REPUBLIC OF KENYA

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

PHASE I

MARCH 1984

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

M P N
M N

REPUBLIC OF KENYA

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

PHASE I

MARCH 1984

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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 of four members in 1983, the first year of the survey project, and dispatched the team to Kenya during the period from October 7 to December 29, 1983.

The on-site survey was completed as scheduled with the cooperation of the Kenyan Government, particularly the Kerio Valley Development Authority and Mines and Geological Department of Ministry of Environment and Natural Resources.

This report describes the survey results in the first year and will form a part of a final report.

Lastly, we would like to express our heartful gratitude to the members concerned of the Government of 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 all of whom extended their kind cooperation to us in executing the aobve-mentioned survey.

March, 1984

Keisuke Arita
President,
Japan International Cooperation Agency

Masayuki Nishiie
President,
Metal Mining Agency of Japan

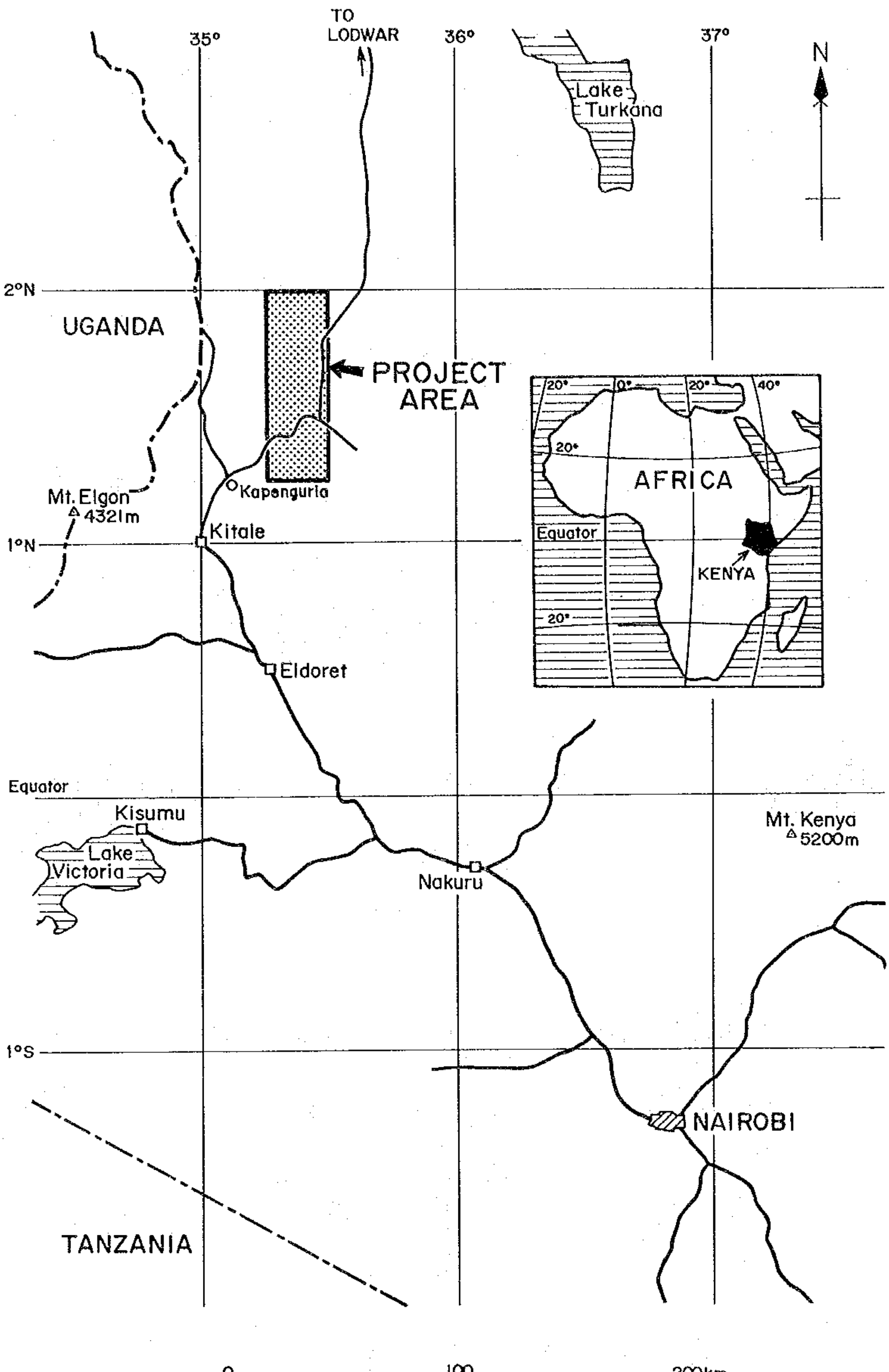


Fig. 1 Location Map of The Project Area

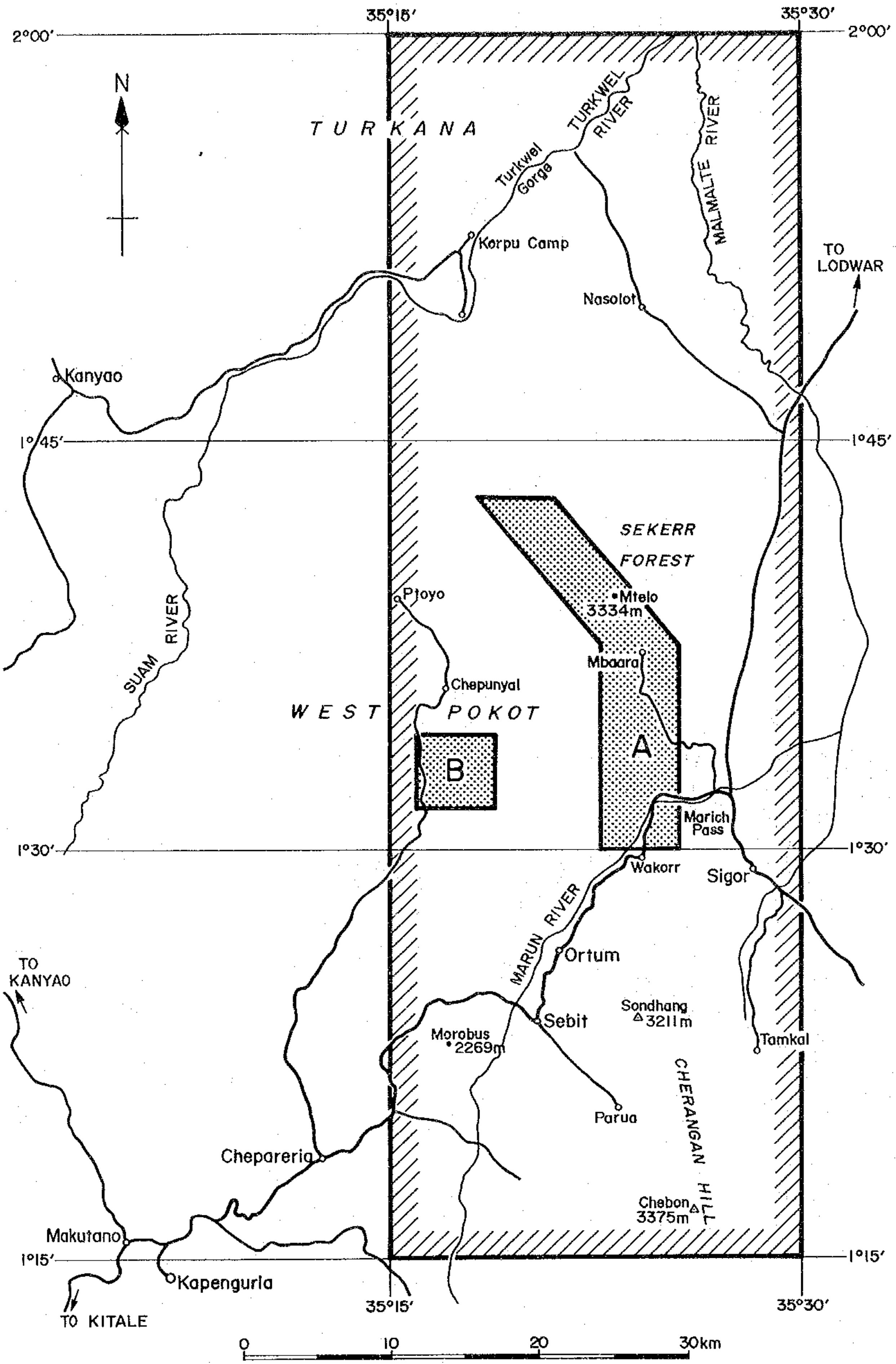


Fig. 2 Location Map of Phase I Survey Area

Abstract

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

For this purpose, geological mapping and geochemical exploration were carried out in an area of about 2300 km^2.

The project area comprises Regional Survey Area (R.S. Area), Semi-detailed Area-A (120 km^2) and Area-B (25 km^2). The first is for regional reconnaissance and covers the whole project area, while the second and the third are selected in the vicinity of the known mineral occurrences.

The geology of the project area consists of Pre-Cambrian metamorphic rocks which are usually classified as Basement System, in previous references, and intrusive rocks which range from granitic to ultrabasic in composition.

The whole project area structurally forms the westernmost block of the Rift Valley, where the most prominent structure is a NNW-trending regional syncline. The block is also characterized by the development of overturned folds and fault systems of N-S to NNW-SSE, NE-SW and NW-SE.

The Area-A is an area where major localities of ultrabasic rocks are located, while the B is the one where abundant pegmatite veins are observed.

Stratigraphical sequence in each area is established in this report.

The major mineral deposits so far confirmed within the project area are gold deposits and chromium-nickel ones.

The gold deposits include alluvial and eluvial, and both are being mined in very small scale by local people. The former is considered to be related with granitic and/or ultrabasic rocks, and the latter with ultrabasic respectively.

The chromium-nickel deposits occur associated with ultrabasic rocks: At Tulot, lenticular-formed small bodies of massive chromite, and stain and crack-filling of garnierite are observed in a serpentinite mass. There is a possibility that there might occur higher grade portions somewhere, as the areal extent of the mineralization is fairly large.

During the present programme two copper showings, other than small ones, which had previously been described, were newly located as well as a molybdenite vein.

Geochemical exploration which was carried out in the present programme includes stream-sediment sampling for R.S.A. and soil for Semi-detailed areas.

In the Regional Survey Area, 1,552 stream-sediment samples were collected and tested for 6 elements; Au, Cu, Pb, Zn, F, and Cr. In the Area-A, 206 soil samples were tested for 5 elements; Cr, Ni, Co, V, and Pt, whereas in the Area-B, 50 soil samples were tested for 6 elements; Nb, Ta, Li, Sn, W, and F.

As a result, some anomalous areas are selected for Au, Cr, Ni, Co, Zn, and Cu. The gold anomalies well reflect known deposits. The Cr, Ni, and Co anomalies also well coincide with the distribution of ultrabasic rocks which accompany known Cr-Ni deposits. Among them, a Ni anomaly in the Area-A is strong in intensity and fairly extensive in area. Zn anomalies in the southern part of the R.S.A. are apparently situated at the intersections of inferred faults, and some anomalous copper values seem to occur in the vicinity of the granitic mass that often accompanies skarn minerals.

All these results have been integrated and carefully studied, and following areas are selected as targets for follow-up programme. These are the Tulot anomaly for Ni and Au, the Sebit for Zn and Cu, and Akeriamet for Cu.

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF APENDICES

LIST OF PLATES

CHAPTER 1 INTRODUCTION

1-1 Introduction

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.

For this purpose, geological mapping and geochemical exploration were carried out in an area of about 2,300 km^2.

Some reconnaissance works covering the project area have been already done by Geological Survey of Kenya (present Mines and Geological Department: M.G.D.), and some local geology and mineral occurrences covering small areas in the project area have been also reported by M.G.D. and private companies. Therefore the following programme was designed for the first year of a three year programme, based on those available data and information.

The programme comprises two categories of works in term of exploration stages. One is a Regional Survey designed to cover the whole project area (2,300 km) and the another is a Semi-detailed Survey in the proximities of known mineral occurrences (Area A: 120 km^2, Area B: 25 km^2).

The Regional Survey is designed to asses the mineral potential in the project area, and to locate target areas that are worth further follow-up works in the 2nd Year.

The Semi-detailed Survey Area A is chosen to cover known chromite outcrops and prospects. The aim is to clear the distribution of ultrabasic rocks which are the host of chromite deposits.

The Semi-detailed Survey Area B is selected to cover known occurrences of pegmatite dykes and their proximities. The purpose is to study whether there are any mineral occurrences related to the dykes.

1-2 Outline of Survey

The survey of this year consists of two kinds of works, namely, geological survey and geochemical survey, and the survey area is classified into Regional Survey Area covering the whole project area and two Semi-detailed Survey Areas in it (Areas A and B).

Geological survey was carried out by each four Japanese and Kenyan geologists. In Regional Survey Area, geology was mapped in a 1/25,000 scale and compiled into three 1/50,000 scale geological maps. In Area A, geology was mapped in a 1/10,000 scale and compiled into 1/25,000 map, and in Area B, in a 1/5,000 scale, and 1/10,000, map. Mineral showings were also investigated in each area. Prior to the field survey, the selection of routes were done after examination of available data and information, landsat image and aerial photographs.

Geochemical survey was carried out at the same time and on the same routes as geological survey. In Regional Survey Area and Semi-detailed Survey Areas, stream sediments and soil sanples were collected respectively, and analysed for each element according to their purposes.

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

Table 1-1 Outline of Geological Works and Geochemical Survey

Item	Area to be Covered	Length Surveyed	Geological Map
Regional Survey Area	2,300 km^2	658 km	Scale 1:50,000 3 Sheets
Semi-Detailed Survey Area A	120 km^2	63 km	Scale 1:25,000
Semi-Detailed Survey Area B	25 km^2	17 km	Scale 1:10,000

Table 1-2 Laboratory Works Carried Out

Item	No. of Samples	Remarks
Geochemical samples		
(1) Stream sediment (Regional Survey Area) Au,Cu,Pb Zn,F,Cr	1552	
(2) Soil		
Area A Cr,Ni,Co V, Pt	206	61 Samples were also analyzed For Au
Area B Nb,Ta,Li Sn,W, F	50	
Chemical Analysis		
(1) Rocks: SiO_2, TiO_2, FeO, Fe_2O_3, MgO, CaO, K_2O, BaO, MnO, Na_2O, Al_2O_3, P_2O_5, LOI	12	Whole-rock analysis
(2) Mineralized materials		
Regional Survey Area: Au, Ag	10	
Area A: Cr,Ni,Co,Cu,Pt,V,Fe,Al	20	
: Co,Ni,Cu	21	
Area B: Nb,Ta,Sn,W,Li,F,U	10	
Thin Sections of Rock	63	
Polished Sections of Ore	13	
X-ray diffraction	11	

1-3 Previous Works

Literatures described below are the principal previous works concerning on the geology and mineral deposits in the project area and the surroundings.

(1) McCall, G.J.H (1964) : Geology of the Sekerr Area, Rep. 65, Geol. Surv. Kenya

(2) Miller, J.M. (1956) : Geology of the Kitale - Cherangani Hills Area, Rep. 35, Geol. Surv. Kenya

Quadrangle geological Maps attached to these reports are 1/125,000 in scale and cover the whole project area.

In addition to these works, many of reports concerning with geology and mineral occurrences in limited areas in the project area are kept in M.G.D. and most of these are used for this survey.

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

(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)

1-4 Organization of the Survey Team

The Personnel who particiated in the survey are as follows:

Japan, Planning and Negotiation

Toshio Sakasegawa	Metal Mining Agency of Japan
Ken Nakayama	do
Yoshitaka Hosoi	do
Hideyuki Ueda	do
Yosuke Suzuki	do (Nairobi representative)
Takayoshi Hagio	Embassy of Japan
Susumu Yanai	Japan International Cooperation Agency, Nairobi
Takaichi Nagashima	do
Hayao Takenaka	do

Kenya, Planning and Negotiation

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

Japan, Survey Team

Kinsuke Uchida (Leader)	Metal Mining Agency of Japan
Haruo Watanabe	do
Masahiro Hase	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

1-5 Procedure of Survey

This survey is the first Cooperative Mineral Exploration Project in Kenya between the Governments of Japan and Kenya.

So it was needed for both Japanese and Kenyan geologists to establish common procedure of works in operating field and desk works.

The survey team prepared the flow chart shown in Fig. 1-1, and carried out the works confirming the progress of each part of it.

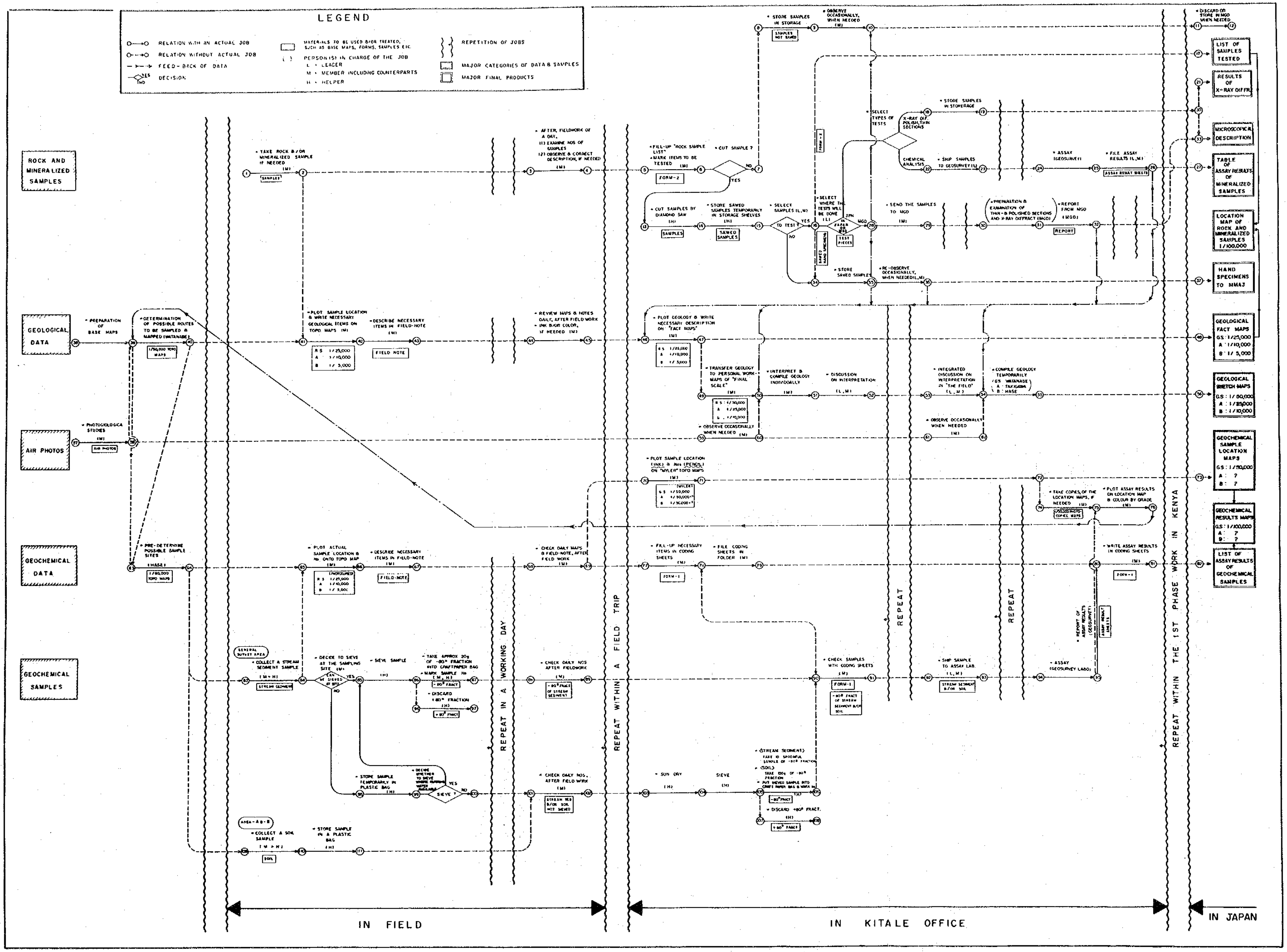


Fig.I-I Flow Chart of Job in Kenya

CHAPTER 2 GENERAL INFORMATION

2-1 Gneral Condition

The Republic of Kenya is located in the central part of the eastern Africa and covers a total area of 582,644 km^2. Its population is about 15.69 million in 1980, 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 1979 reached to the amount of $5,820 million and is estimated to be $380 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, textiles etc. and the mining products are rather small in quantity.

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

The mother tongue and the official language are both Swahili. English is widely used in the urban areas, but Swahili is main in provinces and in the undeveloped area, tribes use their native speakings.

The currency of the country is the Kenyan shilling and the exchange rate for U.S. dollers was 15.5 K.S. per 1 doller on 15th October, 1983. U.S. doller and U.K. pound enable to exchange in general bank in both cases of cash or traveler's check.

2-2 Location and Communication

Area surveyed is included in the Province of Rift Valley, and mainly belongs to the West Pokot district and the remainder to the Turkana district. Total area is about 2,300 km^2, forming oblong, bounded by the 1°20'N. and 2°00'N. latitudes and 35°15'E. and 35°30'E. longitudes (Fig. 1).

Access to the surveyed area from Nairobi is as follows: Nairobi-Nakura-Eldoret-Kitale(basecamp), through all-weather highway 400 km (about 6 hours by car). From Kitale, highway which crosses the northern part of Kenya to Sudan can be used to Ortum, center of the area surveyed. It takes about 1.5 hours by car (about 100 km). The high way is now under construction by the aid of Norwegian government and was quite useful for survey because the way cuts the area obliquely in the south, and again cuts through the eastern central part of the area.

Tracks and trails in the area are, on the contrary, quite poor and are all unpaved. A car with four wheel drive or lorries are necessary to go through these mountain paths.

The paths were mainly constructed along the steep slopes and it is difficult to pass through in rain or after rain. Accordingly, it is impossible to pass in rainy season or flooded term.

2-3 Physiographical Features

The area surveyed is situated just on the west of the eastern rift belonging to a part of so-called Afican Great Rift Valley. The eastern side of the area is bounded by a great fault scarp which makes the western side of the Valley.

The scarp makes a steep cliff of 800 to 1,000 m high, and the eastern side of the cliff forms a flat basin (bottom of the Valley) of 700 to 1,000 m above the sea. The western side of the cliff (included in the area) forms steep mountains of 1,000 to 3,300 m above sea level.

Mountains located in the west of the cliff are characterized by the ranges extending in N-S or NNW-SSE, roughly parallel to the geological structure of the area.

The mountaineous land which extends from the Cherangani Hills in the south to the Mtelo mountain (highest peak, 3,334 m above the sea in the area) in the central part, constructs a great range of 2,000 to 3,300 m aobve the sea, and is covered by thick forest forming a wooded region. Both sides of the range also construct steep mountains, 1,200 to 2,400 m above sea level.

In these mountain ranges, there distribute several plains (near Chepunyal, Matong-Mbaara etc.) of 2,000 m and also plains of 3,000 m or so (Cherangani Hills) above the sea. The plains are thought to be remnants of peneplain occurred by the erosion in the past.

Also along the Suam-Turkwel River in the north, and the Marun River in the south, there distribute plains in small scale, about 1,000 to 1,500 m above sea level.

Drainage systems in the area are two in number, namely, Suam-Turkwel system in the north and the Marun system in the south. The both two flow into the Weiwei-Malmalte River which flows northwardly at the foot of the Sekerr-Turkwel fault scarp.

The drainage system form subsequent valleys in parallel with the elements of geological structure and many of them show a pattern of straight line in the trends of N-S or NNW-SSE. These lines are mostly in parallel with the strike of the Basement System or the fracture systems observed in the Basement System.

The main streams of the Rivers Turkwel-Suam and Marun, which form the two large drainage systems in the area, flow in the direction of NE-SW, making a right angle with the general trend of the Basement System. The Marun River seems to have been controlled by the existence of a fault trending NE-SW at the middle reaches. The Turkwel-Suam River seems to flow without any relations to the strike or fracture observed in the Basement System.

2-4 Climate and Vegetation

Area surveyed is cross to the equator. Generally speaking, the climate shows an annual variation of equatorial type. In Kenya, generally from January to March, the climate is hot and dry. Main rains come between the end of March to June. June to September is cool and dry and after that it comes into light rainy season. However, in our area, hot and dry season seems to start from December, and they say that the heavy rainy season continues irregularly so long or too short, and the annual change is rather severe.

Greater part of the country, from the central part to the south, shows a hilly savannah of 1,700 m high, and in spite of the location on the equator, the average temperature is about 20°C and the climate is warm and mild.

In the area, the eastern part belong to the lowland of 800 to 1,000 m high, and continues to the Rift Valley. The western part belongs to the mountain ranges having 2,000 meters difference in their heights. Owing to the differences of topographic condition, the climate of each portion of the area is variable from the wet-forest type at the highland of cool and wet, to the semi-arid type in the lowland of the Rift Valley.

In the semi-arid region, day-time temperature goes up nearly to 35°C and comes down below 20°C at night. Annual precipitation is measured to more or less 300 to 800 mm.

In contrast to the above, at the mountaineous region in the west, day-time temperature goes up nearly to 25 to 33°C, and comes down below 10°C at night although it is quite variable owing to the height. In the mountains higher than 3,000 m, they say that the temperature often goes down below 0°C at night. In these mountains in the west, rainfall is estimated to be 600 to 1,200 mm or so. However, considerable rainfall more than that is supposed to be there because the area is often covered by clouds and the quantity of running water in the valleys is large in the forest regions more than 2,500 m above the sea.

Rainfall at Sigor and Chepunyal in the Area and at Kongolai to the west of the Area is shown in Table 2-1.

Table 2-1 Reinfall in Sekerr Area

Station	Year			Average	No. of years records taken
	1955	1956	1957		
Kongolai	776.2	1,101.9	531.6	821.6	5
Sigor	857.0	790.4	555.8	704.0	6
Chepunyal	872.7	988.6	870.2	859.8	5

McCall, G.J.H. et al. (1964)

(Figures were changed from inches to milimeters)

Vegetation status in the area will be divided into four zones as follows: In the semi-arid zone in the Rift Valley, vegetation is classified to the thicket of assorted trees where the thorny plants are sparsely grown. In the mountains at the west, a thicket zone of assorted trees where the thorny plants and the acacia are grown, the grassland zone where the shrubberies are sparsely grown and the wet-forest zone observed in the height more than 2,000 m above the sea. In the thicket zone, cactuses are obserbable, and near the top of the wet-forest zone, bamboos can be seen, and cryptomeria or some heath are said to be observable.

Cultivation is generally progressed on the land higher than 1,500 m, especially on the highland more than 2,000 m above the sea, and the products are mainly corn.

CHAPTER 3 GEOLOGICAL SURVEY

3-1 Method of Survey

The survey of this phase was initiated by grasping the outline of geology by investigating the existing geological maps and reports, and investigation by photogeological interpretation and analysis of Landsat image were added to establish the survey routes. Next, a comprehensive geological analysis was made on the basis of the geological data obtained in the field together with the laboratory tests of geological samples. The geological maps were completed based on the field geological data incorporating the result of reinterpretation of aerial photographs.

Topographical Maps

The topographical maps 1 : 50,000 edited by the Survey of Kenya (62/2 Turkwel Gorge, 62/4 Sekerr, 75/2 Sigor) were used for the survey of this phase as the basic maps. For the fact maps of the field survey, these were enlarged to 1 : 25,000 (Regional Survey Area), 1 : 10,000 (Semi- detailed Survey Area A) and 1 : 5,000 (Semi-detailed Survey Area B). For the geological maps, that of 1 : 50,000 itself in the Regional Survey Area and those enlarged to 1 : 25,000 and 1 : 10,000 in the areas such as Semi-detailed Survey Area A and B respectively, were used.

Aerial Photographs

Ninety-four sheets of aerial photographs (approximately 1 : 50,000 in scale) were used for the survey of this phase. The numbers and locations of the principal points of these photographs are shown in Fig. 3-1.

Landsat Image

The Landsat image used for the survey are the false color image 1 : 125,000 in scale synthesized from the bands 4, 5 and 7 of the MSS data (Multispectural scanner data). The false color image was synthesized by Geosurvey International. The data used are as follows:

Path : 182, Raw : 059, 1-Feb-73

3-2 General Geology

3-2-1 Outline of Geology

Fig. 3-2 shows the outline of geology of Kenya.

The Precambrian rocks occupy the most part from the center to the western part and a part of the northeastern part of Kenya. The Precambrian group consists of metamorphic rocks, which are roughly divided into four systems from the base upward such as Nyanzian, Kavirondian, Basement and Bukobon. The systems such as Nyanzian, Kavirondian and Bukobon show only a small distribution on the eastern coast of the Lake Victoria, and the Basement system occupies the most part of the Precambrian. These Precambrian systems belong to the Mozambique metamorphic belt formed by an orogenic cycle from late Precambrian to early Palaeozoic (600 ± 200 million years). The rocks of the zone is generally composed of schistose rocks of high metamorphic grade, showing a notable northerly trending pattern in general.

The Palaeozoic and the Mesozoic are distributed in two

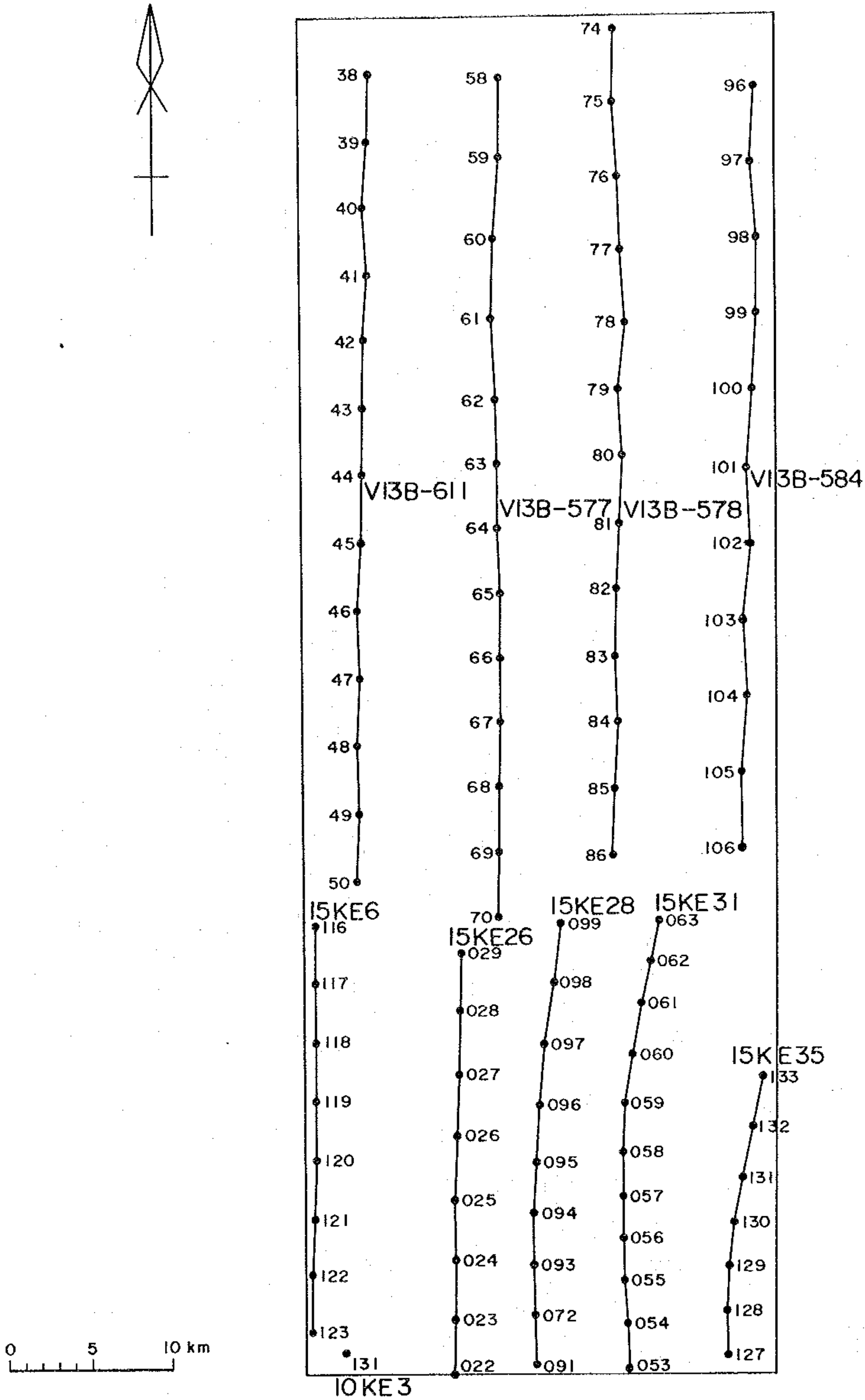


Fig. 3-1 Index Map of Aerial Photographs

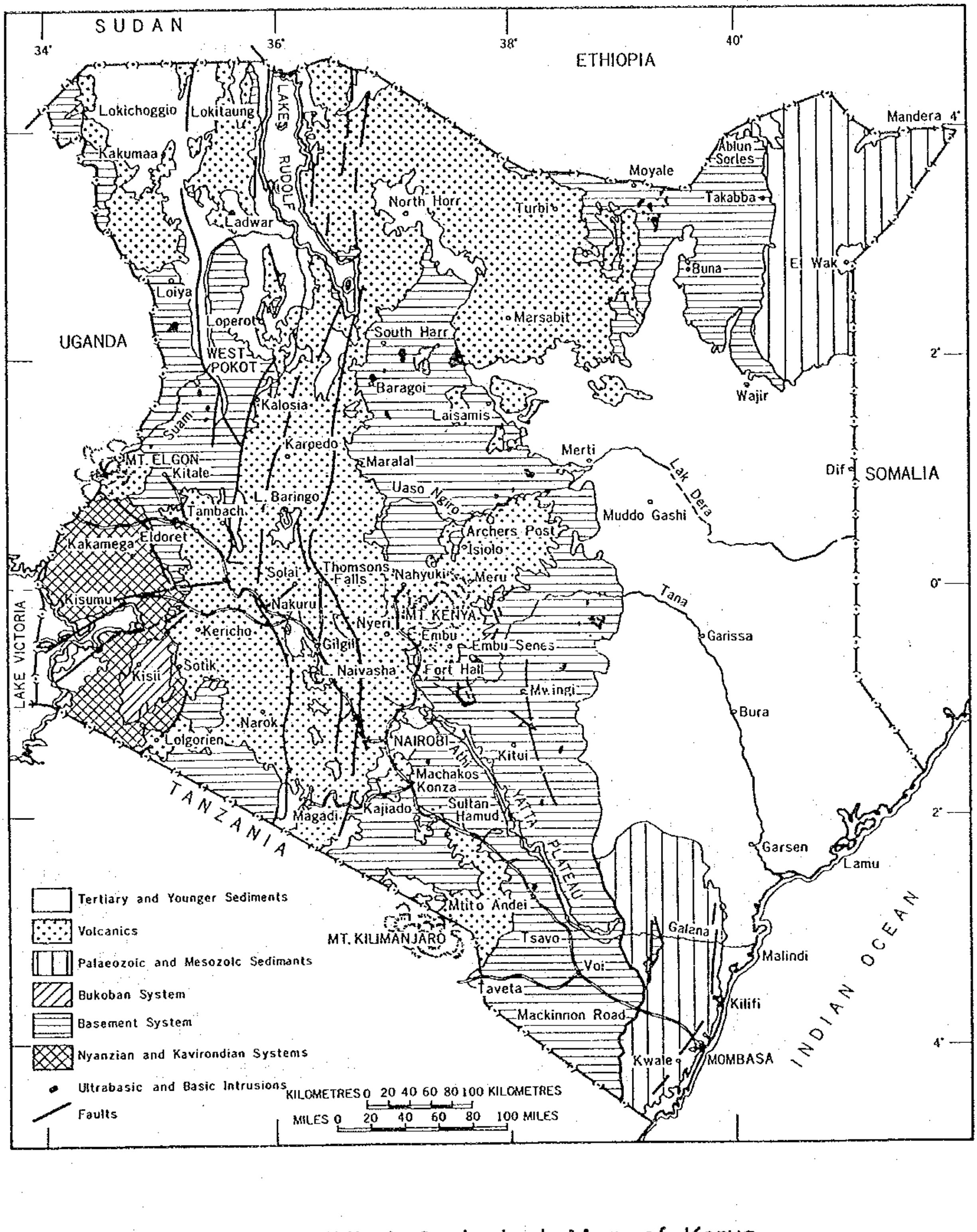


Fig. 3-2 Simplified Geological Map of Kenya

(*After* Pulfrey, W. and Walsh, J. 1969)

places of the northeastern part and the southeastern part of Kenya. These consist of sedimentary rocks such as the one correlated to a peculiar continental sediments called the Karroo System deposited from late Palaeozoic to early Mesozoic and the marine sediments mainly composed of limestone and sandstone deposited from Jurassic to Cretaceous.

The geology of Cenozoic consists of the volcanic rocks distributed mainly in the Rift Valley running on the western side of the country and the sedimentary rocks mainly distributed in the surrounding area of the Lake Turkana in the northwestern part.

The volcanic rocks were formed mainly associated with activity of the Rift Valley, which began with the activity of basalt took place from the Miocene downward accompanied by eruption of nephelinite and effusion of carbonatite. In the later stage of Miocene, lava plateaus of phonolite were formed by fissure eruption on a large scale, and welded tuff of trachytic rocks was deposited. Volcanic activity associated with formation of caldera continued into Quaternary.

The sedimentary rocks are composed of Tertiary marine sandstone, Quaternary sandstone and coral reef on the eastern side, and the lacustrine deposits from late Miocene to Pliocene in the surrounding area of the Lake Turkana.

Most of the survey area is situated on the western side of the Rift Valley, being composed of the Basement System and the intrusive rocks intruding in the above. The eastern side of the area, which is in the Rift Valley, is mainly occupied by the Quaternary sediments.

Fig. 3-3 shows the outline of geology of the survey area and Fig. 3-4 shows the generalized geological columnar section.

3-2-2 Basement System

The Basement System had been considered to be the basement in Kenya, but it was made clear that it was younger than the Nyanzian and Kavirondian Systems in the latter half of 1966. Accordingly, the name of Basement is a miscall. However, because it has hitherto been used and because the name has been used in many publications, it is accepted to follow suit (Pulfrey et al., 1964).

(1) Classification of Basement System

Miller (1956) classified the Basement System into the metamorphic rocks derived from sedimentary rocks and volcanic rocks, migmatite, metasomatite and intrusive rocks, and made classification of rock facies. He mentioned, however, that it was difficult to establish the stratigraphical relationship because the metamorphic rocks of the area show a isoclinal structure and because the schistosity plane is not always consistent with the bedding plane.

McCall (1964) mentioned that the Basement System in the Sekerr area consists of continuous stratigraphy becoming younger toward the east. According to it, the estimated thickness of the system becomes about 60,000 feet, which is too thick for the stratigraphy of a single geosyncline. He claimed, however, that it could be inferred from the structural considerations. He classified the stra-

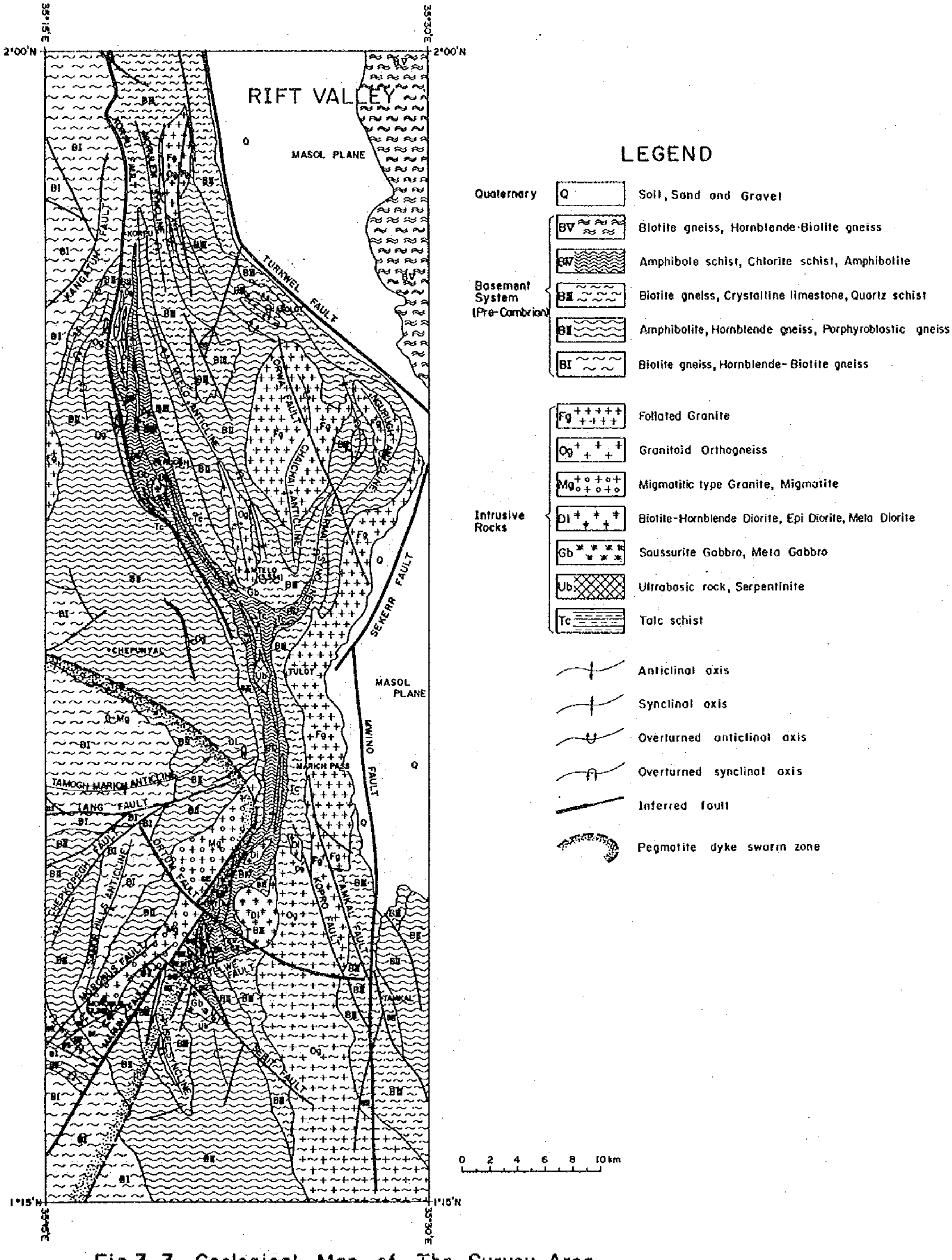


Fig. 3-3 Geological Map of The Survey Area

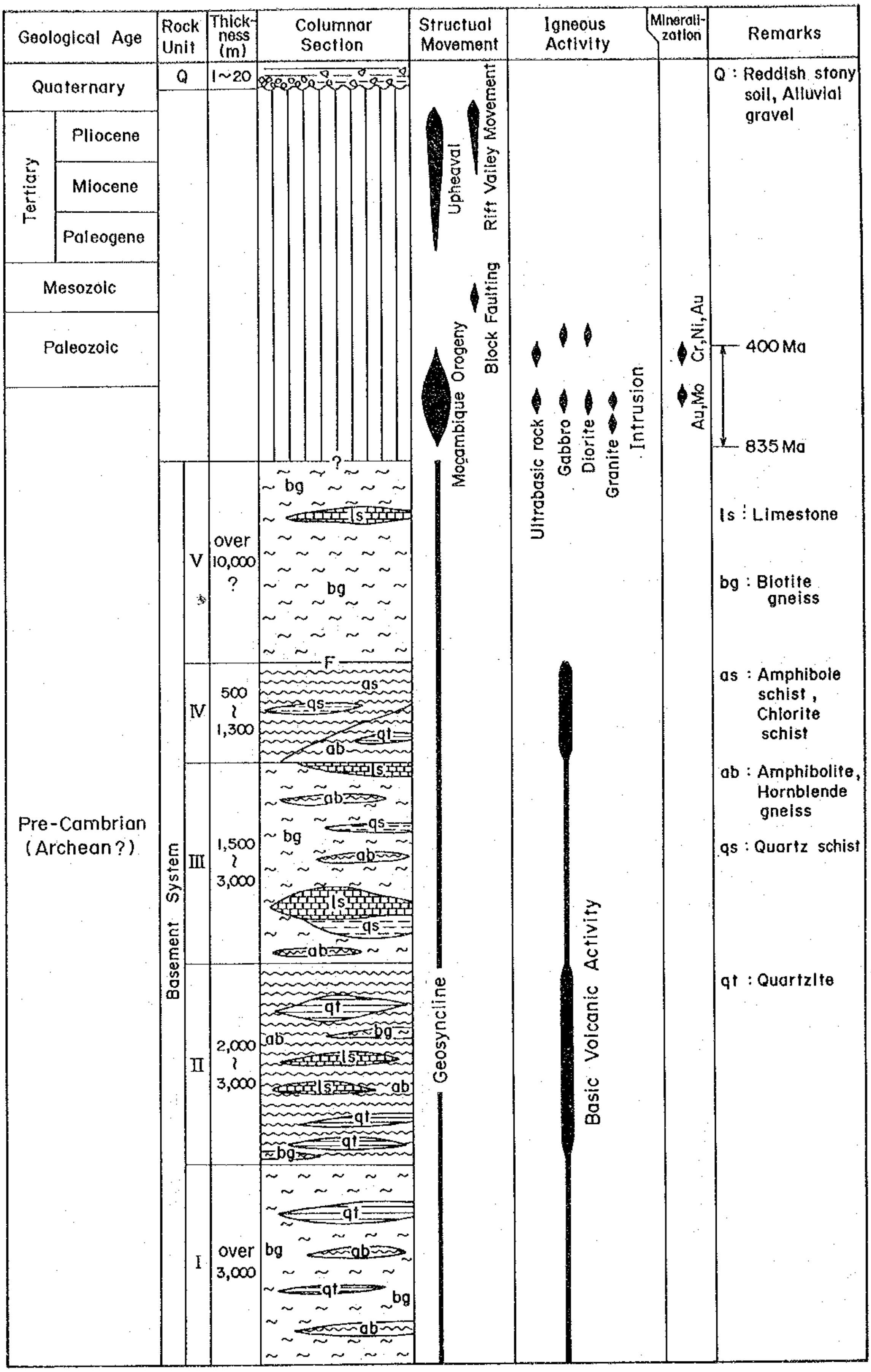


Fig. 3-4 Generalized Geological Columnar Section of Survey Area

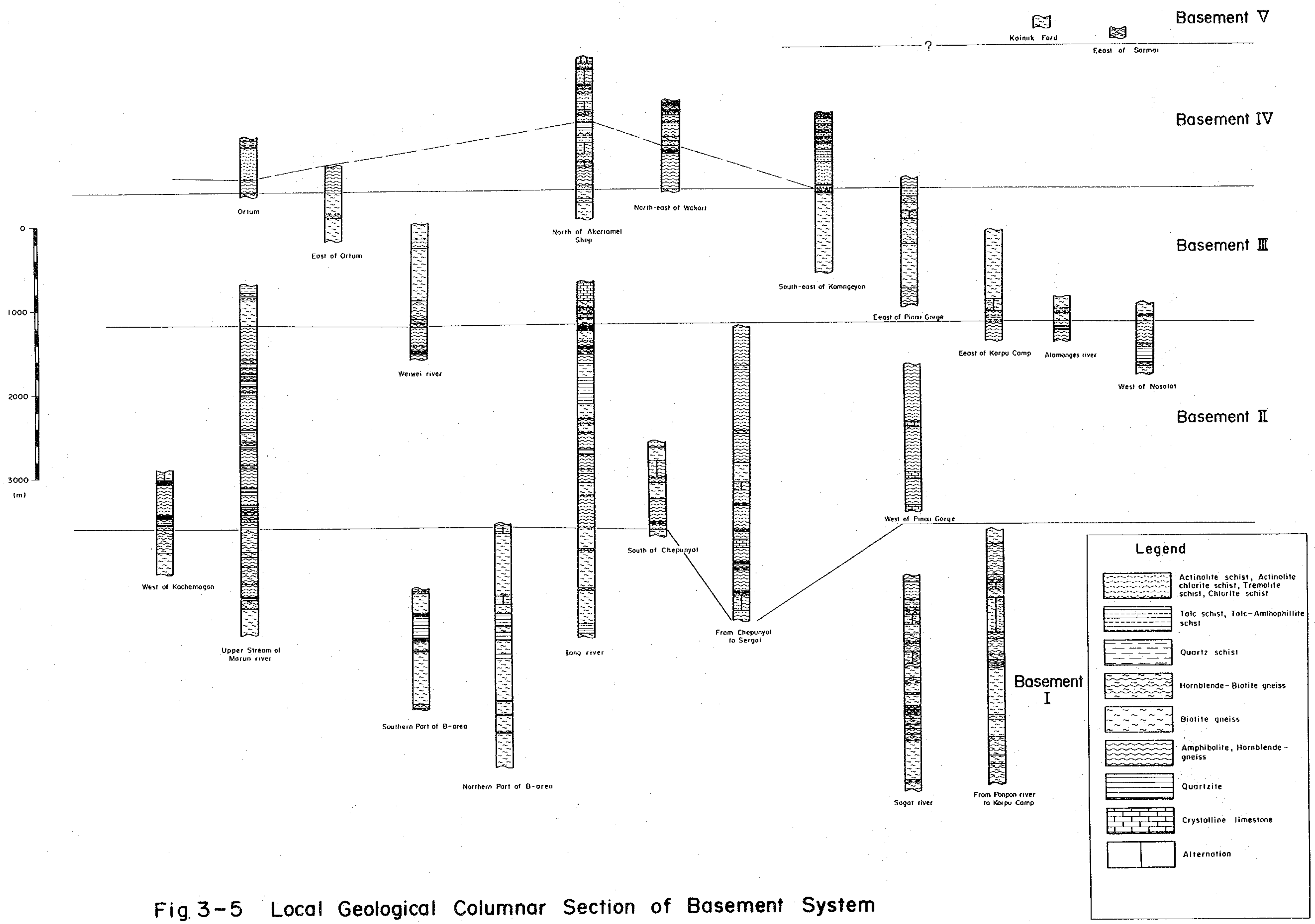


Fig. 3-5 Local Geological Columnar Section of Basement System

tigraphy of the Sekerr area into the four as in the following.

		Estimated thickness
(4)	Malmalte Semi-pelitic Gneisses	20,000 feet
(3)	Marich-Korpu Schists	10,000
(2)	Chepunyal-Burgich Plagioclase Amphibolites Gneisses	10,000
(1)	Tamau-Kunyao Semi-pelitic Gneisses	20,000
	Total	60,000

Tamau-Kunyao Gneisses are composed of dominant semi-pelitic rock accompanied by amphibolite with scanty limestone. On the other hand, Chepunyal-Burgich Gneisses are predominated by amphibolite. In the members of Marich-Korpu Schists, the rocks of volcanic origin and those of sedimentary origin are found almost in equal amount. Malmalte Gneisses consist of semi-pelitic gneiss accompanied by amphibolite and some limestone, and it is said that they considerably resemble Tamau-Kunyao Gneisses.

It became clear from the survey of this phase that distribution of the rock facies is close to the opinion of McCall as a whole.

It is, however, likely that the amphibolitic rocks corresponding to Chepunyal-Marich Gneisses and those distributed on the western side of Malmalte Gneisses make their appearance in the Marich-Korpu Schists zone by a remarkable folding. It seems, therefore, that the opinion that the sequences continually become younger toward the east is not necessarily reasonable.

Because it is not always sufficient for the grasp of stratigraphy and geologic structure at the stage of reconnaissance survey, it was given up in this phase to classify the Basement system into the formations given specific name, and an attempt was made to divide it tentatively into five formations of Basement I, II, III, IV and V.

(2) Characteristics of Each Formation of Basement System

Fig. 3-5 shows the columnar section of Basement System in each area.

The Basement I Formation mainly consists of biotite schist accompanied with quartzite. It is more than 3,000 meters thick.

The Basement II Formation consists of amphibolite, hornblende gneiss, crystalline limestone, quartzite, psammitic schist and porphyroblastic gneiss, and it is characterized by a notable occurrence of amphibolite and hornblende gneiss which indicates geosynclinal volcanic activity. The thickness is 2,000 to 3,000 meters.

The Basement III Formation consists of biotite gneiss, crystalline limestone, quartzite, psammitic schist and biotite-muscovite schist, which is characterized by the distribution of biotite schist and crystalline limestone of good continuity. The thickness is 1,500 to 3,000 meters.

The Basement IV Formation consists mainly of amphibole schist and chlorite schist accompanied with amphibolite and hornblende gneiss. The formation were intruded by ultrabasic rocks and talc schist throughout the area, showing a peculiar rock facies. The thickness is 500 to 1,300 meters.

The Basement V Formation is distributed in the north-eastern corner of the survey area apart from the others. It is mainly composed of biotite gneiss, accompanied by crystalline limestone. The relation between the formation and the former four such as I to IV has not been known. The thickness is estimated to be more than 10,000 meters.

The geological description of each formation is discussed in Section 3-3 in detail.

3-2-3 Quaternary System

The Quaternary system of the survey area is composed of soil, river bed sand and gravel, and talus deposit, which covers the Basement System 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 at the rivers such as Marun, Iang and Turkwel. The talus deposit is distributed in zones at the bottom of the fault scarps such as Turkwel and Sekerr.

3-2-4 Intrusive Rocks

The intrusive rocks in the area include acidic rock to ultrabasic rock and vary in rock facies. The acidic rock is classified into granitoid orthogneiss, foliated granite, migmatitic type granite and pegmatite, the intermediate rock into diorite and epidiorite, the basic rock into gabbro and meta-gabbro, and ultrabasic rock into dunite, serpentinite and talc schist.

Many of the intrusive rocks are the products of igneous activity at the time of preorogeny to orogeny, and has more or less been subjected to metamorphism, which altered the granitic rocks to orthogneiss and schistose rock. Meta-diorite and meta-gabbro have also been altered to the 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 the orogenic belt. Many of the pegmatites seems to have been formed by the similar origin.

On the other hand, the 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. Ultrabasic rocks, gabbro and diorite correspond to this category.

These intrusive rocks are found as sheet and small stock or dyke, and the large-scale one such as batholith has not been observed.

Chromium and nickel deposit, and gold deposit are the ore deposits associated with the intrusive rocks. The former is associated with the ultrabasic rocks and the latter with the granitic rocks and the ultrabasic rocks.

3-2-5 Metamorphism

(1) 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. The metamorphic grade of the area belongs mostly to amphibolite facies judging from the mineral assemblage of metabasite. The dominant mineral assemblage in the metabasite is hornblende-andesine-quartz with occasional garnet, epidote, zoisite, diopside, biotite and sphene. The occurrences of staurolite and kyanite in metasediment indicate that the metamorphism is of medium pressure type (kyanite-sillimanite type).

(2) Ultrametamorphism

The Ortum migmatitic granite seems to have been formed by ultrametamorphism. Field evidences which show the effects of granitizing fluids-emanations, can be observed in surrounding areas of the granite especially along the Marun River near Ortum. Some of the evidences will be described below with figures.

a) Growing of constituent minerals along the foliations of gneiss (Fig. 3-6): The coarse grained layer includes unaltered fine-grained parts and the boundaries between the coarse-grained parts and fine-grained are sometimes transitional. It is assumed that the emanations permeated along the foliations and made the minerals grow.

b) Presence of migmatite including paleozome (Fig. 3-7): The foliation of wall rock is parallel to that of paleozome as well as the ghost foliation in migmatite. The feature shows the migmatization have statically proceeded as metasomatism.

c) Development of porphyroblastic microcline or perthite in augen gneiss: The augen gneiss is mainly exposed in a limited area along the northwestern border of Ortum migmatitic granite, and makes bands with biotite gneiss at the transitional zone of them. This also shows the effect of emanations to biotite gneiss.

The origin of pegmatites can be considered to have some relationships with ultrametamorphism. According to the textbook of petrology by Miyashiro and Kushiro (1977), they regarded the pegmatites which intruded densely in metamorphic rocks of higher metamorphic grade than the grade of moderate temperature of amphibolite facies, as the products of partial melting of pelitic to psammitic metamorphic rocks. This idea seems to interpret well the occurrences of many pegmatites in the area.

The pegmatites are distributed mainly in the north west of Ortum migmatitic granite with no appearrance of considerable granite intrusives but migmatite. In addition, a fairly number of pegmatite intruded concordantly in the gneisses, and some of them show transitional change into the wall rock (Fig. 3-8). These evidences suggest the anatexis origin of pegmatites.

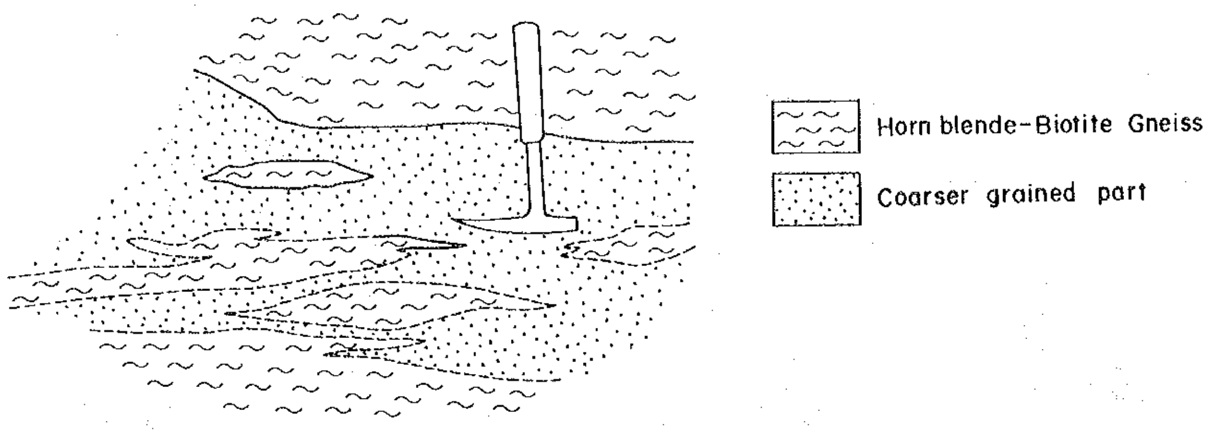


Fig. 3-6 Sketch Showing Effect of Emanation, Marun River

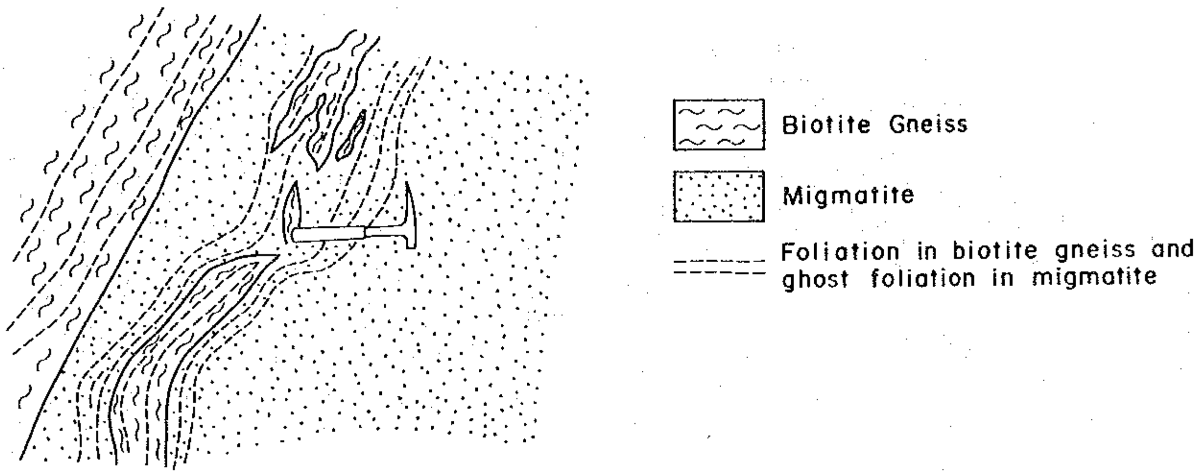


Fig. 3-7 Sketch Showing Relation between Biotite Gneiss and Migmatite, Marun River

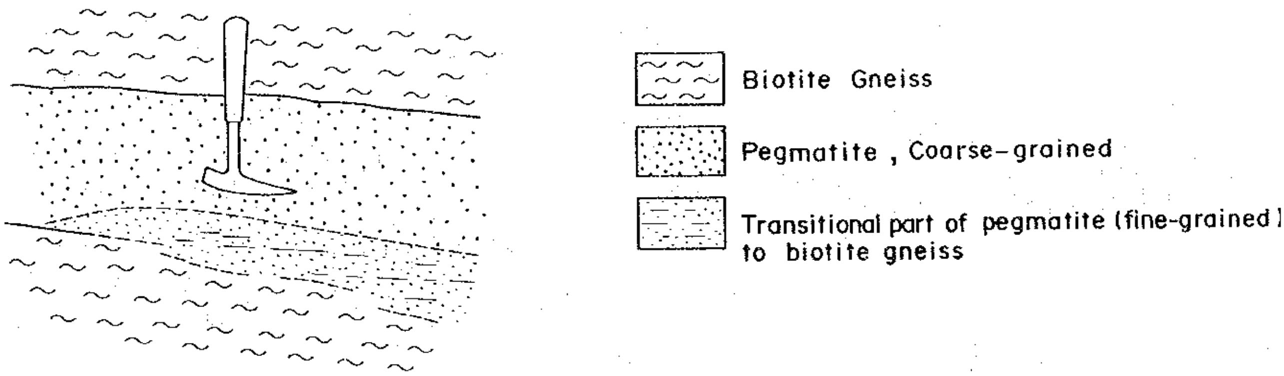


Fig. 3-8 Sketch Showing Relation between Biotite Gneiss and Pegmatite, Tamogh River, Area B

(3) Retrograde Metamorphism

Lower-grade metamorphic rocks corresponding to green schist facies are found in a narrow zone along Endogh-Tulot synclinal axis. The rocks are fine grained and composed of chlorite schist, chlorite-actinolite schist and tremolite schist, which are main members of BIV Formation.

The green schists show a considerable degree of shearing indicated by the intense schistosity and the elongation of magnetite megacrysts in chlorite schist, consequently, the green schists are thought to have been formed as the result of diaphthoresis or retrograde metamorphism of rocks of the amphibolite facies.

The green schist zone is marked by the existence of intruded ultrabasic to basic rocks, by the development of folded structure and by the presence of major faults, Korpu fault and Marun fault, along the zone. These characteristics suggest that the zone is a kind of tectonic zone, and the retrograde metamorphism might have been related to shearing along the tectonic zone.

The green schists grade into the original amphibolite where the effect of shearing is weak or none.

(4) Contact Metamorphism

A skarnized rock crops out at the road between Marich pass and Mbaara. The rock is in the biotite gneiss of BIII Formation with lenticular form and composed mainly of diopside, hornblende, biotite and garnet with subordinate amounts of pyrite (thin section DR-22). This skarn might have been produced by contact-metamorphic effect of foliated granite (Fg) to a calcareous bed in BIII Formation.

A skarn float collected in the Weiwer River near Tamkal is garnet-hornblende-diopside-epidote skarn with chalcopyrite -pyrite dissemination (thin section CR-30).

An uncertain rock with pyrite dissemination, which is represented in the geological map of Area A as garnet-enstatite porphyroblastic rock, is possibly a skarn (thin section BR-152).

3-2-6 Geological Structure, Geological History

(1) General Remarks

Structural elements of the area are shown on the Fig. 3-3, and the lineaments obtained from the Landsat image are also shown on the Fig. 3-9.

Geological structure is controlled by the fundamental structural elements of the Basement System directed in NNW-SSE, and roughly speaking, is based on the synclinal structure extending in NE-SW at the southern central part and in NNW-SSE at the northern central. Accordingly, the strata of the same horizon distribute in the both sides, east and west, put the synclinal axis in between.

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

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

The central part is characteristically composed of the

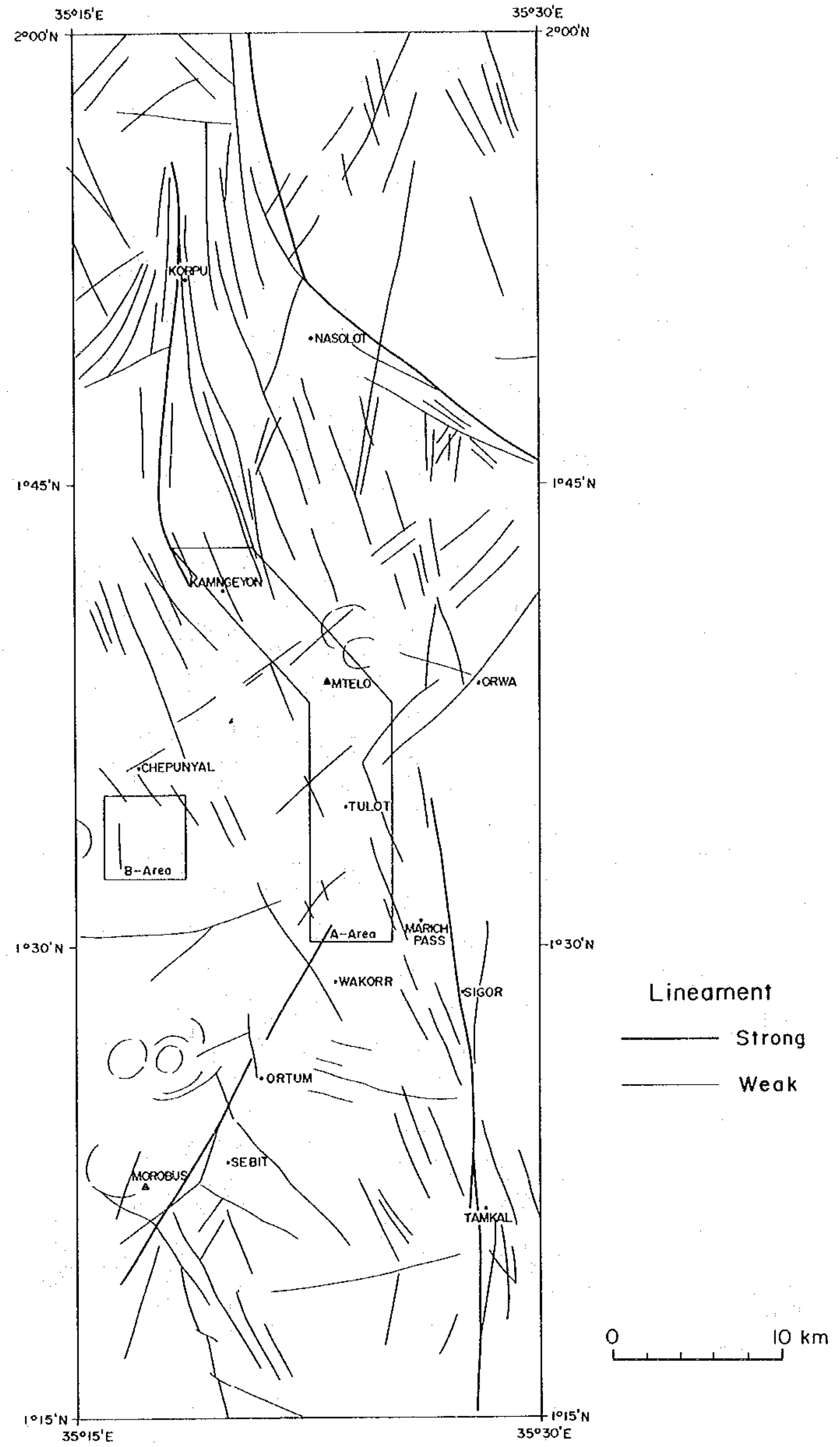


Fig.3-9 Lineaments from Landsat False Colour Image

strata belonging to a rather simple, asymmetrically folded structure in which the strata gently incline in the western side while steeply in the eastern side.

In contrast to the both above, many faults have been developed in the southern part resulting the blocking of the folded strata. Considerably folded structures show irregularly distorted axial planes.

(2) Faults

a) Faults in the directions of N-S or NNW-SSE.

Main ones are named the Turkwel, Korpu, Orwa, Mwino, Tamkal and Kopro faults from the northern side.

The Turkwel fault is able to recognize on the air photograph or Landsat image as a clear lineament, and the elongation of the fault reaches to more than 30 km. The fault belongs to one of those faults which formed the Rift Valley, and the throw of the fault is thought to be more than 1,000 m.

The Korpu fault shows its elongation in the length of more than 30 km, and the Orwa fault also shows a clear lineament although the quantity of its displacement is not so large.

The Mwino fault shows its length to be more than 30 km, and is considered to be happened in the recent movement because its elongation is able to recognize in the Rift Valley.

The both, the Tamkal and Kopro faults, form a couple of parallel fault elongated in the direction of NNW-SSE, and are cut by the Mwino fault.

b) Faults in the NE-SW system

The Marun, Sekerr, Chepkopegh, Morobus and Ketelwe faults belong to the group. The Marun fault cuts through the eastern boundary of the Ortum granitic mass and elongates more than 30 km to the outside of the area.

The Sekerr fault is also the one which formed the Rift Valley like the Turkwel fault and enable to recognize on the air photograph and the Landsat image. The throw of the fault is estimated to be more than 1,000 m.

The Chepkopegh fault has its elongation in 13 km, not so long, and the schistosity planes of the strata in both side of the fault have remarkably different features. The elongation of Morobus fault is estimated to be 10 km.

c) Faults in the E-W system

The Iang fault, occurred at the southern wing of the Tamogh-Marich anticline, belongs to this group, and elongation of the fault reaches to more than 15 km.

In both sides of the fault, the schistosity planes of the strata show remarkably different features.

d) Faults in the NW-SE system

The Ortum and Sebit faults belong to the group. Elongation of the two faults is 20 km and 15 km respectively. The both cut the Marun fault.

(3) Folds

Considerably folded structures are observable in the whole area, and the majority of them is thought to be the overturned folds seeing from the rock facies and the features of the schistosity plane.

The folded structures continue well from the central part to the northern part of the area. For example, the Endogh-Tulot syncline continues from the vicinity of Wakorr to the downstream of the Tamogh River through the southern part of Mt. Mtelo.

Around the Mt. Mtelo, the synclinal structure is an overturned one, in which the both wings incline to the east, however, it shows normal type, namely, both wings symmetrically incline 40° - 70° in the area between the Mt. Mtelo and the downstream of the Tamogh River. In the area further down the Tamogh River, the structure shows again the overturned syncline in which the axial plane inclines toward east.

In the northern part, there appears the Morulem syncline, Mtelo anticline and other folded structures in small scale, resulting the repeated developments of the Basement III Formation.

Granite intrudes into the Chaichai and Ngurugh anticlines, and the Sarmai syncline develops in between the two anticlines.

The two folded structures having special character develop in the central and southern parts of the area, and are named the Tamogh-Marich anticline and the Samor Hills anticline respectively. The former has a dome-like feature having an axis in the direction of E-W, plunging to the east. The latter is an overturned anticline having curved axial plane from the direction of NW-SE to that of NE-SW.

(4) Geological History

Geological history will be described below with reference to Miller (1956), McCall (1964) and Baker et al. (1972).

In the Precambrian age probably Archean mudstone, sandstone and limestone of the Basement System mixed with basic volcanics have been accumulated in the geosynclinal trough unconformably covering the volcanics of the Nyanzian System along the eastern periphery of the Tanganyika Craton and the alternating beds of sandstone and mudstone of the Kavirondian System.

Regional metamorphism in the Mozambique orogeny began (835 Ma), and in the first stage of the metamorphism, granite (gneiss) intruded into the pre-existed rocks. Folded structure extended in the direction of NE-SW to NNW-SSE began to form owing to the compressive force directed to E-W at first. When the deformational movement reached to its climax, migmatitic type granite and pegmatite were formed. Simultaneously, diorite, gabbro and ultrabasics (talc schist) intruded and continuously later, granitics (foliated granite) succeeded. After the movement, faults running roughly parallel to the folded structure were occurred in the direction of N-S to NNW-SSE.

According to the change of the direction of compressive force in N-S Trend, faults in the direction of NW-SE, namely, the Ortum and Sebit faults were formed.

Furthermore, owing to the compression continued in the direction of N-S, the Tamau-Marich anticlinal structure in E-W Trend was formed. Successively, the Iang fault in the

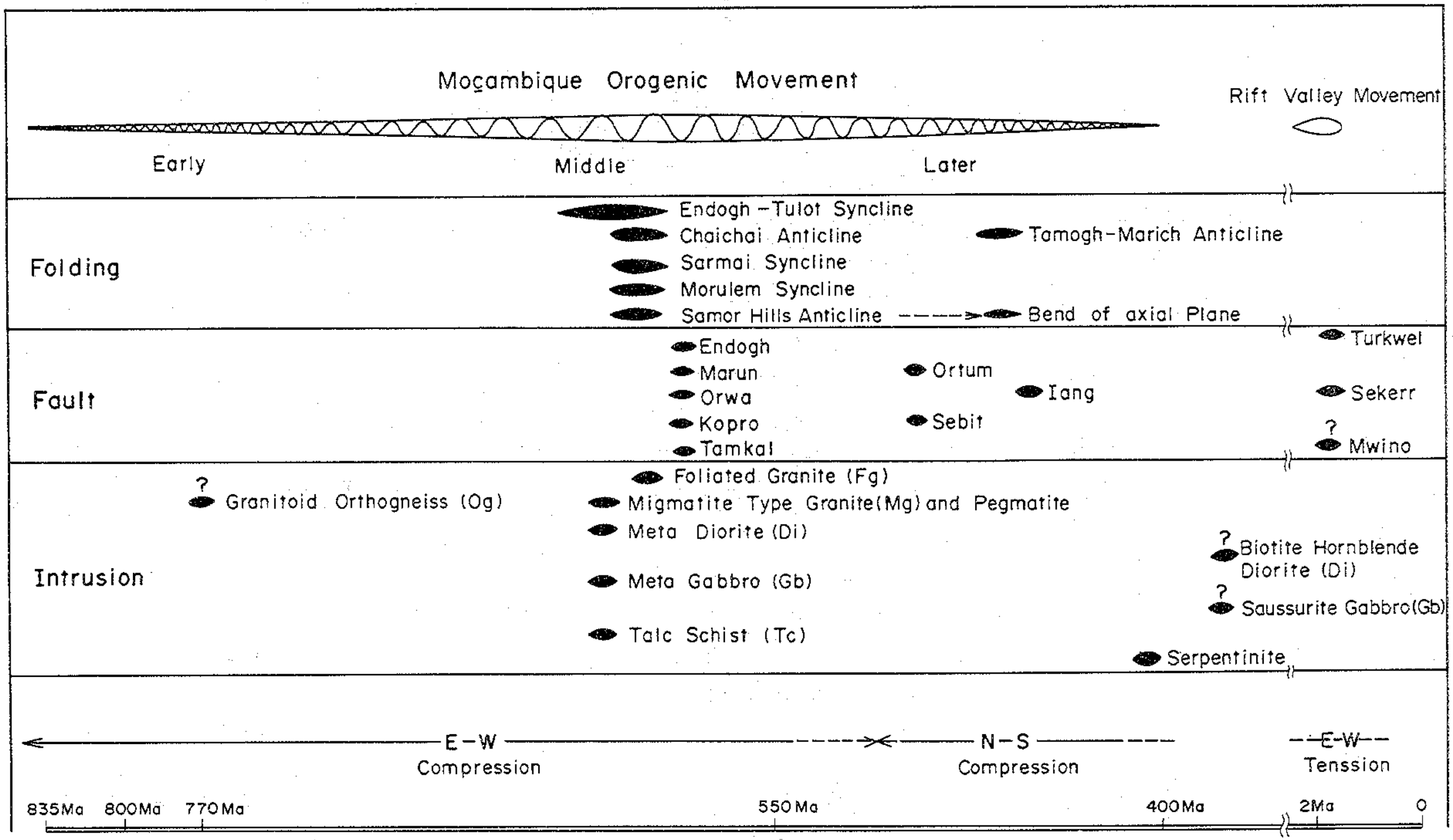


Fig. 3 – 10 Tectonic Movements and Igneous Activity

same trend was occurred.

Serpentinite which was not deformed, intruded in the latest stage of orogeny. Saussurite gabbro (Gb) and meta-diorite (Di) which intruded into the serpentinite and effected the thermal metamorphism to the latter, occurred at the end.

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.

At 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 of 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.

3-3 Geology of the Regional Survey Area

The Regional Survey Area covers an area of about 2,300 km^2, and namely equals to the whole area of this project. Geology of the area consists of Basement System, Intrusive Rocks, and Quaternary System. The outline of geology was already shown in 3-2.

3-3-1 Basement System

The Basement System is stratigraphically divided into I, II, III, IV and V Formations in ascending order. These formations are composed of regional metamorphic rocks of geosynclinal sedimentary rocks and basic volcanic rocks in origin. The total thickness is estimated to be 20,000 meters.

(1) Basement I Formation

The formation intermittently distributed in the west of the area is composed mainly of the biotite gneiss (BIbg), intercalating quartzite (BIqt). The formation is estimated to be more than 3,000 meters thick.

(1)-1 Biotite gneiss (BIbg)

Distribution The rock is distributed in the west side of the area.

Thickness The lower limit is not clear, however, the thickness is estimated to be more than 3,000 meters.

Rock facies The rock consists of biotite gneiss and hornblende-biotite gneiss with subordinate thin hornblende gneiss.

Biotite gneiss is commonly composed of fine biotite, quartz (<1 mm) and feldspar (0.5 - 1 mm) showing gneissose texture. Epiodote, zoisite and diopside are partly observed. Schistosity is usually very weak, but some rocks containing abundant biotite show strong schistosity.

Hornblende-biotite gneiss is predominant at the uppermost of this unit and is intercalated everywhere as thin layers in biotite gneiss. Lithologic character of the rock is similar to biotite gneiss, but it contains fine acicular hornblende. On the west of Korpu pinkish fine garnet and epidote are also contained in it.

Hornblende gneiss is intercalated everywhere as thin layers of dozens centimeters to dozens meters in abovementioned rock facies. The rock consists of greenish black hornblende, plagioclase, and a small quantity of epidote.

Stratigraphic relations The lower limit of the unit is uncertain.

Original rock Geosynclinal pelite with basic tuff.

(1)-2 Quartzite (BIqt)

Distribution The rock is distributed in the southwest of the area.

Thickness 50 - 300 meters.

Rock facies The rock is fine-grained biotite-muscovite quartzite, and shows weak schistosity like psammitic schist.

Stratigraphic relations The rock is intercalated in biotite gneiss (BIbg).

Original rock Geosynclinal psammitic rock.

(2) Basement II Formation

The formation widely distributed all over the area, is lithologically divided into four units: the major one, amphibolite, hornblende gneiss (BIIab), subordinate quartzite, quartz schist (BIIqt), crystalline limestone (BIIls) and porphyroblastic gneiss (BIIpq). The latest occurs zonaly along the contact with the migmatitic type granite on the west of Ortum-Morobus area. The formation is estimated to be 2,000 meters thick in the north and more than 3,000 meters in the central and south.

(2)-1 Amphibolite, Hornblende gneiss (BIIab)

Distribution — This unit has the largest exposure in the area, and it is distributed continuously from south to north exception of isolated distribution on the east of Weiwei River.

Thickness — Though it is difficult to estimate the thickness of this unit because of conspicuous folding and the existence of faults, the thickness is supposed to be about 3,000 meters in the south and about 2,000 meters in the north. Whereas, in the central part where the structure is regarded as monoclinic, the thickness is estimated to be more than 3,000 meters.

Rock facies — Amphibolite with thin intercalation of biotite gneiss is major facies of the unit. Hornblende gneiss which has coarser and gneissose texture is locally observed.

Amphibolite shows schistose or massive structure in general and is dark green, fine to medium-grained rock. It consists essentially of green or bluish green hornblende and plagioclase. with accessory of epidote and rare actinolite. The microscopic character of the specimen collected from the south of Mt. Morobus is summarized as follows.

Rock name: Epidote Amphibolite (AR201)

Texture: Weakly schistose, granoblastic

Mineral composition:

Epidote>hornblende>plagioclase≫quartz > sphene

Epidote: anhedral, granular crystal.

Hornblende: anhedral crystal, very weakly pleochroic from pale green to pale greenish gray.

Plagioclase: anhedral, granular crystal, 30 - 35% An

Quartz: anhedral crystal, filling up the spaces among other minerals.

The specimen obtained in the east of the Endogh-Tulot Syncline, which shows strong schistosity, is as follows under microscope.

Rock name: Garnet spot-staurolite-hornblende schist (CR126)

Texture: schistose,

Mineral composition:

Quartz=plagioclase>muscovite>biotite=hornblende =garnet>staurolite≫calcite

Quartz: anhedral, granular crystal.

Plagioclase: anhedral, granular crystal, about 25% An

Muscovite: flaky.

Biotite: flaky, pleochroic from pale greenish blown to pale yellow.

Hornblende: anhedral crystal, pleochroic from light yellowish green to grayish green or light blue.

Garnet: anhedral crystal, partly poikiloblast.

Staurolite: anhedral, amoebiform poikiloblast, pleochroic from golden yellow to very pale yellow.

The hornblende gneiss exposed on the east of Weiwei River shows following character under microscope.

Rock name: Hornblende gneiss (CR32)

Texture: Gneissose, granoblastic

Mineral composition:

Hornblende>plagioclase≫quartz≫biotite

Hornblende: prismatic or tabular anhedral crystal, pleochroic from very pale green to very pale yellowish green.

Plagioclase: granular anhedral crystal, partly sericitized, 30 - 40% An

Quartz: granular anhedral

Biotite: flaky

Besides, as peculiar facies, hornblende gneiss which contains very coarse hornblende (maximum length: 6 cm) is found along Suam River near Korpu Camp.

Stratigraphic relations The unit overlies the biotite gneiss (BIbg).

Original rock Geosynclinal basic volcanic rocks.

(2)-2 Quartzite, Quartz schist (BIIqt)

Distribution Many thin beds of the unit are distributed to the southeast and west of the Mt. Morobus. A wide body is exposed to the east of Weiwei River and a narrowly extended bed in N-S direction to the east of Sergoi River.

Thickness 10 to 50 meters in the west of Morobus, more than 600 meters to the east of Weiwei River and 100 to 150 meters to the east of Sergoi River.

Rock facies The rock is generally of white, medium-grained and compact. The rock to the west of Morobus has schistosity of one to several centimeters in thickness and has fissility, on the other hand, the one to the east of Weiwei River has coaser and massive characters. Main constituents are mossaic aggregates of quartz with accessary of flaky biotites and muscovites.

The rock to the east Weiwei River is quartz-feldspar para-granulite (Miller 1956).

Stratigraphic relations The unit is intercalated in the amphibolite, hornblende gneiss (BIIab)

Original Rock Geosynclinal psammitic rock.

(2)-3 Crystalline limestone (BIIls)

Distribution Several beds are observed on the west of Mt. Morobus, to the north of Chepunyal and to the west of Korpu.

Thickness 10 to 50 meters

Rock facies The rock is white, coarsely crystallized and massive. Pink colouration or greenish banding is partly observed.

Stratigraphic relations The rock is intercalated in the amphibolite, hornblende gneiss (BIIab) unit.

Original rock Geosynclinal calcareous rock.

(2)-4 Porphyroblastic gneiss (BIIpg)

Distribution The rock continuously extends from the north of Kalapot to the north of Mt. Morobus. It is also distributed at the east foot of Mt. Morobus.

Thickness 500 to 1,000 meters.

Rock facies The rock has porphyroblasts of coarse feldspars grown from original feldspar contained in biotite gneiss or hornblende gneiss. Feldspars forming rectangular or oval porphyroblasts are surrounded by biotites. At the marginal part, finely crystallized biotite gneiss or biotite seams are alternatively intercalated in the rock. In the adjacent part of the rock to the amphibolite, hornblendes take the place of biotites as main mafic minerals. The microscopic character of the specimen taken from the north of Mt. Morobus is as follows.

Rock name: Augen gneiss (BR48)

Texture: porphyroblastic

Mineral composition:

Potash feldspar>biotite>quartz>hornblende=diopside =plagioclase>ore mineral

Potash feldspar: ovoid porphyroblast, mainly composed of perthite.

Biotite: flaky, surrounding alkali feldspar, pleochroic from light brown to pale brown.

Quartz: granular, fine-grained anhedral crystal.

Hornblende: anhedral crystal, pleochroic from grassy green to pale greenish yellow.

Diopside: granular, anhedral crystal in intergrowth with biotite and hornblende.

Plagioclase: filling up the spaces among augens, without zonal structure, 30 - 35% An.

Stratigraphic relations It grades into biotite gneiss (BIbg) or amphibolite (BIIab) distributed in the west flank of the body.

Original rock The porphyroblastic gneiss is considered to have been mostly derived from biotite gneiss or amphibolite through ultrametamorphism (see 3-2-5).

(3) Basement III Formation

The formation zonally and continuously extends from southern to northern part of the area. Particularly in the northern part, the formation is repeatedly exposed in parallel zones by foldings. The formation is mainly composed of biotite gneiss (BIIIbt) with subordinate crystalline limestone (BIIIls), quartz schist, quartzite (BIIIgs) and biotite-muscovite or biotite-muscovite-hornblende schists (BIIIms). Total thickness of the formation is generally 1,000 to 1,500 meters, but 2,000 to 3,000 meters in the vicinity of the Weiwei River.

(3)-1 Biotite gneiss (BIII bg)

Distribution The rock is distributed in the central zone of the area from the south to the north.

Thickness 700 to 1,000 meters in the vicinity of Sebit, 2,000 to 3,000 meters in the Weiwei River and 1,000 to 1,500 meters in the central and northern part of the area.

Rock facies The rock shows gneissose structure and locally schistose structure. The main constituents are biotite, feldspar and quartz associated with muscovite, epidote, zoisite and diopside. Hornblende is locally contained, and garnet, 0.5 to 2 centimeters in size, are also contained around the downstream of Endogh River. The microscopic character of the typical specimen obtained near the Twin Bridge is as follows.

Rock name: Diopside-biotite gneiss (CR43)

Texture: gneissose, granoblastic

Mineral composition:

Plagioclase>biotite>quartz=diopside>> hornblende

Plagioclase: granular anhedral crystal without zonal structure, 30 - 35% An

Biotite: flaky, pleochroic from light grayish brown to very pale brown.

Quartz: granular anhedral crystal.

Diopside: granular anhedral crystal.

Hornblende: anhedral crystal in intergrowth with pyroxene.

The schistose specimen taken from the downstream of Endogh River shows following feature under microscope.

Rock name: Siliceous-muscovite-biotite schist (AR116)

Texture: *nematoblastic*, schistose

Mineral composition:

Plagioclase= quartz>muscovite>biotite≫ calcite

Plagioclase: spindle anhedral cystal, almost without zonal and twin structure, 25 - 30% An

Quartz: granular anhedral

Muscovite: flaky

Biotite: flaky or tabular crystal, pleochroic from light brownish yellow to pale yellow.

Stratigraphic relations *The* rock *overlies the* amphibolite and hornblende gneiss (BIIab).

Original rock Geosynclinal pelitic rock

3-(2) Crystalline limestone (BIII ls)

Distribution The rock is distributed in the vicinity of Sebit and Ortum, in the upper stream of Weiwei River and to the west of Wakorr and Akeriamet Shop.

Thickness The rock is dozen to several hundred meters thick in the vicinity of Sebit and Ortum, about 150 meters in the vicinity of Wakorr and 900 meters in the Weiwei River.

Rock facies The rock is mostly white, coarsely recrystallized and massive. Foliation is rather weak in general, but green seams are frequently observed and show complicated minor folding structure.

The rock which cropped out on the Marich road between the Marun River and Sebit village is dolomitic in composition (Miller, 1956).

Stratigraphic relations The rock overlies the biotite gneiss (BIIIbg) or is locally intercalated in it.

Original rock Geosynclinal sedimentary rock

(3)-3 Quartz schist, Quartzite (BIIIgs)

Distribution The rock is distributed in the vicinities of Pusel Ridge and Endogh

Thickness 50 to 500 meters in the vicinity of the Pusel Ridge and 150 to 400 meters in Endogh.

Rock facies Quartz schist is dominant, and medium-grained quartzite is locally present. Quartz schist is gray in colour, shows clear schistosity and consists of plagioclase, quartz and minor amount of flaky muscovite and biotite. The microscopic character of the specimen taken from the vicinity of the Endogh is as follows.

Rock name: Muscovite-biotite-quartz schist (AR176)

Texture: schistose, microgranoblastic

Mineral composition:

Plagioclase>quartz>muscovite=biotite

Plagioclase: granular anhedral crystal without zonal structure, 20 - 30% An, microgranoblastic with quartz

Quartz: granular anhedral crystal.

Muscovite: flaky

Biotite: flaky, pleochroic from light brownish yellow to pale yellow

Stratigraphic relations The rock overlies the biotite gneiss (BIIIbg) or is intercalated in it.

Original rock Geosynclinal siliceous rock or psammitic rock.

(3)-4 Biotite-muscovite schist, biotite-muscovite-hornblende schists (BIIIms)

Distribution The unit is exposed in the north-west part of the area.

Thickness It is estimated to be about 1,500 meters thick.

Rock facies Field occurrence of the rock has not obtained yet. From the interpretaion of aerial photographs, the boundary between this rock and surrounding biotite gneiss (BIIIbg) is vague, and these two units seems to grade into each other.

This unit is composed of biotite-muscovite schist and biotite-muscovite-hornblende schist (McCall 1964).

Stratigraphic relations The rock grades into the biotite gneiss (BIIIbg).

Original rock Geosynclinal pelitic rock.

(4) Basement IV Formation

The formation is zonally distributed from the southern to northern part of the area, surrounded by the Basement III Formation. The formation is divided into two units: Amphibole schist, chlorite schist (BIV as) is dominant facies in the central and northern part of the area, and amphibolite, hornblende gneiss (BIVab) in the southern part. Thickness of the formation is usually 1,300 to 1,500 meters, but at the Pinau Gorge in the north it reduces to 500 meters.

(4)-1 Amphibolite, Hornblende gneiss (BIVab)

Distribution The unit is zonally exposed along the both sides of synclinal axis from Ortum to Tulot, and cut by the Ketelwa fault in the south of the area.

Thickness It is estimated to be about 1,000 meters in maximum thickness.

Rock facies The unit mainly consists of amphibolite and hornblende gneiss with subordinate quartzite and actinolite schist.

Amphibolite shows dark green in coulour, and consists of fine hornblende and feldspar with accessary of actinolite. Schistosity is sometimes clear and along the schistosity plane abundant biotite and garnet are locally observed.

Hornblende gneiss consists of granoblastic aggregates of coarse hornblende (1 - 3 mm in size) and feldspar. Actinolite is also frequently contained in it, and rarely, coarse garnet is observable.

Stratigraphic relations The unit overlies the biotite gneiss (BIIIbg) or crystalline limestone (BIIIls).

Original rock Basic volcanic rocks intercalating psammitic rock.

(4)-2 Amphibole shicst, chlorite schist (BIV as)

Distribution The unit is zonally distributed along the anticlinal axis from Sebit in the south to Pinau Gorge in the north of the area.

Thickness 300 to 500 meters.

Rock facies The unit consists mostly of amphibole schist and partly of chlorite schist.

Amphibole schist includes actinolite schist, tremolite schist and chlorite-actinolite schist. Fresh part of these rocks show dark green or greenish gray and weathered part, greenish brown to gray or pale greenish gray. The rocks have strong schistosity and contain fine needle-like crystals of amphibole group minerals occurring on the schistosity planes in parallel.

The microscopic character of the specimen taken from Endogh is as follows.

Rock name: Tremolite schist (AR 122)

Texture: nematoblastic, very fine grained

Mineral composition:

Tremolite>>epidote=zoisite

Tremolite: Spindly anhedral crystal with strong preferred orientation.

Epidote and zoisite: granular anhedral crystal.

The specimen taken from Ortum is as follows under microscope.

Rock name: Chlorite-actinolite schist (CR 6)

Texture: schistose, nematoblastic

Mineral composition:

Actinolite>chlorite>>ore mineral

Actinolite: prismatic crystal with strong preferred orientation, pleochroic from very pale green to colorless.

Chlorite: flaky with strong preferred orientation, chlorite rich layer and actinolite rich layer show banded texture.

Ore mineral: scattered or limonitized-veinlet is formed along the schistosity.

Stratigraphic relations The rock overlies biotite gneiss (BIIIbg) and amphibolite hornblende gneiss (BIVab).

Original rock It is possible to say that the rock is a kind of retrograde metamorphic rock derived from amphibolite or hornblende gneiss crushed through the tectonic movements, and resulting the texture and mineral assemblage of the rock affected by the retrograde metamorphism (see 3-2-5).

(5) Basement V Formation

The formation is distributed in the north-east corner of the area belonging to the Rift Valley. The stratigraphic relationship between this formation and other formations has not obtained yet, but structually this formation may be located in the upper horizon than others, because the faults which have caused the Rift Valley are of the type of tension stress. This formation consists of biotite gneiss (BVbg) and a thin bed of crystalline limestone (BVls).

(5)-1 Biotite gneiss (BVbg)

Distribution The rock is widely exposed in the north-east part of the area.

Thickness It is presumed to be more than 10,000 meters.

Rock facies Fine-grained biotite gneiss is observed in the vicinity of Kainuk, and hornblende-biotite gneiss in the north-east of Sarmai. From the results of interpretation of aerial photographs showing the characteristic homogeneous rock body, the unit is regarded to consist of biotite gneiss with subordinate hornblende-biotite gneiss.

Stratigraphic relations From the structural viewpoint, the rock is estimated to be the uppermost unit of the Basement System in the area.

Original rock Geosynclinal pelitic rock.

(5)-2 Crystalline limestone (BVls)

Distribution The rock is exposed in the north-east corner of the area, trending in the NNW-SSE direction.

Thickness It is estimated to be 50 to 100 meters thick.

Rock facies Field occurrence of the rock has not been obtained yet. The existence is estimated by the interpretation of aerial photographs, so the rock facies are vague.

Stratigraphic relations The rock is intercalated in the biotite gneiss (BVbg).

Original rock Geosynclinal calcareous rock

3-3-2 Quaternary System (Q)

The Quarternary deposits of the area consist of soils, river gravels and talus deposits, covering Basement System and Intrusive Rocks. Only the deposits exposed widely in the Rift Valley are shown on the geological maps.

The soils include stony soils, forest soils and alluvial soils. Stony soils are widely distributed in the Masol Plane, and consist of lateritic reddish soils and breccias (pebble to boulder size). Forest soils composed of brownish black humus soil, are exposed in the rainy forest areas on the highlands such as Sekerr Forest and Cherangani Hills. Alluvial soils occur narrowly along the Suam-Turkwel River and Marun River, and are composed of fine sand and clayey soil.

River gravels occur in the downstream of the Marun River and the upper stream of the Turkwel River, where the rivers are wide, water is fairly abundant and the river beds gently slope. Alluvial gold is yielded from the gravel beds underlying the surface sands in these rivers.

Talus deposits are mainly distributed along the foot of the escarpment of the Turkwel and Sekerr Faults which draw a line of west demarcation of the Rift Valley.

3-3-3 Intrusive Rocks

The intrusive rocks distributed in the area include granitoid orthogneiss, foliated granite, migmatitic type granite, gabbro, meta-gabbro, diorite, meta-diorite, ultra-basic rock, serpentinite and talc schist, and all these intruded into the Basement System.

(1) Granitoid Orthogneiss (Og)

[Distribution and Occurrence]

The rock is distributed at the western mouth of the Turkwel Gorge, Murkoria Hill and south of it in the northern part of the survey area, from the top of Mt. Mtelo to the north of it in the central part, and at the top of the Cherangani Hills with the northerly trend in the southern part.

Those distributed in the central part and the northern part form the sheets intruded in parallel with the structure of the Basement I and II Formations on a relatively small scale.

The one distributed at the Cherangani Hills in the southern part (Cherangani Mass) is a large mass with the width of about six kilometers extending more than 25 km in the N-S direction. Although the mass has intruded roughly in parallel with the structure of the Basement I and II Formations, the form of intrusion is shown to be inharmonious in many places as a whole.

[Rock Facies]

The masses in the central part and the northern part: The typical rock facies is shown in pale grey medium to fine-grained rocks with marked foliation.

Potash feldspar, plagioclase, quartz, muscovite and biotite are observed with the naked eye, among which muscovite is more dominant than biotite in amount. 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. Porphyroclast of potash feldspar is often observed.

Southern Cherangani Mass: The rock is mainly composed of grey medium to coarse-grained rocks with notable banded structure. Megascopically, the constituent minerals are potash feldspar, plagioclase, quartz and biotite, sometimes containing hornblende. In the upper reaches of the Wakorr River which marks the boundary with the Basement II Formation, the black xenoliths elongated in parallel to the banded structure are often contained. These xenoliths are intermediate to basic igneous rocks in many cases.

(2) Foliated Granite (Fg)

[Distribution and Occurence]

The rock is distributed in four places: the adjacent area of the Turkwel Gorge in the northeastern part of the area (hereinafter referred to as Turkwel Foliated Granite), the area from the northeastern part of the Sekerr Forest to Sarmai in the northern-central part (the two masses are called Sarmai Foliated Granite collectively), the vicinity of Ptoyo in the downstream of the Sinjo River (Ptoyo Foliated Granite) and the southern side of the Sekerr-Murio fault in the eastern-central part (Marich Foliated Granite).

Turkwel Foliated Granite: The mass has formed the Turkwel Gorge, having an extent of 2 x 8 km extending northerly. The rock shows schistosity in parallel with the structure of amphibolite and gneiss in the Basement II and III Formations striking northerly and dipping 70°E. Although the rock was only observed at the western mouth of the Turkwel Gorge, the occurrence of xenolith and pegmatite has not been observed there.

Sarmai Foliated Granite: The rock forms the two masses such as a large mass on the western side (6 x 13 km) and a small mass on the eastern side (2 x 6 km). Both two masses were markedly deformed by folding, it is, however, likely to be the same continuous mass structurally. While the two masses intruded into the Basement II Formation which consists mainly of amphibolite, they seem to be the sheet-like intrusive rocks. Although pegmatite has not been observed in the masses, the swarm of pegmatite dykes which are accompanied by mica deposit in the vicinity of Nasalot to the north of the western mass is considered to be genetically related to this rock.

Ptoyo Foliated Granite: The rock forms a mass having an extent of 3.5 x 7.5 km being elongated northwesterly, and a part of it is distributed in the area. The rock has been described to be composed of a group of sheets consistent with the structure of amphibolite of the host rock (McCall, 1964).

Marich Foliated Granite: The rock forms the fault scarp of the Sekerr- Mwino fault at the western periphery of the Rift Valley, being elongated northerly for 35 km with a maximum width of three kilometers. The rock shows a remarkable schistosity in parallel with the structure of the Basement II and III Formations, striking northerly and dipping 70° to 80° easterly at the western entrance of the Marich Pass, while striking northerly and dipping 30° to 40° easterly at the eastern exit. The rock is composed of a swarm of fine-grained leucocratic sheets intruded in a banded form in parallel with the structure of biotite gneiss and amphibolite, showing a tendency to become homogeneous and coarser toward the center of the mass. An intrusive form of ptygmatic vein is shown at the eastern boundary of the mass. Numerous schlierens are contained throughout the mass. Although these consist mainly of biotite gneiss and amphibolite, intermediate to basic igneous rocks are also included. Pegmatites are found inside and outside of the mass. Skarn has been locally formed in biotite gneiss near the entrance of the road of Marich Pass to Mbaara.

[Rock Facies]

The typical rock facies is shown in schistose, pale grey fine to medium-grained biotite granite. In addition, fine-grained muscovite granite, muscovite-biotite granite and leucocratic granite are found. The results of microscopic observation are as follows.

Micro granite with flowage (DR 28)

Texture: gneissose, fine-grained granoblastic

Mineral composition:

Plagioclase>quartz>potash feldspar>>biotite>muscovite

Plagioclase is tabular, euhedral or subhedral crystal and corresponds to 30 - 35% An.

Quartz is granular, anhedral crystal.

Potash feldspar is microcline.

Biotite is flaky, pleochroic dark brown to pale brown with strong preffered orientation.

Muscovite is flaky with strong preffered orientation.

Leucocratic granite (AR 62)

Texture: massive, holocrystalline, equi-granular

Mineral composition:

Plagioclase=quartz>potash feldspar>>muscovite=biotite>>garnet

Plagioclase is tabular subhedral crystal with no zonal structure and corresponds to 25 - 35% An.

Quartz is anhedral crystal.

Potash feldspar is microcline, tabular anhedral crystal.

Muscovite is flaky.

Biotite is plechroic from dark gray to pale greenish yellow.

Garnet is granular anhedral crystal.

(3) Migmatitic Type Granite (Ortum Migmatitic Granite, Mg)

[Distribution and Occurrence]

The rock is distributed from Mt. Morobus in the southwestern part of the survey area to the confluence of the Iang and Marun Rivers in the southern-central part of the area being elongated northeasterly for 21 km with a maximum width of four kilometers. The extent of distribution is limited to the northern side of the Marun fault. Although the boundary of the mass was mainly determined by the observation in the surrounding area of Ortum to Morobus, that of the northeastern part of the mass was determined by interpretaion of the aerial photograph. A structure of NE-SW system is observed inside the mass from the photo-interpretation, which is harmonious with the structure of metamorphic rock in the surrounding area. On the other hand, inharmonious relation of contact is shown at the both boundaries of north and south.

At the contact with the surrounding rocks in the surrounding area of Ortum, the mass consists of a swarm of numerous sheets intruded in parallel with the structure, increasing the intrusive parts relatively toward the center of the mass to become homogeneous gradually. Many xenoliths which are the same as the surrounding rocks such as amphibolite, biotite gneiss and granitoid orthogneiss are also found in the rock. It is assumed based on these facts that the mass is composed of the swarm of sheets intruded in parallel with the structure of the surrounding rocks being intruded.

On the other hand, the mass is accompanied with a large number of pegmatites inside and outside of it. 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 in the western-central part of the area are the areas distributed by a vast number of pegmatites. 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. It seems that many of these pegmatites were formed in the process of metamorphism (3-2-5).

[Rock Facies]

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

The results of microscopic observation are as follows.

Migmatite (BR 9)

Texture: almost massive, coarse-grained, granoblastic

Mineral composition:

Quartz=plagioclase=potash feldspar>biotite>hornblende

Quartz is granular, anhedral crystal.

Plagioclase is granular, anhedral crystal with no zonal structure and corresponds to 30 - 35% An.

Potash feldspar is microcline or perthite and partly shows myrmekite texture at the contact part between it and quartz or plogioclase.

Biotite is flaky, pleochroic from light brwon to greyish yellow.

Hornblende is granular, pleochroic from bluish green to light yellow.

Gneissose mignatite (CR 56)

Texture: somewhat gneissose, equi-granoblastic, porphyritic (patash feldspar)

Mineral composition:

Plagioclase>potash feldspar>quartz>biotite>calcite >>sphene>ore mineral

Plagioclase is granular, anhedral crystal with no zonal structure and corresponds to 25 - 30% An.

Potash feldspar is microcline or perthite, which are in same amount. Porphyritic crystal is 2 - 5 mm in size.

Quartz is granular, anhedral crystal.

Biotite is flaky, pleochroic from green with brown tint to pale yellow.

Calcite is locally filling up the space among other minerals.

Ore mineral is pyrite with euhedral form.

(4) Gabbro and Meta-gabbro

[Distribution and Occurrence]

Gabbro: Three masses in total are distributed in the survey area, such as the two large and small masses in the vicinity of Mt. Kamngeyon in the northwestern-central part of the area and a small mass about 1.5 km to the southwest of the top of Mt. Mtelo in the central part.

The mass at Mt. Kamngeyon forms a peculiar conical landform protruded from the surroundings, having an extent of exposure of one square kilometer, which is likely to be connected below the surface with the small mass. The mass intruded into the Basement IV Formation, and at the same time separated the serpentinite mass which extend northerly.

The occurrence of the mass to the southwest of Mt. Mtelo is not distinct because only the floats are found there.

Meta-gabbro: The rock is distributed in the middle reaches of the Sebit River in the southern part of the area, and forms elliptical mass with an area of exposure of about three square kilometers. It is assumed to be a sheet-like mass from the structure of the intertrappean intruded rocks remained in the mass.

[Rock Facies]

Gabbro: See Clause 3-4 (Geology of Area A)

Meta-gabbro: It is dark greyish green medium-grained holocrystalline rock, showing banded texture.

The result of microscopic observation is as follows.

Meta-gabbro (BR 23)

Texture: somewhat gneissose, equi-granular in the part that euhedral plagioclase is gathered, grano-blastic in the part that anhedral hornblende is gathered.

Mineral composition:

Hornblende>plagioclase>>epidote>>biotite

Hornblende makes spot and is granular anhedral crystal, pleochroic from light yellow to light green or light blue.

Plagioclase is prismatic or tabular, subhedral crystal with no zonal structure, corresponds to 50 - 60% An and is altered to very fine-grained sericite.

Epidote is prismatic, euhedral crystal.

Biotite is flaky.

(5) Diorite and Meta-diorite (Di)

[Distribution and Occurrence]

Diorite: The rock is distributed in three places, such as east of Ortum and south and southwest of Wakorr, along the Marun River in the southern part of the survey area. The areas of these exposures are ten square kilometers, one square kilometer and one square kilometer respectively, showing an irregular elliptical outline.

Because the occurrence of these masses was all determined on the basis of the floats, the shape of intrusion is not necessarily accurate. They are, however, considered to have formed the stock on a small scale.

Meta-diorite: The rock is distributed two kilometers to the east of the confluence of the two rivers of Iang and Tamogh. The area of exposure is about 0.3 square kilometer, and the relationship with the surrounding rock is not clear.

[Rock Facies]

Diorite: It is dark grey medium-grained holocrystalline rock.

The results of microscopic observation are as follows.

Biotite-hornblende diorite (BR 66)

Texture: holocrystalline, equi-granular, somewhat porphyritic

Mineral composition:

Plagioclase>hornblende>biotite>diopside>ore mineral >quartz>apatite

Plagioclase is tabular, euhedral or subhedral crystal with zonal structure. Its maximum size is 4 mm and common size is 1.0 - 1.5 mm. Its central part corresponds to 45 - 50% An and marginal part to 35 - 40% An.

Hornblende is granular, anhedral crystal, pleochroic from grass green to pale yellow.

Biotite is flaky, pleochroic from dark brown to pale yellow.

Diopside is granular anhedral crystal and often remains in the center of hornblende.

Ore mineral is granular, anhedral magnetite, which is scattered in the rock.

Quartz is interstitial and anhedral.

(6) Ultrabasic Rock and Serpentinite (Ub)

[Distribution and 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: They are distributed in the Basement IV Formation in a lenticualr form, and most of them are the sheets intruded in harmonious with the structure of the intruded rocks (the details are described in Clause 3-4).

The one distributed to the southeast of Sebit: The mass is distributed at the part where meta-gabbro is in contact with the Sebit fault, being enclosed in it.

[Rock Facies]

They consist of wehrlite, lherzolite, dunite and serpentinite (see Clause 3-4).

(7) Talc Schist (Tc)

[Distribution and Occurrence]

It is distributed mainly in the Semi-detailed Survey Area A, and in addition, in the western central part on a small scale.

Those distributed in the Semi-detailed Survey Area A:

Most of them have intruded into the Basement IV Formation which consists mainly of amphibole schist, and a part intruded into biotite gneiss of the Basement III Formation.

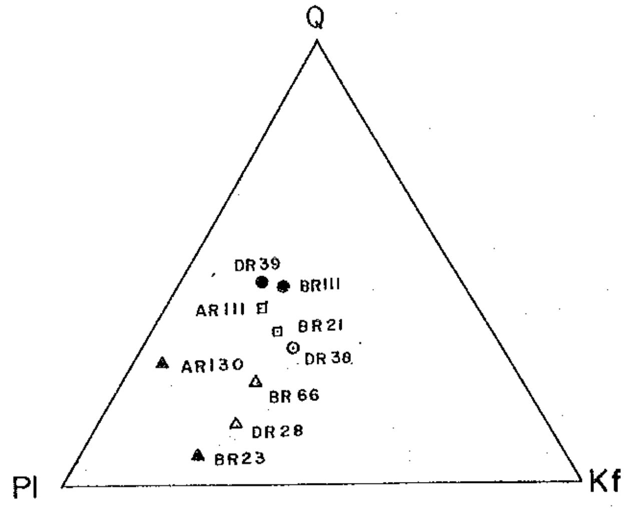
Those distributed in the western central part: They are distributed in amphibolite of the Basement II Formation in a lenticular form having a width of less than 100 meters, and the area of distribution is limited in a narrow zone several kilometers wide. They are likely to be the sheets intruded in parallel with the bedding of the host rocks.

[Rock Facies]

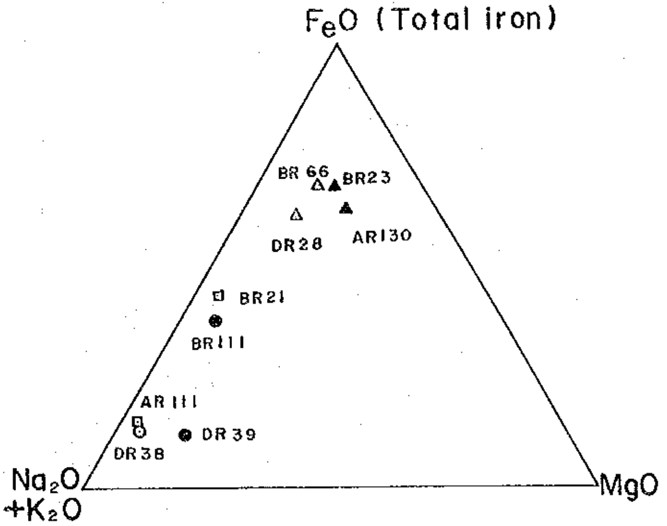
It is white to pale grey massive rock, sometimes showing weak schistosity. Although the rock consists of only talc magascopically, the part contaminated by iron oxide minerals in a vermicular form is sometimes found.

(8) Chemical Composition of Intrusive Rocks

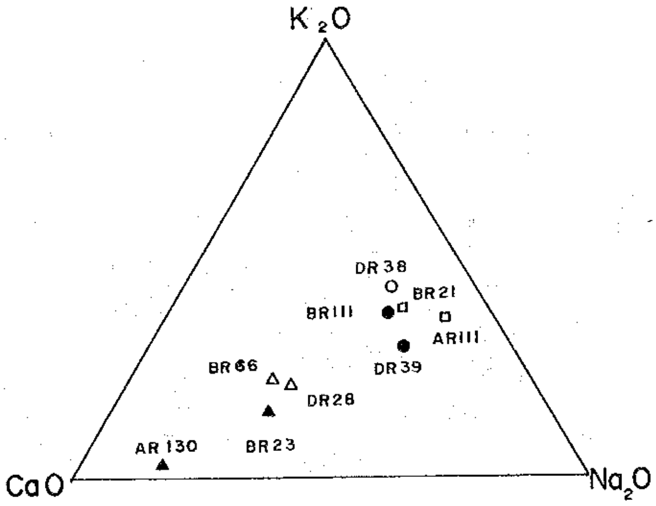
Twelve samples of the intrusive rocks distributed in the survey area were tested for whole rock chemical analysis, and the results of the chemical analysis are shown in Table A-6 (appendices). Some diagrams from the results of it are also shown in Fig. 3-11.



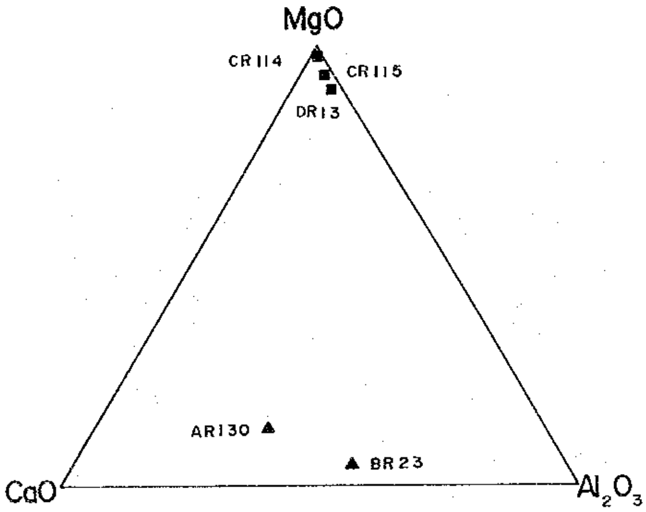
A. Normative Q-PI-Kf diagram for granitic rocks and gneisses



B. AMF diagram for granitic rocks and gneisses



C. Alkalis and lime ratio of granitic rocks and gneisses



D. Mgo-CaO-Al_2O_3 diagram for gabbros and ultrabasic rocks

Legend

○ Foliated granite ● Pegmatite △ Diorite ▲ Gabbro

■ Ultrabasic rock □ Orthogneiss and banded gneiss

Fig.3-11 Diagrams from Results of Whole Rock Analysis

3-4 Geology of Semi-Detailed Survey Area A

3-4-1 General Remarks

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

The altitude ranges from about 1,000 meters to reach up to 3,334 meters which is the height of Mt. Mtelo, the highest peak in the survey area, and the topography is steep.

Geology of the area consists of metamorphic rocks of sedimentary origin and the intrusive rocks. The former is further divided into the Basement II, III and IV Formations. The intrusive rocks are composed of granitoid orthogneiss, foliated granite, migmatitic type granite, metadiorite, metagabbro, serpentinites (serpentinite, dunite and peridotite) and talc schist.

The main geologic structure in the area is the Tulot syncline, along which the intrusion of ultrabasic rocks, talc schist and metagabbro, and distribution of schists with strong schistosity are observed, showing a character of tectonic zone.

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. The alluvial gold placer desposits are found along the rivers such as Marun and Iang.

3-4-2 Basement System

(1) Basement II Formation

The Basement II Formation is the sequence in the lower-most part of the Basement System of the area. It is distributed to the northwest of Mt. Mtelo and in a narrow zone on the west of the Korpu fault in the northern part of the area, and further a little extensive distribution is found in the southwestern part of the area. The thickness is estimated to be more than 700 meters. The main rock facies is medium to fine-grained amphibolite (BIIab). It is, in addition, interbedded with thin layers of biotite gneiss (BIIbg) and quartzite (BIIqt).

(2) Basement III Formation

The Basement III Formation conformably overlies the Basement II Formation. It shows a relatively wide distribution on both sides of the Basement IV Formation in which the Tulot synclinal axis runs through. 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 intertrappean beds includes crystalline limestone (BIIIls), amphibolite (BIIIab) and muscovite quartzite (BIIIqt). Crystalline limestone (BIIIls) is exposed along the Iang River and composed of two beds, 70 meters and 300 meters thick respectively. It is strongly variable in thickness, and shows a poor continuity.

(3) Basement IV Formation

The Basement IV Formation conformably overlies the Basement III Formation. It shows a narrow distribution one to two kilometers wide on both sides of the axis of the Tulot syncline. It is also distributed along a syncline diverged eastward from the above showing a width of about 1.3 kilo-

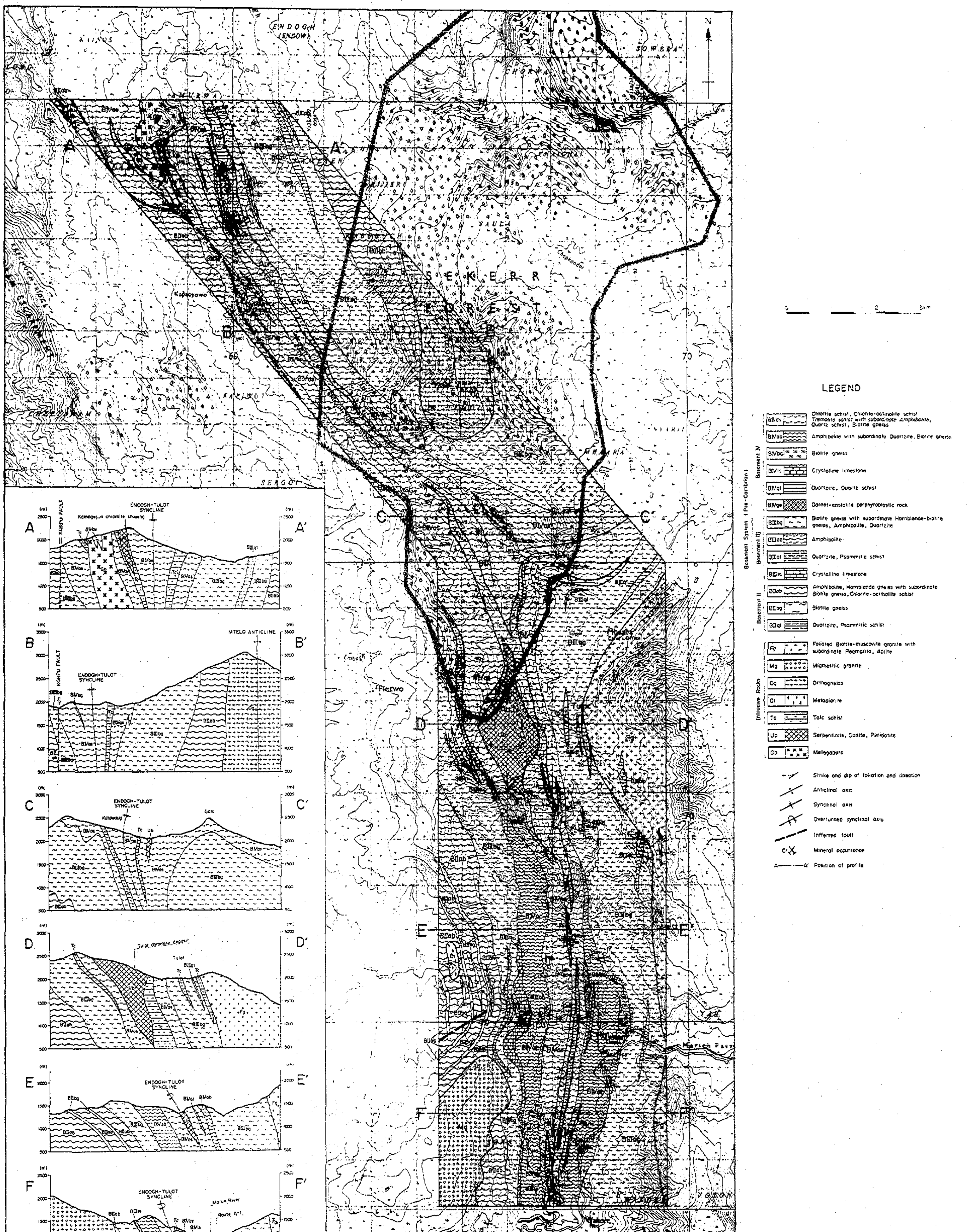


Fig.3-12 Geological Map and Profiles, Semi-Detailed Survey Area A

meters on the northeast of Matokolal. The thickness seems to be 600 to 800 meters in the survey area.

Bedded to lenticular masses of ultrabasic rock and talc schist are found in abundance in the formation showing a harmonious shape of intrusion. The schists, especially green schists (BIVas) are the rock facies that characterizes the formation.

Green schists (BIVas) show a strong schistosity and consist of chlorite schist (section CR-103, DR-6), chlorite-actinolite schist and tremolite schist (section AR-122). In the chlorite schist in the Tulot area, deformed euhedral magnetite grains several milimeters to two centimeters in diameter are observed, which is a characteristic of the rock. It seems that green schists were altered from amphibolites by retrograde metamorphism.

Green schists intercalate amphibolites, hornblende gneiss (section CR-85), quartzite, quartz schist (BIVgt), biotite gneiss (BIVbg) and crystalline limestone (BIVls) beds. Quartz schists are further classified into hematite-(BIVls). Quartz schists are further classified into hematite-magnetite-quartz schist (section AR-141), muscovite-biotite-quartz schist (section AR-76) and hornblende-quartz schist (section AR-183).

Amphibolite and hornblende gneiss 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 Tulot.

A white to pale purple, coarse to medium-grained quartzite-like rock is exposed on the ridge for about 200 meters in width 1.5 kilometers to the northwest of Akeriamet Shop. Microscopic observation of the rock shows that it has a pecular mineral assemblage such as orthopyroxene > quartz > garnet > muscovite = iron minerals. It is a rock possibly to be skarn or metamorphic rock of granulite facies, and it is expressed on the geological map as garnet-orthpyroxene porhyroblastic rock. Orthopyroxene is enstatitic to bronzitic from the value of 2V.

3-4-3 Intrusive Rocks

(1) Granitoid Orthogneiss (Og)

The rock is distributed at the axial part of the Mtelo anticline extending northerly from the top of Mt. Mtelo toward the north. The rock facies is pale gray to pale pink, medium to fine-grained rock, mainly consisting of quartz, potash feldspar, plagioclase, biotite and muscovite. Muscovite is more abundant than biotite in general. The rock shows banded structure. Porphyroblasts probably of potash feldspar, one to three milimeters in diameter, are sometimes observed.

(2) Foliated Granite (Fg)

A part of the Marich granite mass is distributed at the eastern periphery of the area in the surrounding area of Mbaara and Tulot. The rock consists mainly of pale gray, medium to fine-grained biotite granite, and the schistosity consisting of parallel orientation of biotite is well observed. Xenolithic masses of amphibolite and hornblende schist are sometimes contained. Pegmatite veins are also observed.

(3) Migmatitic type Granite (Mg)

The northern end of the Ortum Migmatitic type Granite

Mass is distributed at the southwestern corner of the area. The rock is composed of gray medium-grained biotite granite showing schistosity.

(4) Metadiorite (Di)

The rock is exposed in the river bed of the Iang River for about 200 meters. Although the shape of instrusion and the size are not clear, it is likely to be a small stock. It is a greenish gray medium-grained massive rock. The microscopic observation shows the primary minerals such as plagioclase > common hornblende $\geq$ apatite, and the secondary minerals such as plagioclase, common hornblende, zoisite and quartz. Although holocrystalline equigranular texture is observed basically, mozaic texture of plagioclase and quartz resulted from recrystallization is also observed (section AR-72).

(5) Metagabbro (Gb)

Metagabbros mainly intruded into the Basement IV Formation in the northern half of the area, are found as five stock-like masses of large and small. The large masses are observed in the Kamngeyon area and on the southwest of Mt. Mtelo. The one found in the Kamngeyon area forms a protruded landform of a conical shape, and consists of pale green to dark green medium-grained massive rock.

The microscopic observation shows the main constituent minerals such as common hornblende >> plagioclase > zoisite > apatite. Plagioclase has undergone remakable saussuritization and the rock corresponds to the one to be called saussurite gabbro (section AR-130).

Although the floats of diorite or epidiorite which was metamorphosed having the survived texture of pyroxene gabbro are observed in the mass, the distribution and intrusive relations have not been made clear.

The mass located to the southwest of Mt. Mtelo was inferred by distribution of the floats. The rock facies is greenish gray medium-grained and schistose. It is observed under the microscope that the constitutent minerals are common hornblende (uralitic) > plagioclase > > epidote = zoisite. Plagioclase has been highly saussuritized (section CR-112).

(6) Serpentinites (Ub)

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

Although the grade of serpentinization is varied, it has generally been advanced in the small masses and in the surrounding part of the large masses. Those containing chromite have been completely altered to serpentinite which is composed of antigorite (section DR-15, 16, 49, 50, 51 and 53). Antigorite, talc and calcite are observed as the secondary minerals associated with serpentinization. Weakly serpentinized part is observed in the Tulot mass, in which olivine occupies 80 to 90 percent of the minerals (section CR-115).

The identification of the original rock of sepentinites based on relic minerals leads to classification of the rocks in the Tulot mass as wehrlitic ones (sections DR-12 and DR-14) and lherzolitic ones (sections CR-115 and DR-54). Both types are found in the surroundings of chromite deposit.

The serpentinite mass at Kamngeyon is a peculiar rock in which tremolite has been formed affected by thermal metamorphism associated with intrusion of metagabbro, and the original rock is assumed to be dunitic one (section CR-206-2).

The internal structure of serpentinite is not clear because of almost absence of flow structure as well as bedded structure. Weak schistosity is often observed, which takes a harmonious direction with the surrounding schistose rocks. Under the microscope, this schistosity is caused by preferred orientation of antigorite (section AR-149).

Many serpentinites are pale green to dark green fine-grained rocks, showing a pattern of light and shade caused by the difference of serpentinization. Magnetite grains about one milimeter acrsoss are often observed in the Tulot mass.

(7) Talc Schist (Tc)

It is distributed mainly as lenticular to bedded intrusive mass in the Basement IV Formation independently or associated with serpentinites. It semms that it is in harmonious with the schistose rocks in the surroundings, and 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 white to pale gray, weakly schistose rock, in which the vesicules covered by iron oxide film are often observed. It is almost composed of talc megascopically.

Since it is considered that talc schist is formed by addition of silica to ultrabasic rock, it is likely that the original rocks are the ultrabasic rocks closely associated with the rock.

3-4-4 Geologic Structure

The principal geologic structure of the area A has been controlled by the Tulot syncline. The Tulot syncline has its axis in the green schist zone of the Basement IV Formation, and the synclinal axis strikes approximately northerly from Wakorr to Matokolal, shifting to northwesterly from Matokolal to Amurwa. Many small folds are found at the synclinal axis, showing a complicated structure, which makes difficult to express the Tulot syncline as a single syncline. It shows a structure of overturned syncline steeply dipping toward the east on the southern side of the Tulot area.

Many intrusive rocks such as ultrabasic rocks, talc schist and metagabbro are distributed along the synclinal axis, and moreover, the metamorphic rocks in the surroundings have been altered to green schist with strong schistosity, having resulted in to form a zone which has the character of tectonic zone.

The other folds include the Mtelo anticline and a overturned syncline diverged from the Tulot syncline and extending eastward in the vicinity of Matokolal.

As to faults, the extension of the Korpu fault runs along the northwestern margin of the area in the direction of NW-SE, which makes the Basement IV Formation to be directly in contact with the Basement II and III Formations.

3-5 Geology of Semi-Deailted Survey Area B

The area is situated in the western part of the Regional Survey Area, having an area of 25 square kilometers (Fig. 2).

Geology of the area consists of metamorphic rocks of sedimentary origin (Basement System), a small body of migmatite and numerous small pegmatites.

The geologic structure in the area is rather simple: the Basement System strikes in WNW direction and dips 30 degrees to NNE direction in the north, and strikes N-S direction and dips 30 degree to east in the central and south.

This area is selected to cover known occurrence of pegmatite dikes and their proximities, and the purpose is to study whether there are any mineral occurrences related with the pegmatite dikes.

3-5-1 Basement System

The Basement System of the area consits of Basement I and II Formations.

(1) Basement I Formation

The formation occupies almost whole of the mapped area. It consits mainly of biotite gneiss (BIbg) with subordinate quartzite (BIqt) and amphibolite hornblende gneiss (BIab).

Biotite gneiss (BIbg) is exposed widely in the area, and the thickness is presumed to be more than 2,500 meters. The rock is commonly composed of fine biotite (less than one milimeter in size), quartz and plagioclase ($\geq$1 mm). Hornblende is scarcely seen, and epidote is rarely present in the leucocratic gneisses. Thin pegmatite layers are often concordantly banded with foliation of biotite gneiss, and near the contact of pegmatite layer, quartz and feldspar in the biotite gneiss grow in large, and as a whole it grades into biotite pegmatites.

Hornblende gneiss or Amphibolite (BIab) is distributed as thin lenticular bodies in the central to western part of the area. The thickness of each strata is one to thirty meters. Medium to coarse-grained hornblende gneiss is dominant facies of the unit and fine-grained schistosed amphibolite is associated with it.

Quartzite (BI qt) layers are distributed in the east to the north of the area. Among them, the biggest one has a large exposure of about 300 to 1,000 meters in width. The thcikness of these layers are several to dozens meters in general, but 200 to 300 meters in case of the biggest layer. The rock facies of thinner layers is of biotite bearing fine-grained muscovite quartzite with weak schistosity. On the other hand, that of the biggest layer is a little bit different: the lower part is almost same as the former, but the middle and upper parts have coarse granular texture.

(2) Basement II Formation

The formation is widely distributed in the Regional Survey Area, but in the Area B, it is limited only in the north-eastern corner, and it consists only of amphibolite, hornblende gneiss (BIIab) unit. The unit is about 600 meters thick in the area. The rock facies is almost similar to these of Basement I Formation, and it overlies concordantly the Biotite gneiss (BIbg).

3-5-2 Migmatite (Mg)

The migmatite is distributed in the center of the area as a small body of 80 meters wide (E-W) and 300 meters long

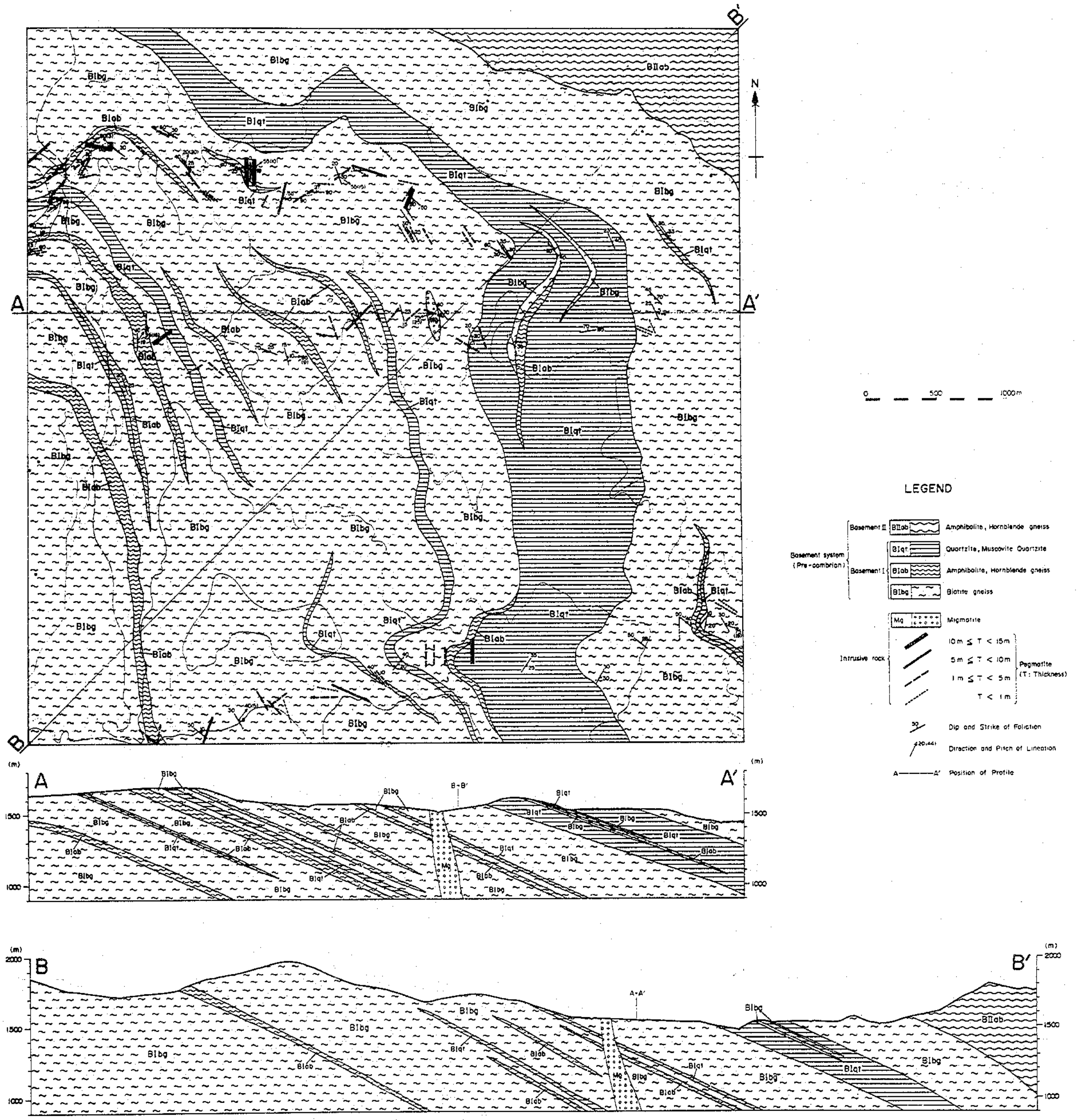


Fig.3-13 Geological Map and Profiles, Semi-Detailed Survey Area B

(N-S). The rock intruded into the biotite gneiss (BIbg) and shows the appearance of granitoid orthogneiss with gneissose texture. It consists mainly of biotite, quartz and feldspar. The microscopic character of the rock is summarized later, and from the result of it, the rock observed is regarded as migmatite of intrusive type.

Rock name: Gneissose migmatite (BR 106)

Texture: gneissose, grnoblastic

Mineral composition:

Plagioclase > quartz > potash feldspar = biotite >> epidote = rutil

Plagioclase: granular, ovoid, anhedral crystal without zonal texture, 30 - 35% An

Quartz: anhedral crystal as filling

Potash feldspar: orthoclase > microcline

Biotite: flaky, pleochroic from dark brown to light yellow with strong preferred orientation

Epidote: granular or short prismatic crystal

3-5-3 Pegmatite (Pg)

Numerous pegmatites occur throughout the Area B, especially, a swarm of large pegmatites (more than 10 meters in width) occurs immediately under the thickest quartzite layer (BIqt).

Thickness Identified pegmatites are seventy-eight bodies. 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.

Rock facies Most pegmatites contain biotite as main mafic minerals, and only two pegmatites containing muscovite more than biotite (less than one meter thick) are exposed in the east of the area. Biotite pegmatites are composed mainly of biotite, quartz and cream-coloured feldspar. Muscovite is partly present. Size of biotite is usually one to two centimeters in diameter, however, crystals of biotite of more than seven centimeters, being banded and cracked, are partly found in the northwestern part of the area. Muscovite usually form flakes less than one centimeter in length.

Feldspar consists of pinkish white microcline and whitish plagioclase. Microcline is usually less than ten centimeters in length, partly thirty centimeters. The microscopic character of the specimen taken from northwestern corner of the area is as follows.

Rock name: Pegmatite (BRIII)

Texture: holocrystalline, equi-granular, being composed of big crystalls of ±2cm in size.

Mineral composition:

Plagioclase > quartz > potash feldspar

Plagioclase: tabular, anhedral big crystal of over 2 cm in size without zonal texture, weakly altered to sericite, 25% An

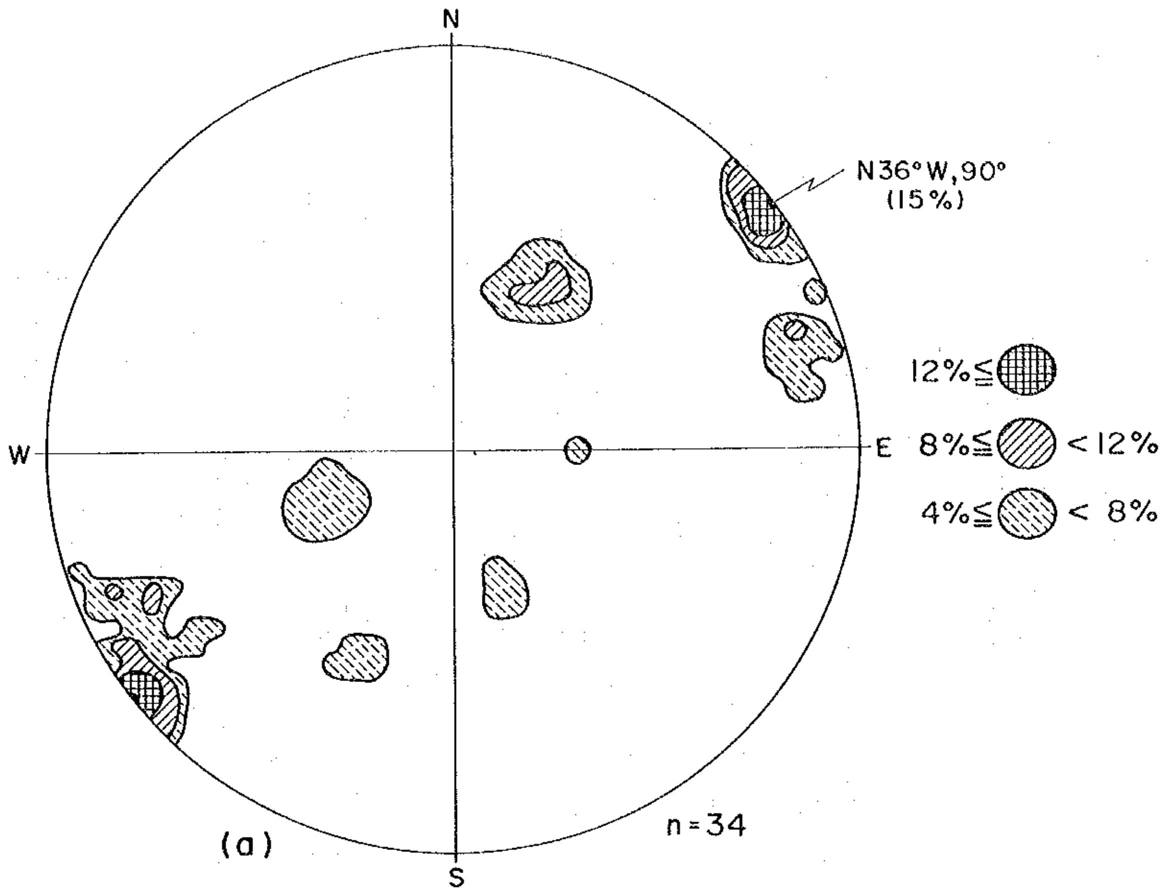
Quartz: anhedral crystal of 1 - 2 cm

Potash feldspar: microcline, varing in size (maximum 1 cm).

Minerals such as columbite and samarskite, which contain rare elements and are expected to occur in the pegmatites of the area, have not been observed in this survey. The fact is in accordance with the assay results of soil samples in which high contents of Nb and Ta were not detected.

Structure The results of equal area projection of poles to contact planes of pegmatites and wall rocks are shown in Fig. 3-14. From the figure, the direction of contact planes is read almost to be in NW-SE, and the area contoured by 25% density curve is concentrated around N32°W (strike) and 33°NE (dip). This orientation is almost in parallel with the general one of foliation planes of gneisses. This is in consistent with the field evidence that most pegmatites contact concordantly with foliation of wall rocks.

Genesis of pegmatites The fact that most pegmatites seem to intrude concordantly into biotite gneiss, grade into the latter and no granite body is present around the pegmatites, suggests that the pegmatites have some genetical relations to ultrametamorphism in the area, not to the intrusion of granitic magma (see 3-2-5).



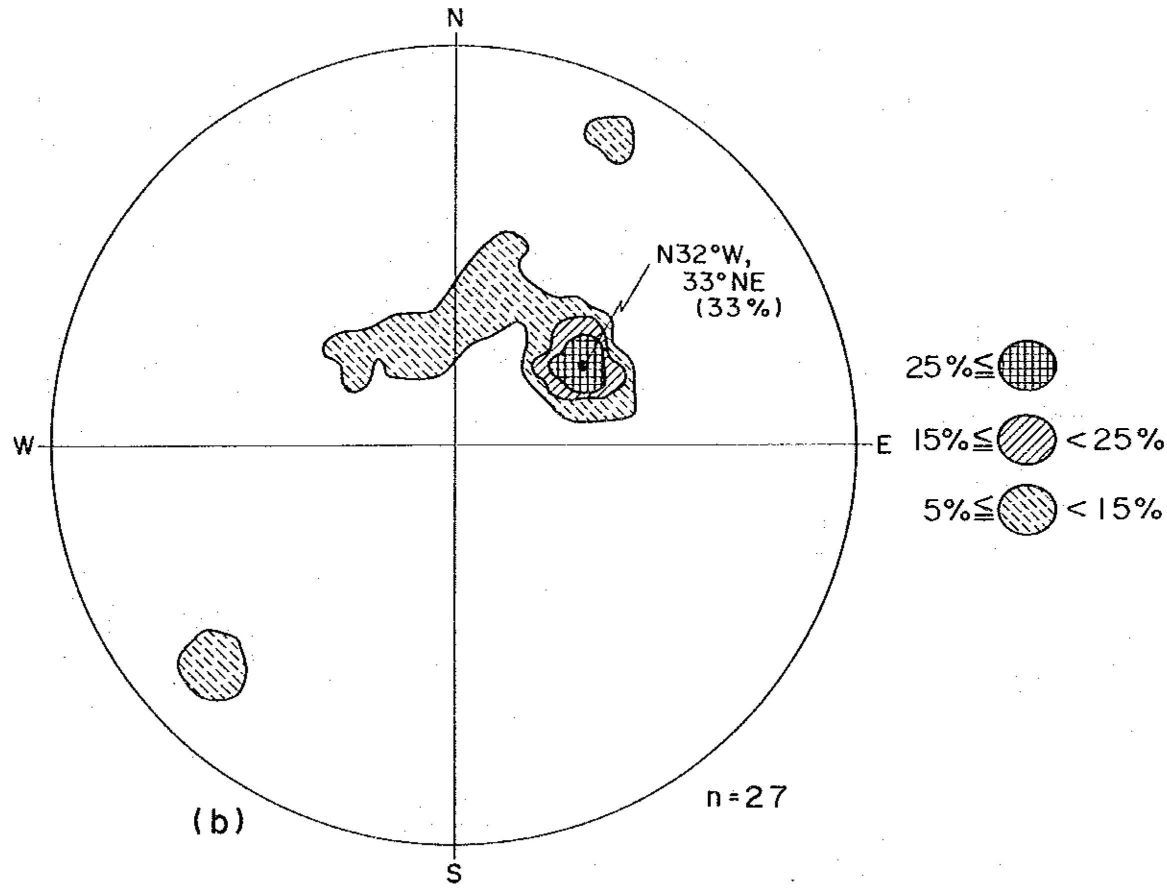


Fig. 3-14 Equal-Area Projection of Pegmatite dikes on Schmidt Net (Upper hemisphere)

(a) Reconnaissance area (except semi-detailed area-B)

(b) Semi-detailed area-B

3-6 Ore Deposit

3-6-1 General Features

Panning of alluvial and eluvial gold by the local residents on a small scale is the only mining activity being carried out in the survey area. The other is a survey by drilling for limestone conducted by the Mines and Geological Department.

On the other hand, the deposit ever put on record on operation other than the alluvial and eluvial gold is only the mica deposit at Nasalot in the northern part of the area. Those which were the object of survey or exploration are the chromium and nickel deposits at Tulot as well as the showings of copper and kyanite scattered in several places.

Among these, the survey and exploration were conducted several times for the Tulot deposit. In recent years, the exploration by a Japanese company including drilling was performed in 1977. Panning of the alluvial gold being carried out at the Suam-Turkwel River and Marun River is a worthy way of earning cash income for the local residents, though it is small in scale.

In the survey of this phase, 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 geochemical survey.

3-6-2 Distribution of Mineralized Zones

The ore deposits and showings are shown in Table A-1 and Plate 7. Table 3-1 shows a compilation of these for elements and types.

Table 3-1 Classification of Mineral Showings

Element or Mineral	Type	Ore deposit of mineral showing
Au (Ag)	Alluvial gold	Suam-Turkwel Riv., Marun Riv. Endogh Riv.
	Eluvial gold	Endogh Riv., Tulot
	Hydrothermal vein	Iang
Cr	Orthomagmatic, lense	Tulot, Kamngeyon
Ni	Secondary deposit	Tulot
Cu	Hydrothermal vein	Twin Bridge, Parua, Akeria-met, Nakang
	Dissemination	Chepkopegh, Talon, Tulot(?)
Mo	Hydrothermal vein	Chaichai
Mica	Pegmatite	Nasalot
Kyanite	Vein	Nakang, Nasalot, Marun, Sostin

The occurrence of metallic ore deposit and showing is limited to those of gold (silver), chromium, nickel and molybdenum.

(1) Gold Deposit

Alluvial deposit and eluvial deposit are known. The alluvial deposits are found at Suam-Turkwel River, Endogh River and the Marun river system, and these are 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.

(2) Chromium Deposit and Nickel Deposit

The chromite deposits distributed at two places, Tulot and Kamngeyon are emplaced in a lenticular form in ultrabasic rock extending discontinuously in the NNW-SSE direction in the central part of the area. Nickel is contained in the garnierite deposit formed in serpentinized part of ultrabasic rock at Tulot. Beside the above, the serpentinite mass that has a sufficient scale to be the host rock of chromite deposit can not be found in the survey area.

(3) Copper Showing

Although the copper showings known at seven places are scattered in the area, they are all positioned in the intrusive rock or in the vicinity of it from the standpoint of general view. They are distributed in the surrounding area of schistose granite at Nakang and Talon in the northern part, within the serpentinite mass at Tulot in the central part and in metadiorite at Chepkopegh in the western part respectively. They are also found near foliated granite at Akeriamet and in the surroundings of migmatitic type granite at Twin Bridge and Parua in the southern part. Among these, Twin Bridge and Parua are located on the fault, and especially Twin Bridge is positioned at the intersection of the faults.

(4) 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.