper into five units such as the Basement I formation, II formation, III formation, IV formation and V formation.

However, it has been becoming common in Kenya that the rocks of this belt are called the Mozambique belt rocks. Therefore, it was decided to discontinue the name of the Basement and to call the metamorphic rocks of the zone as the Mozambique metamorphic rocks.

The geology of the area consists of Mozambique metamorphic rocks, intrusive rocks and Quaternary formation.

(2) Mozambique Metamorphic Rocks

The Mozambique metamorphic rocks in the area are divided into five formations, M-1, M-2, M-3, M-4 and M-5 formation in apparent ascending order. Relative sequence of each formation is not necessarily definite order because it was difficult to discern the primary sequence of each rock facies due to the presence of markedly overturned fold structure and strong metamorphism.

Moreover, apparent sequence of M-5 formation is not definite because of its separated distribution from other four formations.

These devided five formations are to be correlated to the Basement I, II, III, IV and V formation respectively used in Phase I survey.

(a) M-1 Formation

The formation is zonaly distributed in the west of the area and widely in the south part of the area. The thickness of the formation is estimated to be more than 5,000 meters.

The formation is dominated by gneissose rocks derived from pelitic and psammitic sedimentary rocks and it is also characterized by the occurrence of high-grade metamorphics such as granulite and porphyroblastic gneiss.

The rock facies observed in the formation can be divided into six units: biotite gneisses with subordinate hornblende-biotite gneisses and minor bornblend gneisses (P-mg^{b}-1), quartzites; quartz schists (P-mq-1), hornblende gneisses (P-mg^{h}-1), potash-feldspar porphyroblast gneisses (P-mg^{f}-1), garnet porphyroblast gneisses (P-mg^{g}-1) and calc-silicate granulites (P-mt-1).

(b) M-II Formation

The formation is widely distributed all over the area especially central part of the area and shows repeated distribution by remarkably overturned folding structure. The thickness of the formation is estimated to be more than 3,000 meters.

The formation is characterized by a notable occurrence of hornblende gneisses which indicate geosynclinal basic volcanic activity.

The rock facies observed in the formation can be divided into five units: hornblende gneisses with subordinate biotite gneisses and hornblende-biotite gneisses (P-mg^{h}-2), potash feldsper porphyroblast gneisses (P-mg^{f}-2), quartzites; quartz schists (P-mq-2), crystalline limestones (P-mc-2), quartz-feldspathic paragranulites (P-mt-2).

(c) M-3 Formation

The formation extends zonaly and continuously from northern to southeastern part of the area. Particularly the formation is repeatedly exposed in parallel zones by the folds in the northern part. The thickness of the formation is 3,000 meters in maximum.

The formation is dominated by biotite gneisses and characterized by the occurrence of crys-

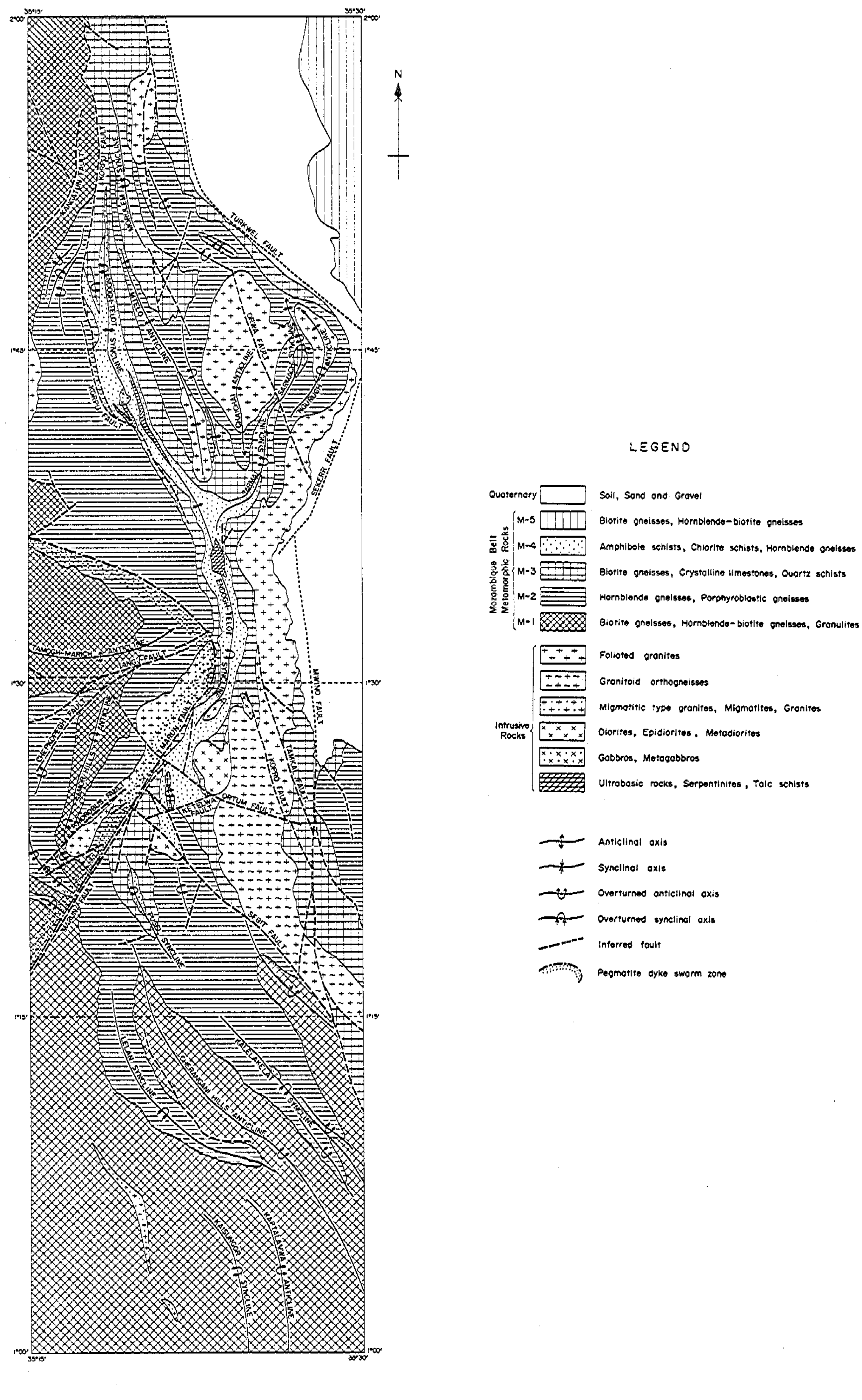


Fig. 2-1 Simplified Geological Map of the Survey Area

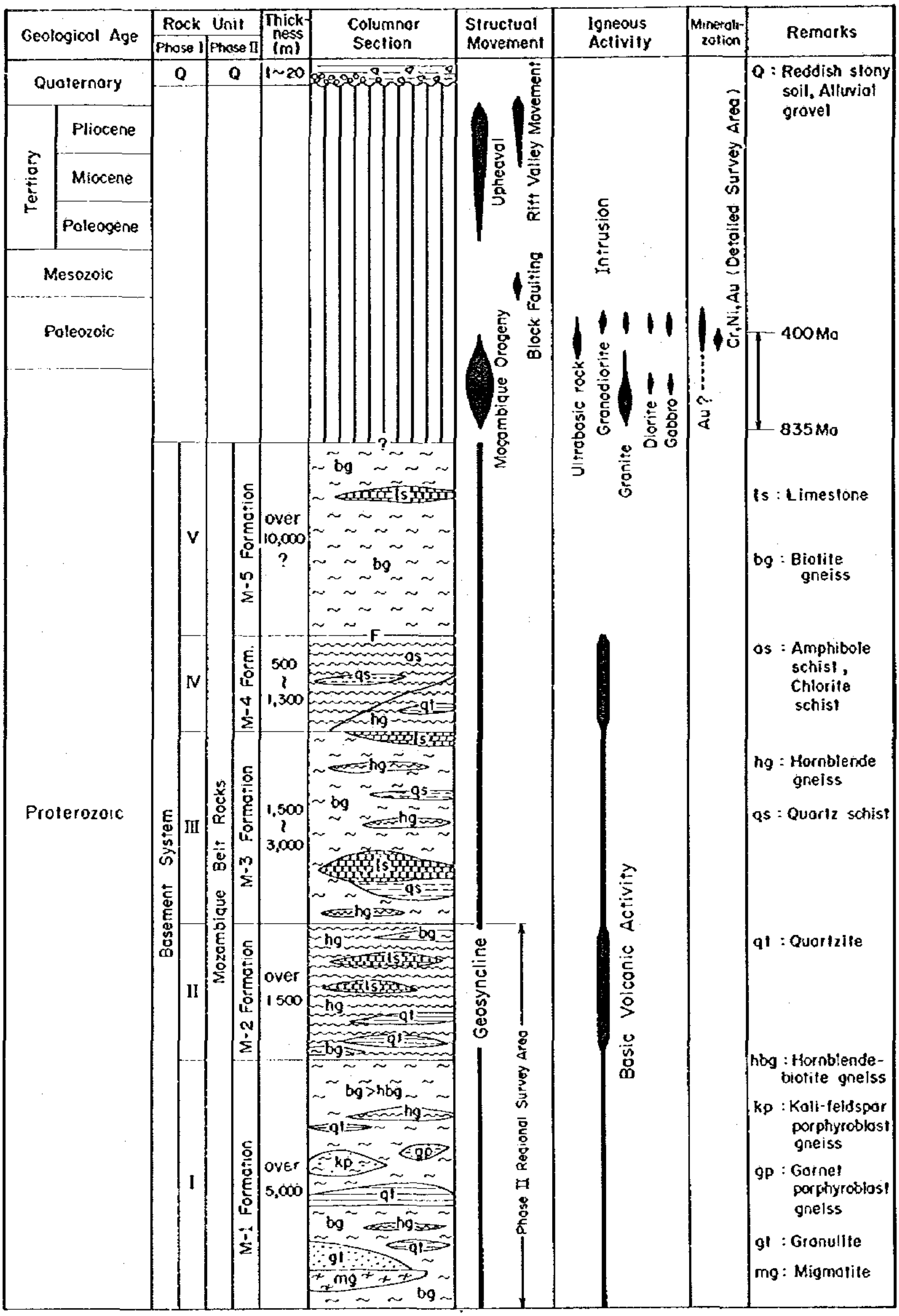


Fig. 2-2 Generalized Geological Columnar Section of Survey Area

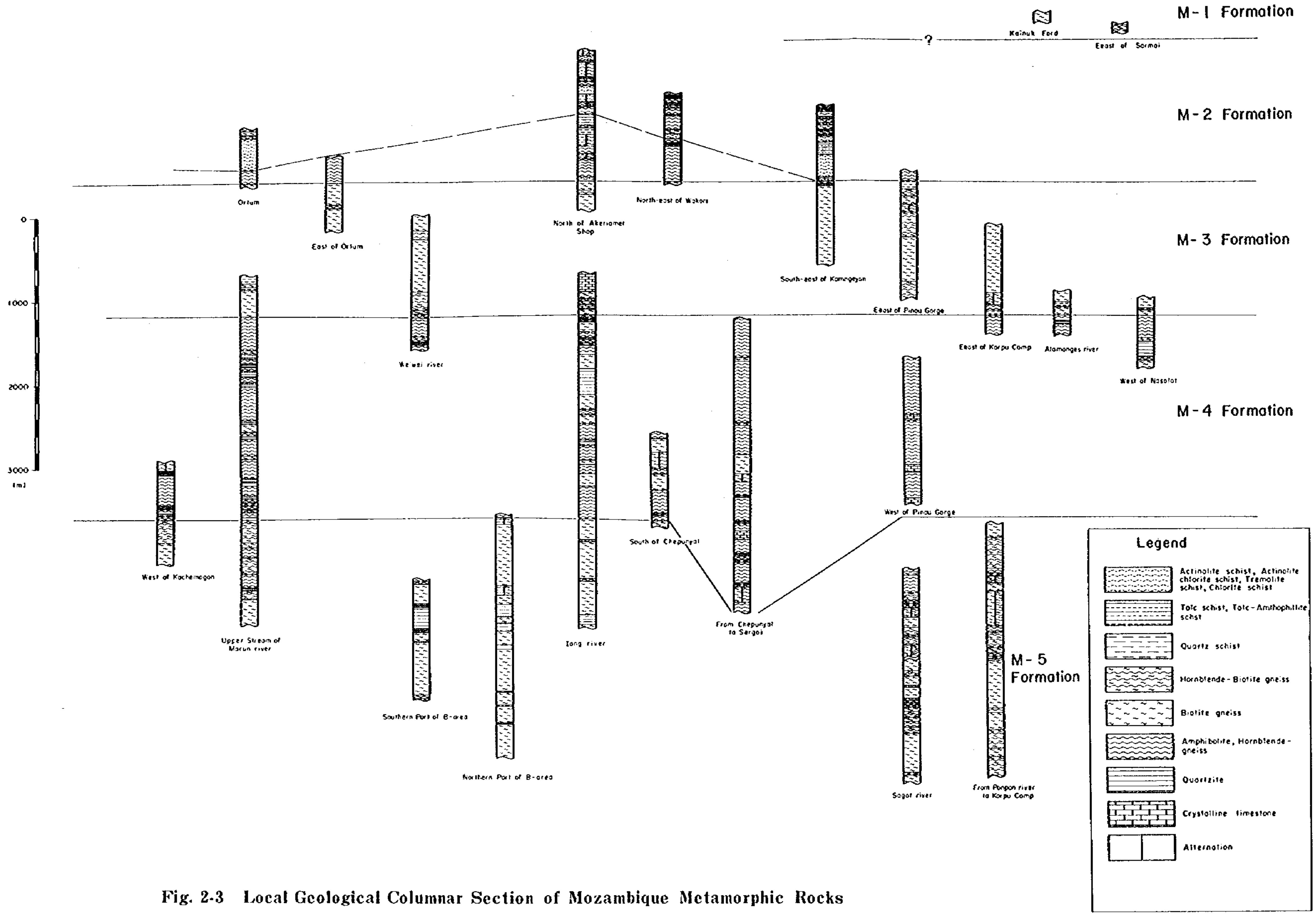


Fig. 2-3 Local Geological Columnar Section of Mozambique Metamorphic Rocks

talline limestone with good continuity and considerable thickness.

The rock facies observed in the formations are divided into the following four units: biotite gneisses with subordinate hornblende-biotite gneisses and hornblende gneisses (P-mg^{b}-3), biotite-muscovite schists; biotite-muscovite hornblende schists (P-ms^{bm}-3), quartz schists; quartzites (P-ms^{q}-4), crystalline limestones (P-mc-3).

(d) M-4 Formation

The formation shows narrow zonal distribution in the middle and north part of the area being surrounded by M-3 formation. The thickness of the formation is estimated to be 1,500 meters.

The formation is characterized by the remarkable occurrence of low-grade metamorphic rocks corresponding to green schist facies which is different from amphibolite facies of general metamorphic one in the area, and the green schist zone is intruded by ultrabasic and basic rocks forming a tectonic zone.

The rock facies observed in the formation is divided into two units; amphibole schists; amphibole-chlorite schists with subordinate amphibole gneisses, quartzites and quartz schists (P-ms^{a}-4), hornblende gneisses with subordinate amphibole schists; quartzites and quartz schists (P-mg^{h}-4).

(e) M-5 Formation

The M-5 formation is distributed in the northeastern corner of the survey area apart from other four formations. The stratigraphic relation with other formation has not obtained yet. The thickness of the formation is estimated to be more than 10,000 meters.

The formation is dominated by biotite gneisses, and divided into two units: biotite gneisses with subordinate hornblende gneisses (P-mg^{b}-5), crystalline limestones (P-mc-5).

(3) Quaternary System

The Quaternary system (Qr) of the survey area is composed of soil, river bed sand and gravel, and talus deposit, which covers the Mozambique metamorphic rocks and the intrusive rocks. The soil consists of pebbly soil, forest soil and alluvial soil, and the pebbly soil is dominant in the Masol lowland. The forest soil is dominantly found in the rainy forest zone on the highlands such as Sekerr and Cherangani Hills, and the alluvial soil is distributed as narrow zones along the major rivers.

The river bed sand and gravel are found at the river bed of every river, and placer gold is mined in the rivers such as Marun, lang and Turkwel. The talus deposit is distributed in zones at the bottom of the fault scarps such as Turkwel and Sekerr.

(4) Intrusive Rocks

The intrusive rocks in the area include acidic rocks, intermediate rocks, basic rocks and ultrabasic rocks, and vary in rock facies.

Acidic rocks comprise granitoid orthogneisses, foliated granites, migmatitic granites, and pegmatites. Intermediate rocks comprise granodiorites and metadiorites. Basic rocks comprise gabbros and metagabbros. Ultrabasic rocks are divided into serpentinites and talc schists.

Many of these intrusive rocks are the produdts of igneous activity at the time of preorogeny to orogeny, and have more or less been subjected to metamorphism, which altered the granitic rocks to orthogneiss and schistose rock. Meta-diorite and meta-gabbro are also those rocks which show a distinct tectonic structure. Migmatitic type granite is also distributed, which is considered to have been formed by ultrametamorphism which sometimes takes place at the deeper part of orogenic belt. Many of the pegmatites seems to have been formed by the similar origin. On the other hand, intrusive rocks which have hardly been subjected to the effect of metamorphism and seem to have intruded from the later stage of orogenic movement to the post orogenic time, are also distributed. Serpentinites, granodiorites, granites, grabbros and diorites correspond to this category.

These intrusive rocks are found as sheets and small stocks or dykes, and no large-scale ones such as batholiths have been observed.

(a) Granitoid orthogneisses (P-mG)

Distribution, Occurrence

Granitoid orthogneisses are distributed at the western mouth of the Turkwel Gorge, Murukoria Hill, the top of the Mt. Mtelo and Cherangani Hills, and have a northerly trend. Most of the rocks form relatively small sheets intruded in parallel with the trend of Mozambique metamorphic rocks. The Cherangani Hills one, on the other hand, is a large mass with the width of about six kilometers extending more than 25 km in the N-S direction and has inharmonious intrusion form as a whole.

Rock facies

The rock facies of the masses in the central part and the northern part is pale gray medium to fine-grained rocks with marked foliation. The rocks are megascopicaly composed of potash-feldspar, plagioclase, quartz, muscovite and biotite. The banded structure is formed by the bands of felsic minerals (one to several milimeters) and thin layers of mica, and mica forms the aggregate of shreds. Porphyroclasts of potash feldspar are often observed.

The rock facies of the Cherangani Hills mass is gray medium to coarse-grained rocks with notable banded structure. It is composed of potash-feldspar, plagioclase, quartz and biotite, sometimes containing hornblende. Black xenoliths of intermediate to basic igneous rocks are often contained in the rocks elongating in parallel to the banded structure.

(b) Foliated granites (Gf)

Distribution, Occurrence

Four major masses of foliated granite occur within the area; in the adjacent area of the Turkwel Gorge, in the area from the northeastern part of the Sekerr Forest to Sarmai, in the vicinity of Ptoyo and in the southern side of the Sekerr Mountains.

There are various intrusion styles of foliated granites in the area, but they usually show more or less apparently concordant contacts with the surrounding metamorphic rocks, and have remarkable schistosity in parallel with the structure of the gneissose rocks. They are composed of swarm of fine-grained leucocratic sheets intruded into surrounding biotite gneisses and hornblende gneisses at marginal parts and show tendency to become homogeneous and coarser toward the centre of the masses. Numerous schlierens composed of biotite gneisses, hornblend gneisses and intermediate to basic igneous rocks are contained throughout the rocks. Pegmatites are sometimes found inside and outside of masses. In the Marich Pass area, the hornfels zone is seen outside of the mass.

Rock facies

There are many variants of the foliated granites, but the dominant rock facies is pale gray fine to medium grained biotite granite with strong schistosity. Fine-grained muscovite granite, muscovite-biotite granite, leucocratic granite are also common in some places. Microscopically foliated granites are holocrystalline equigranular rocks with schistose structure and composed mainly of plagioclase, quartz, patash-feldsper and minor amounts of biotite and muscovite. Garnet is also contained at times.

(c) Migmatitic type granites, Migmatites, Pegmatites (P-mm)

Distribution, Occurrence

Migmatitic type granites or Migmatites occur mainly in two places as large masses, in the central part of the area along Marun River and in the southwestern part of the area centering on the Kiptaberr Hill.

The former mass has a dimension of 21 km in length and 4 km in maximum width extending northeasterly. At the contact with the surrounding rocks, the mass consists of a swarm of numerous sheets intruded in parallel with the structure of surrounding rocks. The intrusive parts increase relatively toward the center of the mass to became homogeneous gradually. Many xenotiths including hornblende gneiss, biotite gneiss and granitoid orthogneiss are also found in the mass.

Two modes of occurrence are seen in the latter area, one is a large-scale mass centering on the Kibtuberr Hill, and the others form lenticular thin layers, intercalated in biotite gneiss in the surrounding area.

Although a large number of thin layer is distributed, only those which have a thickness of more than several tens of meters can be shown on the geological map. Most of others are less than several meters thick, which have not been shown on the geological map.

The rock is characterized by numerous felsic veins injected parallel along the schistosity or banding of biotite gneiss, and it is hard and compact. It is thought that the monadnock of Kiptaberr which protrudes above the surrounding area is a hill of peculiar shape mainly due to the hardness of the rock.

The numerous pegmatites occur inside and outside of the mass along Marun River. Most of the pegmatites outside the mass are observed on the northern side of the Marun fault, and thus the basins of rivers such as Marun, Iang and Tamogh up to the vicinity of Chepunyal are the peculiar area of pegmatite occurrence.

These pegmatites are generally less than several meters in width, showing the maximum of 10 meters, and various occurrences are shown, such as cutting the structure of host rock, in parallel with the structure and markedly intergradational with the host rock.

Rock facies

The rock is weakly schistosed to banded, light gray medium-grained holocrystalline, often showing porphyritic texture and migmatite-like texture near the boundary.

Under the microscope, the main constituent minerals are quartz, plagioclase and potash feldspar, and the accessory minerals are biotite, apatite, zircon and iron minerals. The rock shows gneissose texture and cataclastic texture. The porphyroblasts consisting of quartz, plagioclase and potash feldspar are anhedral, and show an ovoid shape, being more than two millimeter in diameter. These show wavy extinction.

The cataclastic parts consist of fine grains of minerals showing sutured texture, in which quartz shows wavy extinction. Biotite shows flaky or tabular form less than two millimeters across oriented in a form of banding.

(d) Granites (G)

Distribution, Occurrence

Granites occur in the southeastern part of the area as small-scale stocks and dykes which has intruded into the M-1 and the M-2 formations composed of the metamorphic rocks. The largest one is a mass found to the north of Kalelaikelat, forming a stock 1 kilometer long and 0.5 kilometer wide. Granites are found, however, in most cases, in form of small dykes, several tens of centimeter to several meters wide intruding in parallel with the structure of the surrounding rocks. But these are not shown on the geologicap map.

Rock facies

Macroscopically, the rock is pale grey to pinkish, fine-grained holocrystalline rock, and has various texture i.e. homogeneous without foliation, weak banding, and aplitic. As mentioned later, although the microscopy revealed that they all showed a migmatitic texture, those without foliation have granitic texture to a considerable extent, being abundant in euhedral crystals. However, mode of occurrence of these bodies is almost the same, which together with the fact that they are found close to each other and that their chemical composition is similar, leads to the assumption that the rock was formed from gneissose rocks of pelitic origin, that those with strong granitic texture were solidified after a part of it reached the molten state, and that aplite was formed by intrusion of the molten material into the country rocks.

In a thin section of a typical specimen, the rock is seen to be composed of irregular lenticular quartz with wavy extinction, microcline of equal amount with quartz, subhedral to andehral plagioclase which has the composition of oligoclase to andesine. Flaky or prismatic biotite and muscovite, and small amount of apatite are also contained in the rock.

(e) Granodiorites (Gd)

Distribution, Occurrence

Two bodies of the rock are observed in the area distributed by the M-1 formation in the northeastern part of the area as small stocks less than 100 meters wide.

Rock facies

Macroscopically, the rock is greyish green, medium-grained hollcrystalline rock, showing an appearance to have been slightly altered.

In thin section, a specimen from a small stock is seen to have a granitic texture composed of plagioclase of andesine to labradorite in composition, anhedral granular quartz and potash-feldspar together with accessory minerals of hornblende, biotite, apatite and iron minerals. Since any affects which is considered to be caused by regional metamorphism has not seen in the rock, the time of intrusion is considered to be after the latest stage of the orogenic movement.

(f) Diorites, Metadiorite (D)

Distribution, Occurrence

Diorites occur in three places along the Marun River; east of Ortum, south of Wakorr and southwest of Wakorr. The areas of these exposures are ten square kilometers, one square kilometer and one square kilometer respectively, showing an irregular elliptical outline. Although the form of intrusion is not clear because of poor outcrops, they are considered to be small stocks from their distribution.

A metadiorite is exposed in the river bed of the Iang River for about 200 meters. Although the shape and size are not clear, it is estimated to be a small stock.

Rock facies

Diorites are macroscopically dark gray medium-grained holocrystalline rocks. In thin section, they have equi-granular, some porphyritic texture composed of plagioclase, hornblende, biotite, diopside, ore mineral, quartz and a little apatite.

The metadiorite is greenish gray and fine-grained macroscopically. In thin section, it is seen to be composed of plagioclase, hornblende and apatite as primary minerals. As secondary minerals, plagioclase, hornblende, zoisite and quartz are also recognized. Although holocrystalline equigranular texture is observed basically, mozaic texture of plagioclase and quartz resultant from recrystallization are also observed.

(g) Gabbros, Metagabbro (B)

Distribution, Occurrence

Gabbros occur in the vicinity of Mt. Kamngeyon and near the top of Mt. Mtelo. The mass at Mt. Kamngeyon forms a peculiar conical landform protruded from the surroundings and has an extent of exposure of one square kilometer. It is a stock intruded into M-4 Formation and separating the serpentinite mass which extends in a northerly direction.

A Metagabbro mass occurs in the middle reaches of the Sebit River and forms elliptical body with a dimension of three square kilometers.

Rock facies

The Gabbros, which are pale green to dark green and medium-grained, are composed of abundant common hornblende and minor amounts of plagioclase, zoisite and apatite. Plagioclase shows remarkable saussuritization and the rock type corresponds to the one of saussurite gabbro.

The metagabbro, which is dark grayish green, medium-grained and holocrystalline, has banded structure. In thin section, the rock shows somewhat gneissose texture, and is equigranular in the zone that euhedral plagioclases are gathered and granoblastic in the part that anhedral hornblendes are gathered. It is composed of hornblende, plagioclase and accessary minerals of epidote and biotite.

(h) Serpentinites (Us)

Distribution, Occurrence

Most of the rocks are distributed in the Semi-detailed Survey Area A in the central part of the survey area, and further a small mass is distributed to the southeast of Sebit in the southern part.

Those distributed in the area A occur in the M-4 formation in a lenticular form, and most of them are sheets intruded in harmonious with the structure of the surrounding rocks. The latter small mass occurs in the metagabbro mass as a xenolith.

Fock facies

Original rocks of serpentinites are mainly consist of wehrlite, lherzolite and dunite (see Clause 2–2).

(i) Talc rocks, Talc schists (Ut)

Distribution, Occurrence

Talc rocks and talc schists occur mainly in the Semi-detailed Survey Area A, and in addition, in the western central part on a small scale.

In the area A, most of them have intruded M-4 Formation which is mainly consists of schists.

In the western central part, they are distributed in hornblende gneisses of M-2 Formation in a lenticular form having a width of less than 100 meters, and the area of distribution is limited in a narrow zone several kolometers wide. They are likely to be sheets intruded in parallel with the bedding of the host rocks.

Rock facies

Talc rocks and talc schists, which are white to pale gray and massive, show sometimes weak schistosity. The rocks consist of only talc megascopicaly, but the parts contaminated by iron oxides in a vermicular form are often in Telot area in the area A.

(5) Metamorphism

(a) Regional Metamorphism

The project area is located in the western margin of the Mozambique belt which is formed by the Pan-African orogenic movement (600 ± 200 Ma). The rocks in the Mozambique belt comprise highly metamorphosed foliated rocks with remarkable north-south structural trend.

Metabasite distributed in the area contains common hornblende, plagioclase (andesine composition) and quartz as the main consitituent minerals, and some of those such as garnet, epidote, zoisite, diopside, biotite and sphene as accessory minerals. This mineral assemblage shows that the metamorphic facies belongs to the amphibolite facies and that the type of pressure to the medium pressure type (- high pressure type). Also, staurolite, kyanite and garnet are often contained in the pelitic metamorphic rocks. This assemblage shows that the facies belongs to medium pressure (- high pressure) type amphibolite facies.

(b) Retrograde Metamorphism

The distribution of green schists composed of chlorite schist, amphibole schists and amphibole-chlorite schist is observed in a narrow zone along Endogh-Telot synclinal axis in the center of the area.

The zone of green schists in the area is marked by the intrusion of serpentinites and basic intrusive rocks, by the development of the strong folded structure and by the present of major faults. On the other hand, green schists grade into hornblende gneisses where shearing is weak or none. For these green schists, which are lower in metamorphic grade than gneissose rocks belonging to amphibolite facies in the surrounding area, it is most possible that they were formed by retrograde metamorphism associated with the formation of fracture zones.

The calc-silicate granulite belonging to the M-1 formation in the southwestern part of the area shows a higher-grade metamorphic facies than the amphibolite facies in the surroundings, since it has a mineral assemblage of granulite facies. However, it is recognized that there seems to be a trace that the rock has undergond retrograde metamorphism in epidote amphibolite facies or amphibolite facies, in thin section. Because it is considered that the metamorphic facies of the survey area belongs to the amphibolite facies, it is hard to assume that only the area with the calc-silicate granulite distribution has reached granulite facies locally. That is the possibility suggested that the metamorphic rock which had a mineral assemblage of granulite facies intruded in a solid state at the time of the Mozambiquian metamorphism, and has undergone retrograde metamorphism in amphibolite facies.

(c) Ultrametamorphism

The rocks in the following indicate the occurrence of ultrametamorphism in the area: migmatitic type granites near Ortum, migmatites distributed centering on the Kiptaberr Hills in the south western part of the area; potash feldspar porphyroblast gneisses in the central and southern parts of the area, and felsic veins, aplites and pegmatites found in the surroundings.

(d) Contact metamorphism

Diopside–common hornblende-biotite-garnet skarn and garnet–common hornblende skarn occur near Marich Pass and to the south of it where foliated granites are distributed.

Small occurrences of wollastonite bodies are found in two places within the crystalline limestone terrain in the northeastern part of the area. These are considered to have been formed by contact metamorphism during the intrusion of granite or granodiorite bodies distributed in the adjacent area.

No metal mineralization has been found in these area related with the skarnization.

(6) Geological Structure, Geological History

(a) Geological structure

The structural elements of the area are shown on Fig. 2–1, and the lineaments obtained

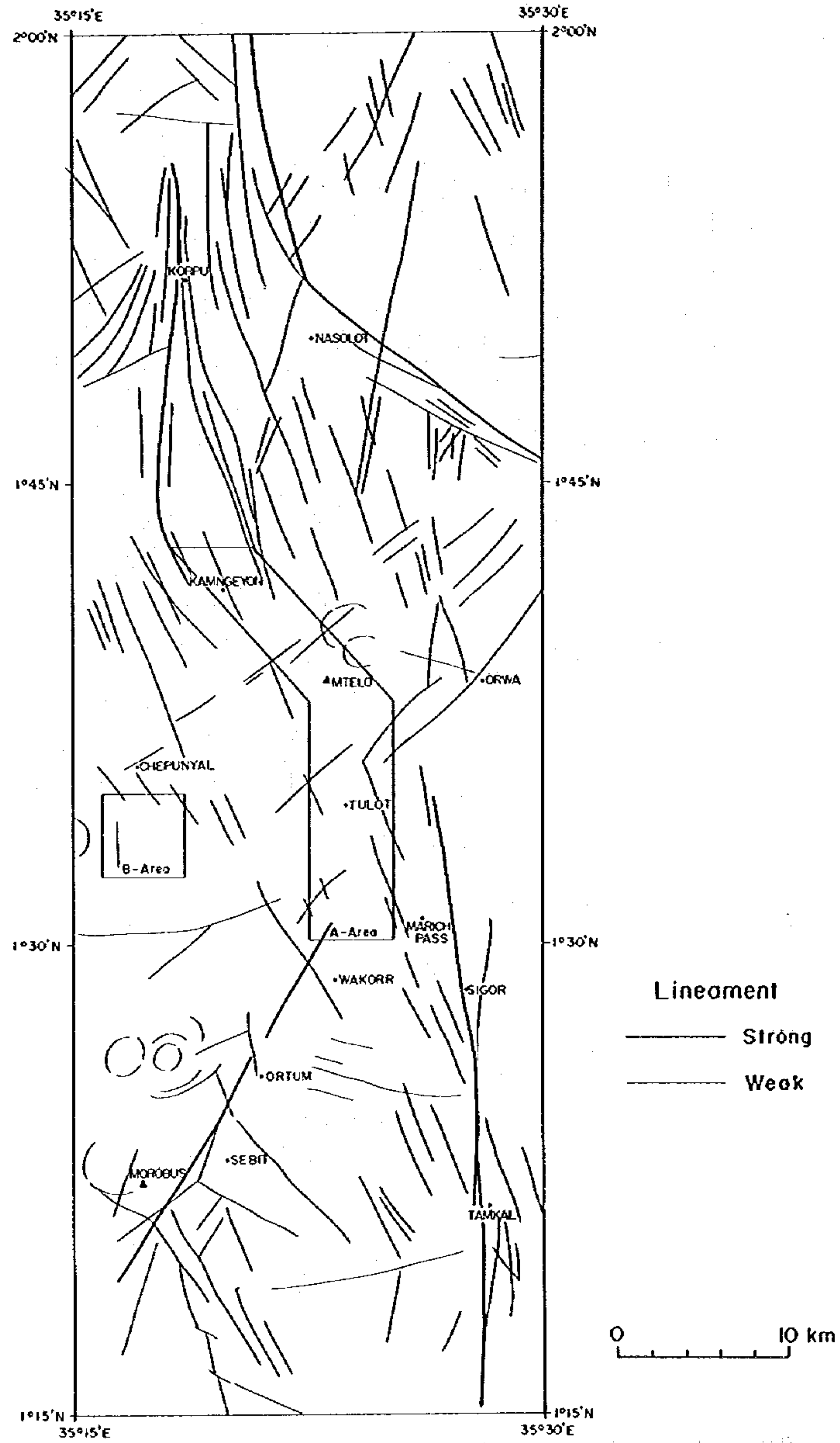


Fig. 2-4 Lineaments from Landsat False Colour Image, Phase I

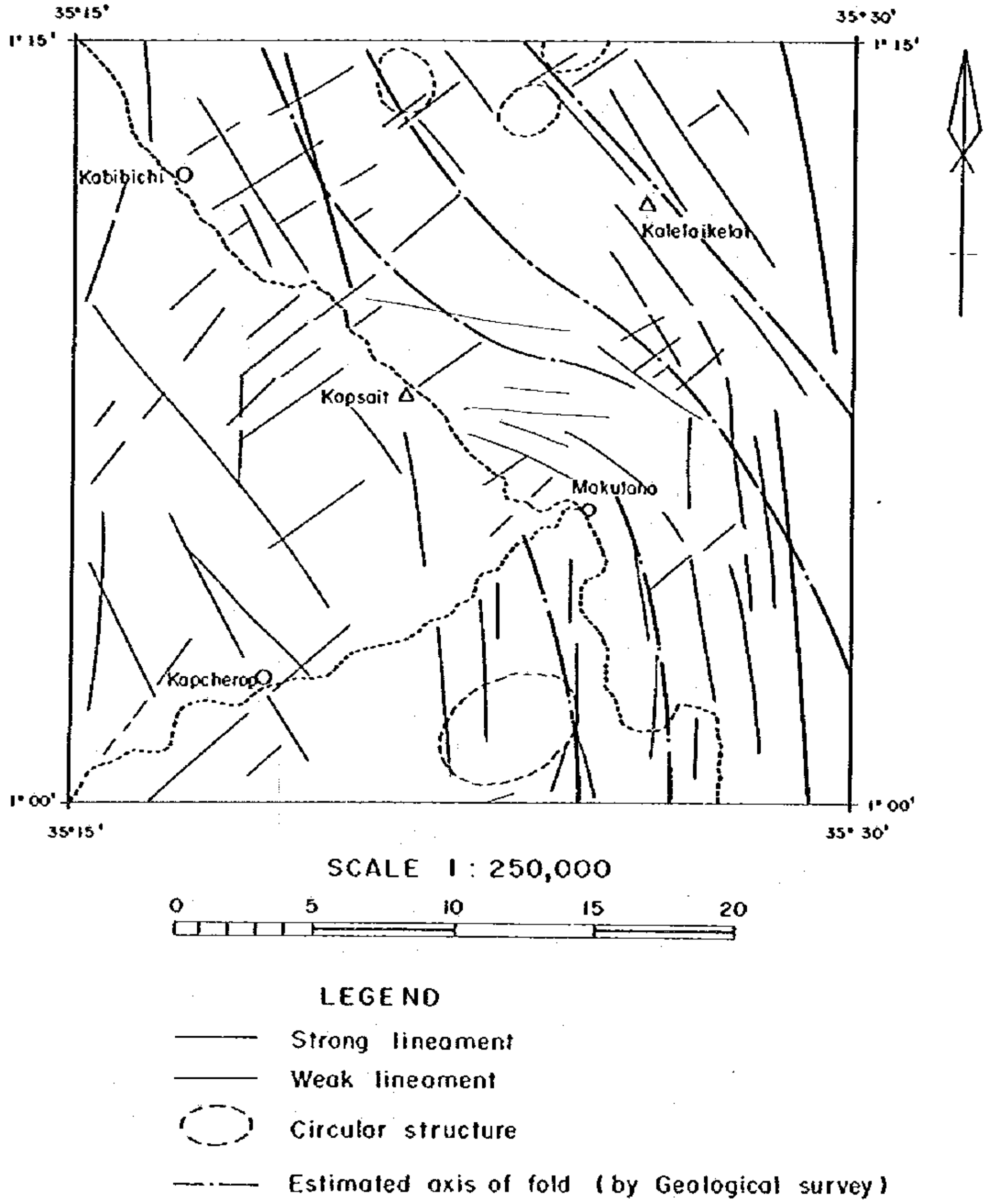


Fig. 2-5 Lineaments from Landsat False Colour Image, Phase II

from the Landsat images are also shown on Fig. 2–4 (Phase I) and Fig. 2–5 (Phase I).

Geological structure of the area is basically controlled by the fundamental structure of the Mozambique Metamorphic Rocks directed in N-S and NNW-SSE, and roughly speaking, is based on the synclinal structure extending in NW-SE in the southern central part, in NE-SW in the central and in NNW-SSE in the northern central part. Accordingly, the strata of the same horizon distribute on both sides of the synclinal axis.

In detail, the northern, central and southern parts have their characteristics in each part.

The northern part is characterized by the overturned fold system extending in a fan shape from north to south, and is characterized also by the faults running in parallel with the axis of the structure.

The central part is divided into two sections, north half and south half. The north half is controlled by a rather simple and asymmetrically fold system in which the strata gently incline in the western side while steeply in the eastern side. In contrast to the north half, many faults have been developed in the south half resulting the blocking of the folded strata. Considerably folded strata show irregularly distorted axial planes.

The south part is controlled by a group of overturned folds, the axial plane of which strikes north-northwest in the northern part, swinging north in the southern part, and dipping 30° to 40° towards the northeast and east.

The most remarkable fault structure is the Rift Valley Fault which runs in N-S direction in the east of the area, and is called Turkwel, Sekerr and Mwino faults respectively from north to south. These faults have a continuity of more than sixty kilometers in total in the area and the throw is estimated to be more than 1,000 meters. The escarpment facing east on to the Masol plain and separating the Sekerr Mountains and Cherangani Hills from the Fift Valley is a fault scarp following the line of the series of faults. The Marun fault passing the central part of the area in NE-SW direction bounds the eastern margin of the large mass of migmatitic type granite and also divides the area into two brocks, the north and the south block.

Among the many folds in the area, the most prominent one is the Telot-Endogh Syncline which controlles the basic structure of the area. The fold changes from open fold to tight overturned one from north to south and continues to the south being cutted by many faults. In the central and northern part of the area centering the area of the Telot serpentinite body, many faults occur in the synclinal axis part of the fold resulting to form a tectonic zone. Accompanying with the tectonic movement, retrograde metamorphism caused the gneissose rocks to form schistosed rocks.

(b) Geological history

Metamorphic rocks in the Mozambique belt are considered to be dominantly late Proterozoic in age (Kennedy 1964, Fleck et al. 1976, Hashad 1980), and also it has been considered that at least part of the Mozambique belt is composed of reworked Archean rocks (Vearncombe 1983).

Although the age of the rocks of the Mozambique belt found in the survey area has not been accurately determined, Vearncombe (1983) determined the age by radiometric dating of the rock derived from the andesitic volcanic rock distributed in the surrounding area of Marich Pass belong to Late Precambrian, and it is assumed that the geologic age of the rock in the area also corresponds to the age of the rocks of the Mozambique belt as a whole.

It is reported that the radiometric age of the Mozambiquian orogenic belt ranges from 835 Ma to 400 Ma for the whole belt and that the time of orogenic movement ranges from the later stage of the Precambrian to the early Paleozoic (Cahen and Snelling 1966).

On the other hand, Shibata and Suwa (1979) reported that, in the Machakos Mountains in the central part of Kenya where metamorphic rocks derived from the superficial beds surrounding the granitic gneiss dome in the Mozambique belt, the granite intruded primarily from mantle 770 Ma ago and that regional metamorphism took place 530 Ma ago, based on Rb-Sr isochron dating and initial ratio of $^{87}Sr/^{86}Sr$.

Reffering to these data, it is thought that the geologic age of the Mozambique metamorphic rocks of the area is mainly of the later stage of the Proterozoic and that the orogenic movement initiated around 800 Ma and ended 400 Ma ago. It is judged, therefore, that the rock was metamorphosed approximately 500 Ma ago.

Regarding the igneous activity, the major intrusion to the Mozambique metamorphic rocks is granitic rocks, which are classified into granitoid orthogneiss, foliated granite, migmatitic granite (migmatite) and granite. The period of intrusion into Mozambique metamorphic rocks ranges from the beginning to the latest stage of Mozambique orogeny as described in Clause 2–1–3. Serpentinites, in which chlomite deposits occur, are thought to have intruded at the later stage of orogeny because of the weak deformed structure.

Block movement in the Mesozoic and the Rift Valley tectonic movement in Cenozoic are summarized as follows.

In the Mesozoic era, the Cherangani surface and the Cherangani high surface were formed according to the progress of the block movement.

In the Cenozoic era, the western part of Kenya (including the survey area) became to the central part of the broad upheaval of a dome-like feature, and the peneplanation in the area was progressed.

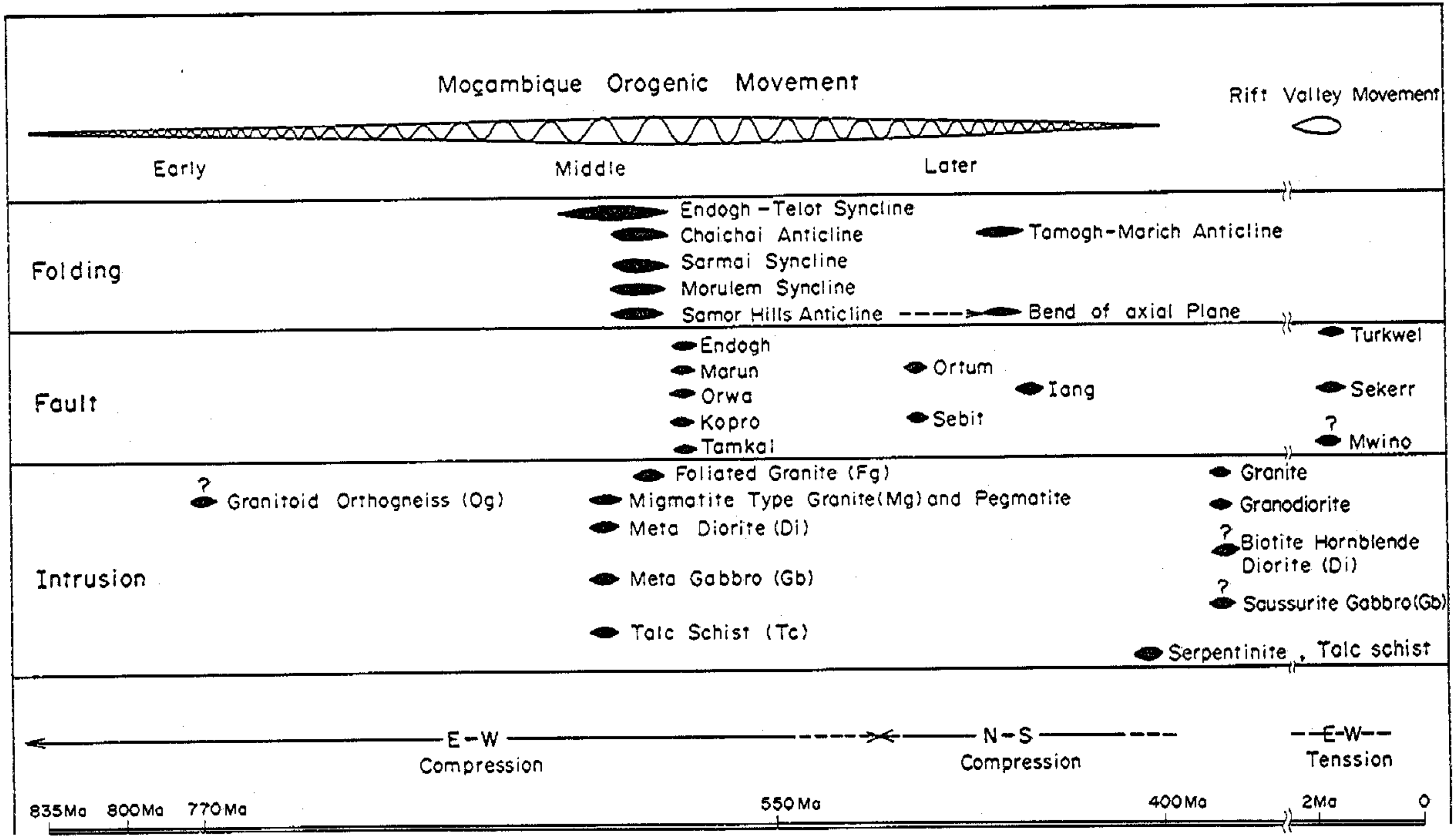


Fig. 2-6 Tectonic Movements and Igneous Activity

Table 2-1 List of Mineral Localities

No. on Geological Map	Name of Mineral Localities	Metal of Minerals	Type of Mineralization	Location			Information Source	Host Rock	Ore Mineral	Occurrence	Remarks
				Survey of Kenya, Map	UTM co-ord. X	UTM co-ord. Y					
1	Turkwel – Suam River	Au	Alluvial gold	62/2 Turkwel Gorge	757 ~763	208 ~213	McCall (1964) Theuri (1976) Bridge (1977) JICA/MMAJ (1984)[1]	Alluvial gravels	Native gold	The gold in the river bed ismainly found in gravels.	Production 1953–1960 Au: 1,160.80 Fine ounces Ag: 54.38 Ounces Recently operation is only held in dry season by local people.
2	Marun River (Wakorr-Marich)	Au	Alluvial gold	62/4 Sekerr 75/2 Sigor	767 ~774	165 ~170	McCall (1964) Miller (1965) Theuri (1976) JICA/MMAJ (1984)[1]	Alluvial gravels	Native gold	The deposits are restricted to superficial soils, alluvial gravel etc. in the river bed.	Production 1951–1955 Au: 232.72 Fine ounces Ag: 11.09 " Panning is being operated by local people in a small scale.
3	Endogh River	Au	Eluvial and alluvial gold	62/4 Sekerr	761	186 ~192	JICA/MMAJ (1984)[1]	Weathered Talc schist, Act. schist	Native gold	The eluvial gold is digged from weathered rock or talus composed of talc schist and actinolite schist. The alluvial gold occurs in the river bed downward.	Panning operation is flourishing by local people all the year.
4	Telot	Au	Eluvial gold	62/4 Sekerr	766	176	McCall (1964) Kaye (1967, 1968) JICA/MMAJ (1984)[1,2]	Weathered Serpentinite	Native gold	The eluvial gold occurs in weathered serpentinite or talus composed of serpentinite.	Geochemical anomaly covers the area of 5 km². Small scale panning is being continued by local people.
5	Iang	Au	Alluvial gold	62/4 Sekerr	757 ~768	167 ~176	JICA/MMAJ (1984)[1]	Alluvial gravels	Native gold		
6	Moiben River (Upperstream)	Au	Alluvial gold	75/4 Cherangani	773 ~776	117 ~127	JICA/MMAJ (1984)[2]	Alluvial gravels	Native gold	The gold is found in river-bed deposits.	Panning of gold is being operated by local people in a very small scale.
7	Sarmai River	Au	Alluvial gold	62/2 Turkwel Gorge	769 ~770	200 ~201	JICA/MMAJ (1984)[1]	Alluvial gravels	Native gold	The gold occurs in detrital sediments.	Small scale panning by local people.
8	Sarmai	Au	Alluvial gold	62/4 Sekerr	776 ~778	190	JICA/MMAJ (1984)[1]	Alluvial gravels	Native gold	ditto	ditto
9	Chepkotet	Au Cu	Hydrothermal vein	75/4 Cherangani	770 ~771	137 ~139	JICA/MMAJ (1984)[2]	Quartzite	Native gold Chalcopyrite	A very small amount of chalcopyrites and golds occurs in strongly silicified quartzites.	The area of silicified zone is estimated more than 1 km².
10	Iang	Au	Hydrothermal vein	62/4 Sekerr	759 (?)	167 (?)	McCall (1964)	Metamorphic rocks	Gold, Pyrite	The quartz-pyrite veins occur in a small swarm which traverses the bed of Iun River.	Assay Au: 0.3 dwt. per short ton
11	Telot	Cr Ni	Magmatic segregation Secondary enrichment	62/4 Sekerr	766	176	McCall (1964) Kaye (1967, 1968) Kokan Kogyo (1977) JICA/MMAJ (1984)[1,2]	Serpentinite	Chromite Kämmererite Garnierite	The podiform chromite bodies occur in the Telot serpentinite body. Garnierite occurs mainly as impregnation patchily distributed in the layers of the banded serpentinite. Thin seam of a mixture of Hematite and Malachite in the serpentinite - talc schist complex.	Prospecting included 412 m (11 Holes) of drilling was done by Japanese Company. Assay: see JICA/MMAJ (1984)[2]
12	Kamngeyon	Cr	Magmatic segregation	62/4 Sekerr	758+	189	McCall (1964) JICA/MMAJ (1984)[1]	Serpentinite	Chromite	Scattered chromite ores occur on the surface of weathered serpentinite covering the area of 80 x 50 m.	Traces of prospecting are seen in the area.
13	Twin Bridge	Cu	Hydrothermal vein	75/2 Sigor	759	155+	Miller (1956)	Quartzite	Malachite Pyrite Chalcopyrite	The malachite stainning occurs in a band of quartzite. An irregular vein-like streak of pyrite and chalcopyrite about two feet in length occurs in a contorted aplite dyke.	Assay Cu: 0.105%
14	Chepkopegh	Cu	Primary impregnation	75/2 Sigor	751–	162	Miller (1956)	Meta-diorite	Malachite Bornite Azurite Chalcopyrite	The malachite occurs as a local impregnation of Meta-diorite.	15 localities in 3,000 x 800 yards country. Most part is in the outside of the survey area.
15	Parua	Cu	Hydrothermal vein	75/2 Sigor	766	148	JICA/MMAJ (1984)[1]	Hornblend gneiss, Crystalline limestone	Malachite Bornite Chalcopyrite Chalcocite Pyrite	Quartz vein; Floats	Old pit or tunnel is said to be upper part of the float zone. Assay: Cu 1.1%
16	Akeriamet	Cu	Hydrothermal vein	62/4 Sekerr	767	170	McCall (1964)	Foliated granite	Chalcocite Malachite	Quartz-calcite vein with ore minerals.	Very small outcrop.
17	Nakang	Cu	Hydrothermal vein	62/2 Turkwel Gorge	759	209	McCall (1964)	?	Malachite	The copper is present in small and sparsely distributed lodes (quartz vein).	Very small outcrop.
18	Talon	Cu	Primary dissemination	62/2 Turkwel Gorge	771	199	JICA/MMAJ (1984)[1]	Amphibolite	Malachite	Several floats; the source is not found.	Assay of a chip sample Cu: 1.92%
19	Chaichai	Mo	Hydrothermal vein	62/4 Sekerr	769	187	JICA/MMAJ (1984)[1]	Muscovite qurtzite	Molybdenite	The molybdenite occurs in a small quartz vein.	Width: 0.15 m Length: 7 m Depth: ?
20	Nasalot	Mica	Pegmatite	62/2 Turkwel Gorge	772	202	McCall (1964)	Schist	Mica Feldspar Quartz	The mica occurs in a swarm of large pegmatites of rather unusual dike-like form ranging 1 mile wide.	Operated in 1928–1929. 3,645 pounds of cut mica Another operation in 1929, 0.5 Ton of low grade mica
21	Nakang	Kyanite	Hydrothermal vein	62/2 Turkwel Gorge	759	209	McCall (1964)	?			Very small outcrop.
22	Nasalot	Kyanite	ditto	62/2 Turkwel Gorge	772	202	McCall (1964)	?		The Kyanite is concentrated in bluish gray patches of crystals up to three inches long.	Bigger than other three outcrops.
23	Marun	Kyanite	ditto	62/4 Sekerr	768	169	McCall (1964)	?			Very small outcrop.
24	Sostin	Kyanite	ditto	62/4 Sekerr	768+	170+	McCall (1964)	?			Very small outcrop.
25	Telot	Talc	Alteration, massive	62/4 Sekerr	765 ~767	175 ~179	JICA/MMAJ (1984)[1,2]	Talc rock Talc schist Serpentinite		Large amount of talc rocks occur surrounding and inside the Telot serpentinite body.	Investigation of reserves and quality is recommended.
26	Sebit	Limestone	Sedimentary origine	75/2 Sigor	758 ~763	146 ~159	MGD Report	Crystalline limestone		Folded enlarged crystalline limestone.	Preliminary drill work has finished by MGD. Feasibility study should be needed for exploitation.

During the middle of Miocene, the dome was upheaved about 300 m, and the phonolite of the fissure-eruption type flowed out everywhere near the center of the dome in the direction N-S. In the survey area, volcanics of this type are unexposed.

Accompanied with the eruption of phonolite, formation of graben along the fractural structure in the direction of N-S was started in the Mozambique metamorphic belt. Until the end of Pliocene, the dome was upheaved about 1,500 m resulting the formation of the Sekerr and Turkwel faults, and the graben subsided more and the present topography was formed.

Owing to the erosion in Quaternary, fault scarps retreated backwards and the surface of the graben was flattened.

2–1–2 Ore Deposits

(1) General

The ore deposits and showings are shown in Table 2–1 and attached geological map. Table 2–2 shows a compilation of these for elements and types.

In the survey of the project, new showings of copper and molybdenum were discovered at several places in addition to those known showings. Moreover, other several showings, especially of gold, were confirmed by the geochemical survey.

Table 2–2 Classification of Ore Deposits and Showings

Elements or Mineral	Type	Ore Deposit or Mineral Showing
Au (Ag)	Alluvial Gold	Turkwel-Suam R., Marun R., Endogh R. Iang, Moiben R., Sarmai R., Sarmai
	Eluvial Gold	Endogh R., Telot
	Hydrothermal Vein	Iang, Chepkotet
Cr	Magmatic Segregation, Podiform	Telot, Kamngeyon
Ni	Secondary Deposit	Telot
Cu	Hydrothermal Vein	Twin Bridge, Parua, Akeriamet, Nakhang, Chepkotet
	Dissemination	Chepkopegh, Talon
Mo	Hydrothermal Vein	Chaichai
Mica	Pegmatite	Nasalot
Kyanite	Vein	Nakang, Nasalot, Marun, Sostin
Talc	Secondary Alteration	Telot
Limestone	Crystalline	Ortum-Sebit

(2) Distribution of Mineralized Zones, Relation with Geology

(a) Gold deposit

Alluvial deposit and eluvial deposit are known. The alluvial deposists are found at Suam-Turkwel River, Endogh River, the Marun River system, and the upper reach of Moiben River and these are estimated to be derived from granitoid orthogneiss, foliated granite, ultrabasic rock, gneiss and schist which had been subjected to mineralization in many cases. The eluvial deposits found in two places are evidently associated with ultrabasic rock and talc schist.

(b) Chromium and nickel deposits

The Chromite deposits distributed in two places, Telot and Kamngeyon are emplaced in podiform in ultrabasic rocks extending discontinuously in the NNW-SSE direction in the central part of the area. Garnierite nickel deposits occur in the weathered serpentinite at Telot. Beside the above, no serpentinite of a sufficient scale to be host rocks of chromite deposit has not be found in the survey area.

(c) Copper showing

Seven copper showings are sporadically distributed in the area, but they are all positioned in or near intrusive rocks, or on the inferred faults.

Nakang, Talon and Akeriamet showings are located in the sorrounding area of foliated granites. Chepkopegh showing in the west of area is located in metadiorite, and Chepkotet in the south of the area are near granodiorite. Twin Bridge and Parua showings are located on fault, and especially Twin Bridge is positioned at the intersection of faults.

(d) Molybdenum showing

The molybdenite-quartz vein at Chaichai is situated to the south of foliated granite mass, being controlled by the distribution of foliated granite as in the copper showings at Talon and Nakang.

(e) Non-metallic ore deposit

The pegmatite dykes, the host rock of mica deposits, are accompanied by veins of leuco-cratic granite, both of which are considered to belong to crystallization in the later stage of intrusion of foliated granite distributed to the west. The kyanite showings are also all distributed in the surrounding area of foliated granite mass. It is likely that the mineralization of mica and kyanite was brought about by the intrusion of the foliated granite.

Talc rocks at Telot are alteration products of serpentinite and the crystalline limestone bodies at Sebit-Ortum are due to enlargement of strata by folding.

(3) Details of Ore Deposits and Showings

The main placer gold deposits and the newly found showings of copper and molybdenum in the area are described in this clause. The chromium, nickel and gold deposits at Telot are described in the Clause 2–4.

(a) Placer gold deposit at Suam-Turkwel River

The deposit was discovered in 1953, and it is recorded that 1,160.86 fine ounces of gold and 54.38 ounces of silver were produced during the period from 1953 to 1960. At present mining by panning is carried out from December to March when the river runs dry by prospectors and local residents.

Fig. 2–7 shows the distribution of the intrusive rocks in the surroundings of the deposit, the panning locality and the position where gold was detected by geochemical survey in the values above detection limit.

The result shows that the placer gold of the area has not always been brought from only one place of Murkorio Hill as compiled by McCall (1964), but that it is also brought from the auriferous rock in the upper stream of the Endogh River and foliated granite on the eastern bank of the Taogoo River.

In the upper streams of the Endogh River, the eluvial gold deposit is distributed, where gold mining is actively carried out.

(b) Placer gold deposit at Marun River

The deposit was discovered in early 1951, and the record of production shows that four private prospectors recovered 232.72 find ounces of gold and 9.09 fine ounces of silver. Although Tharaka Mining Company operated in 1976, no record of production is available. At present, panning is being continued by the local residents on a small scale.

Fig. 2–8 shows the distribution of the intrusive rocks in the surroundings of the deposit, the panning locality and the position where gold was detected by geochemical survey of this survey in the values above detection limit.

The occurrence of the placer gold is almost similar to that of the Suam-Turkwel River. Gold is markedly concentrated in the Marich Pass and becomes fine-grained toward the lower stream.

The geochemical survey of the project resulted in to detect gold above detection limit in several places along the branches of the two rivers, Iang and Marun. It was also observed that panning was being carried out throughout, though small in scale, in the areas such as between Wakorr and Ortum along the Marun River, the lower to middle reaches of the Iang River and also along the tributaries of the above including Tamogh and Sergoi. Accordingly, it seems to be unreasonable to limit the source of gold to one place as both McCall (1964) and Miller (1956) supposed. An assumption to attribute the origin to the two rivers of Iang and Marun will lead to reasonable explanation on the most concentration of gold in the vicinity of Marich Pass where

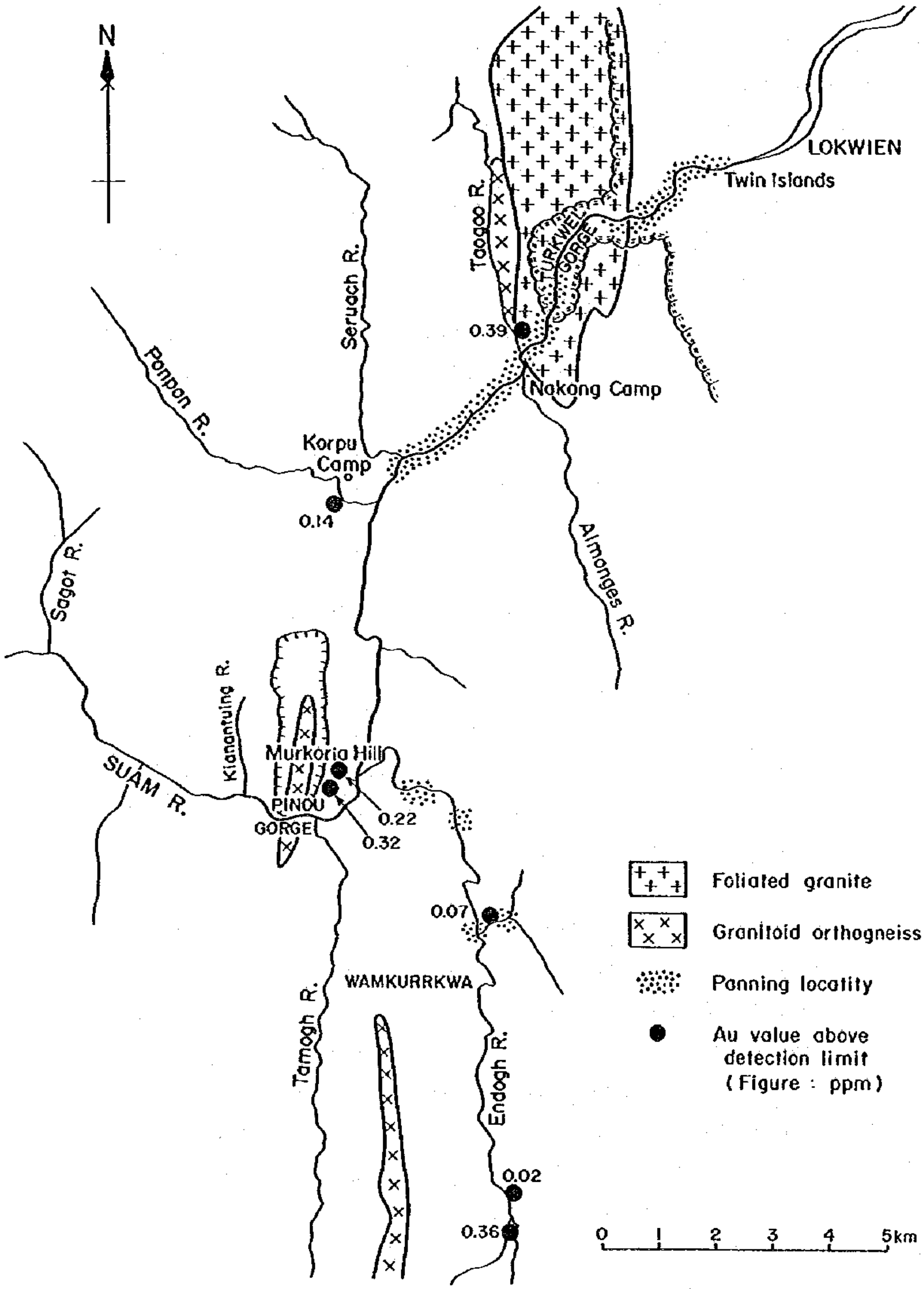


Fig. 2-7 Geological Sketch Map of Suam-Turkwel Alluvial Gold Area

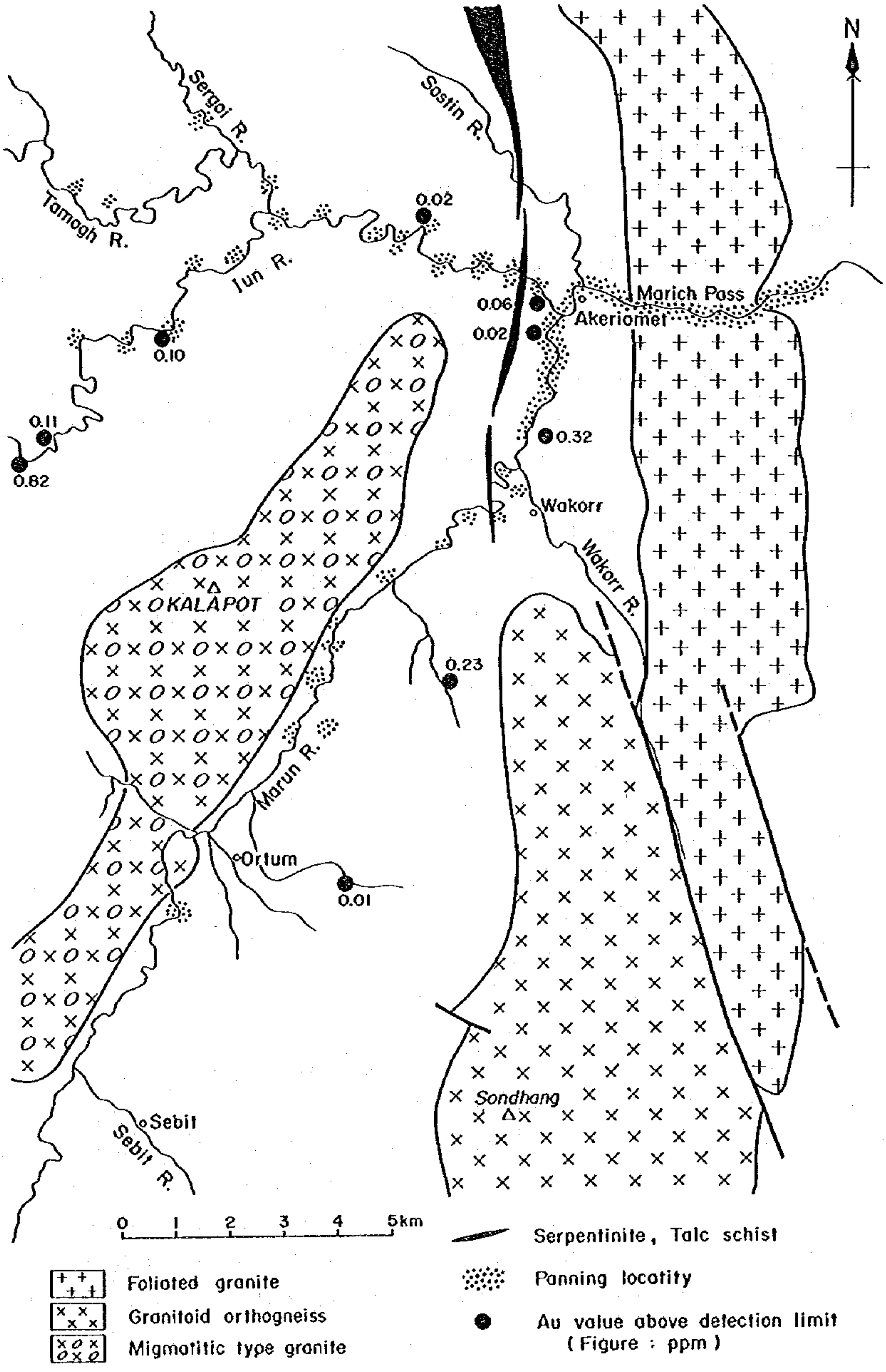


Fig. 2-8 Geological Sketch Map of Marun River Alluvial Gold Area

the two branches merge into one.

(c) Parua copper showing

It is situated in the vicinity of Parua along the upper reaches of Sebit River.

No record is available on the showing. It has been indicated, however, that there was a trace of old tunnel.

The geology in the surrounding area consists of hornblende gneiss and limestone, and the structure is complicated by a fault running parallel with the Sebit River. The floats contaminated by malachite are distributed in a creek crossing the road.

A typical float is composed of quartz vein, in which bornite, chalcocite and pyrrhotite are observed under the microscope beside malachite. The assay values of an ore are as follows.

DR-1; Cu : 1.1%, Co : 40 ppm, Ni : 45 ppm

(d) Talon copper showing

It is situated in the vicinity of Talon four kilometers to the southeast of Nasalot.

Hornblende gneisses occur in the vicinity of the showing, which is often intruded by leucocratic fine-grained granite dykes. A large mass of foliated granite is distributed to the west of the showing.

The ore consists of malachite dissemination along the foliation plane of hornblende gneiss, in which no remains of sulphide minerals are found.

The assay values of an ore are as follows.

AR-2 Cu : 1.92%, Co : <0.01%, Ni : 0.01%

(e) Chaichai molybdenum showing

The outcrop is situated in the river bed of a branch of the Mahang River at an altitude of 1,950 meters above sea leval, at the eastern end of the Sekerr Forest, 2.5 kilometers to the south-southeast of the peak of Mt. Chaichai.

It can be reached by walking a path for about 10 kilometers from Matong, the terminal of car road, and it takes about two and a half hours on foot.

Fig. 2–9 shows a sketch of the vein. The rocks in the vicinity of the vein consist of biotite gneiss and muscovite quartzite. The vein is found in muscovite quartzite, being emplaced along a fault striking N70°W and dipping 70°SW, which runs in parallel with the stream of the creek.

The ore vein is composed of a molybdenite-quartz vein. Molybdenite is contained for an interval of seven meters, among which the section of four meters long shows a concentration, and the grade of molybdenum of several percent is estimated there. Molybdenite is concentrated near the wall of vein in a form of band forming the flake up to 1.5 centimeters long. The altera-

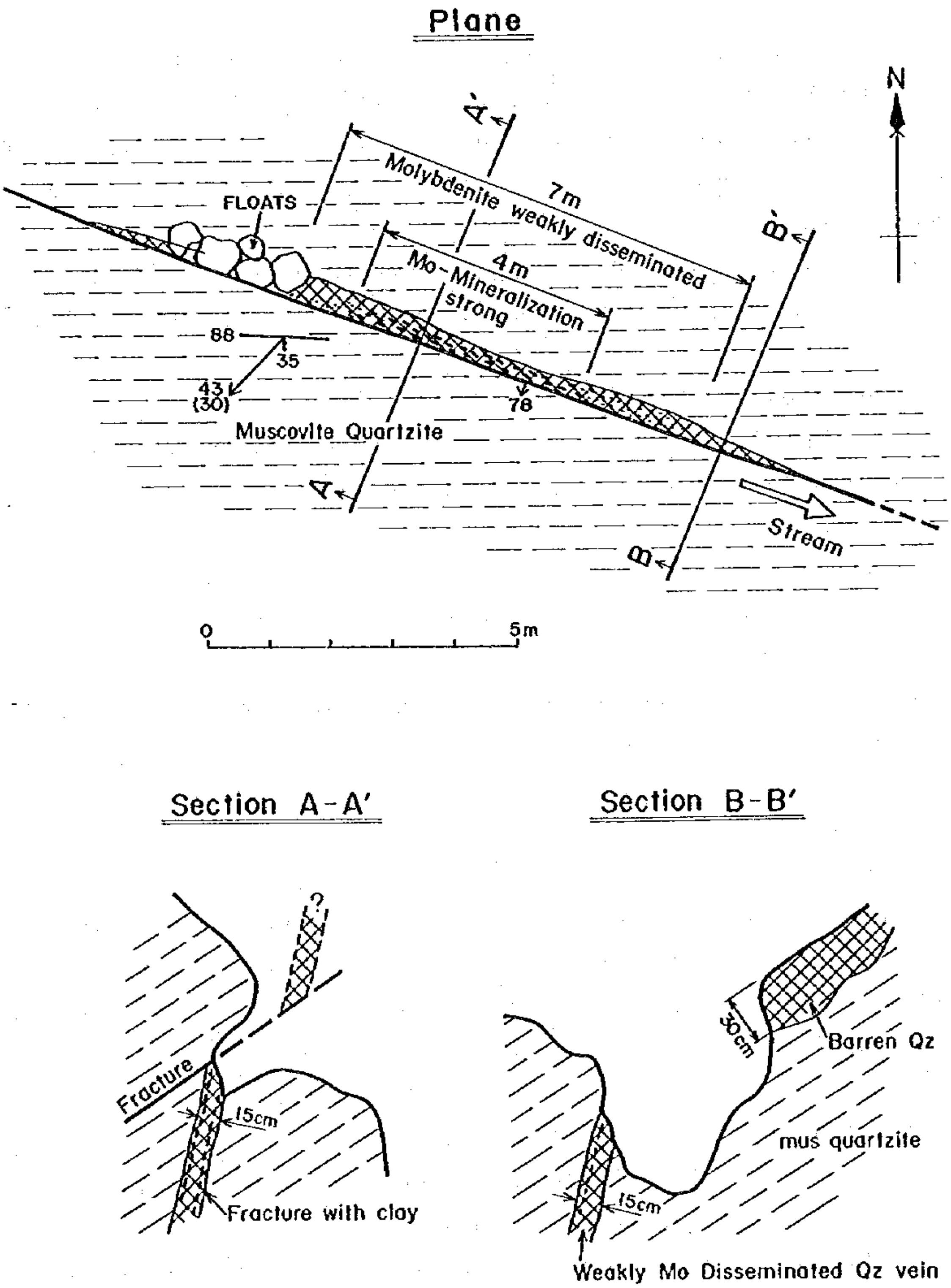


Fig. 2-9 Molybdenite Mineralization at Chaichai

tion zones of wall rock less than several centimeters wide are observed on both sides of the vein. As the result of X-ray diffraction, muscovite, low albite or orthoclase and low quartz were identified. Fine-grained molybdenite is sometimes contained in these alteration zones. The vein width is 15 centimeters in maximum. The quartz vein was traced for 15 meters, but further extension has not been made clear.

Although the vein itself is small on a scale, there is a possibility of occurrence of the similar veins in the surroundings of the foliated granite mass because the vein is located close to the rock on the south of it.

(f) Chepkotet gold-copper showing

A highly silicified zone is exposed in the vicinity of Chepkotet in the southeastern part of the area for more than two kilometers along the motor road, where only quartzite was observed as the host rock.

As a result of microscopic observation of a thin section, quartz, sericite and limonite were observed, and quartz and talc were identified by X-ray diffraction. As a result of microscopic observation of a polished sections, a very small amount of tiny particles of chalcopyrite and gold was observed, leading to the assumption that a weak mineralization took place in association with hydrothermal alteration.

2–1–3 Geochemical Survey

(1) Method of Survey

The Regional Survey area comprises Phase I Area and Phase II Area. Stream sediments were collected in both areas and analyzed for six elements of Au, Cu, Pb, Zn, Cr and F in the Phase I area and five elements of Au, Cu, Zn, Cr and F in the Phase II area. Analysis of F was introduced to study the potentiality of occurrence of carbonatites in the area. In Phase II area, analysis of Pb was excluded because no anomalous values were detected at all in the Phase I area.

(2) Statistical values and Data Processing

Table 2–3 (Phase I) and Table 2–6 (Phase II) show the statistic values of analytical element. The analytical results of Au are mostly under detection limit (0.01 ppm) therefore the results were omitted from treatment. In Phase I, the analytical results of Pb and F under detection limit were processed as 0.4 ppm and 4 ppm respectively. In Phase II, the analytical results of Cr and F under detection limit were omitted from treatment.

Table 2–4 (Phase I) and Table 2–7 (Phase II) give the correlation coefficients between the elements and |R| values of significance test.

Cumulative frequency distribution curves for the elements are illustrated in Fig. 2–10

(Phase I) and Fig. 2–11 (Phase II)

Threshold values were selected as follows considering the cumulative frequency curves, and are listed in Table 2–5 (Phase I) and Table 2–8 (Phase II).

Au: Analytical data were mostly under the detection limit, so 2.27 percent of number of all samples was selected from high value side, and the threshold values were fixed as the minimum value in the selected area. The ratio 2.27 percent signifies the population over $\bar{X} + 2\sigma$ in a normal distribution.

Cu, Pb, Zn, F, Cr: In these elements, it is hard to extract the anomalous population from cumulative frequency distribution curves, so the threshold values were determined as $\bar{X} + 2\sigma$. This means that the data belonging to anomalous population are none or very few.

Anomalous values were classified further into three groups such as AA-grade, A grade and B grade. This classification was done by use of the values of $\bar{X} + 2.5\sigma$ and $\bar{X} + 3\sigma$ for Cu, Pb, Zn, F and Cr, and by the theoritical proportion of samples over $\bar{X} + 2.5\sigma$ and $\bar{X} + 3\sigma$ in a normal distribution for Au. In Phase I, high values in the background population were also selected as high content values on Au and Pb.

Table 2–5 (Phase I) and Table 2–8 (Phase II) summarise the classification of anomalous values, threshold, high content values and number of samples.

(3) Interpretation of Geochemical Anomalies

Fig. 2–12 (Phase I) and Fig. 2–13 (Phase II) give the distribution of anomalous samples, high content samples and anomalous zones. Interpretation of geochemical anomalies for each element is as follows.

(a) Au

A remarkable anomalous zone (Au: 0.09 to 14.25 ppm, Endogh-Au Anomalous Zone) extends over three kilometers in the zone from Kameyen to Silkowa Ridge along the upper stream of the Endogh River. The zone corresponds to the alluvial placer and eluvial gold digging place where many local panners are panning gold from alluvial deposits and residual soil of erpentinites or talc schists. In the zone, Au anomalies were obtained from many tributaries joining the Endogh River, which proves that the mineralization of gold is pretty strong and the zone is wider than the present working sites.

An anomalous zone, namely, Kipnai anomalous zone (Au: 0.03 – 1.30 ppm) can be distinguished. The zone has three anomalous samples with maximum values and second one for Au. No geological evidence which can be related with gold mineralization and no panning works for placer gold have been known in the area. This anomaly may suggest that the area has a possibility of a productive placer gold deposit which can be worked on a small scale.

Table 2-3 Statistic Values of Analyzed Elements, Regional Survey Area, Phase I

Element Unit	Au ppb	Cu ppm	Pb ppm	Zn ppm	Cr ppm	F ppm
Number of Samples	1,552	1,552	1,552	1,552	1,552	1,552
Minimum Value	<10	3	<1	13	3	<10
Maximum Value	14.250	159	38	330	1,532	3,475
Range	>14.240	156	>37	317	1,529	>3,465
Mean	-	23.7	4.0	64.8	103.6	124.3
S.D. (Log)	-	0.25	0.49	0.16	0.27	0.43
M + 2 S.D.	-	74	38	137	355	910
M + 3 S.D.	-	131	118	198	656	2,457
Clarke Number	4	55	15	60	100	620

Table 2-4 Correlation Coefficients, Regional Survey Area, Phase I

	Au	Cu	Pb	Zn	F	Cr
Au	1.00					
Cu	0.03 (52)	1.00				
Pb	0.08 (48)	-0.23 (1361)	1.00			
Zn	0.12 (52)	0.40 (1551)	-0.23 (1361)	1.00		
F	-0.35 (52)	0.14 (1533)	0.18 (1345)	0.26 (1533)	1.00	
Cr	0.11 (52)	0.21 (1551)	-0.06 (1361)	0.20 (1551)	0.12 (1533)	1.00

( ) Number of Paired Samples

R(ϕ,e)
ϕ: degree of freedom
e: significance level

|R|(46,0.01) = 0.368
|R|(50,0.01) = 0.354
|R|(1359,0.01) = 0.070
|R|(1549,0.01) = 0.065
|R|(1343,0.01) = 0.070
|R|(1531,0.01) = 0.066

Table 2-5 Thresholds and Classification of Anomalous Value, Regional Survey Area, Phase I

Element	Anomalies			Threshold	Background
	Grade AA	Grade A	Grade B		High-content Value
Au (ppb)	≥1,844 (2)	1,844>≥360 (8)	360>≥80 (28)	80	80>≥10 (14)
Cu (ppm)	≥131 (1)	131>≥99 (4)	99>≥74 (17)	74	-
Pb (ppm)	- (0)	- (0)	≥38 (1)	38	38>≥21 (32)
Zn (ppm)	≥198 (7)	198>≥165 (13)	165>≥137 (22)	137	-
Cr (ppm)	≥656 (7)	656>≥482 (8)	482>≥355 (22)	355	-
F (ppm)	≥2,457 (2)	2,457>≥1,459(9)	1,459>≥910(31)	910	-

( ) Number of Samples

Table 2-6 Statistic Values of Analyzed Elements, Regional Survey Area, Phase II

Element Unit	Au ppm	Cu ppm	Zn ppm	Cr ppm	F ppm
Number of Samples	709	709	709	709	709
Number of Samples Under Detection Limit	699	0	0	15	3
Maximum Value	1.3	60	200	680	759
Minimum Value	<0.01	1	4	<5	<10
Mean ($\bar{x}$)	-	9.4	46.7	43.4	82.0
Standard Deviation (S.D. in Log figure)	-	0.254	0.235	0.313	0.262
$\bar{x}$ + 2 S.D.	-	30	138	183	274
$\bar{x}$ + 2.5 S.D.	-	41	181	263	371
$\bar{x}$ + 3 S.D.	-	55	237	377	502

Table 2-7 Correlation Coefficients, Regional Survey Area, Phase II

	Cu	Zn	Cr	F
Cu				
Zn	0.704 (709)			
Cr	0.262 (692)	0.401 (692)		
F	0.082 (706)	0.308 (706)	0.374 (689)	

( ) Number of paired sampels calculated

R(ϕ,e)
ϕ: degree of freedom
e: significance level

|R| (687,0.01) = 0.098
|R| (690,0.01) = 0.098
|R| (704,0.01) = 0.097
|R| (707,0.01) = 0.097

Table 2-8 Thresholds and Classification of Anomalous Values, Regional Survey Area, Phase II

Unit: ppm

Element	Anomalies						Threshold
	Grade AA		Grade A		Grade B		
Au	Au≧1.30	(1)	1.30>Au≧0.09	(3)	0.09>Au≧0.01	(6)	0.01
Cu	Cu≧55	(2)	55>Cu≧41	(5)	41>Cu≧30	(13)	30
Zn	-	(0)	Zn≧181	(2)	181>Zn≧138	(12)	138
Cr	Cr≧525	(3)	525>Cr≧295	(10)	295>Cr≧183	(14)	183
F	F≧550	(2)	550>F≧339	(3)	339>F≧274	(3)	274

( ) Number of samples

Three anomalous samples (Au: 0.08 to 0.3 ppm) and three high-content samples are in the Telot area. These are sure to reflect the eluvial gold deposit in the area.

Some anomalous samples are found sporadically in the Turkwel River, Endogh River, Iang River, Marun River and Moiben River, and they have been known as the localities of small placer gold deposits. So these anomalies reflect local concentration of gold in the area.

(b) Cu

Threshold values, 74 ppm (Phase I Area), 30 ppm (Phase II Area) and the maximum values, 159 ppm (Phase I Area), 60 ppm (Phase II Area) are not high values in comparison with the standard contents which are usually contained in various rocks, and no remarkable anomalous zone which has genetic relation with mineralization of copper was detected in the area.

Only one weak anomalous zone extending from the north of Wakorr to Akeriamet Shop area was extracted in the project area. The zone consists of one A-grade and eight B-grade anomalies (Cu: 77 to 159 ppm). Vein-type copper mineralization known as Akeriamet copper showing is located in the zone, and the anomaly is considered to be caused by the weak mineralization of copper.

The fact that the six known copper showings in the area except the Akeriamet showing do not cause any anomalous zone suggests that the copper mineralization is rather weak in the project area.

(c) Zn

Two weak anomalous zones for Zn are located in the Phase I Area. In the larger one named Sebit Zn anomalous zone (Zn: 137 to 300 ppm), no zinc mineralization has been reported, but two copper showings of vein-type, Twin Bridge and Parua showings are known in and around the zone. The anomalies are considered to reflect the vein-type copper mineralization with zinc judging from the correlation coeficient between Cu and Zn, 0.40 which shows the moderate positive correlation.

None of mineralization has been known in and around the smaller one named Wakorr Zn anomalous zone (Zn: 140 to 190 ppm). However, it is considered that the anomalies reflect the weak copper mineralization with zinc similar to Sebit Zn anomalous zone, because of their locality nearby Sebit one.

(d) Pb

The analytical values of Pb are all low in grade. The anomalous sample is only one and its value, 38 ppm is merely two and half times as large as Clarke number. For this reason, it seems difficult to expect any economical lead deposits in the project area.

(e) Cr

Almost all anomalies for Cr are concentrated in the areas underlain by ultrabasic rocks or hornblende gneisses, and as remarkable zones, five anomalous zones of Telot, Tamkal, Noliewer, Kapsangar and Tenden have been distinguished.

Among these zones, the most prominent one, Telot Cr-anomalous zone, extends to N-S with E-W width of about 2 km and N-S length of about 8 km. The zone contains 12 anomalies (Cr: 357 to 1,532 ppm) and corresponds clearly to the distribution of ultrabasic rocks in which the Telot chromite deposit occurrs. Some sporadical anomalies scattered along the Marun River and Endogh River which is the zone extending to the north and south from Telot, are also correspond to the distribution of ultrabasic rocks and Kamngeyon-Cr showing.

In other four anomalous zones, grades of chromium of anomalous samples are not so high (maximum value: 590 ppm in Noliewer anomalous zone) and no ultrabasic rock has been noted, so these anomalies are considered to be caused by hornblende gneisses with relatively high chromium content distributing background zones.

(f) F

Two distinct anomalous zones named Ortum F anomalous zone (F: 920–3,475 ppm) and Kapsangar F anomalous zone (F: 288–759 ppm) were extracted in the area. Fluorine is generally contained much in alkaline igneous rocks for example carbonatite, but the values of anomalous samples are not so high as to connect them to some mineralizations or alkaline igneous rocks in comparison with F content in ordinary rocks.

Migmatite-type granites, potash feldsper porphyroblastic gneisses and pegmatites which are considered to be products of ultrametamorphism in the project area are distributed in the two areas, so these local concentration of F are thought to be caused by some effects of ultrametamorphism.

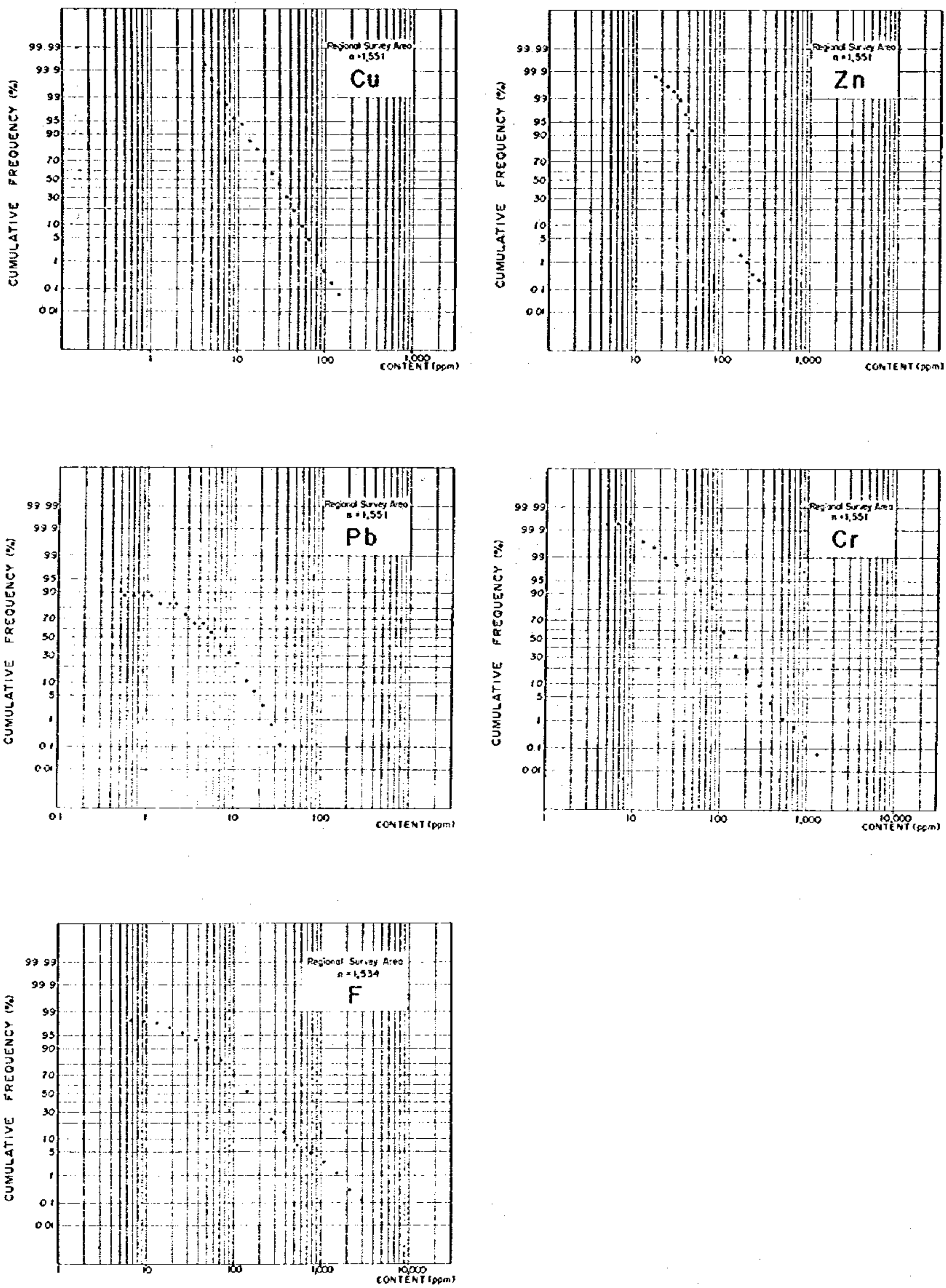


Fig. 2-10 Cumulative Frequency Distribution Diagrams for Analytical Elements, Regional Survey Area, Phase I

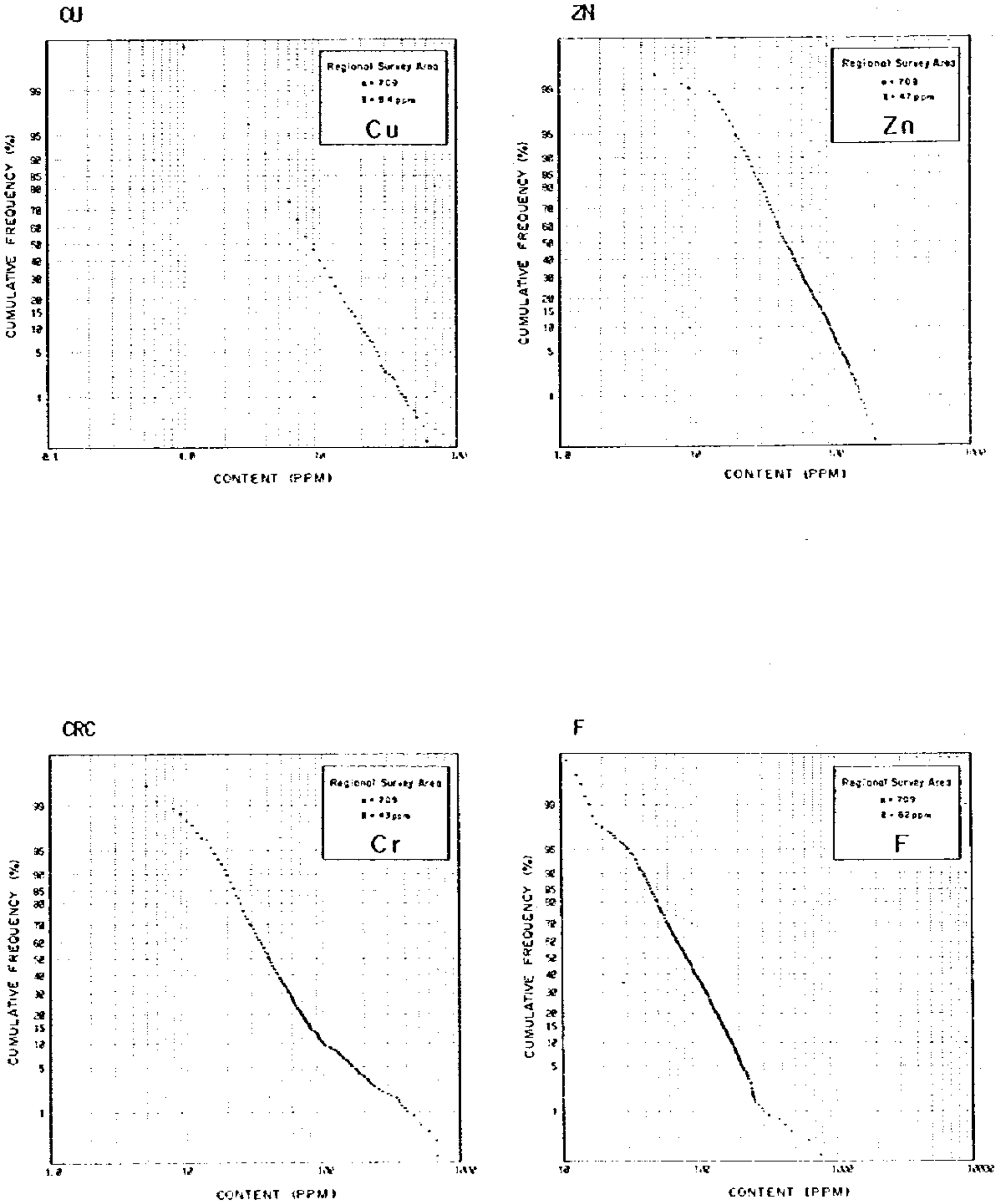
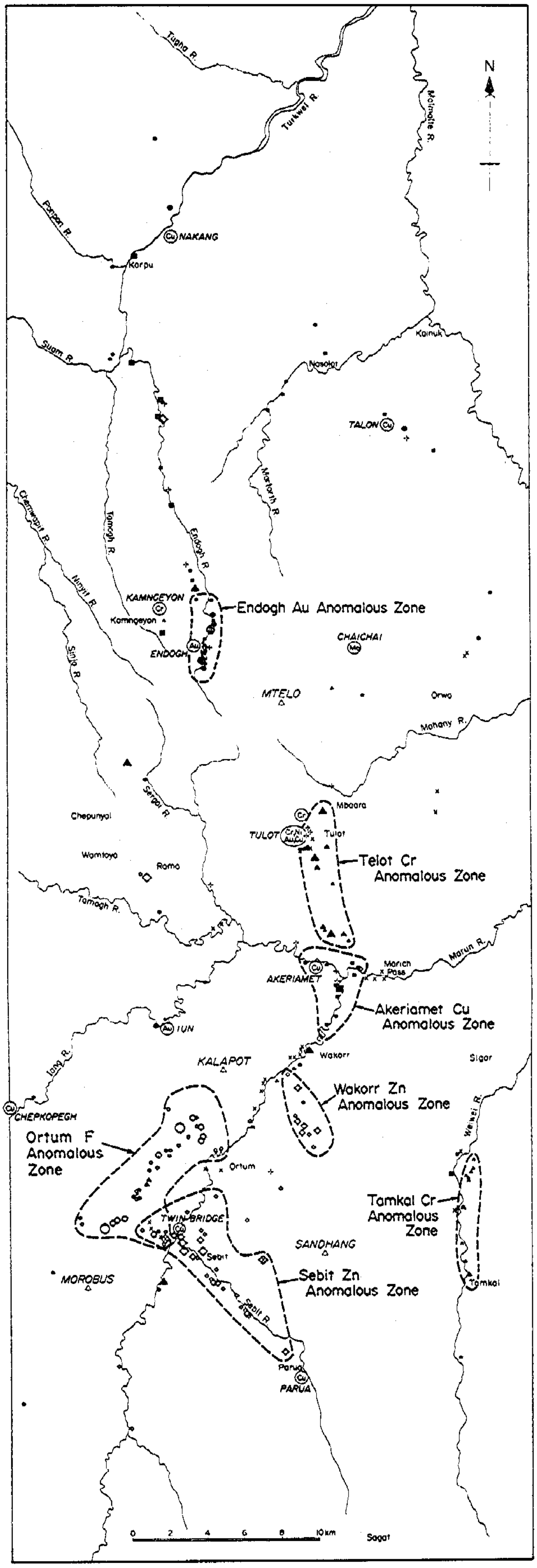


Fig. 2-11 Chmulative Frequency Distribution Diagrams for Analytical Elements, Regional Survey Area, Phase Ⅱ



LEGEND

Au

AA Grade Anomaly	● ≧ 1844 ppb	n=2
A 〃	1844 ppb > ● ≧ 360 ppb	n=8
B 〃	360 ppb > • ≧ 80 ppb	n=28
High Content	80 ppb > ÷ ≧ 10 ppb	n=14

Cu

AA Grade Anomaly	■ ≧ 131 ppm	n=1
A 〃	131 ppm > ■ ≧ 99 ppm	n=4
B 〃	99 ppm > • ≧ 74 ppm	n=17

Pb

B Grade Anomaly	• ≧ 38 ppm	n=1
High Content	38 ppm > × ≧ 21 ppm	n=32

Zn

AA Grade Anomaly	◇ ≧ 198 ppm	n=7
A 〃	198 ppm > ◇ ≧ 165 ppm	n=13
B 〃	165 ppm > ◦ ≧ 137 ppm	n=22

Cr

AA Grade Anomaly	▲ ≧ 656 ppm	n=7
A 〃	656 ppm > ▲ ≧ 482 ppm	n=8
B 〃	482 ppm > ▴ ≧ 355 ppm	n=22

F

AA Grade Anomaly	○ ≧ 2457 ppm	n=2
A 〃	2457 ppm > ○ ≧ 1459 ppm	n=9
B 〃	1459 ppm > ◦ ≧ 910 ppm	n=31

Anomalous Zone

Ⓒr Mineral Occurrence

Fig. 2-12 Geochemical Anomaly Map, Regional Survey Area, Phase I

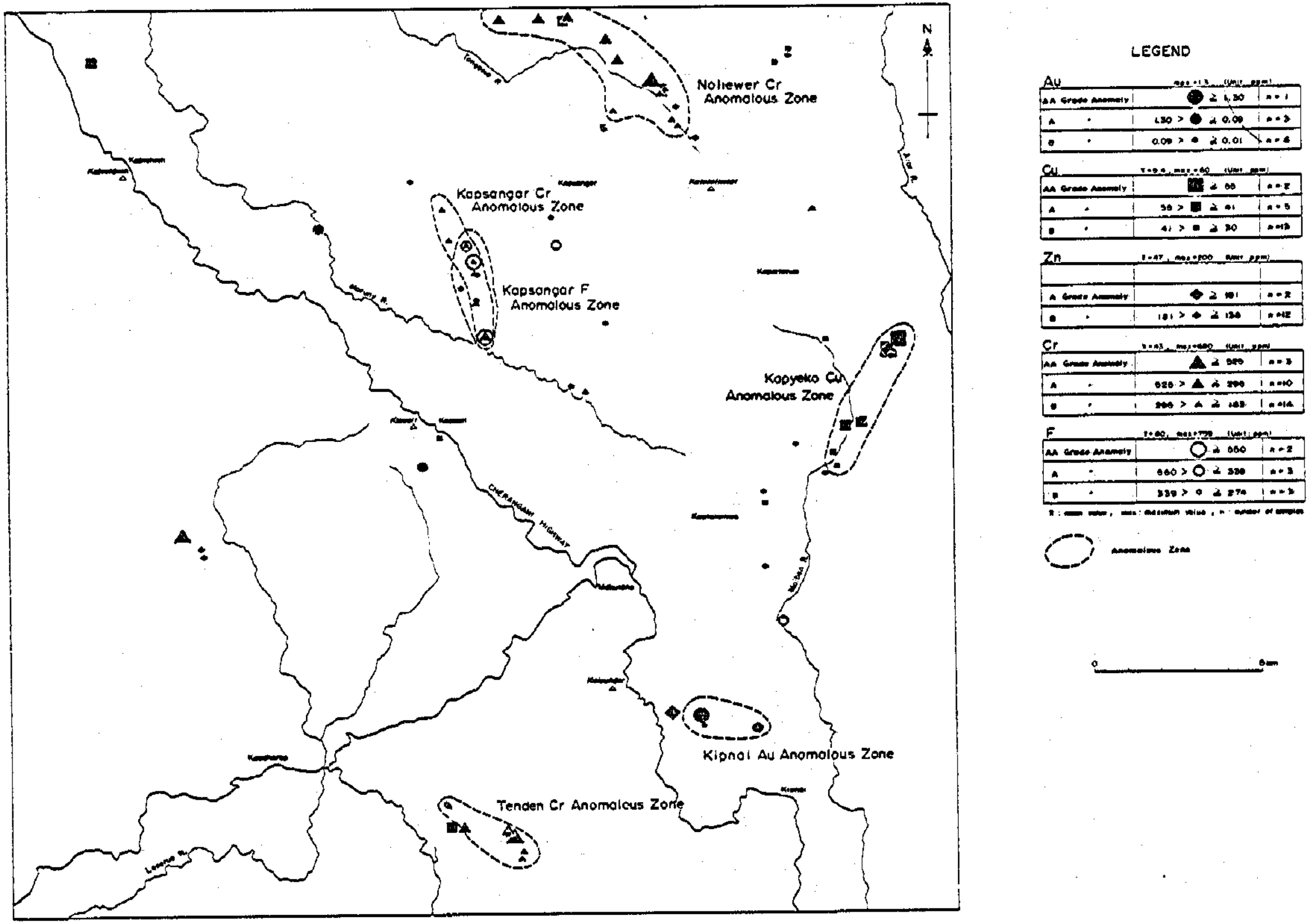


Fig. 2-13 Geochemical Anomaly Map, Regional Survey Area, Phase Ⅱ

2–2 Semi-detailed Survey Area A

The area is situated almost in the central part of the Regional Survey Area, and occupies an area of 120 square kilometers (Fig. 2).

Geology of the area consists of metamorphic rocks of sedimentary and volcanic origin and the intrusive rocks. The former is further divided into the M-2, the M-3, and the M-4 Formations (corresponding to the Basement II, III, IV formations as classified in Phase I). The intrusive rocks are composed of granitoid orthogneiss, foliated granite, migmatitic type granite, metadiorite, metagabbro, serpentinites (serpentinite, dunite and peridotite) and talc schist.

The ore deposits found in the area include the deposits of chromium and nickel, and eluvial gold placer deposit associated with ultrabasic rocks and talc schist.

2–2–1 Geology

The geological map and cross sections of the area are shown in Fig. 2-14. In the Map, symbol of each rock unit used by the Phase I Survey are applied.

(1) Mozambique Metamorphic Rocks

The M-2 Formation is the sequence in the lower-most part of the Mozambique metamorphic rocks in the area. The thickness is estimated to be more than 700 meters. The main rock facies is medium to fine-grained hornblende gneiss (or amphibolite, BIIab). It is, in addition, interbedded with thin layers of biotite gneiss (BIIbg) and quartzite (BIIqt).

The M-3 Formation overlies the M-2 formation and shows relatively wide distribution on both sides of the M-4 Formation. The thickness is estimated to be from 400 meters to 1,500 meters. The rock facies mainly consists of fine-grained biotite gneiss (BIIIbg), which contains muscovite, hornblende and garnet in some places. The intercalated beds includes crystalline limestone (BIIIls), amphibolite (BIIIab) and muscovite quartzite (BIIIqt). Crystalline limestones (BIIIls) are exposed along the lang River and composed of two beds, 70 meters and 300 meters thick respectively. It is strongly variable in thickness, and shows a poor continuity.

The M-4 Formation overlies the M-3 Formation and shows a narrow distribution one to two kilometers wide on both side of the axis of the Telot syncline. The thickness seems to be 600 to 800 meters. The rock facies is as followings.

Green schists intercalate amphibolites, hornblende gneiss, quartzite, quartz schist (BIVgt), biotite gneiss (BIVbg) and crystalline limestone (BIVls) beds. Quartz schists are further classified

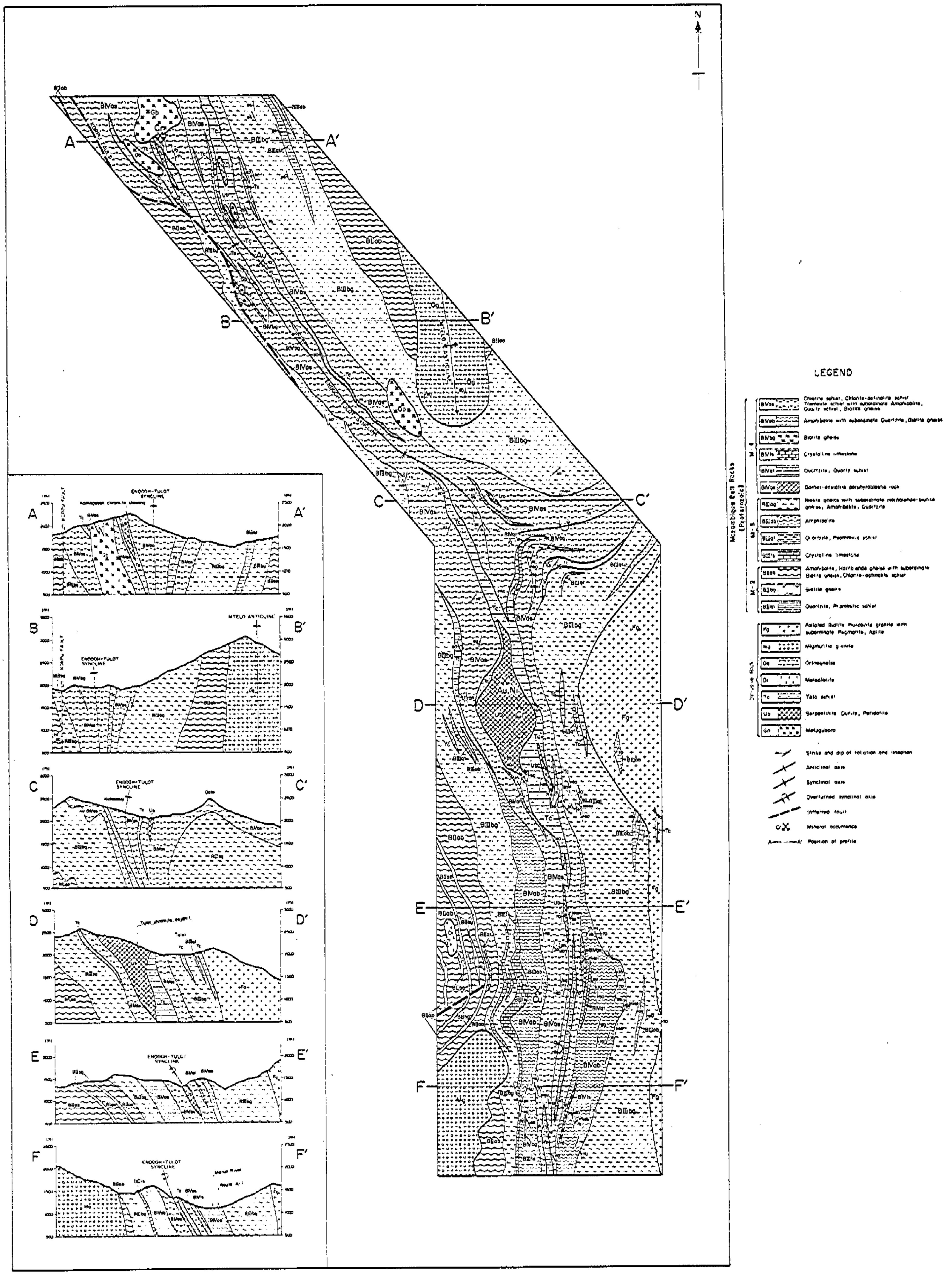


Fig. 2-14 Geological Map and Profiles, Semi-detailed Survey Area A

into hematite-magnetite-quartz schist, muscovite-biotite-quartz schist and hornblende-quartz schist. Amphibolites or hornblende gneisses are found in abundance in green schist beds (BIVas) to the northeast of Matokolal, and further they are distributed in a fairly thick beds underlying the green schist bed (BIVas) on the south of Telot.

(2) Intrusive Rocks

Among the intrusives comprising granitoid orthogneiss, foliated granite, migmatitic granite, metadiorite, metagabbro, serpentinite and talc schist, the most remarkable intrusions are the last two.

Serpentinites are distributed in the M-4 Formation which consist mainly of chlorite schist and amphibole schist as lenticular intrusive masses. Seven masses of serpentinite of large and small sizes are known in the area. The largest one is the Telot serpentinite mass, showing a form of pod extending for 3.5 kilometers with a maximum width of 1.3 kilometers in E-W. The area of exposure is about two square kilometers. Other masses are all small in size, less than several hundred meters in width. It seems that serpentinites have a form of intrusion parallel with the schistosity. The rock is often surrounded by talc schist in the peripheral, which altogether form a intrusive zone of ultrabasic rocks.

Although the grade of serpentinization is varied, it is much more in the small masses and in the surrounding part of the large masses. Antigorite, talc and calcite are observed as the secondary minerals associated with serpentinization. Weakly serpentinized part is observed in the Telot mass, in which olivine occupies 80 to 90 percent of the minerals.

The identification of the original rock of sepentinites based on relic minerals leads to classification of the rocks in the Telot mass as wehrlitic ones and lherzolitic ones. Both types are found in the surroundings of chromite deposit.

Talc schist is distributed mainly as lenticular to bedded intrusive mass in the M-4 Formation independently or associated with serpentinites. It seems that it is in harmonious with the schistose rocks in the surroundings. The width of several meters up to 550 meters and the maximum elongation of eight kilometers have been confirmed. The number of the masses is more than 15, and an intrusive zone several hundred meters to two kilometers wide has been formed in the BIVas unit.

The rock facies is characterized by white to pale gray, weakly schistose rocks, in which the vesicules covered by iron oxide film are often observed. It is almost composed of talc megascopically.

(3) Geological Structure

Assay Result

Sample No.	Type	Cr %	Fe %	Al %	Pt g/t	V ppm	Ni %	Co %	Cu %
CR 201	massive ore	26.20	29.5	7.1	0.10	550	0.04	<0.01	<0.01
CR 203	〃	26.80	27.5	6.4	0.15	600	0.04	<0.01	<0.01
CR 208	〃	27.80	31.6	4.3	0.10	425	0.04	<0.01	<0.01
CR 212	〃	26.30	23.4	5.0	0.10	450	0.05	<0.01	<0.01
Average	—	26.78	28	5.7	0.11	506	0.04	<0.01	<0.01

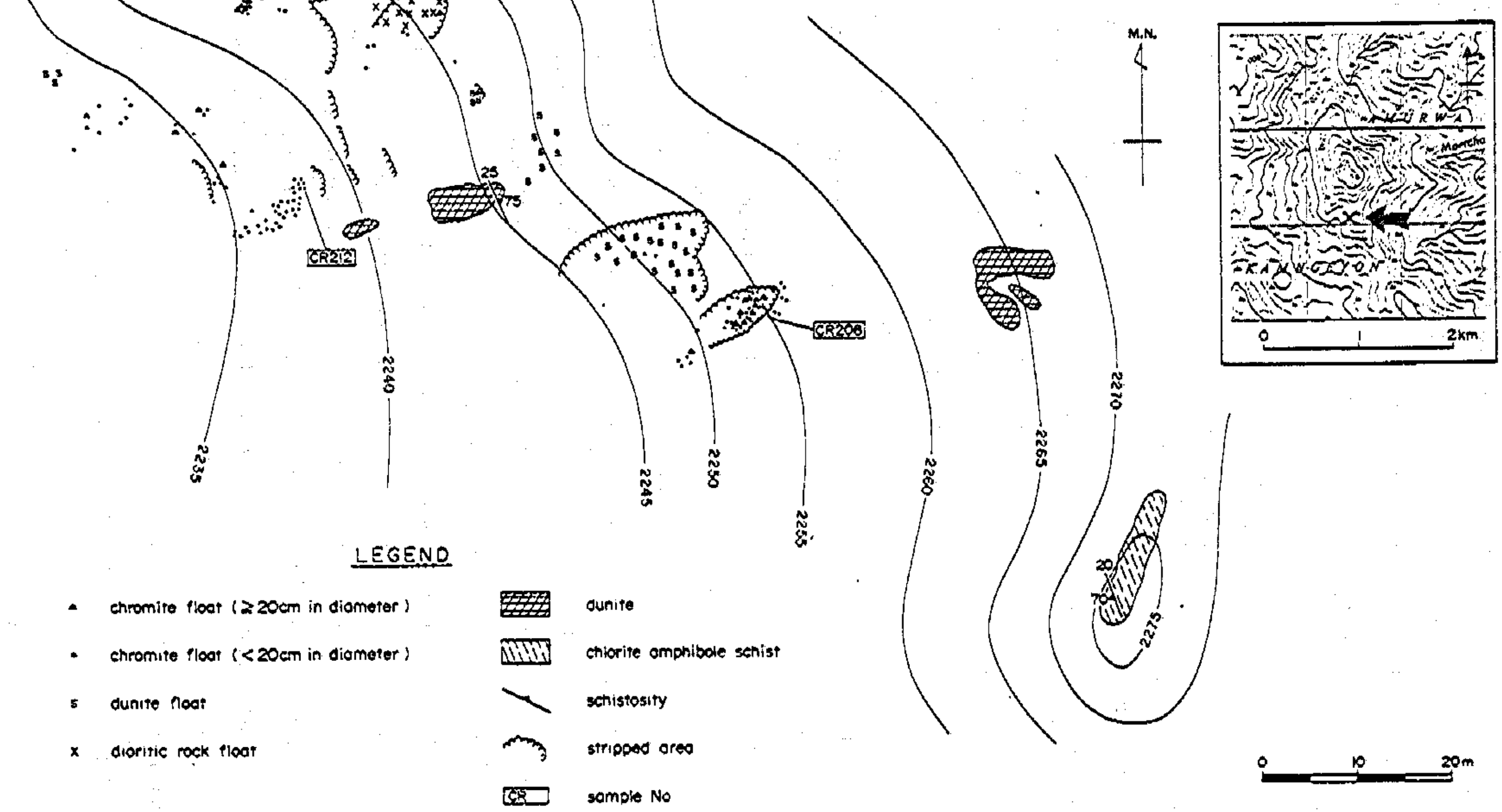


Fig. 2-15 Geological Sketch Map of Kamngeyon Chromite Prospect

The principal geologic structure of the area A is controlled by the Telot syncline. The Telot syncline has it's axis in the green schist zone of the M-4 Formation, and the synclinal axis strikes approximately northwards from Wakorr to Matokolal, shifting to northwesterly from cated structure, which makes it difficult to express the Telot syncline as a single syncline. It shows a structure of overturned syncline steeply dipping toward the east on the southern side of the Telot area.

2–2–2 Ore Deposits

The ore deposits and showing found in the area include the chromium, nickel and gold deposits at Telot and the chromite showing at Kammgeyon. The Telot deposits are mentioned later in the clause 2–4–2.

Kammgeyon chromite showing

Fig. 2–15 shows the geology of the site of the showing. The exposures of serpentinites, amphybole schists and gabbros are observed in the area where chromite floats occur, and talc schists and hornblende gneisses are seen in the surrounding area. The schistose rocks strike N-S to NW-SE and dip 40° to 70°E. The size of the serpentinite body which is likely to be the host rock of the ore deposit is assumed to be three kilometers with a northerly extension and 250 meters in maximum width in E-W. The northern extension of the rock has been cut by an gabbro mass. The Serpentinites are identified as dunite on the basis of microscopic observation.

The chromite showing is composed of chromite floats and no outcrop is observed. The floats are distributed for an extent of 80 m (E-W) x 50 m (N-S), in which three places show a little concentrated distribution. The areas of each place are 5 m x 15 m, 10 m x 15 m and 5 m x 10m. Most of the floats are 5 to 25 centimeters in diameter, reaching up to 60 centimeters.

The assay results of ores are shown in Fig. 2–15. The grades of chromium correspond to 38.29 to 40.63 percent after conversion into Cr_2O_3, which are considerably lower than those of Telot.

Although it is thought that the original chromite bodies of the showing form small lenticular ore bodies similar to that of Telot, the scale seems to be considerably small as compared with that of the Telot ore body judging from the extent of serpentinites and chromite float zone.

2–2–3 Geochemical Survey

(1) Method of Survey

Several ridges crossing the zone of serpentinites and talc schists were selected as sampling lines, and 205 soil samples were collected and analyzed for Cr, Ni, Co, V and Pt. In addition, 59 soil samples collected in the Telot serpentinite body were also analyzed for Au.

Univariate statistical analysis and principal component analysis were applied for statistical analysis.

(2) Statistical Values, Data Processing (Univariate Statistical Analysis)

Table 2–9 lists the statistic values of analytical elements. Au and Pt were excluded from statistic treatment because analytical results for them are mostly under the detection limits.

Fig. 2–16 shows the cumulative frequency distribution curves for each element except Au and Pt.

Table 2–10 gives the correlation coefficients of the elements and |R| values of significance test.

Since the number of samples over threshold value are very few, high values in the background population are selected as high-content values for each element. The values of Cr, Ni, Co and V are over $\overline{X} + 1.5\sigma$ and that of Pt and Au are over detection limit.

Table 2-11 gives the anomalous values, high-content values and number of samples corresponding to them for each element.

(3) Interpretation of Geochemical Anomalies (Univariate Statistical Analysis)

The followings are the interpretation of geochemical anomalies for each element.

(a) Cr

No anomalous sample is in the area. Twenty samples among high-content ones are distributed concentrically in the two areas, Telot and Kamngeyon. It is evident that the ultrabasic rocks in which Telot and Kamngeyon chromium deposits are emplaced, cause the high-content value samples.

(b) Ni

Two anomalous samples (Ni : 6,300, 26,400 ppm) collected from residual soil of serpentinite, are from the Telot area. These anomalies reveal local nickel mineralization. No anomalous samples were obtained around the known garnierite nickel showing and it means the zone of residual nickel mineralization is situated in the deeper place than the sampling depth. The distribution of high-content samples is mostly same as is of Cr.

(c) Co

The Telot serpentinite mass is the parent rock of two anomalous samples (Co : 260, 550 ppm). The lower grade one was taken near the garnierite nickel showing. The distribution of high-content samples is mostly same as it is with Cr and Ni.

(d) V

Anomalous sample (V : 460 ppm) is only one, and was taken at a point about 3 km south of Telot. The distribution of the anomalous and high-content samples shows a limited range centering around the three areas, Kamngeyon, Gato and the area to the southwest of Telot. The parent rocks of the samples are mostly green schist. No relation to mineralization might be estimated.

(e) Pt

Four anomalous samples (Pt : 100 ppb) and thirteen high-content samples (Pt : 50 ppb) were collected in the area. It seems that the distribution of anomalous and high-content samples bears no relation to the ultrabasic rocks but have relations with green schists to some degree. No connection with mineralization might be pointed out.

(f) Au

Fifty-nine soil samples in and around the Telot serpentinite mass were additionally analyzed for Au in consideration of eluvial gold mineralization in the area. An anomalous sample (Au : 120 ppb) and four high-content samples (Au : 120 ppb) and four high-content samples (Au : 30 to 110 ppb) were all collected from residual soil of serpentinites and corresponds well to the known gold occurrence in the area. However, no correlation between Au and Cr, and Ni and Co might suggest the different behaviour in mineralization between Au and other three elements.

(4) Principal Component Analysis

General Remarks

Judging from the high correlation coefficients and the similar distribution of high-content samples in the Telot and the Kamngeyon area, the elements Cr, Ni and Co are estimated to behave geochemically in the same manner. From this viewpoint, principal component analysis was carried out in order that the informations of the three elements may be represented by a parameter selected objectively.

Correlation matrix given in Table 2–10 was used for the treatment except for the coefficient relating Pt and Au. Table 2–12 lists the results of principal component analysis.

The first principal component, Z_1 represents 69 percent of total amount of information on the analytical data, and is strongly affected by the values of Cr, Ni and Co in almost the same rate. This means that Z_1 is the proper indicator representing the elements. The high values and anomalous values of Z_1 are expected to indicate the distribution of ultrabasic rocks and mineralization of chromium or nickel respectively.

The second principal component, Z_2 represents 24 percent of total amount of analytical data information, and is decided mainly by the value of V.

Table 2-9 Statistic Values of Analyzed Elements, Semi-detailed Survey Area A

Element Unit	Cr ppm	Ni ppm	Co ppm	V ppm	Pt ppb	Au ppb
Number of Samples	205	205	205	205	205	59
Minimum Value	4	7	7	15	<50	<10
Maximum Value	5,450	26,400	550	460	100	120
Range	5,446	26,393	543	445	>50	>120
Mean	339.6	195.6	59.6	155.3	-	-
S.D. (Log)	0.62	0.74	0.27	0.23	-	-
M + 1.5 S.D.	2,891	2,520	151	344	-	-
M + 2 S.D.	5,919	6,022	211	446	-	-
Clarke Number	100	75	20	135	5	4

Table 2-10 Correlation Coefficients, Semi-detailed Survey Area A

	Cr	Ni	Co	V	Pt	Au
Cr	1.00					
Ni	0.87 (205)	1.00				
Co	0.81 (205)	0.89 (205)	1.00			
V	-0.20 (205)	-0.25 (205)	-0.12 (205)	1.00		
Pt	-0.03 (17)	0.00 (17)	0.08 (17)	-0.12 (17)	1.00	
Au	0.15 (58)	0.16 (58)	0.18 (58)	0.04 (58)	0.00 (7)	1.00

( ) Number of Paired Samples

R(ϕ,e)
ϕ: degree of freedom
e: significance level

|R|(5,0.01) = 0.875
|R|(15,0.01) = 0.606
|R|(56,0.01) = 0.336
|R|(203,0.01) = 0.180

Table 2-11 Thresholds, and Classification of Anomalous Value, Semi-detailed Survey Area A

Element	Anomalies	Threshold	Background High-content value
Cr (ppm)	≥5,919 (0)	5,919	5,919>≥2,891 (20)
Ni (ppm)	≥6,022 (2)	6,022	6,022>≥2,520 (22)
Co (ppm)	≥211 (2)	211	211>≥151 (15)
V (ppm)	≥446 (1)	446	466>≥344 (8)
Pt (ppb)	≥100 (4)	100	100>≥50 (13)
Au (ppb)	≥120 (1)	120	120>≥30 (4)

( ) Number of Samples

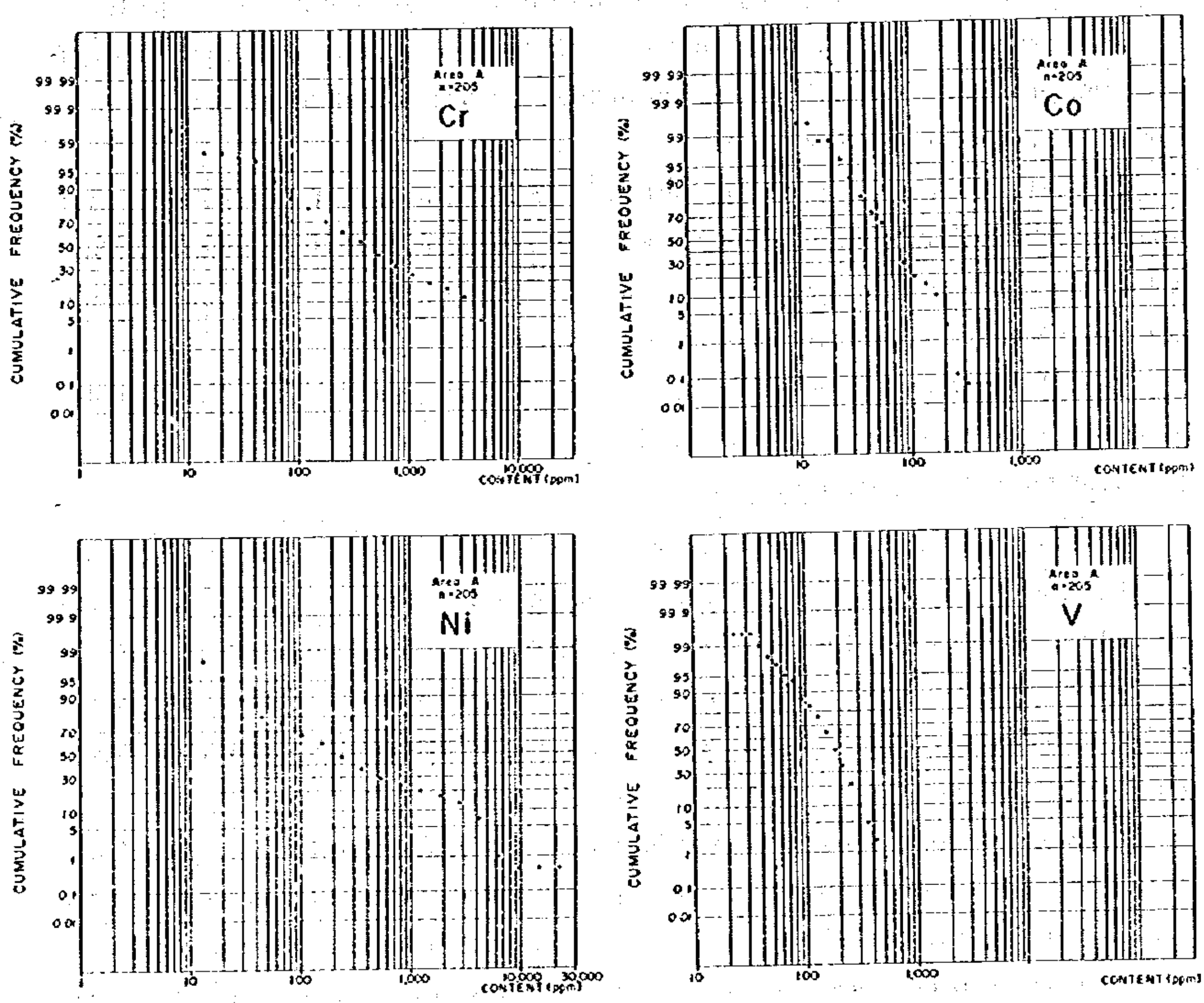


Fig. 2-16 Cumulative Frequency Distribution of Analytical Elements, Area A

Distribution and Classification of Z_1 Score

Univariate statistical analysis was carried out for the population comprizing principal component scores of Z_1. Table 2-13 gives the statistic values of Z_1 score. Fig. 2–18 and Fig. 2–19 show the cumulative frequency distribution curve and histgram of Z_1 score respectively.

Three populations, high score, medium score and low score population with proportion of 18%, 46% and 36% respectively, were resolved from the frequency distribution curve of Z_1 score by the method of A.J. Sinclair (1974).

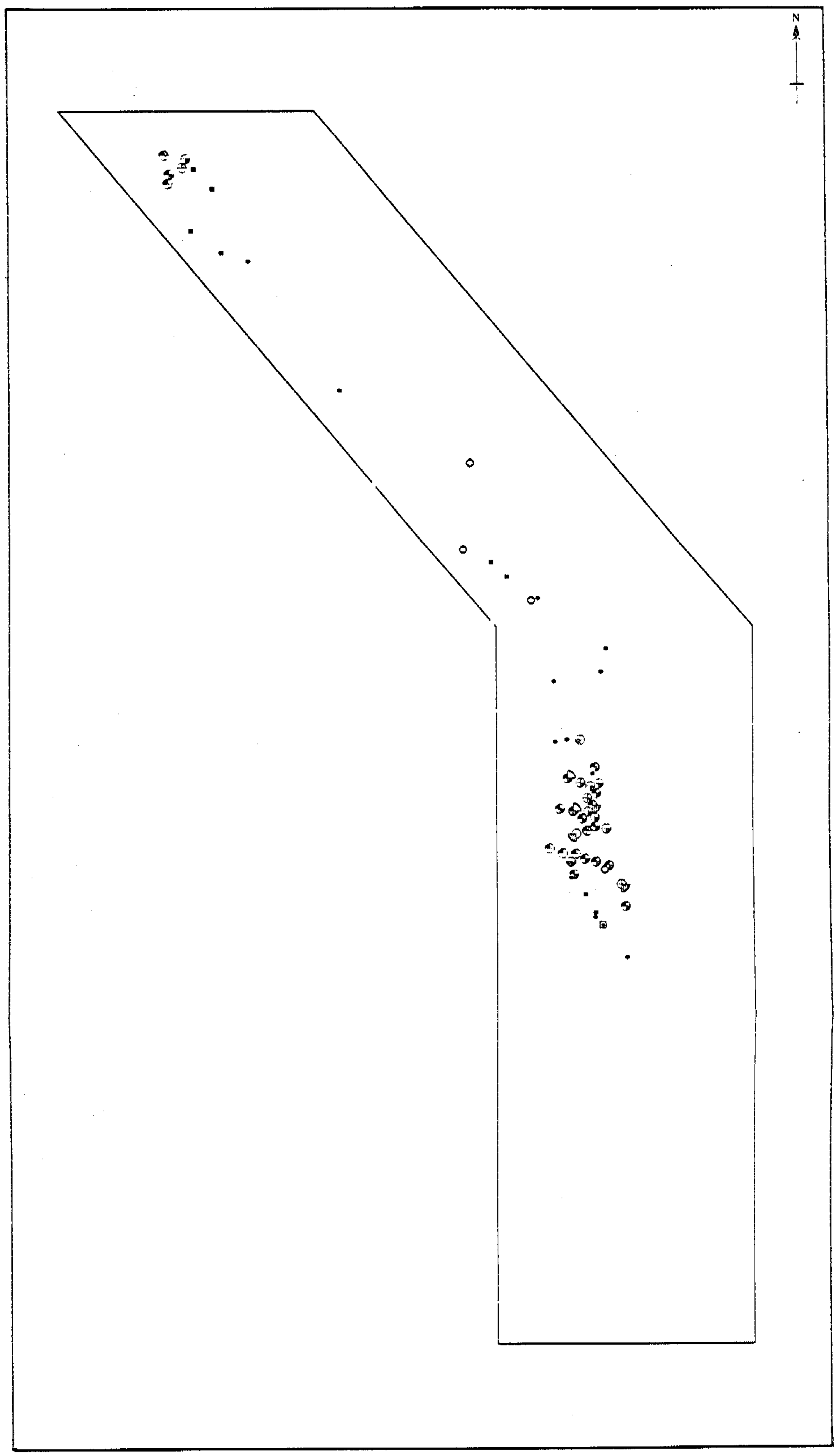
The high score population with proportion of 18% is composed of 36 samples collected from residual soil of ultrabasic rocks or talc schists. The population was classified into five groups, A to E group, bordered by values of 99% level, 84.1% level ($x - \sigma$) 50% level (x), 15.9% level ($x + \sigma$), 2.3% level ($x + 2\sigma$) in probability scale.

Table 2–14 gives a classification of Z_1 scores in high score population. Fig. 2-20 illustrates the distribution of high score samples classified.

Results of Principal Component Analysis

The 36 samples of high score population center in two areas as Telot high Z_1 score zone and Kamngeyon high Z_1 score zone, reflecting obviously the distribution of ultrabasic rocks mineralized and talc schist. The former zone contains thirty high score samples which mean 83% of the total, and covers the Telot serpentinite mass and talc schist in which chromium and nickel mineralizations occur. The latter zone consists of six high score samples and covers serpentinite body in which Kamngeyon chromium showing is emplaced.

It seems that none or very small ultrabasic rock mass is distributed in the sampled area except for the two zones in the Area A. The high score samples over C grade are all in the Telot high Z_1 score zone especially in the eastern half, whereas, the samples in Kamngeyon high Z_1 score zone are of D or E grade. These facts help to suggest that Kamngeyon area is inferior to Telot area concerning not only the size of ultrabasic rock mass but also the degree of mineralization.



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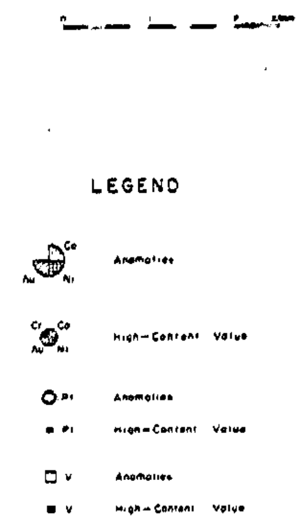


Element	Anomalies	High-Content Value
Cr ppm	≧5,919 (n=0)	5,919> ≧2,691 (n=20)
Ni ppm	≧6,022 (n=2)	6,022> ≧2,520 (n=22)
Co ppm	≧211 (n=2)	211> ≧151 (n=16)
Au ppb	≧120 (n=1)	120> ≧30 (n=4)
Pt ppb	≧100 (n=4)	100> ≧50 (n=13)
V ppm	≧446 (n=1)	446> ≧344 (n=8)

n : number of samples

Fig. 2-17 Geochemical Anomaly Map, Semi-detailed Survey Area A

Table 2-12 Results of Principal Component Analysis, Semi-detailed Survey Area A

Principal Component	Eigen Value	Principal Contribution Ratio %	Cumulative Contribution Ratio %	Eigen Vector				Factor Loading			
				Cr	Ni	Co	V	Cr	Ni	Co	V
Z1	2.77	69	69	0.56	0.58	0.56	-0.18	0.93	0.97	0.93	-0.3
Z2	0.94	24	93	0.08	0.05	0.18	0.98	0.08	0.05	0.18	0.95
Z3	0.19	5	98	-0.77	0.11	0.63	-0.06	-0.34	-0.05	-0.23	-0.26
Z4	0.09	2	100	-0.30	0.80	-0.51	-0.08	-0.09	0.24	-0.15	0.02

Table 2-13 Statistic Values of Principal Component Z1

Principal Component	Number of Cases	Minimum Value	Maximum Value	Mean	Standard Deviation
Z1	205	-3.0062	4.263	0.3106	1.6656

Table 2-14 Classification of Z1 Scores in High Score Population

Grade	A	B	C	D	E
Score	≥4.05	4.05>≥3.50	3.50>≥2.95	2.95>≥2.40	2.40>≥1.70
Number of Samples	1	3	12	13	7

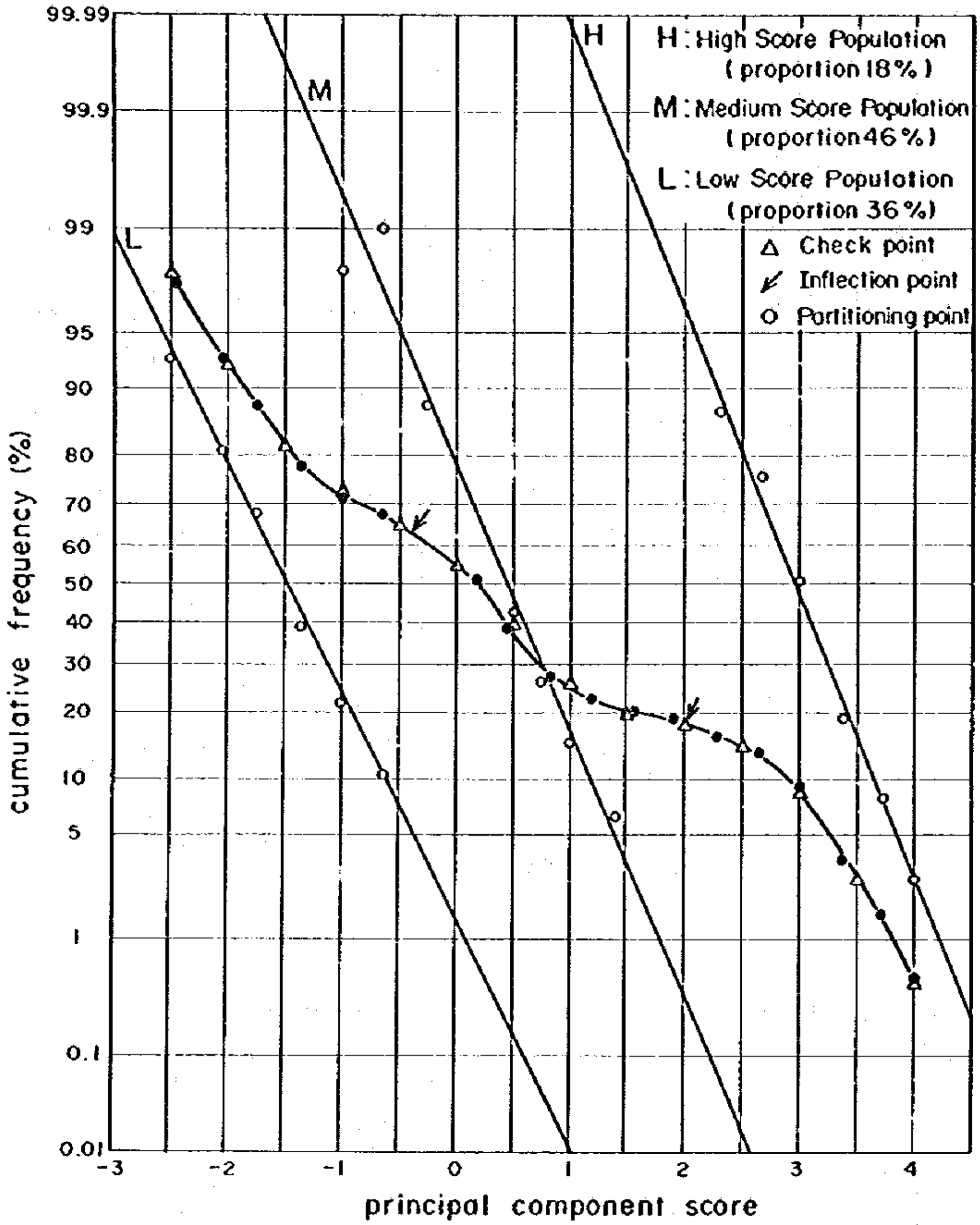


Fig. 2-18 Cumulative Frequency Distribution of Z1 Scores and Separated Three Lognormal Populations, Area A

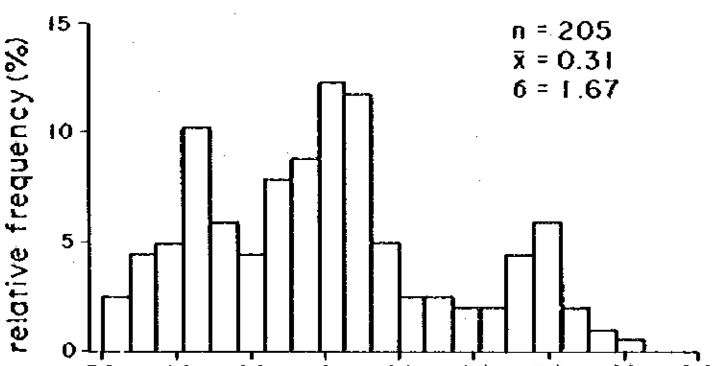


Fig. 2-19 Histgram of Principal Component Score Z1, Area A

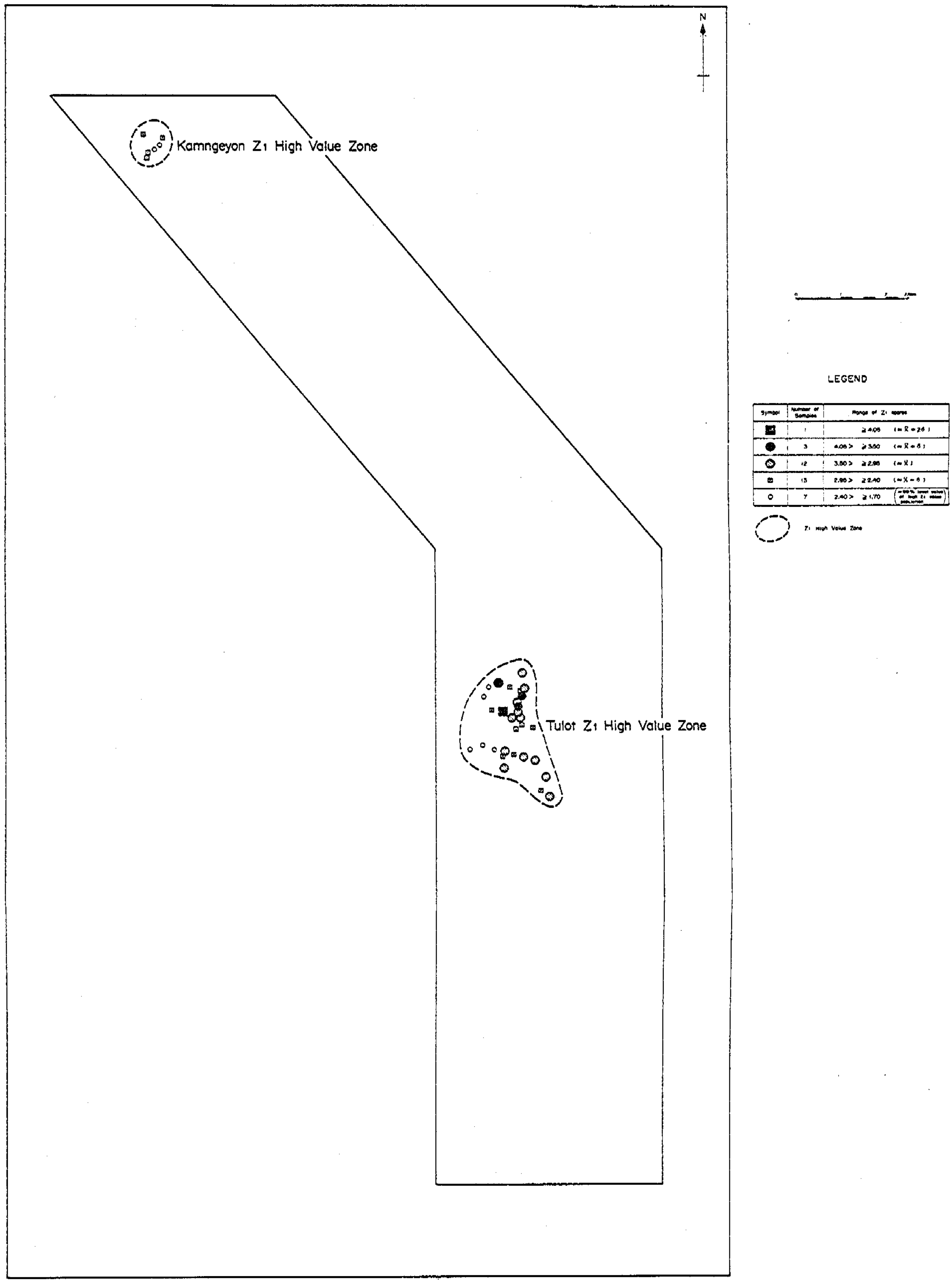


Fig. 2-20 Geochemical Map for Principal Component Z1, Semi-detailed Survey Area A

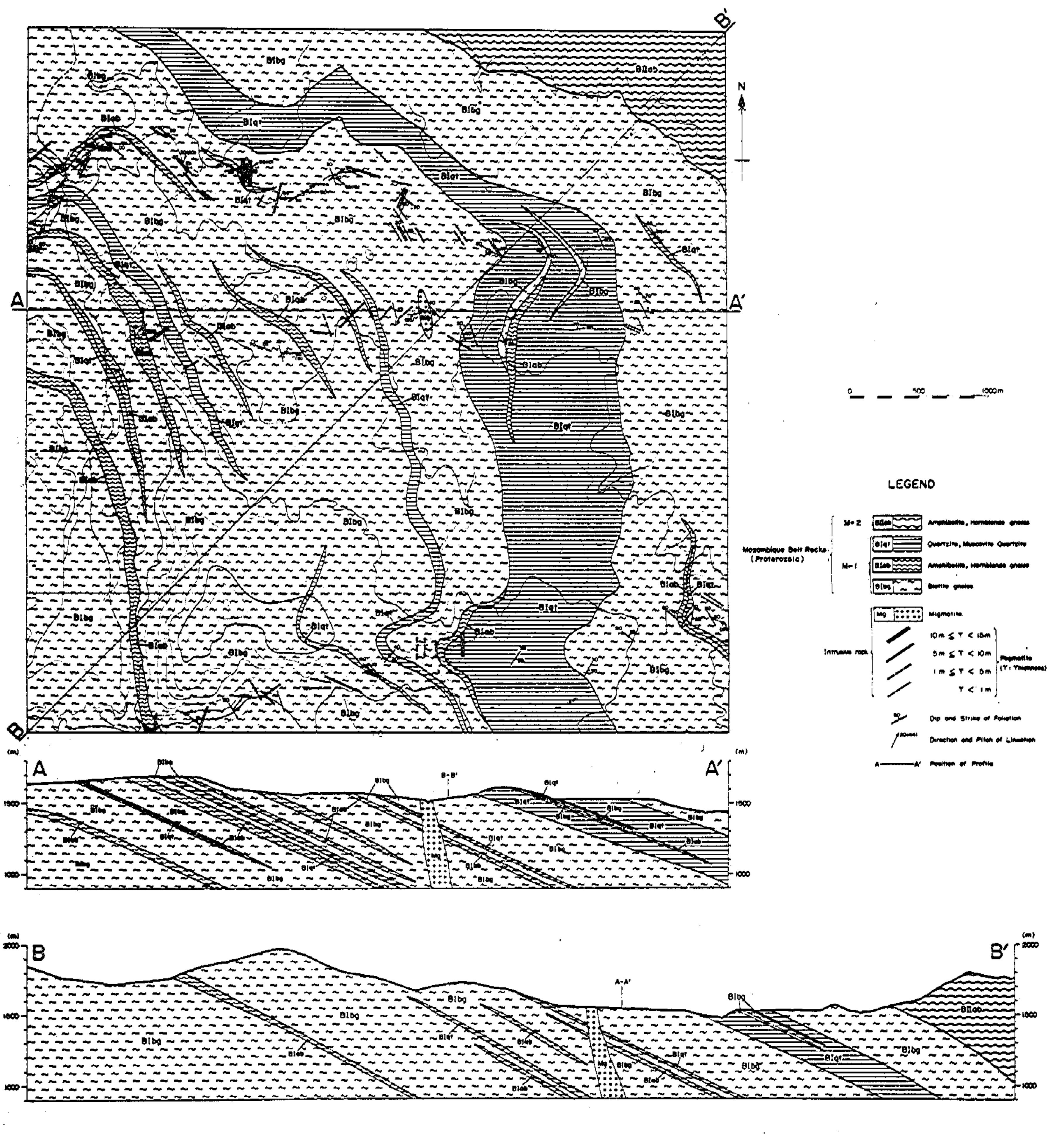


Fig. 2-21 Geological Map and Profiles, Semi-detailed Survey Area B

2–3 Semi-detailed Survey Area B

The area is situated in the west of the central part of the regional survey area and occupies an area of 25 km^2.

Many pegmatite dikes are reported to occur in the area. On the other hand, to the west of northern part of the regional survey area, there are columbite-samarskite-mica deposits occurring in pegmatites at Kenailet, Morukong and Kokusan which were actively worked in the last half years of 1950's.

The object of the survey is to study the potentiality of occurrence of ore deposits related with the pegmatites in the area.

2–3–1 Geology

The geology of the area is composed of M-1 and M-2 formations of Mozambique Metamorphic rocks, numerous small pegmatites and a small body of migmatite (Fig. 2–21).

M-1 formation occupies almost whole of the area and consists mainly of biotite gneisses with subordinate quartzites and bornblende gneisses (amphibolite).

M-2 formation covers in the northeastern corner of the area and consists only of hornblende gneiss (or amphibolites) unit.

A migmatite occurs in the center of the area as a small body of 80 meters wide and 300 meters long.

Numerous pegmatites occur throughout the area and the number of confirmed bodies by the survey is seventy-eight.

Among them, six bodies are about 10 meters thick, another six are 5 to 7 meters, thirty-nine are 1 to 5 meters and twenty-seven are less than 1 meter thick.

The contacts between pegmatites and wall rocks are mostly concordant and some show gradual change, though a small number of pegmatites cut the wall rocks.

Most pegmatites contain biotite as the main mafic mineral, and only two pegmatite contain more muscovite than biotite. Biotite pegmatites are composed of plagioclase, quartz, microcline and biotite. Muscovite is partly observed.

Other minerals such as culumbite and samarskite have not been observed in the survey. The fact corresponds to the assay results that no high contents nor anomalous values of Nb and Ta were detected by geochemical survey.

Statistical results of the contact plane between pegmatites and wall rocks show the direction of intrusion concentrate around N30°W (strike) and 30°NE (dip). This orientation is almost in parallel with the general one of foliation planes of wall rocks.

The fact that most pegmatites in the area seem to intrude concordantly into biotite gneisses, grade into the latter and that there are no intrusive rocks near and around the area suggests genesis of pegmatite to be partial melting of pelitic metamorphic rocks under deeper part of orogenic belt, which is termed ultrametamorphism.

And it means that there is little possibility of any useful mineral occurrences related with the pegmatites.

2–3–2 Geochemical Survey

Survey lines were mainly set in the north and south part of the area where many pegmatite occurrences are known. Fifty soil samples were collected and analysed for six elements as Nb, Ta, Sn, W, Li, and F.

(1) Statistic Values, Distribution and Data Processing

Table 2–15 gives the statistic values of analytical elements. Four elements, Nb, Ta, Sn and W were excluded from statistic processing because their analytical results are mostly under the detection limits. The analytical results of Li and F under detection limit were calculated as 0.4 ppm and 4 ppm respectively. Cumulative frequency distribution curve for Li and F are illustrated in Fig. 2–21.

Table 2-15 Statistic Values of Analyzed Elements, Semi-detailed Survey Area B

Element Unit	Nb ppm	Ta ppm	Sn ppm	W ppm	Li ppm	F ppm
Number of Samples	50	50	50	50	50	50
Minimum Value	10	2	1	2	1	26
Maximum Value	10	2	4	16	8	184
Range	–	2	4	16	8	158
Mean	–	–	–	–	2.7	82.8
S.D. (Log)	–	–	–	–	0.327	0.20
M + S.D.	–	–	–	–	5.7	130.5
M + 2 S.D.	–	–	–	–	12.2	205.8
Clarke Number	20	3.4	2	1.3	20	620

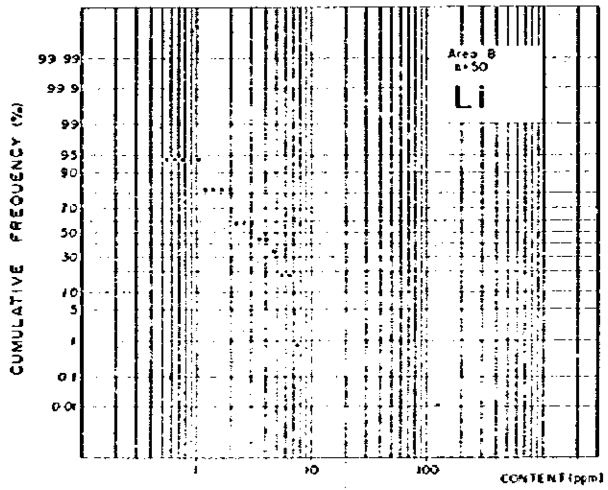
No correlation coefficient was obtained for Nb, Ta, Sn and W because of the existences of abundant analytical results under detection limit except it between Li and F. The correlation coefficient and the |R| (48, 0.01) value between Li and F are 0.18 and 0.361 respectively, but they show the correlation is denied with significance level of one percent.

No threshold value is determined for Nb, Ta, and Sn because their analytical values are mostly under the detection limit and their maximum values are so low as they are almost same as the Clarke number or under it. The maximum value of W, 16 ppm is pretty high compared with all other results under 4 ppm, therefore 16 ppm was decided as threshold value of W. For Li and F, threshold values are determined as $\bar{X} + 2\sigma$, but no sample over the values was found. High-content samples whose values are over $\bar{X} + \sigma = 5.7$ ppm, were distinguished only for Li, because they show maldistribution.

Fig. 2–23 gives the distribution of an anomalous sample and high-content samples for W and Li.

(2) Interpretation of Geochemical Anomalies

All the analytical results show very low in contents. As to Nb, Ta, Li and F even the maximum values are under Clarke number. Only one geochemically anomalous sample was selected for W, but the value is not so high as the mineralization can be expected. Distribution of seven high-



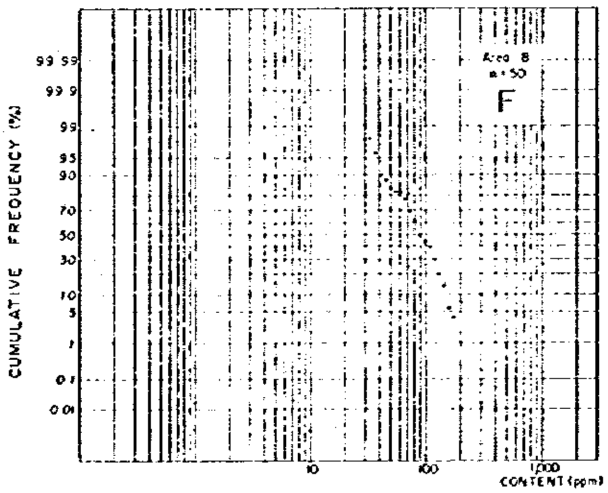
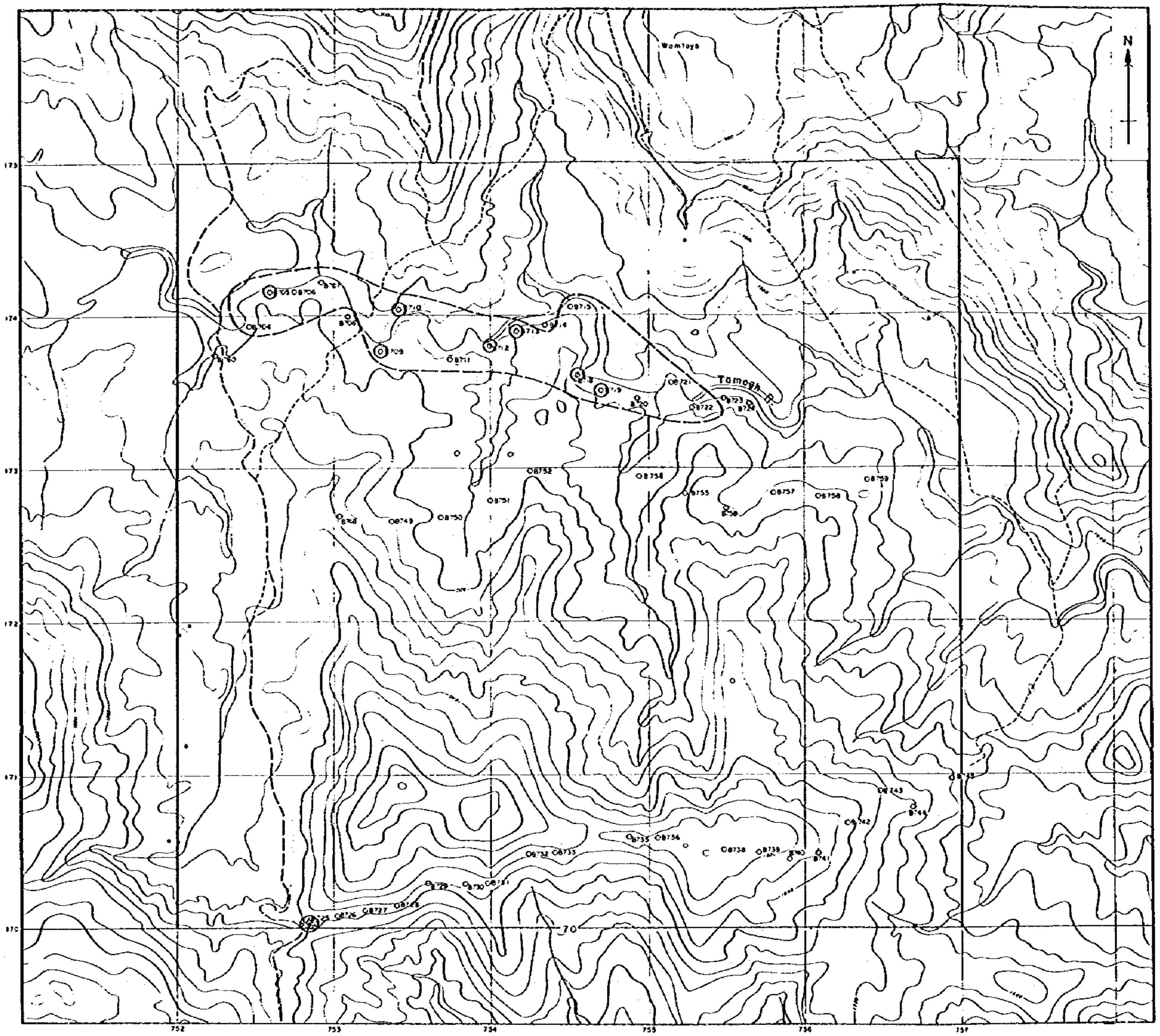


Fig. 2-22 Cumulative Frequency Distribution of Analytical Elements, Semi-detailed Survey Area B



0 — 1km

LEGEND

W : ⊛ Anomalous Sample ≥ 16 ppm

Li : ○ High-Content Samples ≥ 5.7 ppm ($\bar{X}+\sigma$)

◯ High Li Content Zone ≥ 5 ppm

Assay Results of Soil Samples

Unit : ppm

	SAMPLE No	Nb	Ta	Sn	W	Li	F
1	B704	<10	<2	1	<2	5	47
2	B705	<10	<2	<1	3	6	66
3	B706	<10	<2	<1	<2	5	57
4	B707	<10	<2	1	3	5	26
5	B708	<10	<2	1	<2	4	103
6	B709	<10	2	4	2	7	140
7	B710	<10	<2	<1	<2	6	85
8	B711	<10	<2	<1	4	5	119
9	B712	<10	<2	1	2	6	117
10	B713	<10	<2	<1	<2	6	123
11	B714	<10	<2	1	<2	3	70
12	B715	<10	2	1	<2	5	84
13	B718	<10	2	1	2	7	109
14	B719	<10	<2	1	<2	8	110
15	B720	<10	<2	1	<2	5	108
16	B721	<10	<2	3	<2	5	157
17	B722	<10	<2	<1	<2	5	184
18	B723	<10	<2	<1	<2	2	44
19	B724	<10	<2	1	<2	2	90
20	B725	<10	<2	1	16	4	147
21	B726	<10	<2	1	<2	3	96
22	B727	<10	<2	<1	<2	2	170
23	B728	<10	<2	<1	<2	2	104
24	B729	<10	<2	<1	2	5	127
25	B730	<10	<2	<1	<2	4	89
26	B731	<10	<2	<1	<2	3	140
27	B732	<10	<2	<1	2	3	80
28	B733	<10	<2	<1	<2	3	67
29	B735	<10	<2	<1	<2	3	46
30	B736	<10	<2	<1	<2	2	62
31	B738	<10	<2	<1	<2	2	45
32	B739	<10	<2	<1	<2	1	82
33	B740	<10	<2	<1	<2	5	70
34	B741	<10	<2	1	<2	4	58
35	B742	<10	<2	<1	<2	1	129
36	B743	<10	<2	<1	<2	1	66
37	B744	<10	<2	<1	<2	2	39
38	B745	<10	<2	<1	<2	<1	84
39	B748	<10	<2	<1	<2	1	54
40	B749	<10	<2	<1	<2	<1	38
41	B750	<10	<2	<1	<2	2	74
42	B751	<10	<2	<1	<2	1	99
43	B752	<10	<2	3	<2	1	119
44	B754	<10	<2	<1	<2	2	82
45	B755	<10	<2	<1	<2	2	74
46	B756	<10	<2	<1	<2	4	118
47	B757	<10	<2	<1	<2	2	158
48	B758	<10	2	<1	<2	6	38
49	B759	<10	<2	<1	<2	<1	81
50	B760	<10	<2	<1	<2	2	107

○ B712 Sample Number and Location

Fig. 2-23 Geochemical Anomaly Map, Semi-detailed Survey Area B