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

PHASE II

DECEMBER 1984

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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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 Metal Mining Agency of Japan organized a survey team consisting of three members in 1984, the second year of the survey project, and despatched the team to Kenya during the period from July 13 to September 22, 1984.

The on-site survey was completed as scheduled 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 describes the survey results in the second year and will form part of the final report.

Lastly, we would like to express our heartful 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, 1984

Keisuke Arita
President,
Japan International Cooperation Agency

Masayuki Nishiie
President,
Metal Mining Agency of Japan

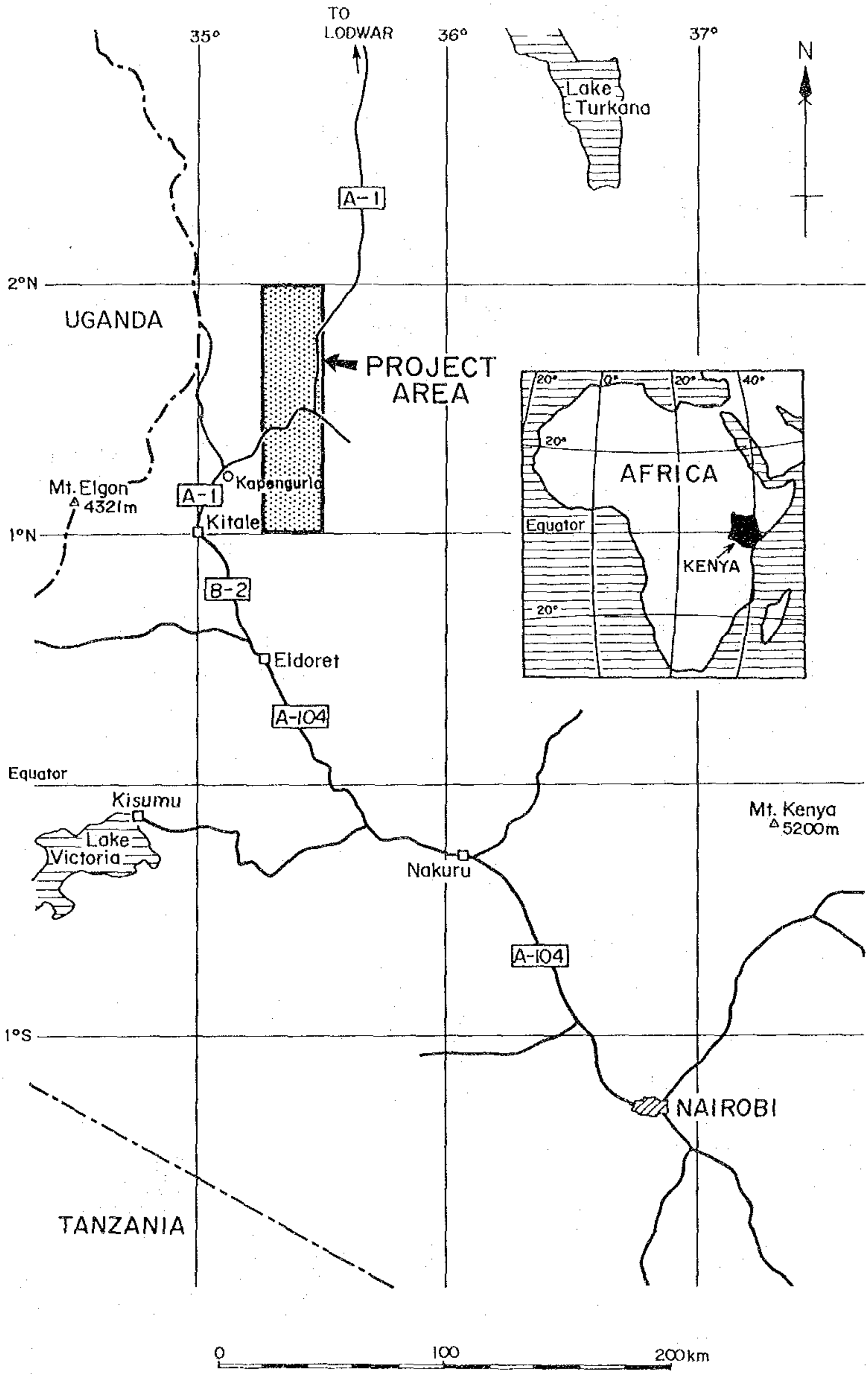

Fig. 1 Location Map of The Project Area

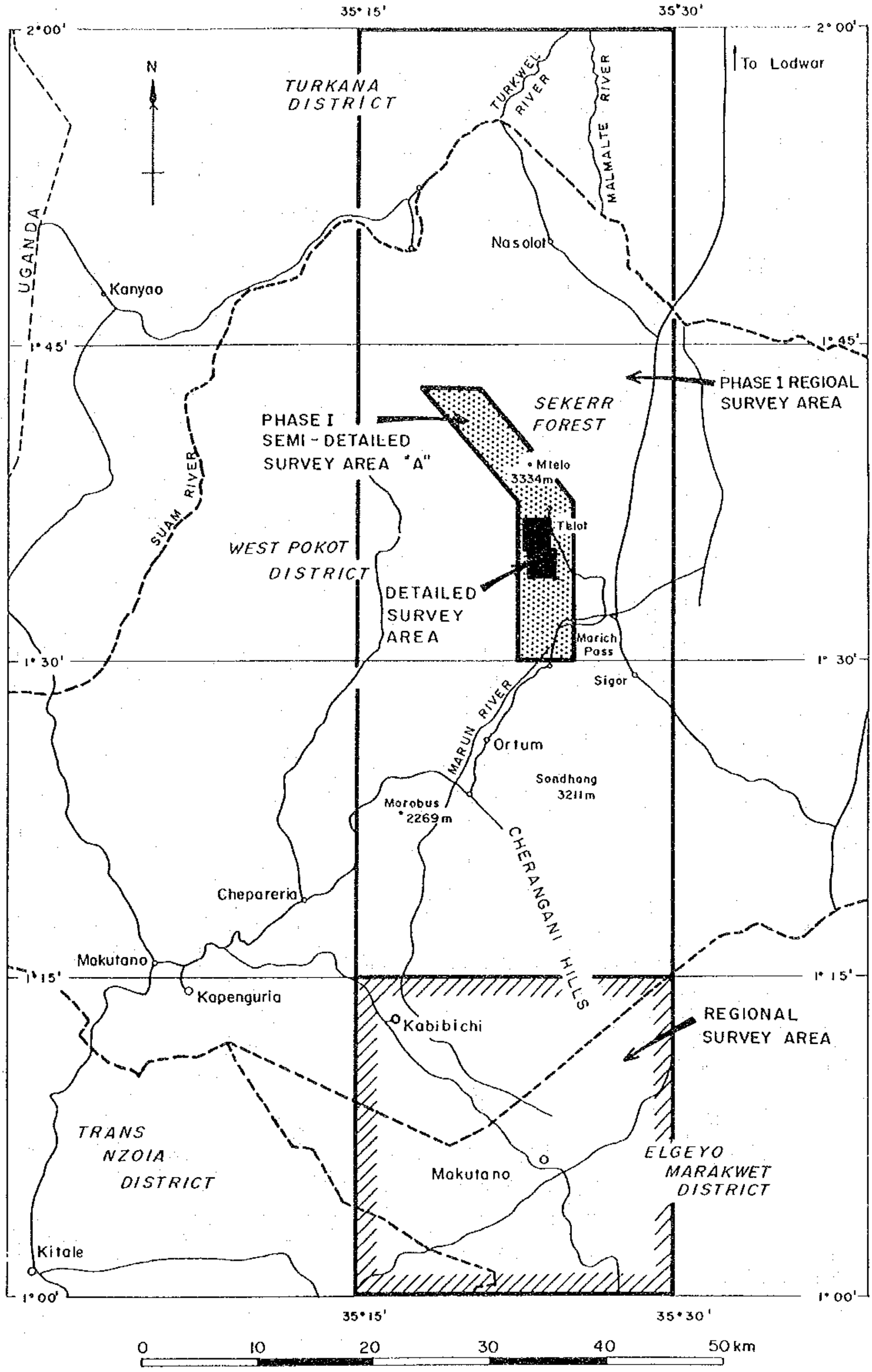

Fig. 2 Location Map of Phase II Survey Area

ABSTRACT

The second year programme of the Mineral Exploration Project in the Kerio Valley Development Authority Area of the Republic of Kenya was conducted for regional survey and detailed survey of both geological survey and geochemical survey. Its' purpose was for the regional survey to extract the promising areas for occurrence of ore deposits by comprehensively investigating the geologic structure and geochemical characters in an area of 770 km^2, and for the detailed survey to make clear the scale and the form of ore deposits by searching into the mode of mineralization of nickel and gold in the Telot area (10 km^2) extracted in the survey of the first year programme.

The survey area is situated in the block mountain on the west of the eastern rift of the African Rift Valley, and belongs to the Mozambiquian Orogenic Belt. The geology is composed of the Precambrian Mozambiquian metamorphic rocks belonging to amphibolite facies and the intrusive rocks intruded the former, showing a notable tectonic pattern with a northerly trend.

The geology of the Regional Survey Area consists mainly of gneissose rocks and quartzite derived from pelitic to psammitic sedimentary rocks and basic volcanic rocks, which is controlled by the group of overturned folds that show a north-northwesterly to northerly trend. In the northeastern part of the area, dykes or stocks of granite and granodiorite small in scale intruded into the above rocks, and skarn and silicified zones are locally observed. Any notable mineralization of useful metals, however, has not been confirmed. The only deposit found in the area is the placer gold in the eastern part of the area, where panning is being carried out on a small scale by the local residents. It is not thought that such a deposit warrants to become a more promising mine because of its insufficient grade and reserves.

The geology of the Detailed Survey Area mainly consists of metamorphic rocks of basic volcanic rock origin and ultrabasic rock intruded into the above. The latter is the type of rock intruding along the axial part of a synclinal fold trending north, outcroping in the central part of the metamorphic rocks, and has altered to serpentinite and talc schist. Many faults are found in the axial part of the syncline, especially in the area with serpentinite and talc shist, forming a tectonic zone. Podiform chromite deposits, garnierite deposits, and eluvial gold deposits are found in the serpentinite. Garnierite deposits are secondary residual deposits formed by weathering of serpentinite, and a relatively sizable mineralized zone is observed in four places within the serpentinite body. The ore reserves calculated by the Mines and Geological Department of Kenya are about five million tons of probable ore reserve (a little more than one percent in nickel grade) and about 14 million tons of possible ore reserve (0.7 percent nickel grade), which are considered to be reasonable

based on the result of surface geological survey and analysis of ores. The eluvial gold deposits are found in the silicified zone trending in the north-south direction in the cenral part of the Telot serpentinite body, showing a possible genetical relation with chalcedonic quartz veins. The length of the silicified zone is two kilometers trending in the north-south direction and about 350 meters east to west. The gold content of the high grade part is assumed to be about one gramme per ton from the result of geochemical survey and from sieving results by local residents, but the extent for each prospect is no more than several tens square meters and the frequency is not so high. In terms of the chromite deposits, 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, and it has been considered of low economical value because of the small quantity of ore reserves.

During geochemical survey in the Regional Survey Area, 709 stream sediment samples were taken, which were analysed for five elements i.e. Au, Cr, Cu, Zn and F. Only the Kipnai Au-anomalous zone (AU: 0.03 - 1.30 ppm) was deleneated as a geochemically anomalous zone caused by mineralization. This anomalous zone has a possibility to be a small-scale panning site of placer gold

In the Detailed Survey Area, 607 soil samples were taken and analysed for three elements: Au, Ni and Cr. Among these, Au and Ni showed geochemically anomalous zone reflecting the known ore deposits, but no anomalous area was detected for Cr. Among these elements, the anomalous values and background values of Au are distributed mainly within a extent of 2 km (N-S) x 350 m (E-W), forming a distinct anomalous zone trending north. This extent overlaps that of the silicified zone, and the northern half of it is a panning site for the local residents. It is therefore judged that the southern half has a possibility of being a new panning site.

The comprehensive consideration of the above result leads to the following conclusion: (1) any promising mineralized zone to warrant further exploration of a higher order has not been confirmed, (2) the nickel ore deposits at Telot in the Detailed Survey Area are low in grade and small in ore reserves, hence being of low economical value, and (3) the gold deposit at Telot is also low in grade and has not enough concentration of the high-grade part, which is not likely to suit for systematic mining, but it is considered that the continuation of the present style of mining by the local residents would be desirable.

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CHAPTER 1 INTRODUCTION

1-1 Purpose of Survey

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

The second year programme comprises Detailed Survey in the Telot area deleneated from the area of the first year as a promising area with occurrence of ore deposits, and Regional Survey in the southern adjacent part to the Regional Survey Area of the first year. Both geological survey and geochemical survey were applied.

The main object is to extract promising area for minerals by comprehensively investigating the relationship between geological structure and mineralization, and geochemical characteristics in Regional Survey, and study the mineralization of nickel and gold and determine the scale and form of the deposits in Detailed Survey.

1-2 Outline of Survey

Regional Survey Area covers 770 square kilometers. In the area, geology was mapped in a 1/25,000 scale and compiled into the 1/50,000 scale map. Stream sediments for geochemical samples were collected on the same route as geological survey and assayed for five elements (Au, Cu, Zn, Cr and F).

Detailed Survey Area extracted from the Semi-Detailed Survey Area A of the first phase and covers an area of 10 square kilometers with an area of three square kilometers for geochemical prospecting. The target minerals in the Area were gold and nickel. Geology was mapped and compiled in 1/2,500 scale map. Pits and trenches were dug in the mineralized area to investigate the details of mineralization. Soils for geochemical samples were collected at the grid points of 50 m by 100 m intervals and assayed for Au, Ni and Cr.

Field and laboratory works carried out are shown in Table 1-1 and 1-2 respectively.

The survey was carried out by three Japanese and four Kenyan geologists. The base camp for the survey was set at the suburbs of Kitale. Detailed Survey was carried out from the sub-camp at Mbaara near Telot, and Regional Survey from Kitale base camp in the first half period and from the chief's rest house at Kabichichi in the later half period.

Preparation for the survey was done at Kitale base camp, assay of geochemical samples by Geosurvey International Ltd. at Nairobi, and analysis work of the data and making the report in Tokyo, Japan.

1-3 Organization of the Survey Team

Table 1-1 Outline of Geological Works and Geochemical Survey

Area	Outline of Works
Regional Survey Area	Area covered : 770 km^2 Length surveyed : 260 km
Detailed Survey Area	Area covered : 10 km^2 Length Surveyed : 64 km Excavation Works Trenching : 100 m (Total length) 150 m^3 (Total volume) 6 Locations Pitting : 60 m (Total length) 150 m^3 (Total volume) 30 Pits

Table 1-2 Laboratory Works Carried Out

Item	Elements Analysed	Amounts
Geochemical samples		
(1) Stream sediment (Regional Survey Area)	Au, Cu, Zn, F, Cr	709
(2) Soil (Detailed Survey Area)	Au, Ni, Cr	607
Chemical analysis		
(1) Rocks (Whole rock analysis)	SiO_2, TiO_2, FeO, Fe_2O_3 MgO, CaO, K_2O, BaO, MnO Na_2O, Al_2O_3, P_2O_5, LOI	5
(2) Mineralized Materials		
For Nickel Mineralization	Ni, Co, Cr, Fe, SiO_2 MgO	50
For Gold Mineralization	Au, Ag	20
Thin Section of rock		30
Polished Section of ore		10
X-ray diffraction		11

The members who particiated in the survey are as follows:

Japan, Planning and Negotiation

Ken Nakayama	Metal Mining Agency of Japan
Yasuhisa Yamamoto	do.
Takashi Kamiki	do.
Yosuke Suzuki	do. (Nairobi representative)
Osamu Nakano	Embassy of Japan
Susumu Yanai	Japan International Cooperation Agency, Nairobi
Toshiichi Nagashima	do.
Hayao Takenaka	do.

Kenya, Planning and Negotiation

H.K. Arap Rotich	Kerio Valley Development Authority
A.M. Ngumi	do.
J.K. Wachira	Mines and Geological Department
F.G. Theuri	do.

Japan, Survey Team

Haruo Watanabe (Leader)	Metal Mining Agency of Japan
Kotaro Tonoda	do.
Akira Takigawa	do.

Kenya, Survey Team

A.M. Ngumi (Co-leader)	Kerio Valley Development Authority
Kennedy L.A. Sogomo	Mines and Geological Department
Kinosthe H. Ndungu	do.
Alfred O. Odawa	do.

CHAPTER 2 GEOGRAPHY

2-1 Location and Communication

The Regional Survey Area is spread over the three districts in Rift Valley Province i.e. West Pokot, Elgeyo Marakwet and Trans Nzoia, and is bound by N 1°00' - 1°15' latitude and E 35°15' - 35°30' longitude, forming an approximate square, which covers 770 km^2. It occupies the southern adjacent area of the Regional Survey Area of the first year programme (Fig. 1, 2).

The Detailed Survey Area is situated almost at the centre of West Pokot District, which is about N 1°30' latitude and E 35°23' longitude (Fig. 2).

The transportation from Nairobi, the capital city, to the survey area is as follows.

From Nairobi up to Kitale where the base camp of the survey team was set up, the paved national highway A-104 and B-2 run through Nakuru and Eldoret which are the main towns of Kenya (400 km, six hours).

Two routes can be used from Kitale to the Regional Survey Area. One is to drive to Kapenguria along Highway A-1 and henceforth along an unpaved highway to reach the northwestern part of the area, and the other is to drive eastward directly from Kitale along an unpaved road to reach the southwestern part of the area. It requires one and half hours to two hours to travel by car using either route.

The road network is well developed in the Detailed Survey Area and the access is relatively easy except for the steep mountainous area in the northern part and the forest zone in the western part.

Access from Kitale to the Detailed Survey Area is by driving along the Highway A-1 to Marich Pass (100 km, one hour), then to ascend the road by four-wheel drive vehicle along the steep slope of the Rift Valley to reach Telot (10 km in horizontal distance, one hour). From Telot beyond, walking is the only way to reach the Detailed Survey Area, which requires 30 minutes. The routes in the area are all by foot paths.

2-2 Physiographical Features

The survey area is situated in the block mountains on the west of the Kenyan Rift Valley. The mountains and the Rift Valley are bordered by the steep fault scarps of Elgeyo Escarpment on the east of the Regional Survey Area and Kaimat Escarpment on the east of the Detailed Survey Area. The difference in altitude between the bottom and the top of the escarpments is 1,000 to 1,400 meters in the former and about 1,000 meters in the latter respectively. The western side of these escarpments consists of steep mountains (Sekerr Mountains: the Detailed Survey Area) and hills (Cherangani Hills: the Regional Survey Area) 1,800 to 3,300 meters above sea level, forming a conspicuous forest zone. Flat land area is found both in the Sekerr Mountains and the Cherangani Hills 1,800 to 2,000 meters above sea level and 2,200 to 2,400 meters above sea level respectively, which are believed to be the remains of peneplain in the geological time.

The Regional Survey Area occupies the western part of the Cherangani Hills, and is divided into two drainage areas by the divide running from the northwest to the southeast of the area. These are Turkana Lake drainage area in the northeastern part and the Victoria Lake drainage area in the southwestern part.The northeastern side of the area is characterized by the remains of peneplain and the valleys deeply downcut on the outer side, and the drainage systems are of NW-SE in the northern part and N-S in the southern part.The southwestern side of the area consists of westerly dipping gentle slope from 2,600 meters to 1,900 meters above sea level bordered by a steep cliff formed by quartzite 200 meters high, continuing to Kitale flat land on the west. The slope is characterized by a shallow drainage system of northwesterly trend.

The Detailed Survey Area is situated in the south of Sekerr Mountains and forms easterly dipping slope from 1,600 meters to 2,600 meters above sea level. The drainage system has an easterly trend.

2-3 Climate and Vegetation

The survey area is situated in the mountainous region along the equator in the East African table land.

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 Regional Survey Area is divided into the highland in the north eastern side (2,600 - 3,300 m) and the lowland in the southwestern side (1,900 - 2,600) separating the area into the Turkana Lake drainage system and the Victoria Lake drainage system.

The highland on the northeastern side has a climate of rainy forest type and it is considerably cool. Although no record of temperatures throughout the year, the temperature in August to September was 8°C minimum and 22°C maximum. The annual precipitation is assumed to be more than 2,000 milimeters judging from the mode of vegetation.

The lowland on the southwestern side shows a climate of rainy forest type, but the temperature is fairly high, showing maximum temperature reaching about 30°C in the lower part.

Vegetation varies with the altitude. Marshy vegetation is common in the western lowland, dominated by podcarpus and similar species. The highland on the eastern side is characterized by the emergence of bamboo forest at an altitude of about 2,600 m accompanying the scrab of protea genus. Coniferous forest dominates area of 3,000 meters and above.

Although the Detailed Survey Area is situated in the southeastern part of the Sekerr Mountains which have a climate of rainy forest type, the area shows a climate of intermediate type between the former and the Rift Valley because it is situated close to the Valley which shows semiarid climate. The temperature varies from 5°C to 30°C in the day, and it is considerably dry, whereas it frosts at night. It is assumed that the annual precipitation is about 1,000 milimeters. Vegetation is scanty because most of the area consist of ultrabasic rocks, where only grass land and copse of small trees are found. However, the conifers are often found at the top of mountains about 2,600 m above sea level.

CHAPTER 3 GEOLOGICAL SURVEY

3-1 Method of Survey

Investigation in the Regional Survey Area was carried out using topographic map of scale 1 : 50,000 published by the Survey of Kenya as base map and mineral survey was based on the topographic map of scale 1 : 25,000 enlarged from the former. Survey routes were perpendicularly selected to the structural elements depending on the examination of pre-existed geological map (Cherangani Hills) and the obtained results of the survey of the first phase. On occasions examination of False Color Images from LANDSAT data were utilized for reference. Geological survey work was carried out simultaneously combination with sampling work for geochemical survey. Geological route maps of scale 1 : 25,000 was then completed and geological map of scale 1 : 50,000 was drawn.

Investigation in the Detailed Survey Area was done based on the topographic maps of scale 1 : 5,000 which were produced from the air-photographs of the area, while the enlarged maps of scale 1 : 2,500 were used for the detailed survey work. Mineralized area was known as a result of the semi-detailed survey of the first phase, accordingly detailed survey was limited to the area having latitudinal length of 2 km and longitidinal length of 5 km. In the area serpentinite body with Ni, Au, Cr deposits was included. To determine the scale and shape of the mineralized zone in the body, geological work was carried out along the grid lines at intervals of 100 m which were placed by the simple land survey. Also to determine the shape and scale of the serpnetinite body itself, geological work was carried out even on the ridges and along trails surrounding the serpentinite body. On the surface of the body, pitting at the points of intersection of grid lines (interval 300 m) and trenchings at the promising sections for Ni and Au were carried out in order to confirm the characteristic of mineralization. Geological sketches 1 : 10 and 1 : 50 in scale respectively were made and finally these data were all included in the geological maps 1 : 2,500 in scale.

3-2 Geology of Regional Survey Area

3-2-1 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 used 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 was indicated that it had been becoming common in Kenya that the rocks of this belt were 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.

In the metamorphic rocks distributed in the Regional Survey Area, it was difficult to determine the relative sequence of each rock facies, because it was difficult to discern the primary sedimentary structure due to the presence of markedly overturned fold structure and strong metamorphism and because of the poor exposure. Accordingly, it was decided that the metamorphic rocks of the zone were to be divided into two formations, the apparent lower formation and the upper formation, which were to be called the M-I and the M-II formations respectively. These are to be correlated to the Basement I formation and the Basement II formation in the first year maps respectively (Fig. 3-3).

The M-I formation is widely distributed throughout the whole area. The formation is divided into two parts outcropping in the eastern side and the western side by a thick quartzite which extends from the northwestern part through the central part to the southern part of the area.

The rocks of the western side mainly consist of biotite gneiss accompanied by granulite and migmatite. On the eastern side, biotite gneiss is the main rock facies, and besides, porphyroblast bearing gneissose rocks are distributed.

The M-II formation are found at two places in the northern part of the area. The formation is predominated by hornblende gneiss which is considered to have been derived from basic volcanic rock, and accompanied by hornblende-biotite gneiss, biotite gneiss, crystalline limestone and quartzite.

A small scale distribution of intrusive rocks is observed in the Regional Survey Area, beside those metamorphic rocks. These are composed of granite and granodiorite, and are distributed in the northwestern part of the area as dykes and stocks.

The Quaternary formation is hardly observed besides small exposure of sandy to gravel deposits in the river beds, muddy sediments in the swampy areas and the soils on the hill sides.

3-2-2 Metamorphic Rocks in Mozambique Belt

The metamorphic rocks in the Mozambique belt distributed in the area are apparently divided into the two formations such as the lower formation (M-I formation) and the upper formation (M-II formation).

Table 3-1 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.

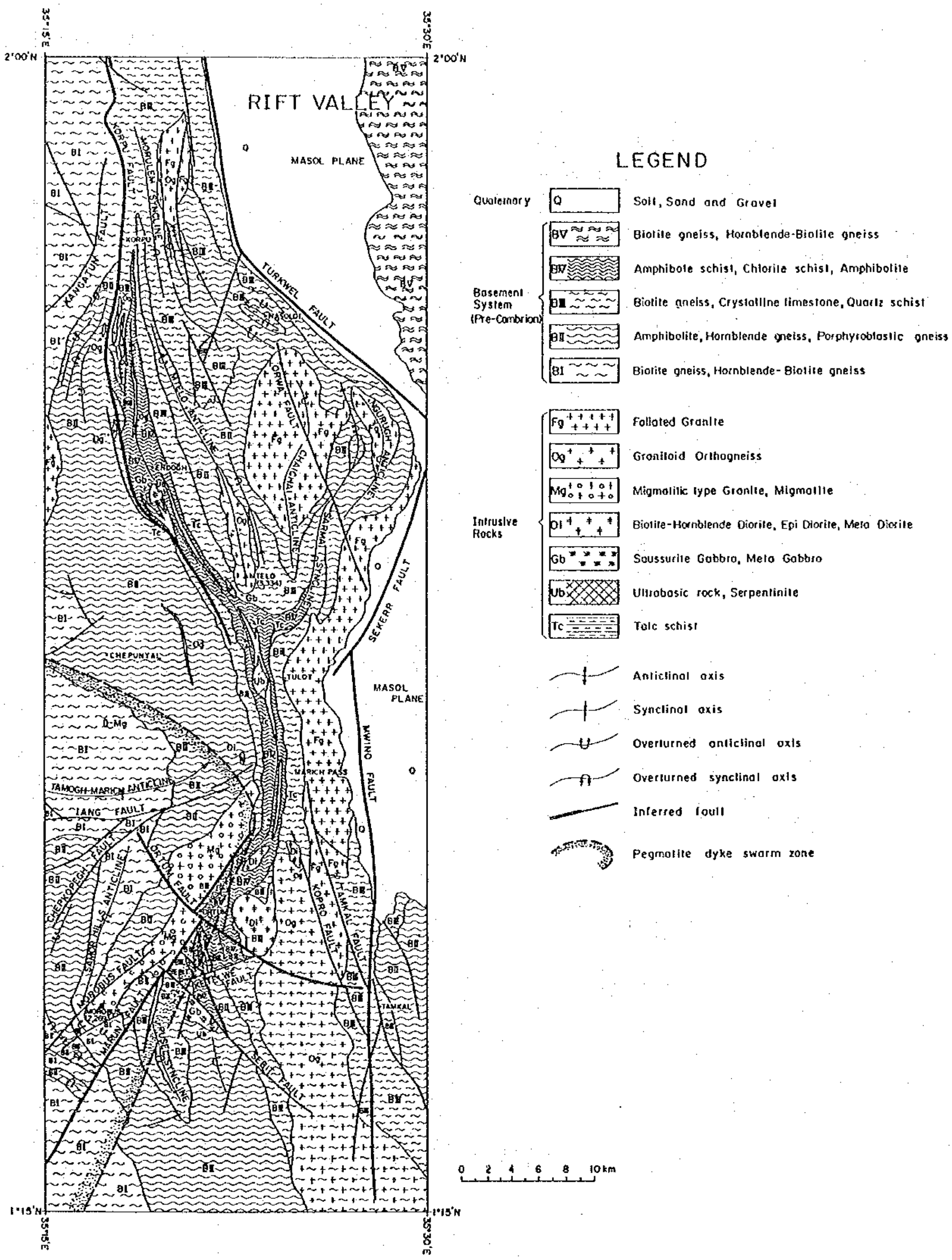


Fig. 3-1 Geological Map of Phase I Survey Area

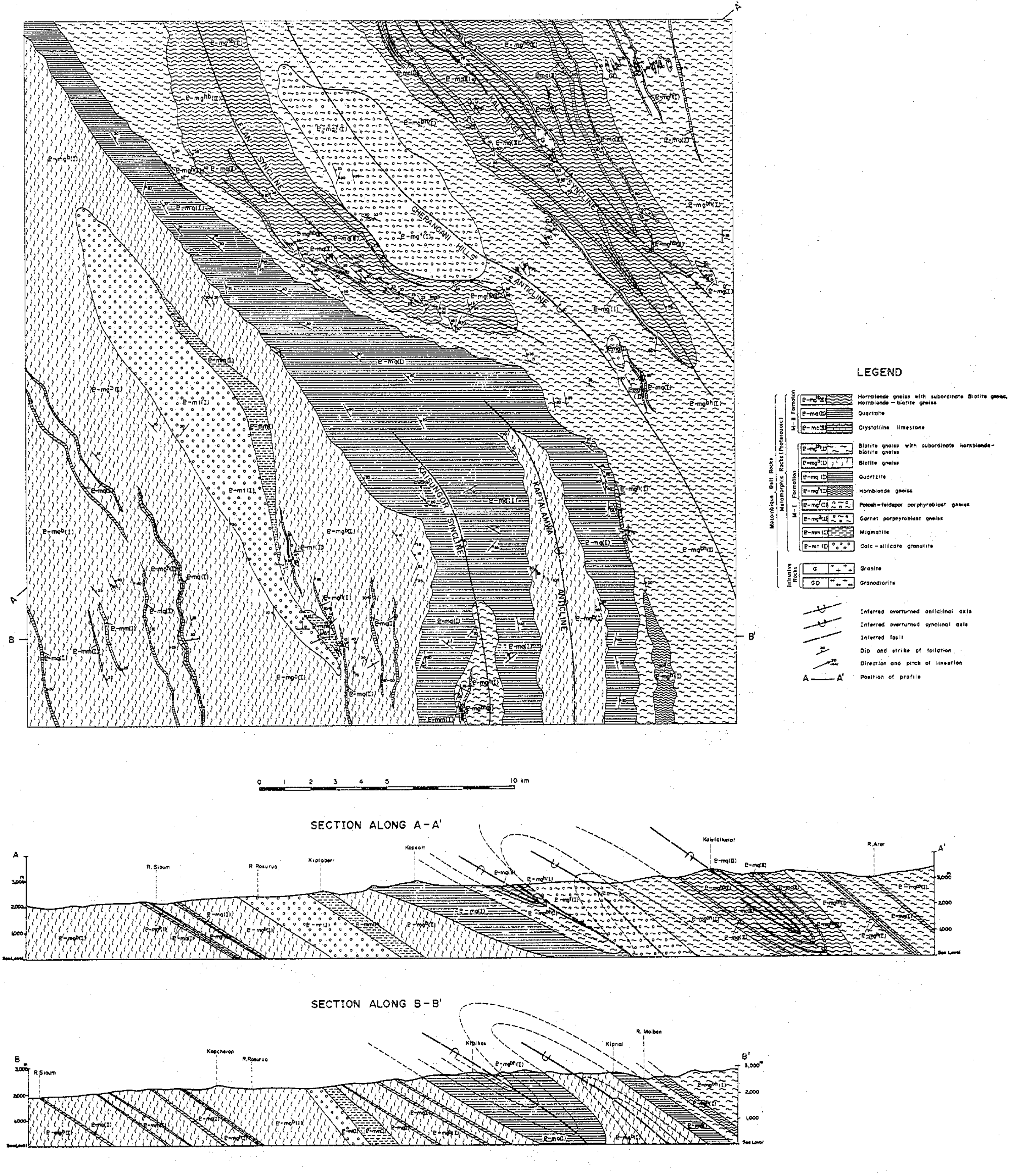


Fig. 3-2 Geological Map and Sections, Regional Survey Area

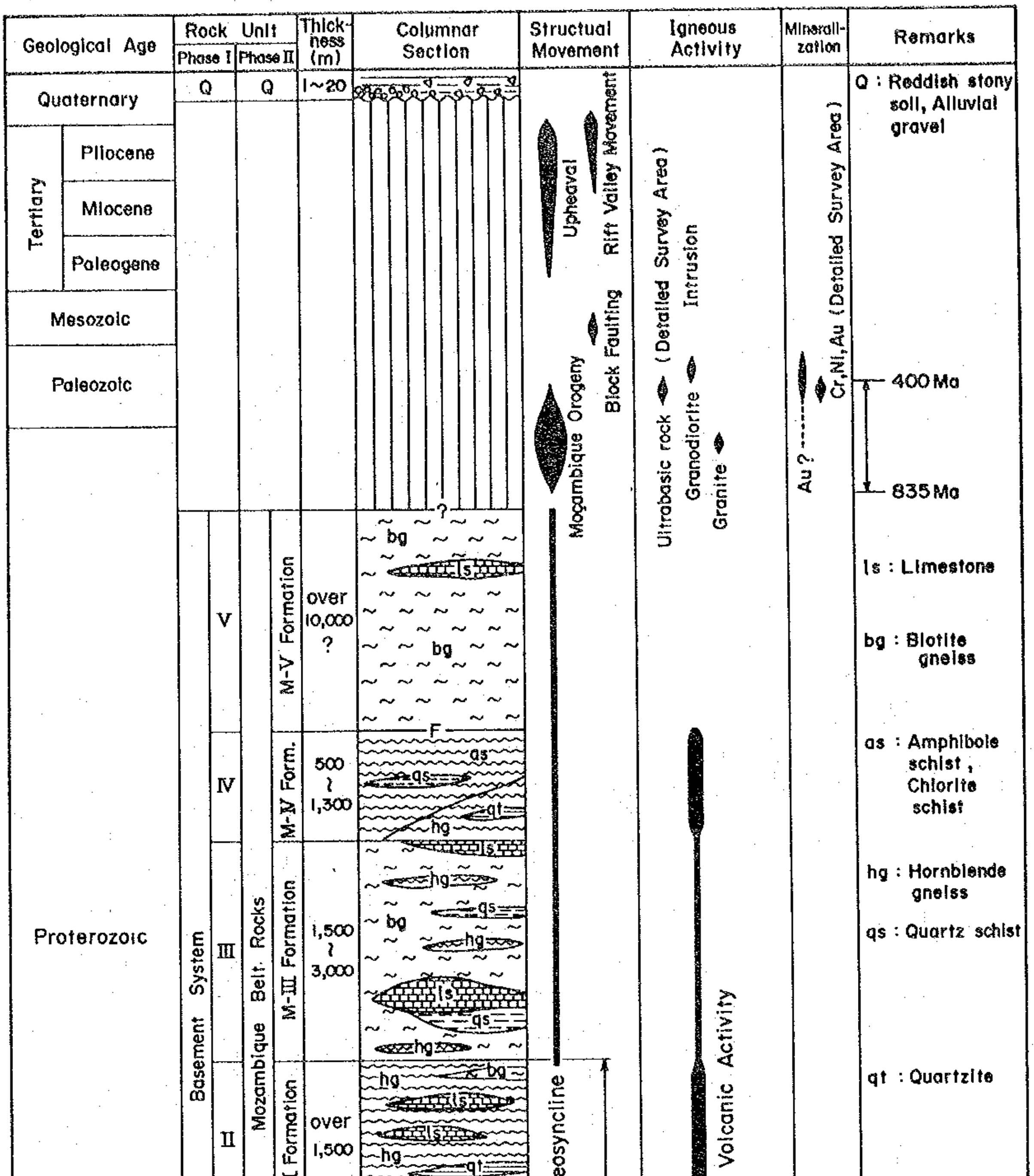


Fig 3-3 Generalized Geological Columnar Section of Survey Area

(I) M-I Formation

The formation is widely distributed throughout the whole area except in the northern part where the M-II formation is distributed. The thickness of the formation is estimated to be more than 5,000 meters though not clear because of the complicated structure due to the marked folding.

The formation is dominated by gneissose rocks derived from pelitic and psammitic sedimentary rocks, and it is characterized by the occurrence of high-grade metamorphic rocks such as granulite, migmatite and prophyroblastic gneiss.

The rock facies observed in the formation can be divided into eight units: biotite gneiss ($P\text{-}mg^{b}(I)$), quartzite ($P\text{-}mq(I)$) biotite gneiss, hornblende-biotite gneiss ($P\text{-}mg^{bh}(I)$), hornblende gneiss ($P\text{-}mg^{h}(I)$), migmatite ($P\text{-}mm(I)$), calc-silicate granulite ($P\text{-}mt(I)$), potash feldspar porphyroblast gneiss ($P\text{-}mg^{f}(II)$), and garnet porphyroblast gneiss ($P\text{-}mg^{g}(I)$).

Biotite Gneiss ($P\text{-}mg^{b}(I)$)

The rock occupies the lower half of the M-I formation, and is widely distributed from the northwestern part to the southwestern part of the area.

The rock is megascopically composed of fine-grained biotite and feldspar, showing a compositional banding of parallel orientation consisting of thin layers of biotite, and those composed of quartz and feldspar. Although the schistosity is generally weak, the portion with dominant biotite shows a strong schistosity, assuming an appearance of schist. On the other hand, the portion scanty in biotite has an appearance of fine-grained quartzite.

In the central southern part, the rock locally forms the alternating beds with the thin layers of hornblende gneiss, and a part of the rock becomes hornblende bearing biotite gneiss.

At the southern extension of the area of distribution of the large masses of granulite and migmatite, the rock sometimes contains spotted euhedral porphyroblasts of red garnet less than five millimeters diameter.

Although a large mass consisting of granulite and migmatite is distributed in the central part of the area dominated by biotite gneiss, many small bodies of migmatite occur on the western side of the mass, often showing a relation of grading between the rock and migmatite. Injection of felsic veins into the rocks as seen in these parts is thought that the rock was subject to the influence of migmatization as a whole.

Quartzite ($P\text{-}mq(I)$)

The rock shows two modes of occurrence: One forms a wide ridge extending from the northwest to the southeast, covering the aforementioned biotite gneiss, and is 500 to 1,500 meters thick. The other forms lenticular beds intercalated in the biotite gneiss and hornblende-biotite gneiss described in the next clause, showing a thickness of several tens to 100 meters. The former is situated almost in the centre of the M-I formation, and exhibits a notable topographic charactristic at the centre of the area, showing an extensive exposure in form of an overturned fold, which occupies a width of 7 kilometers.

The rock is white and medium-grained, mainly consisting of quartz one to four millimeters across, accompanied by a small amount of muscovite, a small amount of biotite is also observed.

Muscovite is fine-grained in many cases, the grain size being less than 1 millimeter, and varies considerably in amount from section to section. The rock with abundant muscovite commonly take a form of thin bedding. Garnet is contained in the rock distributed at the northeastern corner of the area.

Biotite Gneiss, Hornblende-Biotite Gneiss ($P-mg^{hb}(I)$)

The unit forms the main part of the upper part of the M-I formation, and is widely distributed on the eastern side of the thick quartzite mentioned above. Although the main facies of the unit is biotite gneiss, hornblende-biotite gneiss is also distributed to a considerable extent, occupying several tens percent of the whole rock. The two types often form the alternating beds.

The unit is dominant in fine-grained to medium-grained rock facies, but the coarse-grained type is limited in occurrence.

According to microscopic observation of a rock specimen which is similar to biotite gneiss of this type and collected during first year programme, the rock is composed of the bandings consisting of equigranular aggregate of porphyroblasts of quartz and feldspar and thin layers of fine-grained biotite, sometimes accompanied by a small amount of epidote, zoisite and diopside.

Hornblende-biotite gneiss contains a small amount of fine-grained acicular hornblende, and the texture is almost similar to biotite gneiss. The biotite gneiss distributed in the surroundings of garnet porphyroblast gneiss, which is described later, often contains fine-grained garnet.

Hornblende Gneiss ($P-mg^{h}(I)$)

The rock is intercalated in biotite gneiss in the southwestern part of the area in form of several beds, and also several other beds of the rock are distributed in biotite gneiss, hornblende-biotite gneiss unit in the northern part and the eastern part of the area.

The thickest bed is found in the southeastern part of the area and shows a thickness of about 300 meters, but others are less than several tens of meters in thickness. Beside the beds which shows a thickness of several tens of meters, thin layers several centimeters to several tens of centimeters thick are often observed in various places, forming alternating beds with biotite gneiss and hornblende-biotite gneiss.

The rock is macroscopically green and medium-grained, showing a banding structure of parallel orientation consisting of hornblende and plagioclase crystals.

The rock (BR-228') found in the southern part of the area, which was microscopically investigated, shows a peculiar rock facies in that it mainly consists of hornblende, potash feldspar and plagioclase accompanied by accessory minerals such as quartz, augite, vesvianite, zircon, apatite and iron minerals. The felsic minerals display granular texture, showing a rock facies close to granulite facies.

Migmatite (P-mm(I))

The rock is distributed adjacent to a large mass of granulite mentioned later, extending north-northwest in a narrow zone centreing on the Kiptaberr hill in the western part of the area. Two modes of occurrence are found: one is of a large scale as mentioned in the above, and the other form lenticular thin layers, intercalated in biotite gneiss in the surrounding area of the granulite mass.

Although a large number of thin layers are 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 as a hill of peculiar shape mainly due to the hardness of the rock.

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.

Calc-Silicate Granulite (P-mt(I))

The rock forms a large elliptical mass with the major axis of 20 kilometers and the minor axis of 3 kilometers, which extends northwesterly on the southwest of the Kiptaberr hill, being in contact with the migmatite which forms the Kiptaberr Hills. The terrains of this rock consist of a gently rolling slope, in which swamps and dense forest have been formed, showing a peculiar topography. The rock includes both dark green melanocratic part and leucocratic part. The former is generally dominant, while the latter shows a limited distribution in the southern part of the mass. The dark green part consists macroscopically of hornblende, pyroxene, feldspar, quartz and garnet. The garnet is red and contained in a spotted form. The result of microscopic observation of the typical rock facies (BR-246) is as follows:

Main constitutent minerals: hornblende, garnet, diopside
Accessory minerals: plagioclase, quartz, allanite, apatite, iron minerals (spinel)

Texture: granular texture. The felsic minerals display mozaic texture, partly showing banded, gneissose texture. Many of the mafic minerals show porphyroblastic or poikiloblastic texture. Garnet and hornblende are subhedral or anhedral, and garnet reaches up to 3 millimeters in diameter. Diopside shows symplektite texture, having produced garnet. Plagioclase has the composition of An_0 - An_{20}, forming mosaic together with quartz. Although the sample shows the mineral assemblage of hornblende-granulite subfacies, the presence of symplektite texture and formation of allanite suggest the possibility that the rock has undergone retrograde metamorphism in a more lower metamorphic facies. On the other hand, the rock mass contains a rock facies (BR-244) consisting mainly of epidote, hornblende, feldspar and quartz and shows granular texture. This belongs to epidote-amphibolite facies. This fact together with the result of microscopic observation lead to the possibility that the metamorphic rock of hornblende granulite subfacies have been partly or extensively subjected to (epidote-) amphibolite facies metamorphism (retrograde metamorphism) in this rock mass.

Since the biotite gneiss in the area surrounding of the rock belongs to amphibolite facies, it is possible, taking the lenticular shape of the rock into account, that the rock which had once undergone hornblende-granulite subfacies metamorphism has again been subjected to retrograde metamorphism in the stage of the Mozambique metamorphism by having intruded in a solid state.

Miller (1956) assumed that because the rock is in contact with the migmatite mass, that it was formed by injection of migmatizing fluids into an originally calcareous rock.

Potash Feldspar Porphyroblast Gneiss (P-$mg^f(I)$)

The rock is distributed in two places, in the central northern part and the central eastern part. In the central northern part, it forms a rock mass of elliptical shape having the major axis of 11 kilometers and the minor axis of 4 kilometers. In the central eastern part, it takes a form of lenticular body about 1 kilometer long. Both of these bodies are situated along the axial part of the Cherangani Hills anticline. The area distributed by the rock shows a relatively flat topography with gently slope which is considered to be due to the property of the rock that it is brittle and is easy to break.

The rock is characterized by the presence of potash feldspar.

The rock facies varies from melanocratic which is dominated by biotite, partly accompanied by hornblende, to leucocratic. Potash feldspar is more abundant in the latter, which is bluish gray,and reaches up to 2 centimeters in diameter, having an irregularly rectangular outline. Altough the degree of foliation is varied, it is strong in the outer part of the rock mass, which is almost consistent with the structure of the surrounding rock facies.

Microscopic observation of a relatively melanocratic specimen (CR-131) among the rock samples is as follows:

Main constituent minerals: diopside, potash feldspar (perthite)

Accessory minerals: biotite, albite, apatite, iron minerals, sphene

Texture: idioblastic porphyroblastic

The potash feldspar is perthite, and it shows a form of euhedral porpyroblast, reaching up to 1.5 centimeters across. Diopside is euhedral to subhedral, reaching up to 3 millimeters across. It seems to be the chromian diopside. The rock contains tiny grains of oriented iron minerals. Biotite is euhedral to subhedral, showing prismatic or irregular shape. Albite shows anhedral form and is contained in a small amount. Apatite is present filling the interstices between other mineral grains, which is fairly abundant as compared with other rock facies distributed in the area.

The rock is generally distributed with hornblende-biotite gneiss, biotite gneiss ($P\text{-}mg^{hb}(I)$), but part of it is in contact with hornblende gneiss, biotite gneiss ($P\text{-}mg^{hb}(II)$). At the contact between these rocks and the porphyroblast gneiss, felsic veins and veinlets of aplite and pegmatite are often observed.

Because of the presence of granite which is likely to have been derived from migmatite to the east of the area distributed by this rock, it is possible that the rock was formed by injection of emanation associated with migmatization as suggested by Miller (1956).

Garnet Porphyroblast Gneiss ($P\text{-}mg^{g}(I)$)

The rock is distributed in the vicinity of Tamgul at the eastern end of the area in form of lenticular bodies on a small scale.

Macroscopically the rock is pale brown and contains reddish brown, spherical garnet porphyroblast up to 1.5 centimeters in diameter.

Foliation is distinct and is harmonious with the gneissose rocks in the surroundings.

Microscopic observation of the typical rock facies (WR-218) is as follows:

Main constituent minerals: quartz, garnet, plagioclase, potash feldspar

Accessory minerals: kyanite, diopside, staurolite, iron minerals, muscovite

Texture: gneissose and mosaic

Quartz is less than 0.2 millimeter in diameter, showing wavy extinction. Plagioclase and potash feldspar form mosaic texture with quartz without showing lamellae or twinning. Garnet consists of porphyroblasts reaching up to 1.5 centimeters in diameter, and many cracks are commonly present, which are filled with limonite and other iron minerals. It also contains staurolite. Diopside is subhedral to euhedral, reaching up to 0.2 millimeter, and is in abundance. Kyanite and staurolite are subhedral, less than 0.2 millimeter, and contained in a small amount. Muscovite is flaky and contained in a small amount. Iron minerals including limonite fill the cracks.

(2) M-II Formation

The formation is distributed in two locations on the western side and the eastern side in the northern half of the area. Both these are situated in the axial part of the two overturned synclinal folds (Lelan Syncline and Kalelaikelat Syncline). It is thought that the formation, which seems separately distributed in two locations, was formed by repetition of the same formation because of the presence of an overturned anticlinal fold (Cherangani Hills Anticline) between them. The thickness of the formation is estimated to be more than 1,500 meters, though it is not accurately measured because of the complicated folding.

The formation is composed of hornblende gneiss, biotite gneiss, hornblende-biotite gneiss ($P\text{-}mg^{hb}(II)$), crystalline limestone (P-mc(II)) and quartzite (P-mq(II)), and is characterized by dominant distribution of hornblende gneiss and the presence of crystalline limestone.

The characteristics of the rock facies are as follows.

<u>Hornblende Gneiss, Biotite Gneiss, Hornblende-Biotite gneiss ($P\text{-}mg^{hb}(II)$)</u>

Hornblende gneiss dominates in this unit and is intercalated with biotite gneiss. They form often alternating beds. Although hornblende-biotite gneiss is locally distributed in hornblende gneiss, it generally occurs forming thick alternating beds with biotite gneiss.

Hornblende gneiss is generally dark green and medium-grained with marked development of foliation. Macroscopically, it consists of common hornblende and plagioclase, sometimes containing fine-grained garnet spots. Although the melanocratic type is dominant, considerably leucocratic type rich in plagioclase and quartz is locally distributed.

Biotite gneiss is generally fine-grained, with distinct foliation. It sometimes contains garnet spots similar to hornblende gneiss.

Hornblende-biotite gneiss is a rock facies in which biotite gneiss contains fine acicular hornblende.

Various kinds of rock facies are also distributed locally in areas distributed by this facies, for instance: a rock facies mainly consisting of garnet, clinozoisite and kyanite, accompanied by staurolite, muscovite and iron minerals (CR-133), second one mainly consisting of staurolite, diopside and iron minerals, accompanied by muscovite and quartz (WR-212), another mainly consisting of quartz, plagioclase and potash feldspar, accompanied by garnet, kyanite, muscovite, iron minerals, staurolite, tourmaline and diopside (WR-206).

On the other hand, in places close to the area distributed by potash feldspar porphyroblast gneiss which belongs to the M-I formation on both wings of the Cherangani Hills anticline, intrusion of felsic veins, several centimeters wide and silicification are observed in hornblende gneiss, and also porphyroblasts of potash feldspar are found in biotite gneiss, suggesting that the area was under the influence of ultrametamorphism accompanied by metasomatism.

Crystalline Limestone (P-mc(II))

Several layers of this rock are distributed in the area on the eastern side of the area in association with rocks of M-II formation. They are less than several tens of meters thick. The rock is white, fine to medium-grained crystalline limestone, partly containing grey banding.

Wollastonite rock (WR-215') is found in two places within area with this rock distribution. On the east and the southeast of Kalelaikelat. These are considered to be skarn.

Quartzite (P-mq(II))

A layer, 100 meters thick and several other layers less than several tens of meters thick are distributed. They are white and medium to fine-grained, containing some amount of muscovite.

3-2-3 Intrusive Rocks

Intrusive rocks in the area include granite and granodiorite. These are distributed in the northern part of the area, and intruded into M-I and M-II formations .

(1) Granite (G)

The rock is found in the northeastern part of the area as small-scale stocks and dykes which has intruded into the M-I and the M-II 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 geological map.

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.

Result of Microscopic Observation

Fine-grained Granite (WR-216) :

Texture: equigranular, mosaic

Main constituent minerals: quartz, potash feldspar, plagioclase

Accessory minerals: biotite, muscovite, apatite, iron minerals

Quartz is considerably coarse-grained as compared with other minerals, and elongated in an irregular lenticular form, showing wavy extinction. Potash feldspar is mostly microcline, and almost the equal amount with quartz. Plagioclase has the composition of oligoclase to andesine and displays subhedral or anhedral crystal form. Biotite is flaky or prismatic, showing strong pleochroism. Muscovite is flaky or prismatic. Apatite is fine-grained, and contained in small amount.

Migmatite or Gneissose Granite (WR-205)

Texture: gneissose

Main constituent minerals: quartz, potash feldspar, plagioclase

Accessory minerals: Biotite, muscovite, iron minerals, zircon

Most of the felsic minerals show an ovoid form.

Quartz shows a lenticular form and is oriented parallel with micas showing wavy extinction. Plagioclase is subhedral or anhedral, and the composition is mostly An_{30} to An_{50}. Some of these measure 1 millimeter in length, likely to be the porphyroblast escaped from replacement and mylonitization. Potash feldspar consists of ortholase and microcline, and most of crystals are anhedral. Biotite and muscovite are less than 0.5

millimeter long. Although they are oriented in parallel, they are so scanty in amount that they have not formed the banding structure.

Result of Chemical Analysis

Chemical analysis was performed for three samples of the rock. Table A-4 shows the result and normative minerals calculated from it. The result were plotted in each diagram of Q-Pl-Kf diagram of normative minerals, AFM diagram and K_2O-CaO-Na_2O diagram (Fig. 3-4).

(2) Granodiorite

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

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

The result of microscopic observation is as follows.

Biotite-hornblende granodiorite (CR-111)

Texture: granitic texture

Main constituent minerals: plagioclase, potash feldspar, quartz

Accessory minerals: common hornblende, biotite, apatite, iron minerals

Plagioclase forms prismatic crystals less than 2.5 millimeters long, and has the composition of andesine to labradorite. Inside the crystals has been altered. Quartz is anhedral and granular, and the grain size is smaller than that of plagioclase.

Hornblende forms subhedral to anhedral crystals less than 3 millimeters across, and most of them show poikilitic texture. Biotite is prismatic or flaky, less than one milimeter in size.

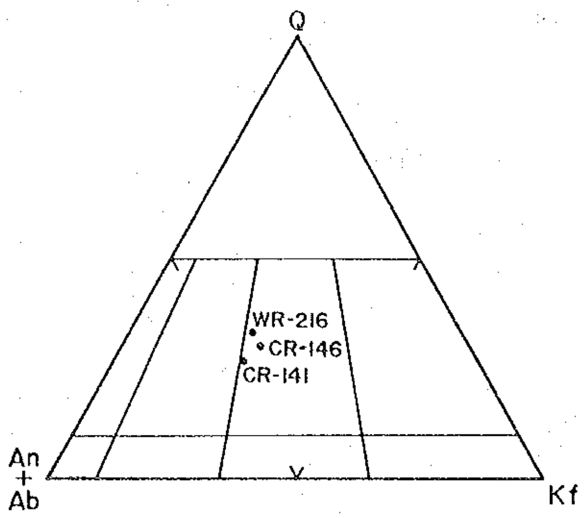
Since it is not likely from the result of microscopic observation of the rock that it has undergone the regional metamorphism, the time of intrustion is considered to have been after the latest stage of the orogeneic movement.

3-2-4 Metamorphism

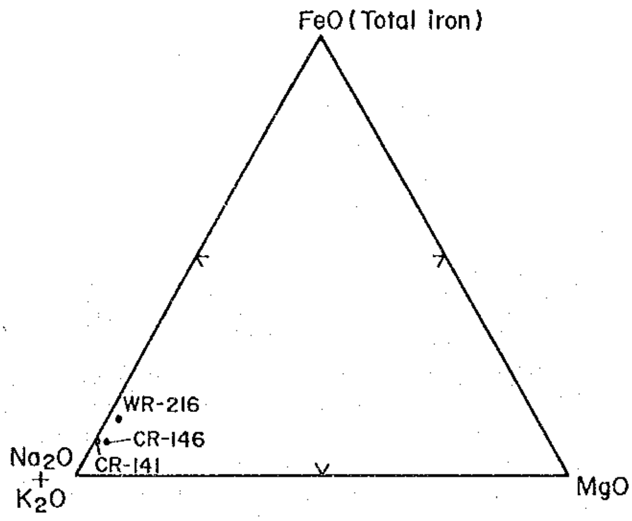
(1) Regional Metamorphism

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, similar to that found in the regional survey area in the first year. This mineral assemblage shows that the metamorphic facies belongs to the amphibolite facies and that the type of pressure to the meidum pressure type (~ high pressure type). Also, staurolite kyanite and garnet are often contained in the pelitic metamorphic rocks. This assemblage shows that the facies

A. Normative Q-PI-Kf diagram



B. AFM diagram



C. Alkalis and lime ratio

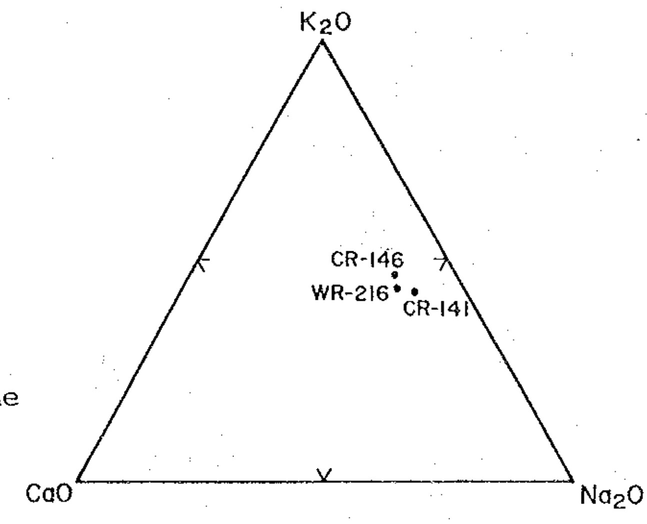


Fig. 3-4 Diagram from Results of Whole Rock Analysis

belongs to medium pressure (- high pressure) type amphibolite facies.

(2) Retrograde Metamorphism

The calc-silicate granulite belonging to the M-I formation in the western 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 the trace that the rock has undergone retrograde metamorphism in epidote amphibolite facies or amphibolite facies, as described in the clause 3-3-2.

Because it is considered that the metamorphic facies of the present survey area including the regional survey area done during the first year belongs to the amphibolite facies, it is hard to assume that only the area with the calc-silicate granulite distribution is 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.

The distribution of chlorite schist and talc schist is observed to the northeast of Kapsangar in the central-northern part of the area. Chlorite schist belongs to green schist facies, which is lower in metamorphic grade than gneissose rocks belonging to amphibolite facies in the surrounding area.

Similarly in survey area of the first year programme, it is most possible that the green schist was formed by retrograde metamorphism associated with the formation of fracture zones, and the other possibility that part of green schist zone accompanied by ultrabasic rock and talc schist distributed to the north of the area would have continued up to this area if the distribution of talc schist in the area is taken into consideration.

(3) Ultrametamorphism

The rocks in the following indicate the occurrence of ultrametamorphism found every where in the area: migmatite distributed centreing on the Kiptaberr Hills in the western part of the area; potash feldspar porphyroblast gneiss in the central and northern parts of the area, and felsic veins, aplite and pegmatite found in the surroundings.

On the other hand, Miller (1956) suggests that the calc-silicate paragranulite distributed to the west of Kiptaberr Hills had been formed from originally calcareous rock by injection of migmatizing fluids in the formation process of migmatites distributed on the eastern side of the paragranulite in contact with it.

(4) Contact Metamorphism

Small occurrence of wollastonite bodies (WR-215') is 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.

3-2-5 Geological Structure and History

(1) Geological Structure

Fig. 3-5 shows lineaments detected from the Landsat image and fold axes infered by the result of geological survey.

The geological structure is controlled by a group of overtuned folds, the axial plane of which strikes north-northwest in the northern part, swinging north in the southern part, and diping 30° to 40° toward the northeast or east.

Metamorphic rock formations often have repeated appearance in form of folds. On the geological map, the fold structure is precisely shown on the eastern side of the area with quartzite extending in the central part. This is likely to be due to the fact that the geological structure of the western side have not sufficiently been mapped because of poor exposure of the rock surface which is covered by a dense forest and swampy land.

The lineaments with good continuity trending north-northwest in the northern part and to the north in the southern part, and those perpendicular to the above were obtained from the Landsat image, which are thought to reflect the fold structure mentioned above.

A continuous lineament trending north-northwest and the short lineaments perpendicular to the above which are observed to the west of Kapsait show the same pattern, suggesting an occurrence of fold structure similar to that of the eastern side.

Among these fold structures, Kalelaikelat overturned syncline is accompanied by second anticlinal folds, forming an anticlinorium.

No large-scale fault has been confirmed from the result of geological survey. However, several strong lineaments observed from the Landsat image might suggest the occurrence of faults which are yet unconfirmed.

Weak circular structure is recognized in several places in the northern part and the southern part from Landsat image. However, no geological structure corresponding to this pattern has been confirmed during the geological mapping.

(2) 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 thought that at least part of the Mozambique belt is composed of reworked Archean rocks (Verncombe 1983).

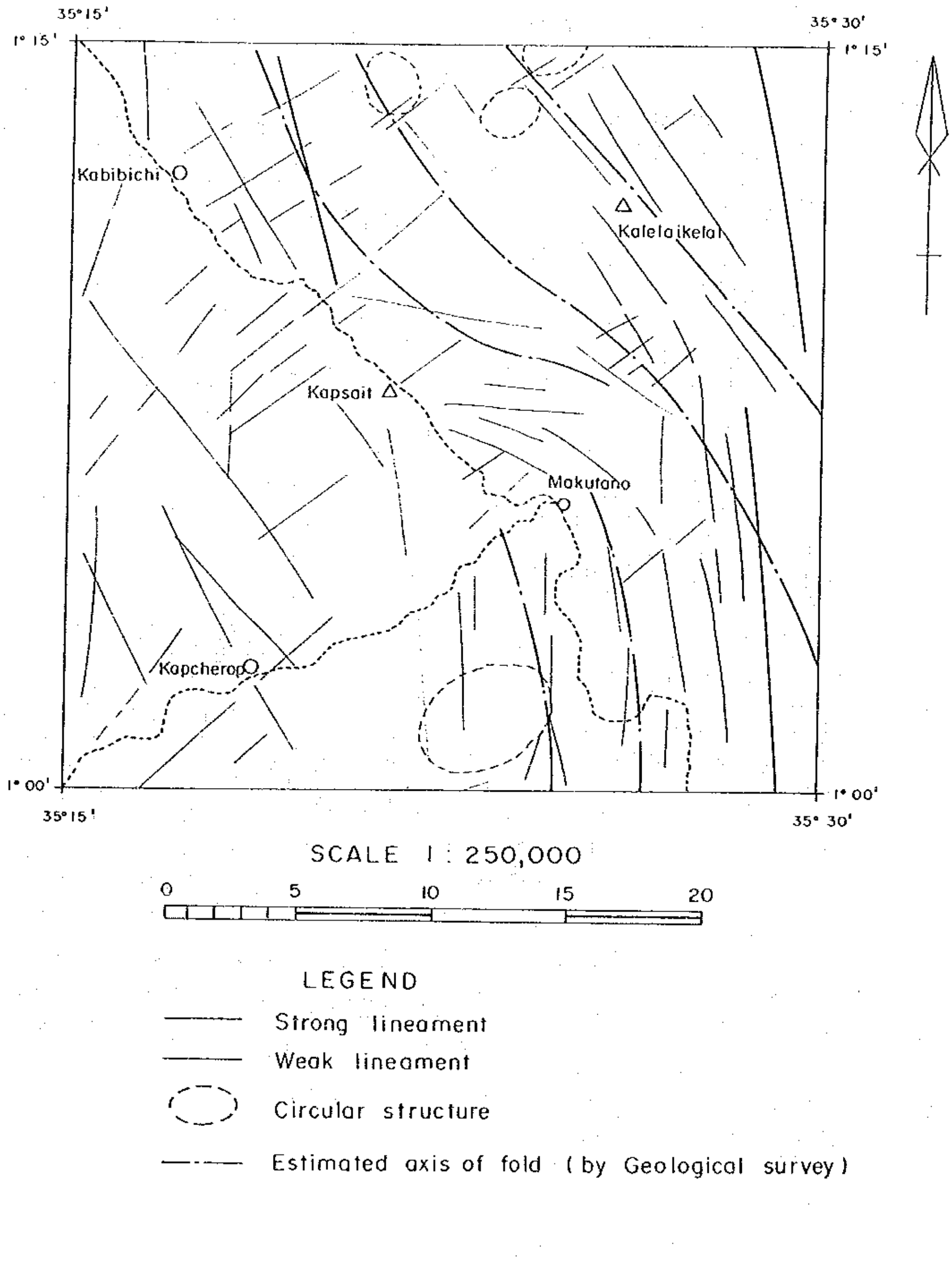


Fig.3-5 Lineaments from Landsat False Colour Image, Regional Survey Area

Although the age of the rocks of the Mozambique belt found in the survey area has not been accurately determined, Verncombe (1983) determined the age by radiometric dating of the rock derived from the andesitic volcanic rock distributed in the surrounding area of Marich Pass which is situated in the survey area of the first year belong to the Late Precambrian, and it is thought that the geologic time of the rock of the area in the southern adjacent part of the above also corresponds to the time almost the same to it.

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 Palaeozoic (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 Mozambiquian 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, it is thought that the granite in the northeastern part of the area is the migmatite-type granite associated with migmatization, having formed at the culmination of the metamorphism. On the other hand, since granodiorite has not been affected by regional metamorphism, the time of intrusion is considered to be at the latest stage of the orogeny or post-orogeny.

In connection with the time of mineralization, it can not be clarified because the origin of placer gold has not been confirmed. However, the silicified zone in the northern part which has a very small amount of gold has not been subjected to regional metamorphism. It is thought therefore that the mineralization took place in association with the intrusion of granodiorite mentioned above.

Block movement in the Mesozoic and the Rift Valley tectonic movement in Cenozoic are as described in the 1st phase report of the survey programme.

3-3 Detailed Survey Area

3-3-1 General Remarks

The area consists of 10 km^2 selected for investigation in the Telot serpentinite body which contains deposits of gold, chromite, and nickel (Fig. 1).

Most of the survey area is situated in the eastern slope of a ridge extending north or north-northwest. The altitude is from 1,600 to 2,650 meters above sea level showing a great difference in height, and a steep landform.

Surface reconnaissance was conducted along survey lines established in east to west direction at interval of 100 meters in the area of geochemical survey. Outside of that area of geochemical survey, reconnaissance was also carried out along the main ridges and the paths on the mountain slope. The scale of the route maps is 1 : 2,500.

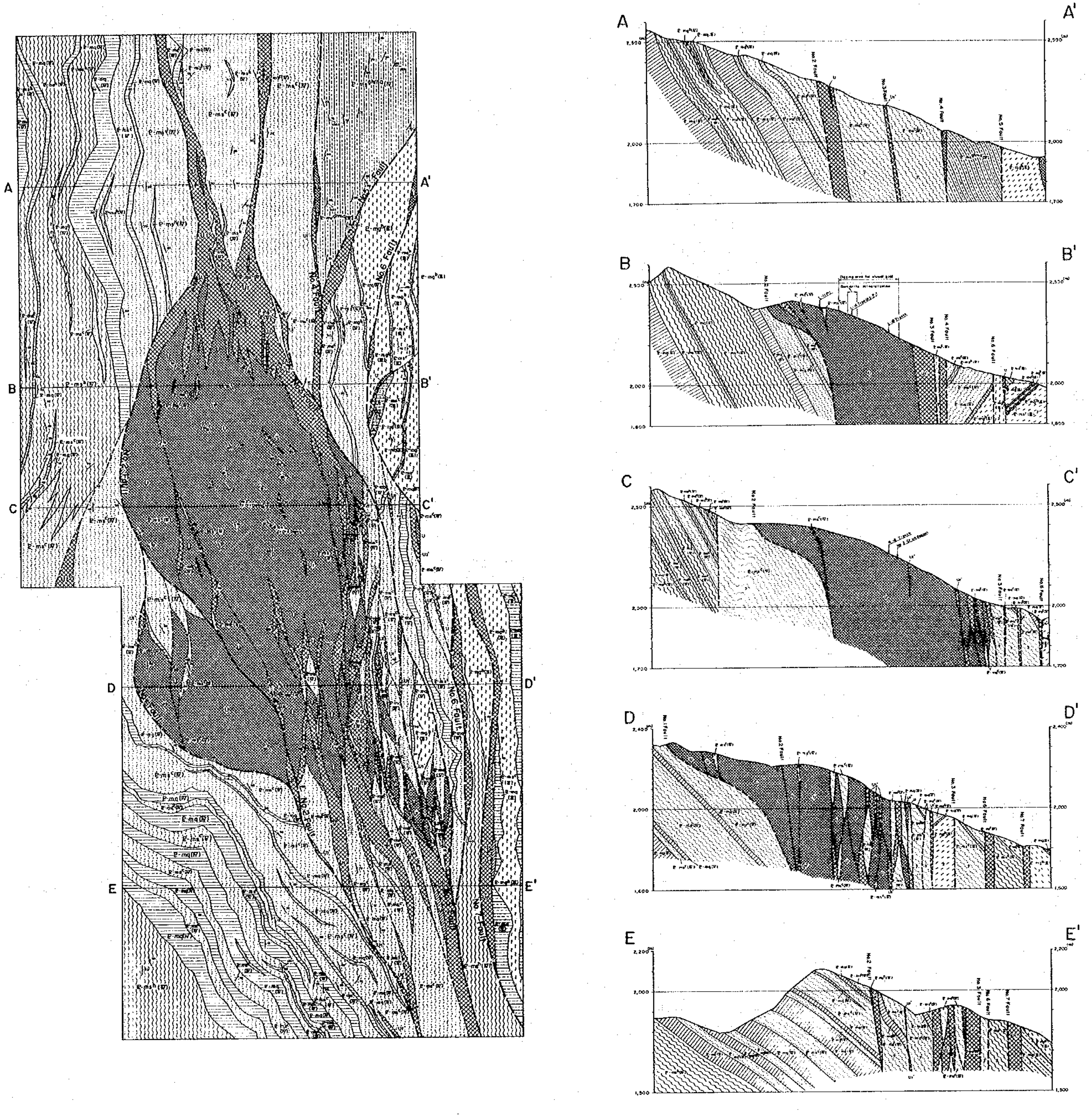
The geology of the area is composed of metamorphic and intrusive rocks. The metamorphic rocks consist of the M-III formation and the M-IV formation of the Mozambique belt metamorphic rocks (corresponding to the Basement III formation and the Basement IV formation as classified in the survey report of the first phase). The main rock facies are hornblende schist, hornblende gneiss, green schists (actinolite schist and chlorite schist), quartzitic rocks, and biotite gneiss. The intrusive rocks include serpentinites and talc schist. Although the metamorphic rocks generally strike north-northwest to north-northeast and dip 30° to 70° east, west dipping is locally observed.

The surveyed area occupies the axial part of the Endogh-Telot syncline which became clear in the survey of the first phase. Along the axial part, intrusion of ultrabasic rocks and occurrence of schists formed by retrogressive metamorphism are recognized, and many secondary faults are assumed from the intermission of rock facies and discontinuity of geologic structures. These indicate the characters of tectonic zone.

The main deposits are found in the ultrabasic rocks: the chromite deposits occur as small-scale lenticular ore bodies in serpentinite, garnierite deposits are found as the residual deposit caused by weathering of serpentinite, and eluvial gold deposits are scattered in-situ as residual deposits in serpentinite and talc schist.

Eluvial gold deposits are being excavated by local residents at present. The detailed survey of this time was carried out in order to know the mode of occurrance of eluvial gold deposits and nickel deposits. The description of ore deposits is compiled in the section 3-4 (Ore Deposit).

The geological maps and the cross sections are shown in Plate 2-1 to 2-3, Plate 3 to 5 and in Fig. 3-6.



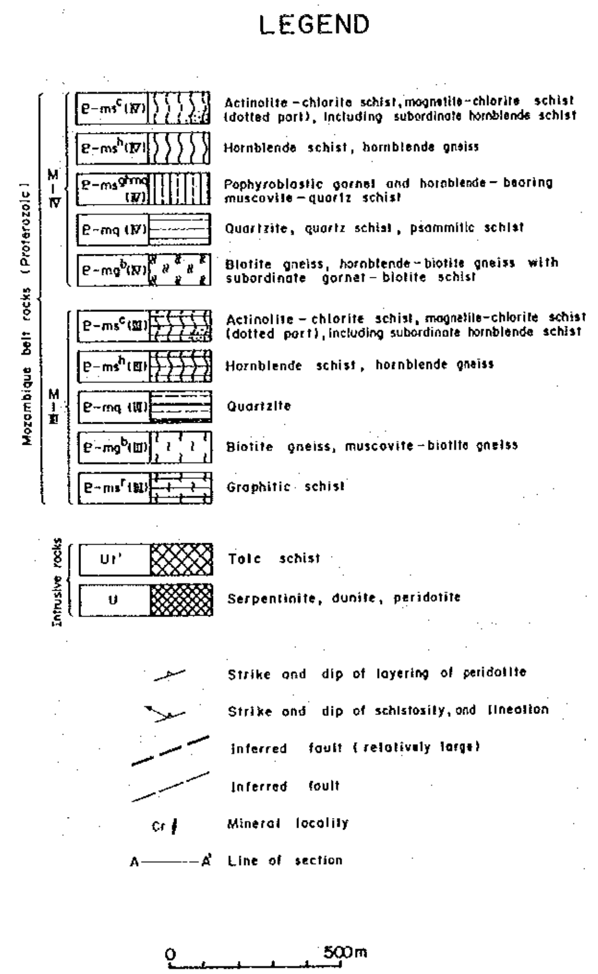


Fig. 3-6 Geological Map and Sections, Detailed Survey Area

3-3-2 Mozambique Belt Rocks

(1) M-III Formation

According to the result of survey of the first year, the M-III formation consists of biotite gneiss, crystalline limestone, quartzite, psammitic schist, and biotite - muscovite schist. The formation is characterized by a continuous distribution of biotite gneiss and crystalline limestone. The thickness of the formation is assumed to be 1,500 to 3,000 meters.

The M-III formation in the area shows a distribution in the eastern periphery extending north with the width of 150 to 300 meters. The formation drawn on the geological map of the Semi-detailed Survey Area A of the first year programme in the southwestern corner has changed to the M-IV formation during current survey, as more facts have became available.

The main rock facies are fine-grained biotite gneiss (P-mg^b(III)) and quartzite (P-mq(IV)), interbedded with thin layers of chlorite schist (P-ms^c(III)), hornblende gneiss (P-mg^h(III)) and graphite schist (P-ms^r(III)). Biotite gneiss is locally associated with muscovite, hornblende and garnet (less than 10 mm in diameter) and porphyroblasts of potash-feldspar (less than 5mm in diameter).

The thickness of the M-III formation is estimated to be 300 m (+) in the area.

(2) M-IV Formation

According to the 1st phase report, M-IV formation is a formation 500 to 1,300 meters which thick which mainly consists of green schist (actinolite schist and chlorite schist) accompanied by hornblende schist and hornblende gneiss, conformably overlying the M-III formation.

The M-IV formation occupies the widest part in the area. From the point of view of rock facies, the green schists (P-ms^c(IV)), including actinolite schist and chlorite schist, are dominant, followed by hornblende schist, hornblende gneiss (P-ms^h(IV)), quartzitic rocks (P-mq(IV)) and hornblende-garnet porphyroblast with two mica-quartz schist (P-ms^{ghmq}(IV)). Biotite gneiss (P-mg^b(IV)) has been observed only in form of thin layers.

The green schists which are considered to have been formed from the hornblende gneisses by retrogressive metamorphism, are fine-grained rocks with a marked schistosity and consist of chlorite-actinolite schist and chlorite schist. In the chlorite schist, porphyroblasts of euhedral magnetite several millimeters to 2 centimeters in diameter are often observed, and those which are subjected to compressive deformation perpendicular to the schistosity are sometimes observed. As shown on the geological map magnetite-bearing chlorite schist is dominant in chlorite schist within serpentinite and the chlorite schist located between Telot No. 2 fault and the Telot No. 3 fault in southern central part of the area. These are the places where existence of a number of faults is estimated, and therefore the presence of magnetite-bearing chlorite schist might indicate areas subjected to intense shearing and retrogressive metamorphism.

Among the basic metamorphic rocks constituting the M-IV formation, hornblende schist and hornblende gneiss have not been subjected to or affected by week retrogressive metamorphism, resulting in that common hornblende survived untouched. They are mainly distributed in the peripheral part of the area like in the northwestern part, the southwestern corner and the southeastern part. In addition, these are scattered in chlorite schist as unaffected parts left untouched from the retrograssive metamorphism.

Because the boundary between the hornblende gneisses and green schist is different from the boundary between the strata, a great amount of survey data will be required illustrate it on the geological map accurately, Since sufficient data has not been obtained in this survey, the boundary was drawn for convenience sake on the assumption that it is similar to that between the strata.

The quartzitic rocks are composed of quartzite and quartz schist. The constituent minerals observed beside quartz are muscovite, biotite, garnet, hematite and manganese minerals (thin section WR-74).

Hornblende-garnet porphyroblast bearing two mica quartz schist is distributed in the area located between the Telot No. 4 fault and the Telot No. 5 fault. The rock was separated from the ordinary quartz schist because it has a characteristic rock facies and because it is distributed in a sizable scale. The distribution of the rock was not noticed in the first phase survey. The rock facies is characterized by well developed schistosity and large porphyroblasts of hornblende (long axis $<$ 4 cm) and garnet (diameter $<$ 2 cm), accompanied by biotite and muscovite (thin sections CR-92, WR-10). Preferred orientation is sometimes observed in porphyroblasts of hornblende which show the direction of S30° -80°E dipping 15° - 75°. Part with abundant porphyroblasts and those less amount are observed in the same rock, and it seems that these are repeated in form of alternating beds on a scale of several centimeters to several meters or more. Although it was assumed that the rock belongs to the M-IV formation, it can not definitely be determined because the regional distribution is not clear.

A small quantity of chlorite, which seems to have been formed by retrogressive metamorphism, is observed in all the thin sections of metamorphic rock belonging to M-IV formation.

The thickness of the formation is estimated to be about 900 meters or more in the southwestern part of the area where the structure is relatively stable.

3-3-3 Intrusive Rocks

Intrusive rocks consist of serpentinites and talc schist derived from serpentinite. Both rocks are found in close association and intruded into the tectonic zone along the Endogh-Telot syncline which became clear in the first phase survey. Although the intrusion is partly harmonious with the surrounding metamorphic rocks, it seems that most of the rocks inconsistently intruded into those which were affected by faults. The trend of the intrusive rocks is the same as of metamorphic rocks and faults, which strike north or north-northwest.

(1) Serpentinites

Serpentinites (U) occurs as lenticular intrusive bodies in metamorphic rocks and talc schist. The form and distribution of serpentinite bodies were investigated very precisely during present survey. They are classified into a large serpentinite body (Telot serpentinite body) and about thirty other small bodies. The Telot serpentinite body extends for about 2.5 km northwards with a width of about 1 km showing an elliptical form, and area of exposure is about 2 km^2.

In northern and southern limits, the exposure of the body terminates abruptly showing an intricate form intercalating a large amount of green schist and talc schist. It is likely that the abrupt termination resulted from the development of faults. The western side of the body is bordered by Telot No. 1 and No. 2 faults, and shows a relatively distinct boundary. On the eastern side, occurrence of many small faults led to intricate distribution of lenticular small bodies of serpentinite, talc schist and green schist making the boundary of Telot serpentinite body indistinct.

Many of the small bodies are several tens of meters wide and 200 to 300 meters long. About twenty bodies are distributed in a relatively concentrated form on the southeast of the Telot serpentinite body, others are scattered along the faults.

In terms of the shape of the rock body in the deeper part, it is thought that the western boundary of the body dips 25° to 50° eastward based on the exposure lines of the Telot No. 1 and No. 2 faults, which is almost consistent with the dip of schistose structure in the body.

The dip of the eastern side is indistinct because the dip of fault can not be determined. If the dip shown by the Telot No. 1 and No. 2 faults is the general one in this area, the eastern boundary would dip eastward. Whereas, if the schistose structure would control the shape of the body at depth, the eastern boundary would be inclined toward the west. McCall (1964) considered the funnel-like shape suddenly becoming narrow toward the depth based on the schistosity and cleavage in the serpentinite.

Layered and schistose structure are observed in the Telot serpentinite body. The layered structure can be observed in the vicinity of the No. 2 chromite ore body and in the walls along road used before for exploration works 100 to 300 meters to the north-northeast of the ore body. It strikes N30° - 50°W and dips 40° - 50°SW, and single layeres are several centimeters to one meter thick in most cases. Although the layered structure was observed only at the place where serpentinite had been excavated to a depth, it is likely that it dominates over the whole rock as the primary structure. Microscopic observation of serpentinite, showing the layered structure, has not been made. The existence of the layered structure and the wehrlite confirmed by microscopic observation in phase I might suggest that the Telot serpentinite body is of cumulate origin.

Although the schistose structure seems to have been formed by shearing of serpentinite, which is observed in various parts of the body, it is not so distinct as to be defined as schistosity. It strikes north to north-northwest and dips, in many cases, 30° to 70° eastward on the western side of the body and 30° to 80° westward in the part from the centre to the eastern side of it. The schistose structure is almost in parallel with the layered structure in the areas where the latter can be observed.

The degree of serpentinization is varied from the fresh rock in which olivine occupies 80 to 90 percent to the rock that is wholly serpentine. The part containing chromite has been highly serpentinized, having been completely altered to antigorite serpentinite. Antigorite, talc and calcite are observed as secondary minerals associated with serpentinization. Although dunite, wehrlite and lehrzolite have been identified as the original rocks of serpentinite under the microscope, it is difficult to distinguish them with the naked eye (thin sections WR-21, 79, 137, 143).

Macroscopically, serpentinites are pale green to dark green fine-grained rocks, frequently containing magnetite grains about one millimeter across. Silicified parts are frequently found in the body forming silicified serpentinite zone. Highly silicified serpentinite is whilte, light gray, and light brown with limonite stain, and sometimes forms small ridges and bare rock zones protruded on the surface. Although chalcedonic quartz veins several millimeters to 10 centimeters wide are frequently observed in the highly silicified zone, quartz or chalcedony veins are widely distributed filling the joints in the serpentinite isolated in places apart from the highly silicified zone.

Table A-1 shows the results of whole rock analysis and the normative values for two serpentinite samples.

Both samples have similar chemical composition. The high MgO/total FeO ratios over 7.5 indicates that the Telot serpentinite body is relatively poor in Fe content as chemical characteristics. MgO x 100/(MgO + total FeO) ratios are 88 to 89% and are plotted in the field of the Alpine type ultramafic rocks. In

$MgO-CaO-Al_2O_3$ diagram, both are shown near the MgO apex, included in the field of metamorphic peridotite by Coleman (1977).

For the normative calculation of the ultramafic rocks, the method proposed by Hayashi (1968) was applied, which is different from the ordinary C.I.P.W. norm calculation in the following three points.

1. FeO and Fe_2O_3 are added to equal amount of Cr_2O_3 and NiO respectively, to make chromite and trevorite.
2. Al_2O_3 left after calculation of feldspars is added to equal amount of MgO to make spinel.
3. An excess of Fe_2O_3 after the calculation of acmite and trevorite is recalculated to FeO for making olivine and pyroxene.

The difference in normative mineral composition between the two samples is shown clearly in the ratios of normative hypersthene and olivine as 34% - 51% (WR-21) and 3% - 83% (WR-137).

(2) Talc Schist

Talc schist (Ut') is distributed as lenticular to bedded-form intrusive bodies, or associated with serpentinites. Most of the talc schist in the area is considered to have intruded in an incosistent relationship to the metamorphic rocks as estimated from the intricate distribution of serpentinite, talc schist and green schist to the south-east of the Telot serpentinite body. Although the width of the exposure is less than 100 meters, it shows a wide distribution at the point where it is tangled with serpentinite in the northern part of the Telot serpentinite body. The rock is well spread along the direction of elongation reaching up to 2 kilometers or more in maximum.

The rock is white to pale grey and weakly schistose. Vesicules coated by iron oxide are often observed. In part of high crystallinity, pale green foliated talc crystals several centimeters in diameter are observed. The talc schist accompanied by anthophylite is reported in the existing literature.

Since talc is a common mineral derived by alteration of nonaluminous magnesium silicate in basic or ultrabasic rocks, or by metamorphism of dolomitic rocks, the original rock of talc schist is considered to be ultrabasic rocks closely associated with the rock.

3-3-4 Geological Structure

(1) General Remarks

The Detailed Survey Area contains a tectonic zone extending in the direction of N-S or NNW-SSE, and the activity of the tectonic zone seems to have resulted in the formation of many faults, intrusion of serpentinite and talc schist, and the formation of green schist subjected to retrogressive metamorphism.

(2) Fold

From the survey results of the Semi-detailed Survey Area A, it turned out that this area corresponds to the part to be passed by the axial part of the Endogh-Telot syncline. It is difficult to show the location of the axial part on the geological map of 1 : 2,500 scale, because the axial part has overlapped the tectonic zone. It is most likely that the synclinal axis is located between the Telot No. 2 fault and the No. 3 fault.

The structure of the metamorphic rocks on the western side of the Telot No. 2 fault which corresponds to the western wing of the syncline, is relatively stable. In the northern half of the western side, it is a feature that the strata strikes NNW-SSE and dips 50° to 80° toward east, but opposite dipping is sometimes observed, leading to the assumption of local folding. In the southern half, the strata strikes N-S to NW-SE, and dips 30° to 60° eastward showing a gentle dipping as compared with the northern half, and the opposite dipping has not been observed. The part in which north-west dipping is observed may lead to suggesting that the original direction of strike was bended by intrusion of serpentinite, as it is observed only in the vicinity of the serpentinite body.

The metamorphic rocks on the eastern side of the Telot No. 2 fault, which is on the eastern wing of the syncline show a complicated distribution and structure. Since the M-IV formation is distributed in the eastern wing extending north, and can not be observed on the western wing, the relative upheaval of the land blocks on the eastern side of the tectonic zone can only be inferred.

Although north-northwestern to north-northeastern trends of metamorphic rocks prevail in the eastern side, those of the east-northeastern to east-southeastern trends are locally observed, suggesting that disturbance took place by faulting. The dip varies from 30° to 70°. In the northern half, the blocks showing the eastward dipping and those showing the westward dipping are separated by a fault. In the southern part, strata dip eastwards in most cases, and syncline structure is overturned.

(3) Faults

All faults on the geological map are inferred. The names of the Telot No. 1 to No. 7 were given for reason of explanation for those with a good continuity and a great amount of displacement. These faults had been inferred on the basis of the geologic evidence as described below.

1 On the southeast of Telot serpentinite body, serpentinite, talc schist and green schist show an intricate distribution, and this part is considered to consist of lenticular blocks which are separated by the faults.

2 Although the hornblende-garnet porphyroblast bearing two mica quartz schist which is distributed on the northeastern corner of the area has a characteristic rock facies which is easily traceable, it does not continue to the southern part. Such a discontinuity of rock facies is also observed in other places.
3 The biotite gneiss of the M-IV formation with distinct bedding is distributed 700 meters to the west of the Telot settlement and shows an opposite direction of dipping at the outcrops which are a 100 meters apart along the strike.
4 It is observed in several places that the green schist accompanied by serpentinite and talc schist in adjacent parts swings its trend of strike from the general trend to the east-west direction, which seems to indicate the rotation of the small blocks by faulting.
5 An inconsistent relationship between the distribution of serpentinite and talc schist and the structure of the metamorphic rocks is observed in many places.
6 The intrusion of serpentinite and talc schist and the presence of retrogressive metamorphic rocks, which are the product of strong shearing and mylonitization, indicate the characters of this zone, and the tectonic zone is characterized by a large number of faults.

Although the faults mainly strike north to north-northwest, those striking north-northeast are inferred in some parts. Regarding the dip of the faults, it is inferred for the section not far off the surface of the Telot No. 1 and No. 2 faults based on the relationship between the line of exposure and topography. Especially, the dip of Telot No.2 fault has a high reliability because it was obtained from an exposure of the fault line which is delineated by the traverse along the survey lines set up at the 100 meters intervals.

The dip of the Telot No. 1 fault is shown to be 50°E from the line of exposure between the survey line Z and line EE to the altitude of 2,275 meters, and approximately 30°E from that of 2,275 to 2,150 meters. That of the Telot No. 2 fault is 50°E from the line of exposure between line P and line V to an altitude of 2,340 meters, and 25°E from the altitude 2,340 meters to 2,250 meters. In either case, it is steep at the place of high altitude and relatively gentle like 25° to 30° at the lower part. Such a gentle dip might suggest that the fault is of thrust type. Although data to help infer the dip of the fault at the more deeper part could not be obtained, it is drawn on the geological sections that it changes to a high angle.

Because of insufficient data to infer the dip of other faults, they were drawn as vertical faults or those dipping steeply toward east.

3-4 Ore Deposits and Mineral Occurrences

Among the ore deposits of chromium, nickel and gold which are associated with the Telot serpentinite body in the Semi-Detailed Survey area A of the first year programme, the nickel and gold deposits were selected for detailed survey during this years programme for which geological survey and geochemical survey were conducted and, at the same time, investigation of ore deposit was performed. A regional survey was also conducted in the southern adjacent area of the Regional Survey Area of the first year programme (topographical map of Cherangani, 1 : 50,000), in which possible occurrence of ore deposit is likely in unexplored areas.

3-4-1 Regional Survey Area

No record of ore deposits or mineral occurrences has been found for the Regional Survey Area. The following were found during this year survey (Fig. 3-7, Plate 6).

(1) Panning Site of Placer Gold

The traces of panning was found in an area about ten kilometers long along the uppermost reaches of Moiben river in the eastern part of the area, and panning of river-bed sand and gravel is carried out by more than a dozen local residents. According to them, the amount of gold that they recover is not so much, and therefore they pan gold in the intervals of farming and cattle breeding.

The geological phenomena associated with the placer gold has not been established.

(2) Silicified Zone

Silicified zones are observed in the vicinity of Chepkotet in the eastern part of the area and in the adjacent area of Kapsait in the central part.

A highly silicified zone is exposed in the vicinity of Chepkotet 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 (CR-135A) (Table A-1), quartz, sericite and limonite were observed, and quartz and talc were identified by X-ray diffraction. As a result of microscopic observation of the polished sections (CR-134B, CR-135B) (Table A-2), a very small amount of tiny particles of chalcopyrite and gold were observed, leading to the assumption that a weak mineralization took place in association with hydrothermal alteration.

In the silicified zone in the vicinity of Kapsait, only magnetite-serictite quartz veinlets were observed at two places in an interval of 1.5 kilometers.

(3) Skarn

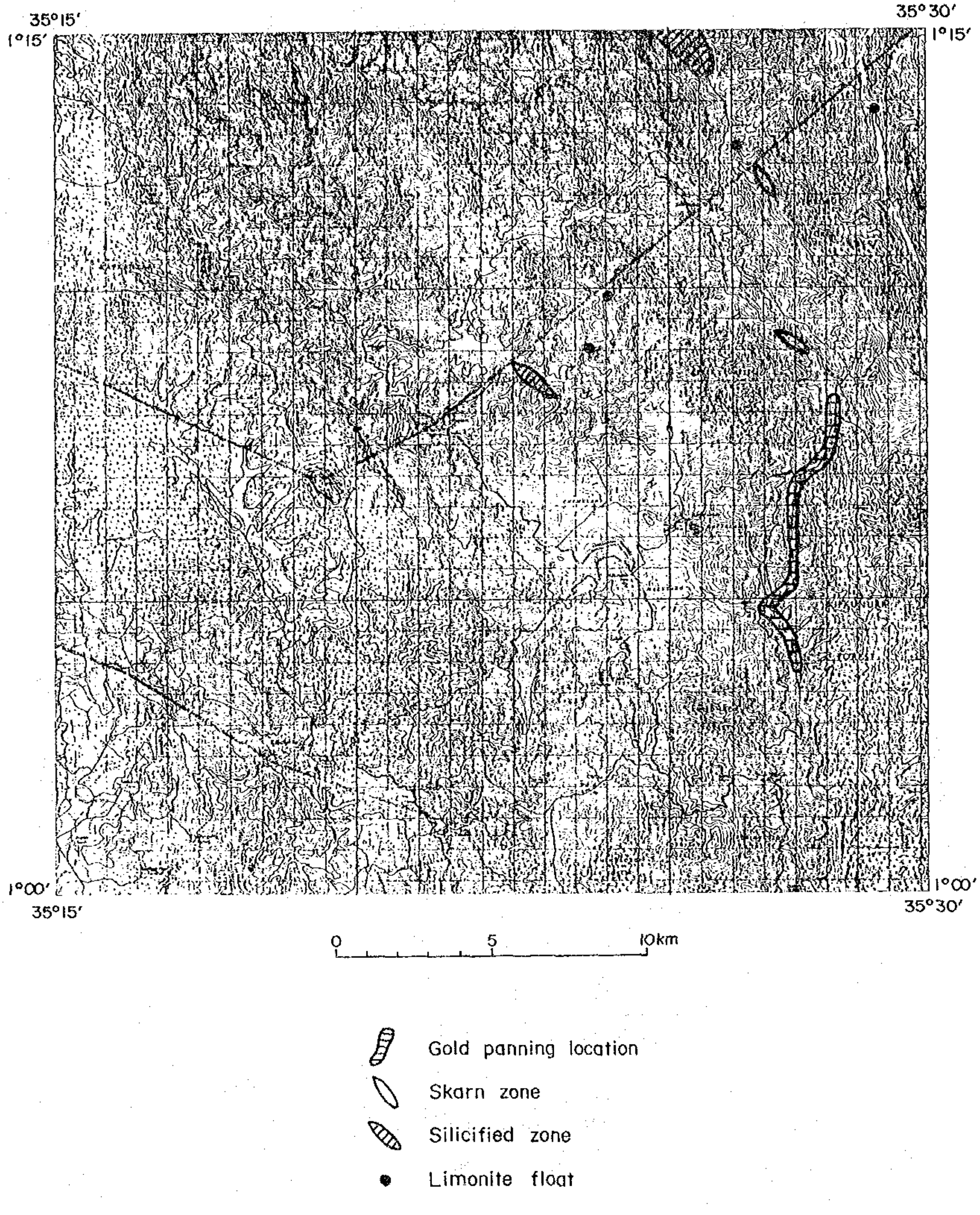


Fig. 3-7 Mineral Occurrence, Regional Survey Area