REPORT ON THE MINERAL EXPLORATION IN THE HOMA BAY AREA REPUBLIC OF KENYA

PHASE Ⅲ

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Republic of Kenya, the Japanese Government decided to conduct a Mineral Exploration in the Homa Bay Area and entrusted the survey to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent a survey team, headed by Mr. Haruo Watanabe, to the Republic of Kenya from 10th July to 9th October, 1989.

The team exchanged views with the officials concerned of the Government of the Republic of Kenya and conducted a field survey in the Homa Bay Area. After the team returned to Japan, further studies were made and the present report has been prepared.

We hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

We wish to express our deep appreciation to the officials concerned of the Government of the Republic of Kenya for their close cooperation extended to the team.

February, 1990

Kensuke Yanagiya

Kensuke Yanagiya.
President,
Japan International Cooperation Agency.

Genichi Fukuhara.
President,
Metal Mining Agency of Japan.

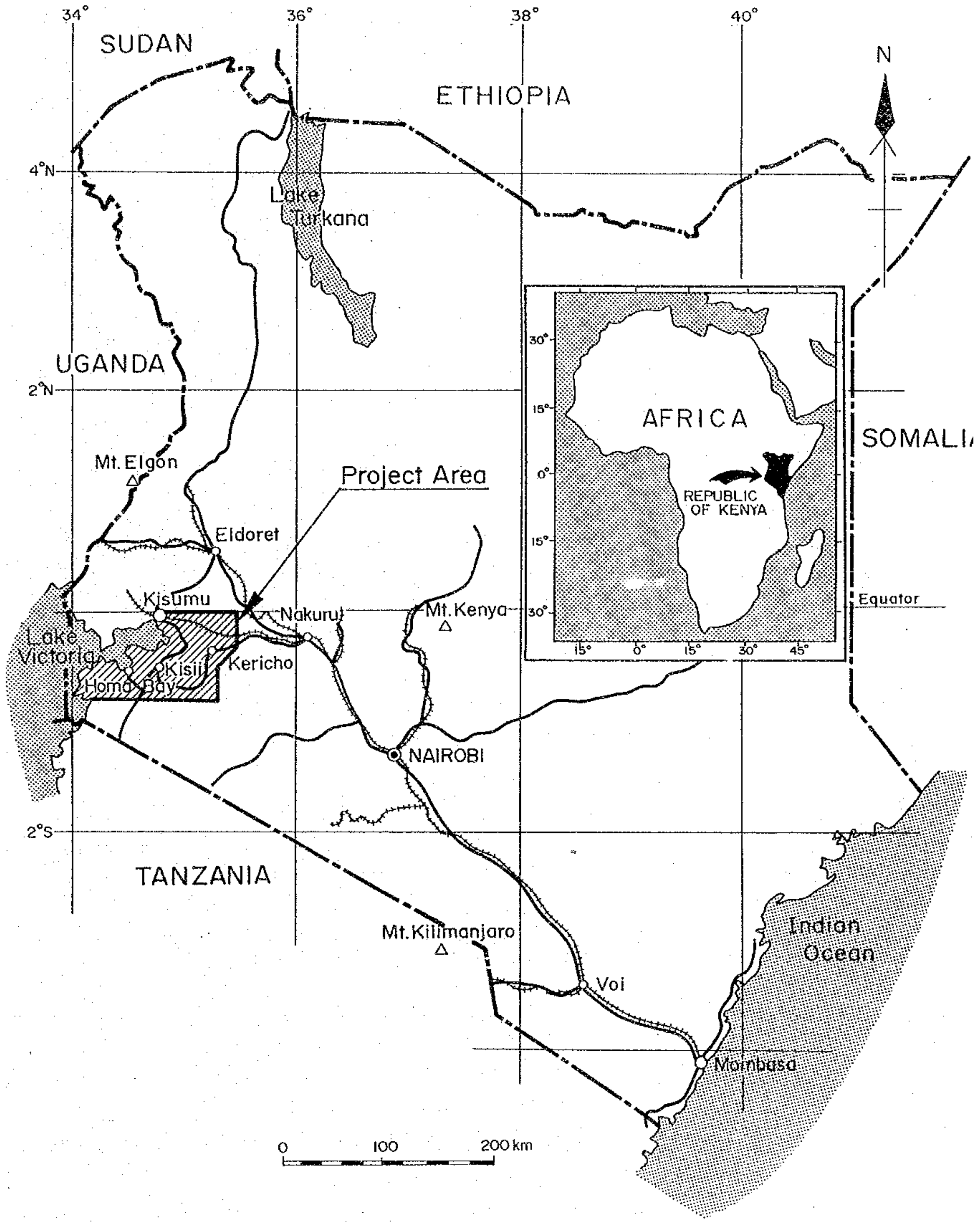

Fig. 1 Location Map of the Project Area

ABSTRACT

The programme of Phase III of the Cooperative Mineral Exploration in the Homa Bay Area in Nyanza Province comprises Drill Survey in the Buru Hill Area and the Kuge-Lwala Area.

The results of the survey are summarized as follows:

(1) Buru Hill

A detailed geological mapping and diamond drills, comprising 30 holes with total lengths of 1,750 m were carried during the last 2 years period.

The Buru Hill consists of a mass of carbonatite intrusion surrounded by basement gneisses. The carbonatite mass carries rare earths elements and can be vertically separated into two zones, the Upper Oxidized (or weathered) and the Lower Reduced (or primary) zones. The Upper Oxidized Zone is secondarily enriched in rare earths elements to form a rare earths ore body. The ore reserves are estimated to be approximately 10.7 millions tonnes of crude ore with average grades of 2.07% of light rare earths elements (La + Ce + Nd), 370 ppm of middle (Sn + Eu + Tb) and 38 ppm of heavy (Yb + Lu), or to be approximately 280 thousands tonnes of contained total rare earths oxides (TREO) with the average grade of 2.63% TREO. The average grade of TREO is low compared with those of the rare earths ore deposits being mined elsewhere in the world and may be so low to commercially develop this ore body at the present time. However, the deposit is with a favourable configuration for a facile applicability of opne pit mining operation and with a favourable accessibility. It is presumed that the ore body may be warrantedly examined with some economical possibility in future when more detailed ore reserves are established and an applicable mineral processing technology is developed.

(2) Kuge-Lwala Area

The occurrence of the ferrocarbonatite body in the Kuga-Lwala Area was elucidated by the detailed geological and geochemical surveys as well as by diamond drills, comprising 6 holes with a total length of 360 m. The ore body is associated with a number of ferrocarbonatite dikes and extends about 600 m in north-south direction with the maximum width of approximately 60 m or the average width of 30 to 40 m, terminating toward north and south. The average ore grade is 1.57% of light rare earths elements (La + Ce + Nd), 198 ppm of middle (Sm + Eu + Tb), 18 ppm of heavy (Yb + Lu) and 0.06% of Nb, and are much lower than those of the Buru Hill ore body. It is concluded that the Kuge-Lwala ore body is unfeasible for a commercial development.

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PART I GENERAL

CHAPTER 1 INTRODUCTION

1-1 Circumstances of the Survey

The main objective of the Survey is to explore and to assess the mineral potential of the Survey Area, as mentioned in the Scope of Work for the Mineral Exploration in the Homa Bay Area. The Scope of Work was agreed in July 1987 between the Government of Kenya through Ministry of Environment and Natural Resources (MENR), and the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The current Survey is a three-year project commenced in the fiscal year of 1987, and this year is on the third year (Phase III) of the project.

The programme of the first year included a reconnaissance geological survey (Regional Survey) for an area of about 2,700 km^2, and geological and geochemical surveys (Semi-detailed Survey) for 10 known occurrences of carbonatite (190 km^2 in total). The major targets for both surveys are rare earths (REE) and so-called rare metals.

In the Regional Survey Area, four small outcrops of carbonatitic rocks and a very small occurrence of green copper specks were newly located, and a few small gold operations (lodes and placer) were examined. However, all these are too small to warrant further follow-up exploration.

In the semi-detailed survey areas, it was concluded that North & South Ruri Hill (Y and REE), Kuge (Y and REE), and Buru Hill (Y, REE and Nb) were worth further exploration, as a result of synthesizing the geological and geochemical findings, and other factors.

The programme of the second year included a detailed geological survey followed by diamond drill explorations (17 holes, 1,000 m in total length) in the Buru Hill Area (an area of 0.96 km^2), and detailed geological and geochemical explorations in the North & South Ruri Hill Area (an area of 1.68 km^2) and the Kuge-Lwala Area (an area of 1.10 km^2).

From the survey results of two year's programme, it was concluded that Buru Hill and Kuge Hill were worth for further exploration as a results of synthesizing the geological and geochemical findings.

In order to explore and to assess the two target areas, it was recommended to carry out diamond drills and mineralogical test.

1-2 Conclusion and Recommendation for the 3rd Phase

1-2-1 Conclusion

(1) Buru Hill Area

Carbonatites in the Buru Hill Area are of a massive intrusive body which is overlain by weathered, oxidized caps.

Mineralization of REE, Y and Nb is found almost everywhere in the whole hillock (in an area of 0.2 km^2) and this has been confirmed to extend for more than 200 m in depth from the surface by diamond drillings. The mineralized zone can be vertically divided into an upper oxidized layer of supergene enrichement and lower fresh layer at the current ground water level.

Average metal contents for 50 m in the mineralized zone from the ground surface are estimated as follows; La + Ce + Nd: 1.93%, Sm + Eu + Tb: 0.036%, Yb + Lu: 0.0037%, Nb: 0.095% and Y: 0.065%.

Because of a large scale of the mineralized zone and high contents of the elements, it is deserved to carry out further explorations to assess the economic potentiality of the area.

(2) North & South Ruri Hill Area

Three sectors in this area were comprehensively studied through detailed geological and geochemical explorations, and it has turned out that REE and Y concentrate in ferrocarbonatitic rocks which usually occur in the marginal parts of the Ruri Hill carbonatite cone-sheets.

Geochemical anomalies were found in each sector, but they are not potential target areas for the project Phase III because of the small scale and low contents of REE and Y in the ferrocarbonatitic rocks.

(3) Kuge-Lwala Area

Two sectors: Kuge and Lwala were investigated in this area.

Kuge Sector; A ferrocarbonatite body which is located in the eastern part of Kuge Hill comprises a group of dykes, 60 m wide in maximum and more than 600 m long. Covering the body, there are anomalous zones of Th, Y, La + Ce + Nd (maximum value: 2.7%), Eu and Tb. The large scale of the body and the high contents of REE and Y warrant further follow-up explorations.

Lwala Sector: Anomalous zones of Y, La + Ce + Nd and Eu were delineated in a zone underlain by ferruginous breccias which are considered to be effusive facies of carbonatites. The thicknesses of the ferruginous breccias are very small and the contents of REE and Y are very low in comparison with that in other sectors, resulting in a low potential estimation of the sector for mineralization of REE and Y.

1-2-2 Recommendation for the 3rd Phase

It was recommended to carry out following works as the 3rd Phase Programme in the Buru Hill and the Kuge-Lwala Areas.

(1) Buru Hill Area

A programme concentrated mainly in diamond drills and mineralogical tests was recommended.

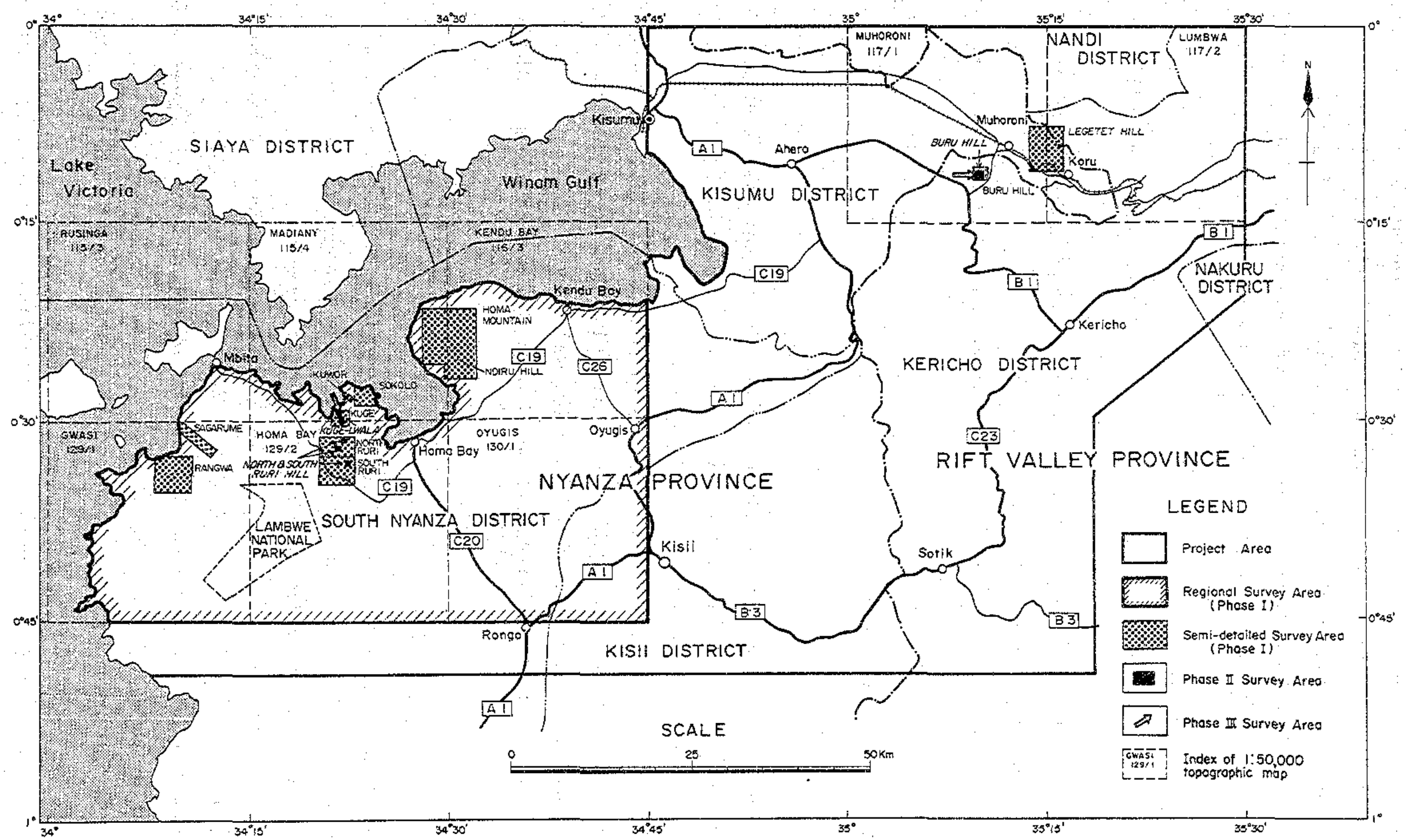


Fig. 2 Location Map of the Phase III Survey Area

The aims of drilling are to elucidate the exact demarcation of the mineralized zone and the shape and character of the supergene enrichment and the lower zones, and also to explore a potential blind carbonatite body that might occur at the depth to the south of Buru Hill.

The aims of mineralogical tests were to research the whole mineral assemblage in both the supergene enrichment and the lower primary mineralization zones.

(2) Kuge-Lwala Area

A programme concentrated mainly in diamond drilling and minreralogical test was recommended.

The aims of drilling is to explore the depths of the group of ferrocarbonatite dykes located in the eastern marginal part of the Kuge Hill.

The aims of mineralogical tests are to elucidate the mineral assemblage of rare earth elements associated with the dykes.

1-3 Outline of the 3rd Year Programme

1-3-1 Location

(1) Location

The project area (Homa Bay Area) is located in the western part of the Republic of Kenya; eastern coast area of the Lake Victoria, and is spread over two provinces, mainly in Nyanza Province, and partly in Rift Valley Province (Fig. 1, Fig. 2).

The followings are the two survey areas of this year (Phase III); Buru Hill located in the northwestern part of the Kericho District in the Rift Valley Province, Kuge-Lwala Area located in the central part of the South Nyanza District of the Nyanza Province.

The central towns of the Kericho and South Nyanza districts are Kericho and Homa Bay, respectively.

(2) Communication

Kericho and Homa Bay towns are accessible by car from Nairobi by the following roads which are asphalted. The road distances from Nairobi to Kericho and to Homa Bay are about 270 km and 400 km respectively and it takes about 4 and 7 hours respectively.

Nairobi - - - - - Makutano - - - - - Kericho - - - - - Sotik - - - - - Kisii - - - - - Rongo - - - - - Homa Bay

A-104 B-1 C-23 B-3 A-1 C-20

The railway between Nairobi and Kisumu passes by Muhoroni which is adjacent to Buru Hill (5 km in distance).

The Buru Hill area is situated 24 km northwest of the town of Kericho and is accessible from Kericho via B-1 (30 km road distance).

The Kuge-Lwala Area is situated 10 km to the west of the town of Homa Bay, and it takes about one hour by car.

1-3-2 Purpose of the survey

The purpose of the survey is to comprehend the modes of mineral occurrences in carbonatite deposits in Homa Bay area through clarifying the geological conditions in the area.

The programme of this year comprises diamond drill exploration in the areas, Buru Hill and Kuge-Lwala.

Major objectives of the survey in each area are as follows:

(1) Buru Hill Area: The vertical and horizontal variations of REE, Y and Nb distributions and the size of the deposit are to be determined. The economical potentiality of the deposit is to be investigated by diamond drill exploration in connection with geological and mineralogical research.

(2) Kuge-Lwala Area: An eluciation of size and character of the Kuge anomaly, which covers the ferrocarbonatite body in the Kuge Hill with high geochemical anomalies for Y, Sm, Eu and etc..

1-3-3 Methods of the work

Diamond drill exploration works were carried out for the current survey programme in the Buru Hill Area and in the Kuge-Lwala Area.

All the work carried out by the current programme is listed in Table I-1-1.

(1) Diamond Drill Explorations

Number of drill holes in the Buru Hill Area are 13 holes (two holes of 100 m - depth each and 11 holes of 50 m - depth each), totaling 750 metres in length, meanwhile, in the Kuge-Lwala Area are 6 holes (6 holes of 50 m - depth each), totaling 360 metres in length.

(2) Interpretation of Results and Preparation of Report

All the results of the field work and the laboratory tests were comprehensively interpreted together with available existing data and reports.

Analytical works and laboratory tests are listed in Table I-1-2.

Table I-1-1 Content and Quantity of Boring Exploration

Area	DDH Number	Planned Length (m)	Inclination	Bearing, degrees from GN	Drill Length (m)
BURU HILL	BR-17	50	-90°	-	50.20
	BR-18	50	-90°	-	52.50
	BR-19	50	-90°	-	50.10
	BR-20	50	-90°	-	50.20
	BR-21	50	-90°	-	50.10
	BR-22	50	-90°	-	50.10
	BR-23	50	-90°	-	50.20
	BR-24	50	-90°	-	50.50
	BR-25	50	-90°	-	50.10
	BR-26	50	-90°	-	50.40
	BR-27	50	-90°	-	50.10
	BRL-2	100	-90°	-	100.50
	BRL-3	100	-90°	-	100.70
KUGE-LWALA	KG-1	60	-50°	40°	60.10
	KG-2	60	-50°	70°	60.10
	KG-3	60	-50°	70°	60.10
	KG-4	60	-50°	70°	60.10
	KG-5	60	-50°	110°	60.10
	KG-6	60	-50°	90°	60.10
Total	19 Holes	1,110			1,114.30

Table I-1-2 Outline of Laboratory Tests

	Mode of analysis	Amounts
1.	Microscopic examinations of rocks in thin section	20
2.	Microscopic examinations of ores in polished thin section	20
3.	Chemical analysis	
	Rocks:	
	SiO_2, Al_2O_3, TiO_2, T.Fe_2O_3, FeO, MnO, MgO, CaO, BaO,	12
	K_2O, Na_2O, P_2O_5, L.O.I., F, CO_2 (15 elements)	180 elements
	Ores:	
	U, Th, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, Nb, Sr, Y, Ba, P	240
	(15 elements)	3600 elements
	Concentrated Minerals:	
	U, Th, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, Nb, Sr, Y, Ba, P	10
	(15 elements)	150 elements
4.	EPMA test	10
5.	Dating (K-Ar method)	1
6.	Measurement of size of rare-earth minerals	10
7.	Measurement of Oxygene Isotopes	10

1-3-4 Members of the teams

The members of the preliminary mission are listed in Table I-1-3 together with those from the Kenyan side. The member list of the field team is shown in Table I-1-4.

Table I-1-3 Preliminary Mission and Kenyan Personnel attended the Meeting

JAPANESE SIDE		KENYAN SIDE	
Dr. Masatsugu Ogasawara	GSJ *1	Mr. S. Abiud Wasike	MENR *3
Dr. Hideo Hirano	MMAJ *2	Mr. C.Y.O. Owayo	MGD *4
Mr. Hiroshi Shimotori	MMAJ	Mr. J.K. Wachira	MGD
		Mr. F.K. Muruga	MGD
		Mr. Isaac Onuonga	MGD

Table I-1-4 Member List of Field Team

JAPANESE SIDE		KENYAN SIDE	
Mr. Haruo Watanabe (Geologist) Leader of the Field Team	MMAJ	Mr. Isaac Onuonga (Geologist) Co-leader of the Field Team	MGD
Mr. Katsuei Narita (Drill Eng.)	MMAJ	Mr. William Okech (Geologist)	MGD
Mr. Takehiro Manabe (Drill Eng.)	MMAJ	Mr. Haron Onsomu Maragia (Geologist)	MGD
Mr. Masaaki Fujita (Drill Eng.)	MMAJ	Mr. Albert Mahaja (Geologist)	MGD
		Mr. Adipo Komo (Assistant Geologist)	MGD
		Mr. E. Likhaya (Driller)	MGD
		Mr. Peter Obiero (Driller)	MGD
		Mr. Joseph Ango (Driller)	MGD
		Mr. Chambege Sembe (Driller)	MGD

*1 GSJ: Geological Survey of Japan
*2 MMAJ: Metal Mining Agency of Japan
*3 MENR: Ministry of Environment and Natural Resources
*4 MGD: Mines and Geological Department of Kenya

1-3-5 Period of work

Periods of the work for the field team are summarized as follows; -

Planning and Preparation	: June 10, '89 ~ July 9, '89
Travelling and Preparation in Kenya	: July 10, '89 ~ July 14, '89
Field Work	: July 15, '89 ~ September 28, '89
Reporting to MGD	: September 29, '89 ~ October 7, '89
Travelling	: October 8, '89 ~ October 9, '89
Laboratory Work and Preparation of Report	: October 10, '89 ~ February 9, '90

CHAPTER 2 GEOGRAPHY

2-1 Physiography

2-1-1 Topography

The survey areas of the current works are situated in the Kavirondo Rift Valley, which is considered to be a branch of the Great East African Rift Valley. The Kavirondo Rift is 20 to 30 km in width and 200 km in length, generally trending east-northeastward from the shore of the Lake Victoria (1,136 m above sea level).

The western part of the Rift comprises flat lands covered by alluvium deposits and a group of hills, which are 600 - 1,000 m higher than the surrounding flats, and is composed of Carbonatite-alkaline rock complexes. The Kuge-Lwala Area is situated on a gentle slope between the flat lands and the hills.

The eastern part of the Kavirondo Rift comprises eastern gentle slopes extending to eastward highland covered with volcanic rocks of the Tertiary and western flat alluvium area. The Buru Hill Area is located on this gentle slope close to the flat lands and it is a discrete hill with a relief of about 70 m above the surrounding flat.

2-1-2 Drainage system

The Buru Hill Area is located on the southern bank of the middle stream of the Nyando River which originates from the Mau Forest, the background of the Kericho highland, and passes through the Kusumu Plains emptying itself into Lake Victoria. The Raragewit River which is a major tributary of the Nyando River is to the east of the Buru Hill and has smaller tributaries with their confluences at the south of Hill. The Raragewit River System has a permanent water flow.

There are no big rivers in the area surrounding the Kuge-Lwala Area. Water flow is just seen in gulleys only during the rainy season. The big Lambwe Velley, 10 km maximum width and 30 km in length situated to the south west of the Kuge-Lwala Area, is dry except during the rainy seasons.

2-2 Climate and Vegetation

2-2-1 Climate

The climate in the project area is of semi-arid with an annual precipitation of about 1000 to 1200 mm and humidity of about 60%. There are two rainy seasons; long rains from March to May or June, and short rains in November and December. The air temperature changes little throughout a year, averaging 24°C, but sometimes rising up to 40°C.

2-2-2 Vegetation

In general, the natural vegetation in the project area is rather poor, as its climate is semi-arid, belonging to savanna, and as the area is heavily inhabited.

The plains including the Kuge-Lwala Area are more or less covered with fields of maize, millet, cassava, and cotton. These are often fringed by sisal (Agave sisalana). However, the lands seem to be infertile. Inversely, the flat lands in the proximity of Buru Hill are fully utilized for a large scale sugar cane plantation.

Most of the hilly carbonatite-alkaline centers are in an open grass land, with scattered acacia trees (Acacia drepanolobium and other species), Cactus Euphorbia (Euphorbia ingens), thorn bush and etc..

CHAPTER 3 GENERAL GEOLOGY

The geological map of the Homa Bay Area; Regional Survey Area of Phase I, which includes the Kuge-Lwala Area, is shown in Fig. 3.

The area is bisected by a major fault (Kaniamwia) trending in NE-SW direction. This fault forms the southeastern escarpment of the Kavirondo Rift which branch off westerly from the centre of the Kenya Rift. There occurs plutonic and volcanic rocks of carbonatite-nephelinite series of Tertiary and Quarternary ages, basement granitoid inliers within volcanics and Quarternary alluvials to the northwest of the fault, while the rocks to the southeast of the fault comprise Archean greenstones and sediments (the Nyanzian and the Kavirondian Systems), intrusions and nephelinitic volcanics overlying the Precambrian.

Rangwa, Ruri Hills and Homa Mountain are the three largest carbonatite-alkaline rock complex units in the Homa Bay Area, which project out prominently above the surrounding alluvial plain and are composed of typical cone sheets. There are other small carbonatite-alkaline rock complexes, such as Sagarume, Nyamuguruka, Kuge-Lwala and Sokolo.

Ijolite and carbonatite bodies are known to be distributed at several localities in the Wasaki Peninsula to the west of the town of Homa Bay, where the Kuge-Lwala Area includes a small carbonatite body located in the southwestern end of the carbonatite area mentioned above.

The geology of the area comprise the basement Nyanzian Metabasalt, Tertiary volcanics, carbonatites, carbonatitic breccias and Quarternary surficial deposits.

The geological map of the surrounding areas of the Buru Hill is shown in Fig. 4. The geology comprises undifferentiated granitoid gneisses (currently the Mozambique Metamorphic Rocks), calcareous sedimentary rocks of the Tertiary, the Tindret Volcanic Rocks in the northeast and phonolitic rocks in the south. The Buru Hill is considered to be formed by a carbonatite intrusion into the granitoid gneisses.

The Kaniamuiwa Fault, which is the limit of the southern margin of the Kavirondo Rift, extends to the Kendu Fault, however, it is obscure toward east near the Buru Hill.

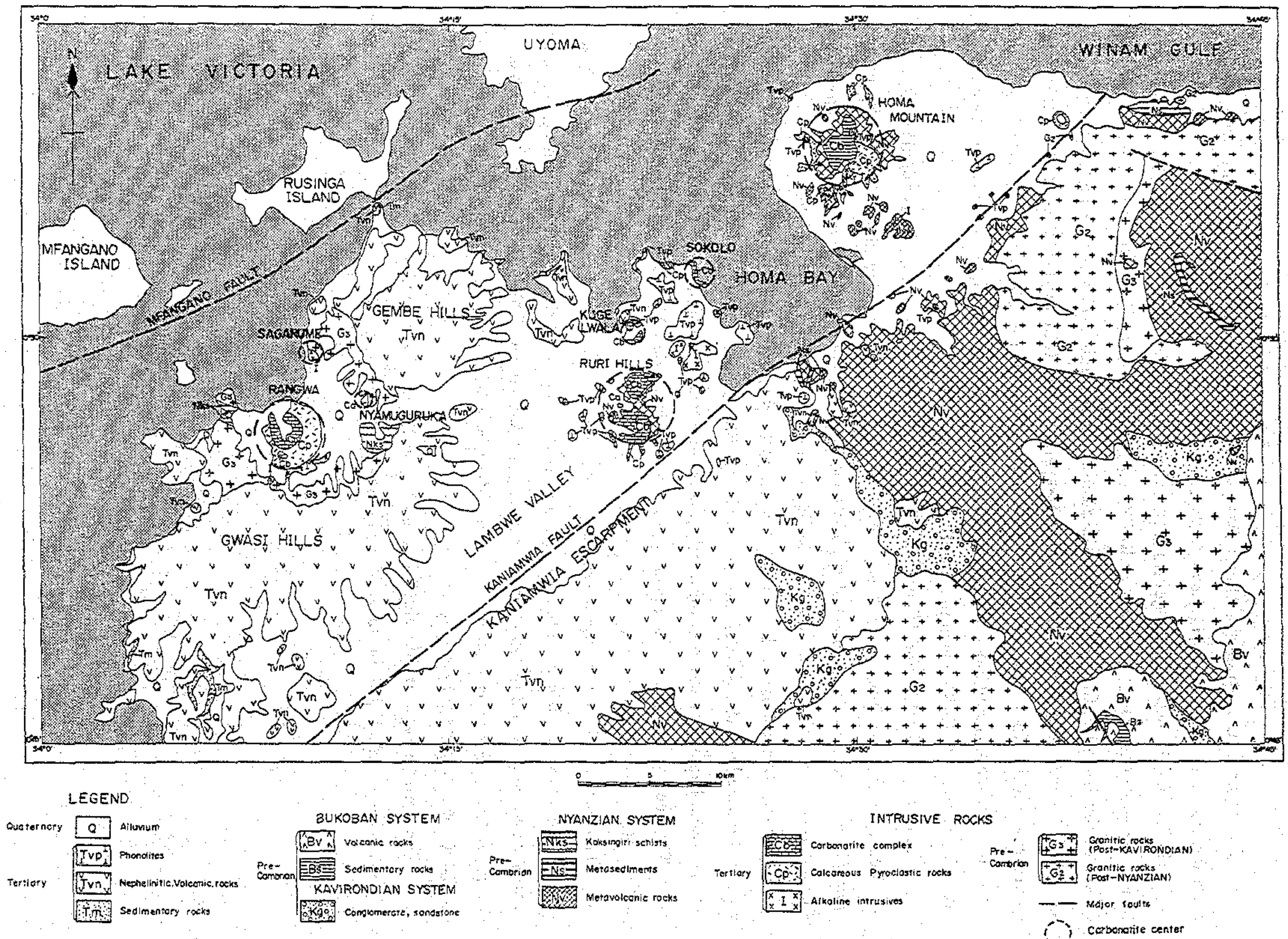


Fig. 3 Geological Map of the Homa Bay Area

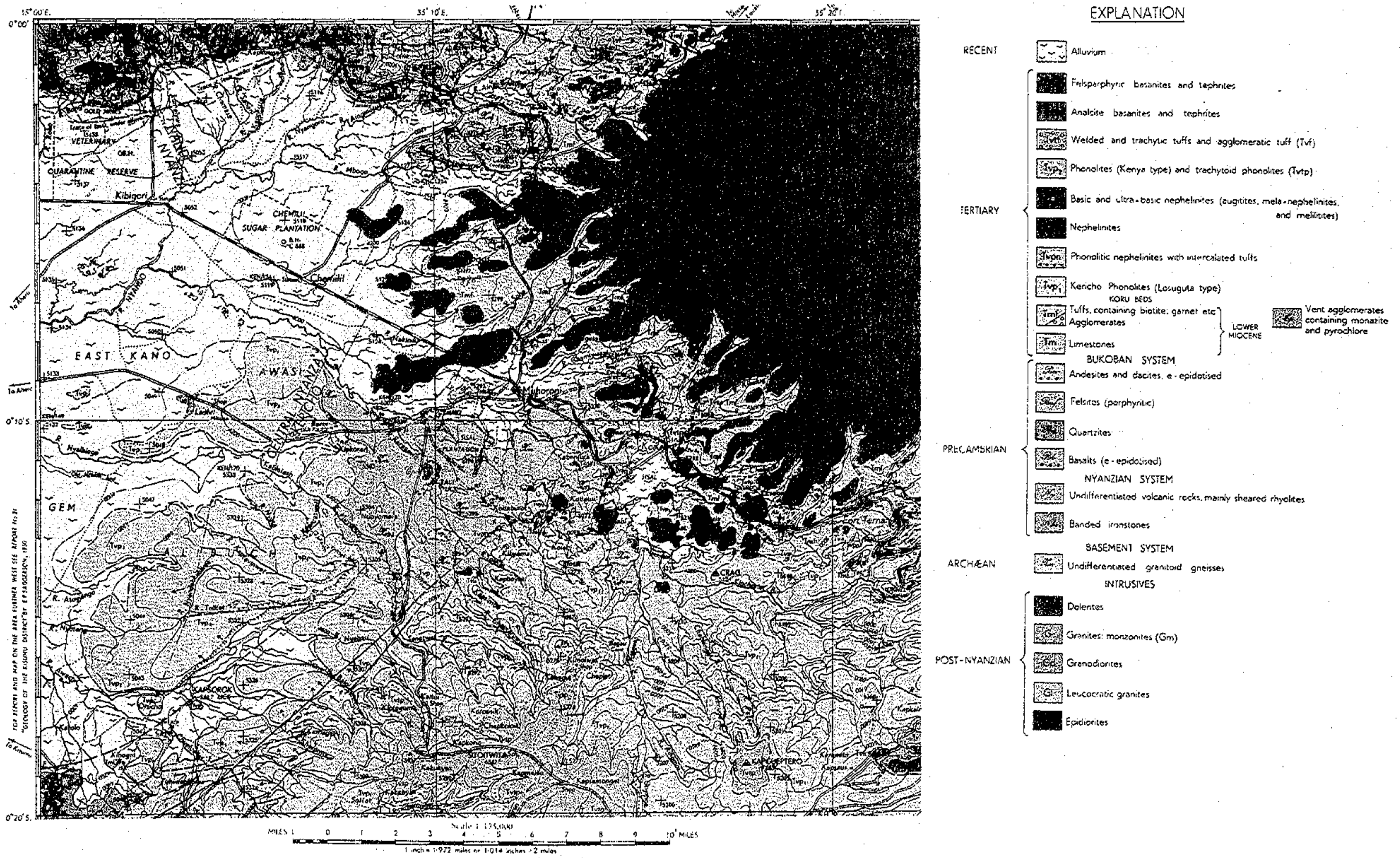


Fig. 4 Geological Map of the Area surrounding the Buru Hill (after Binge, 1962)

CHAPTER 4 GENERAL DISCUSSION ON SURVEY RESULTS

4-1 Geological Structures, Characters and Control of Mineralization

4-1-1 Buru Hill Area

The carbonatite body in Buru Hill area occupies and area of 600 metres north-southerly by 400 metres east-westerly of oval-shape, and shows a cylindrical form dipping 70 degrees to 80 degrees westerly. The body is associated with the subsurface small satellite carbonatite body in the south, which is separated off the main body by the Buru Fault, strikes N60°E. The Buru Hill carbonatite is up-lifted in accordance with a ring-formed intrusion and is surrounded by granitoid gneiss of the basement rock, which is also rippedly up-lifted upward at the contact to the carbonatite body. The carbonatite body shows a steep topographic feature, surrounded by granitoid gneiss, resistive to the erosion effects, being open toward south. Erosion and dissection in the area is considered to be enhanced by the Buru Fault activity to show a brittle rock facies, by what the Bull Hill itself has a gentle slope toward south. The carbonatite body is presumed to have been under the structural shelter by granitoid gneiss to sustain little removal of weathered materials toward outsided periphery.

The Buru Hill carbonatite body, intruded on the stage of the early Neogene Tertiary age, 22 Ma-aged by potash-argon dating, is estimated to have been subjected to weathering and erosion until Recent under the tropical climate condition. It is estimated that the body currently shows a form of cylindrical mass on ground surface, which is considered to be pertaining to subvolcanic facies, after having been subjected to weathering, by which the most portions of volcanic facies in upper part of the carbonatite body, i.e., eruptive facies, ring dykes and cone-sheets, have been eroded off. The current exposure of carbonatite body is covered by soils and/or lateritic earthy materials after weathering. As above mentioned, the total quantity of the weathered products of carbonatite body itself, to be removed toward outsided periphery, is presumed to be little by having been under the surrounding structural shelter of resistive granitoid gneiss to weathering. The structure, the above, by which a concentration, i.e., a secondary enrichment, of the elements such as REE, Nb, Y and etc., insoluble to ground water, have been enhanced, is also observed in the lateritic-weathered zone of the Catalao ore deposit, Brazil (Hirano et el. 1987).

The depth of lateritization by weathering reaches to the elevation of current ground water table, 1,295 metres high above sea level. It is some 20 metres thick at the contact of carbonatite and granitoid gneiss, and 80 metres thick in maximum.

The mineralized zone is formed in the lateric-weathered zone, in which REE have been concentrated by weathering on the level of some 1.3 times of the primary mineralized zone. The concentrated mineral contents in Buru Hill body is considerably low in comparison with that in Brazil, e.g., the Araxa ore deposit, where the content of Total REO exceeds ten (10) percent. This is presumed to be caused by that the period of time of weathering, to which the Buru Hill carbonatite body has been subjected, was relatively short and also the removal of weathered products in Buru Hill has been insufficiently sheltered in the area, particularly due to of opened topographical configuration toward south.

Phosphorus, niobium and etc. have also been concentrated by weathering in Buru Hill carbonatite on the level of some 1.3 times of the primary mineralization, however, a remarkable concentration of these elements, to be graded on the industrial/economical standard, has not been formed, as the natural primary contents of these elements in Buru Hill carbonatite are inevitably low.

4-1-2 Kuge-Lwala Area

The Kuge Hill is an up-lifted mass of oval-shape in an area of 750 metres by 500 metres, extending north-southerly. Carbonititic rocks are distributed in Kuge Hill area. The carbonititic rocks are majorly composed of alvikite and ferrocarbonatite, the former is on the centre and is circumscribed by the latter, and are associated with involvements of metabasalt, the basement rock in the area, which were derived from the deeper part in accordance with an up-lift by the intrusion of carbonititic rocks. The geological occurrence of Kuge carbonititic body is estimated to be showing the upper-most facies of the body on the ground surface, remarked by showing of ring-dykes and cone-sheets, geological structure of which resembles to that on the crest of Ruri Hill. The geological showings of carbonititic rocks in Kuge Hill, the above, are estimated to be likely allegorized to the position of "a cap of mushroom", underneath of which, likely allegorized to the position of "a stalk of mushroom", it may have a far smaller volume of rock mass in size than the upper part.

The erosion and weathering against the carbonititic rocks in Kuge Hill area have been little enhanced toward depth to maintain the possibly natural primary configuration until the Recent.

The ferrocarbonatite body, one of the carbonititic rocks in the area, in which a relatively high concentration of REE is observed, is located in the form of long-extended body, north-southerly, 600 metres long in maximum, 60 metres wide in maximum and 30 metres wide in average, dipping 60 degrees to 80 degrees westerly. Ferrocarbonatite body is located at the foot of a eastern slope of gentle hill, from where the most of weathered products might have likely been removed away through the topographical evenness. The favourable topographical and geological structure to sustain little removal of earthy soil and lateritic materials to be concentrated in-situ is not provided in Kuge Hill area. Consequently, the contents of REE in the area remain inherently on the level of primary concentration to show a lack of supergene enrichment. The primary contents of REE in the Kuge carbonatitic rocks are less than that in the Buru Hill carbonatite with an extremely less possibility to form a REE ore body.

4-2 Potentiality of Rare Earths Elements Mineralization

4-2-1 Buru Hill Area

The zone of supergene enrichment in Buru Hill area, located on the elevation high than the current ground water table, is estimated to solely provide a possibility of potentials of the ore body to be enhanced to the industrial/economical development in future. The most possible elements of potentials is estimated to be of REE and yttrium, meanwhile, niobium and phosphorus contents are so low to recover them as a by-product. The average ore grade of 2.63 percent of Total REO and 0.1 percent of yttrium in Buru Hill carbonatite body is to be estimated to be considerably low in world-wide comparison with the mines, where REE are currently operated as a main or by-product. However, the Buru Hill carbonatite body is situated in favourable location and geometric condition, such as with an easy applicability of open pit mining operation and etc.. A comprehensive evaluation and feasibility study for an economical development of the ore body will be required by some possibility in more details in a future.

4-2-2 Kuge-Lwala Area

The carbonititic body in Kuge-Lwala area shows the element contents of 1.57 percent of LREE (La + Ce + Nd), 198 parts per million of MREE (Sm + Eu +Tb), 18 parts per million of HREE (Yb + Lu), 0.06 percent of niobium and 0.3 percent of phosphorus, are estimated to be unlikely ranked to of industrial/economical standard by the current economical backgrounds. The possible potential of the carbonititic rocks in Kuge-Lwala area is estimated to be very low for an industrial/economical development of carbonatitte-related elements in a future.

4-3 Geological Relations of Geochemistry and Mineralization

4-3-1 Buru Hill Area

The geographical extension of the mineralized zone in Buru Hill area, intersected by the diamond drill explorations of the current programme, shows a coincidence with that of the distribution of geochemical anomalous zone by the 1st-year work. However, the locative correspondence of concentration distribution of the elements between ground surface geochemistry and drill cores geochemistry is estimated to be irrelative. The disparity of the concentration of the elements is presumed to be caused by the difference of modes of leaching and concentration of the elements in the weathered portions of rock in the area between on ground surface and in underground.

4-3-2 Kuge Hill Area

The geographical extension of ferrocarbonatite body, with which the highest values of REE were observed, shows a coincidence with that of the distributions of anomalous zones by surface geochemistry. The element contents in weathered portions of rocks by ground surface geochemistry and drill cores geochemistry show a sufficient coincidence. This is presumed to be caused by little difference of modes of weathering and oxydation of rocks in the area between on ground surface and in shallow underground in the range accessible by a diamond drill. This is also presumed to be caused by a wide removal of weathered materials out of the original site.

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5-1 Buru Hill Area

5-1-1 Conclusion

Geological and geochemical research works, and diamond drill operations of thirty (30) holes, with total depths of 1,750 metres for a two-year programme, were implemented during the term from 1987 to 1989 as a part of the Homa Bay Project, Nyanza Province, Republic of Kenya.

In accordance with the results of the above works, the Buru Hill area is geologically elucidated to be majorly composed of massive intrusive carbonatite bodies, associated with the REE minerals, and is to be surrounded by granitoid gneiss of the basement rock in the area. The carbonatite itself is zonally divided to two zones; i.e., the upper zone of oxydized-weathered part and the lower zone of reduction part.

Concentrations of REE minerals by the supergene enrichment form an ore body in upper zone of the carbonatite body. The REE ore body is mainly mineralogically composed of bastnaésite.

The inferred geological ore reserves are estimated to be of 10,700,000 tonnes of crude ore, the average grade is La + Ce + Nd: 2.07 percent, Sm + Eu + Tb: 370 parts per million, Yb + Lu: 38 parts per million, to be re-calculated to be of Total REO: 2.63 percent, and 280,000 tonnes of Total Rare Earths Oxides.

The mineral content in the Buru Hill ore body is inevitably estimated to be low-graded for the industrial/economical production under the current economical backgrounds in world-wide comparisons with other REE mines in operations. However, the Buru Hill ore body is with a favourable configuration for a facile applicability of open pit mining operation and with a favourable accessibility. It is also presumed that the ore body should be warrantedly examined with some economical possibility in a future when ore reserves and ore-grade values for the mining operation will be satisfactorily ameliorated by additional exploration activities and when an industrially favourable extration technology of REE minerals will be developed.

5-1-2 Recommendation

It should be pointed out that the followings are the major factors to be examined in compliance with a future consideration to establish an industrial/economical estimation of economical possibility of the mining development of Buru Hill ore body, those are;

1) To establish a more reliable estimation of ore reserves and ore grade based on the results by sufficient quantities of diamond drills.
2) To establish a favourable extraction technology of REE minerals by feasible crushing and metallurgical tests.
3) To estimate reasonable capital and operation costs based on the programmes related to mine development, plant construction and mining/mineral processing operations.

4) To establish infrastructural and environmental researches related to the social impacts and associated terms.

For a further reliable establishment of the re-estimation of ore reserves and ore grade, the diamond drill operations on the modes of 50 metre-interval on grid-patterns covering the mineralized zone should be appropriately operated.

5-2 Kuge-Lwala Area

5-2-1 Conclusion

Geological and geochemical research works, and diamond drill operations of six (6) holes, with total depths of 360 metres for a 1989-programme, were implemented during the term from 1987 to 1989 as a part of the Homa Bay Project, Nyanza Province, Republic of Kenya.

In accordance with the results of the above works, the Kuge Hill area is geologically elucidated to be majorly composed of the dykes of ferrocarbonatite and carbonatite, which has an intermediate petrological character of ferrocarbonatite and alvikite. The general occurrence of the dykes in the area is observed in an extension of 600 metres long, 30 metres to 40 metres wide in average, 60 metres in maximum, and is extended north-southerly, dips 60 degrees to 80 degrees westerly. The results of diamond drill works by the current programme show that the oxydation zone in Kuge Hill area is insufficiently developed, resultant in that the concentration of REE minerals, associated with carbonititic dykes, is very limitedly formed. In accordance with the chemical research works of drill cores by the current works, the average grade of ore in the area shows 1.57 percent of La + Ce + Nd, which is approximate to that of the primarily mineralized zone in Buru Hill, that is 1.5 percent. The Kuge Hill ore body is with a limited quantity and quality, which are with less extension and less high concentration of REE. Consequently, it is to be concluded that the REE mineralization in Kuge Hill area is less economical for a future consideration.

5-2-2 Recommendation

Future examinations of exploration programming for an industrial/economical development of the REE minerals in Kuge Hill area are to be unlikely warranted in accordance with the conclusion, the above.

PART II DETAILS OF SURVEY WORKS

CHAPTER 1 BURU HILL AREA

1-1 Methods of Survey

1-1-1 Outline

Diamond drill works have been consecutively implemented during the course of the current programme 1989 in the Buru Hill Area, having an area of 0.96 square kilometre of rectangular-shaped (Fig. 2), which was selected from the semi-detailed-survey area of 4 square kilometres after the first-year programme 1987, and where detailed geological investigation and diamond drill works were carried out on the phase of the second-year programme 1988.

1-1-2 Diamond drill works

The 11 short-hole drills, having a 50 metre-depth each, and 2 deep-hole drills, having a 100 metre-depth each, consequently, 13 holes with 750 metres depths in total, were operated. Diamond drill holes were allocated those that, 1) 9 holes of 50 metre-depth each, being at on 120 metre-interval grids to establish an outward coverage of the second-year programme area for the purpose to elucidate a geological demarcation of the Buru Hill Mineralization Zone, 2) one hole of 50 metres deep at the southern location from the northern-most drill sites, where two drill holes were operated on the second-year programme phase 1988, to define the northern geological boundary of the Mineralization Zone, 3) two holes of 100 metre-depth each, being on northern and southern sides of Hole BRL-1, 200 metres deep, 4) one hole of 50 metres deep, being at the small hill, located southward from Buru Hill, to elucidate an occurrence of carbonatite body.

Detailed examinations of drill cores by unaided eye were carefully made to summarize the drill core logs on a scale of 1:200. Required number of samples of minerals and rocks were collected to be sent to laboratory tests. Mineralized portions of the drill cores were chemically analysed at an every intersected portion of ores. The 162 samples were chemically analyzed. The geological cross sections with drill hole logs projections, on a scale of 1:1,000, were delineated after geological compilations of surface mappings and drill logs. The results of the chemical analyses of ores were applied to the estimations of inferred ore reserves and grades.

1-2 General Geology

1-2-1 Regional geology in the area

The Buru Hill Area is situated in the eastern region of the Kavirondo Rift, east-northeast to south-southwest or east-west directional, and traverses a basement rock area in western Kenya.

The Kavirondo Rift, regarded as one of the branches from the Kenya Rift Valley, is characterized by an alkaline rock occurrence represented by a carbonatite-alkaline plutonic rock activity and also a nepheline bearing volcanic rock activity.

The eastern province of the Kavirondo Rift occupies an extensive volcanic rock area of nephelinite-basalt, which is geologically successive to the Kenya Rift Valley. Tindred volcanic rock is situated in north-eastern portion of the Buru Hill Area, jointly with Kericho phonolite towards south (Fig. 4).

The Tindred valcano is geologically characterized by having both volcanic activities of Rift Valley type and alkaline volcanic type of Kavirondo Rift and is associated with carbonatities in its parasite volcano, the Legetet Hill. The Buru Hill is located on a south-western extension of an alignment connecting the centre of Tindred volcano and Legeted Hill and is considered to be having a possible geological relation to the Tindred volcano.

The Buru Hill, intrudes into gneiss of a 100 square kilometres extent and has an area of 0.4 square kilometre, is observed as a small hill of jutting inlier in the vicinity of the geological boundary of Tindred and Kericho valcanos. Surroundings of the Buru Hill are mostly composed of grantitoid gneiss and are geologically correlated to the Mozambique metamorphic rocks (Fig. 4).

1-2-2 Geology

Generalized geological column in the area is shown in Fig. II-1-1, geological map and geological profiles are shown in Figs. II-1-2 to II-1-4. These illustrations are majorly based on the work results by the second-year programme, however, some revisions have been supplemented by the current works. General geology in the area is majorly composed of basement gneiss, fenitized rock, siliceous breccias, carbonititic rock, ore veins, volcanic rock, lateritic rock, surface weathered rock and etc.. Details are shown below in accordance with rock classification in the geological map.

(1) Amphibole gneiss, amphibole bearing gneiss ($\underline{P} - mg^a$)

Amphibole gneiss and amphibole bearing gneiss, associated with other types of gneiss, forming the basement rocks in the area, are observed in northern and eastern portions of the Buru Hill and partially in north-western portion. They are viridescent to greyish green, and have gneissose texture and/or schistosity, associated with green-chloritized or epidotized amphiboles and felsic minerals. They also show a amphibolite-like facies due to a partial abundant concentration of amphiboles. They are considered to be originated from intermediate to basic intrusive rocks.

(2) Granitoid gneiss ($\underline{P} - mg^g$)

Granitoid gneiss occupies a major body of the basement, which widely occurs in the Buru Hill area and its environs. It also occupies a western foot of the Buru Hill in the area. It is greyish

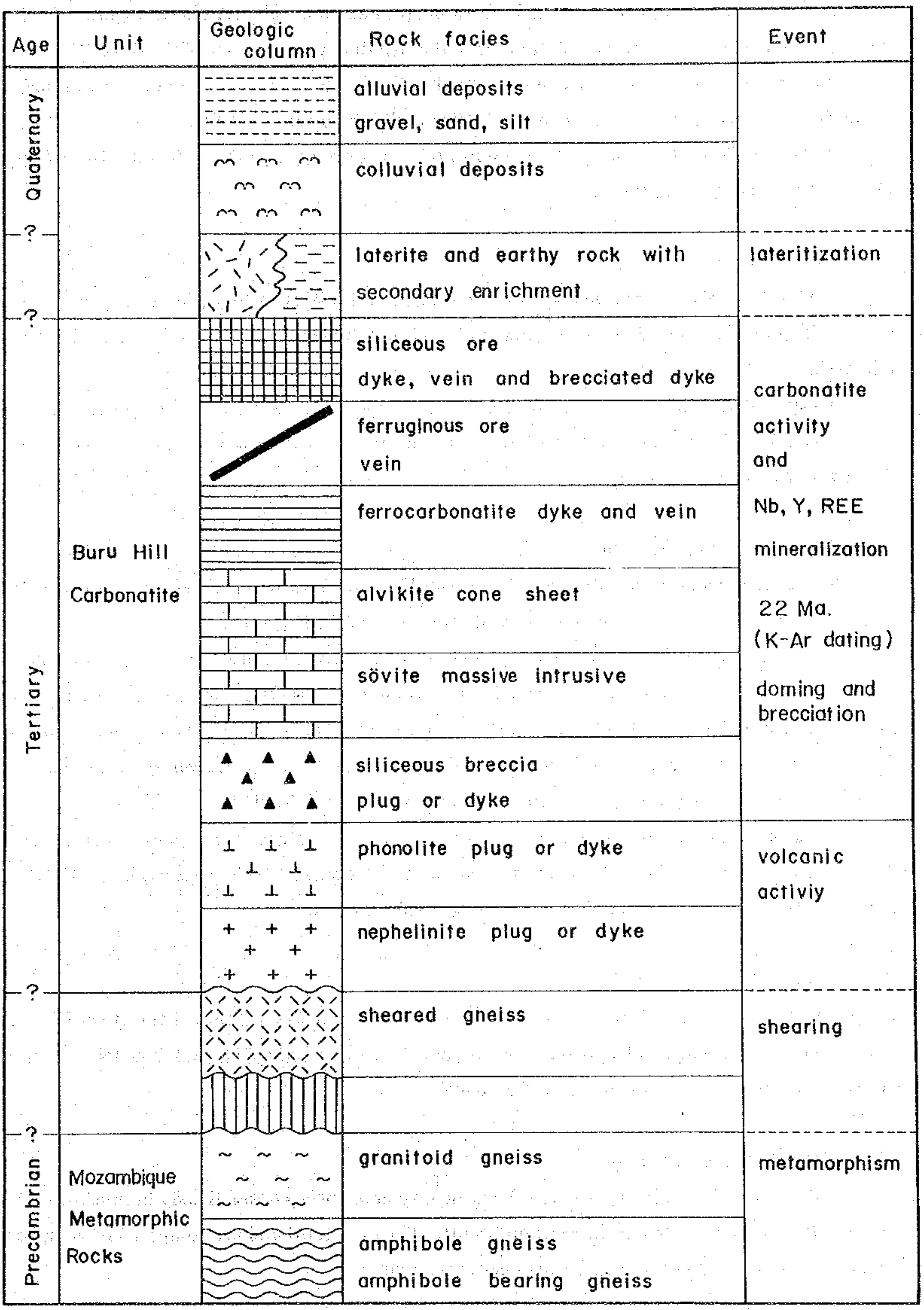


Fig. II–1–1 Generalized Geological Columnar Section of the Buru Hill Area white and shows an evident gneissose texture, felsitic, charactered by carrying porphyroclasts of pinkish potash feldspars, and with little ferro-magnesian minerals. A small amount of mica minerals, biotite mostly, is partially observed in it in north-western portion of the Buru Hill.

Mineralization effects by carbonatite, resultant in frequent occurrences of fine veins and/or networks of iron oxide in the rock are observed from hill foot towards hillside.

It is considered to be of granite origin and is regionally correlated to the Mozambique metamophic rocks (Binge, 1962).

(3) Mylonitic gneiss (P̲ - mg^{s})

Mylonitic gneiss is observed in southern portion of the Buru Hill. Mylonitic gneiss is pale-greyish with well-developed microschistosity and is associated with fine-grained porphyroclasts of feldspars.

Granitoid gneiss in the previous section (2) is partially subjected to mylonitigation or cataclastization (Binge, 1962). Mylonite breccias observed in the rock are also considered to be formed by the identical processes.

(4) Brecciated gneiss (P̲ - mg^{b})

Brecciated gneiss is zonally observed in southern to south-western foots of the Buru Hill and also shows an oval occurrence on the small hill, south of the Buru Hill.

It has a facies of fractured felsitic gneiss in the foot of the Buru Hill, with fragments of about 5 millimetres in diameter mostly, i.e. less than 1 centimetre, and is cemented by fine-grained limonitic matrix. It is pale brown to pale greyish brown and etc. in a whole and is discoloured to liver brown due to limonite stainings. It should be considered to be formed by a shearing activity concurring with a carbonatite intrusion of the Buru Hill.

Brecciated gneiss, observed in southern small hill of the Buru Hill, is mostly composed of the fractured rock with mylonitic gneiss breccias, and shows similar facies to that along the foot of the Buru Hill and is partially subjected to an intense silicification.

(5) Fenitized rock (P̲ – mg^{f})

Fenitized rock is observed in small several locations in eastern foot of the Buru Hill. It consists of hard and slightly fractured or granulated gneiss by fracturing, and is widely intruded by green fine veins, possibly composed of aegirine.

(6) Siliceous breccias (Brcs)

Siliceous breccias are observed in the form of volcanic necks of small body in south-western portion of the area and also as dikes in mid-south. They are hard and are composed of abundant mylonite gneiss fine breccias and a brown matrix of quartz.

(7) Carbonatite (Ca-s)

Carbonatite is observed in a small exposure located on the western crest and in southern foot of the Buru Hill. It is pale greyish, fine and is associated with a small amount of magnetite (corresponds to alvikite).

Carbonatite is frequently discernible in diamond drill cores. Detailes are described below in the following sectins.

(8) Ferrocarbonatite (Cf)

Ferrocarbonatite is discernible in diamond drill cores.

(9) Ferruginous veins (Of)

Ferruginous veins are observed mostly in lateritic rocks and also in surroundings of gneiss, with random directional behaviours of veins and mostly networks, making mineralized zones and ore of less than 10 centimetres wide mostly, less than several ten centimetres in some occasion and 1 metre wide in maximum in Trench BR−T−9 located in mid-eastern portion of the area. The most frequent occurrence of ferruginous veins is observed in the area from daimond drill site BR−1 toward old inclined-shaft working, where several veins, having a 10 centimetres width each, are observed at an every 1 square metre segment.

They are brown, reddish brown, black, orange-coloured and others and make effects of stainings by limonite in veins environs. Iron ions in minerals are mostly oxidized to be of trivalent by weathering, however, iron minerals show a magnetism in some place due to a remmant of primary magnetite. Extreme weatherings of iron minerals are observed on ground surface, where gossans are mostly discernible.

(10) Siliceous ore (Os)

Abundant occurrences of siliceous ore as dikes are observed in a northern half of the Buru Hill area, dominantly in the vicinity from diamond drill sites from BR−4 to BR−12, BR−6 environs and from BR−7 to BR−3.

It is very hard and shows an occurrence of a small rise in general, while, jutting two small ridges near to BR−4 are conspicuous.

It is pale-greyish, brown or dark grey, extremely hard and mostly consists of abundant quartz and oxide minerals. Quartz are of chalcedony mostly, oxide minerals comprise themselves goethite, hematite, lepidochrocite, and magnetite.

(11) Nephelinite, melanephelinite (T-vn)

Nephelinite is observed in a form of small stock in northern part of the diamond drill site BR−12. It is dark greyish, fine porphyritic associated with cloudy fine phenocrysts, feldspathoid presumably and a small amount of mafic minerals with microcrystalline groundmass.

Melanephelinite is observed in the diamond drill cores obtained from the lower portion of diamond drill hole BRL−1. It is green, fine grained and volcanic with an extreme alteration subjection.

(12) Phonolite (T-vp)

Phonolite is observed in south-western portion of the area, in the vicinity of diamond drill site BR−7 in Buru Hill and in lower portion of diamond drill hole BRL−2. Phonolite in south-western portion of the area shows dark greenish grey, porphyritic with vitreous groundmass, associated with phenocrysts of nepheline and feldspar.

Phonolite in the vicinity of diamond drill site BR−7 shows viridescent grey and consits of vitreous groundmass and a small amount of phenocrysts that are clean nepheline, slightly cloudy feldspar and none of mafic minerals by unaided eye.

Phonolite in lower portion of diamond drill hole BRL−2 is fine-grained with laminated texture and shows an apparent facies of tuff.

(13) Laterite and earthy rock (Lt_2)

Laterite and earthy rock are widely observed in the area from mid-hillside toward the crest of the Buru Hill. They are brown, pale brown, orange-brownish, weathered and are associated with abundant iron oxides. The most of laterite and earthy rock are considered to be originated from carbonatite after by microscopic and chemical analytical examinations. Networks of fine iron oxide veins, by which a gentle jutting topography is represented, are well developed in the area. Pisolitic layer, overlain by thin humic soil layer, is rich in iron content, dark brown, ten to several ten centimetres thick and is underlain by extremely weathered leached rock and earthy rock, several to several ten metres thick, partially argillaceous, which are intersected by diamond drill holes.

(14) Hard laterite crust (Lt_1)

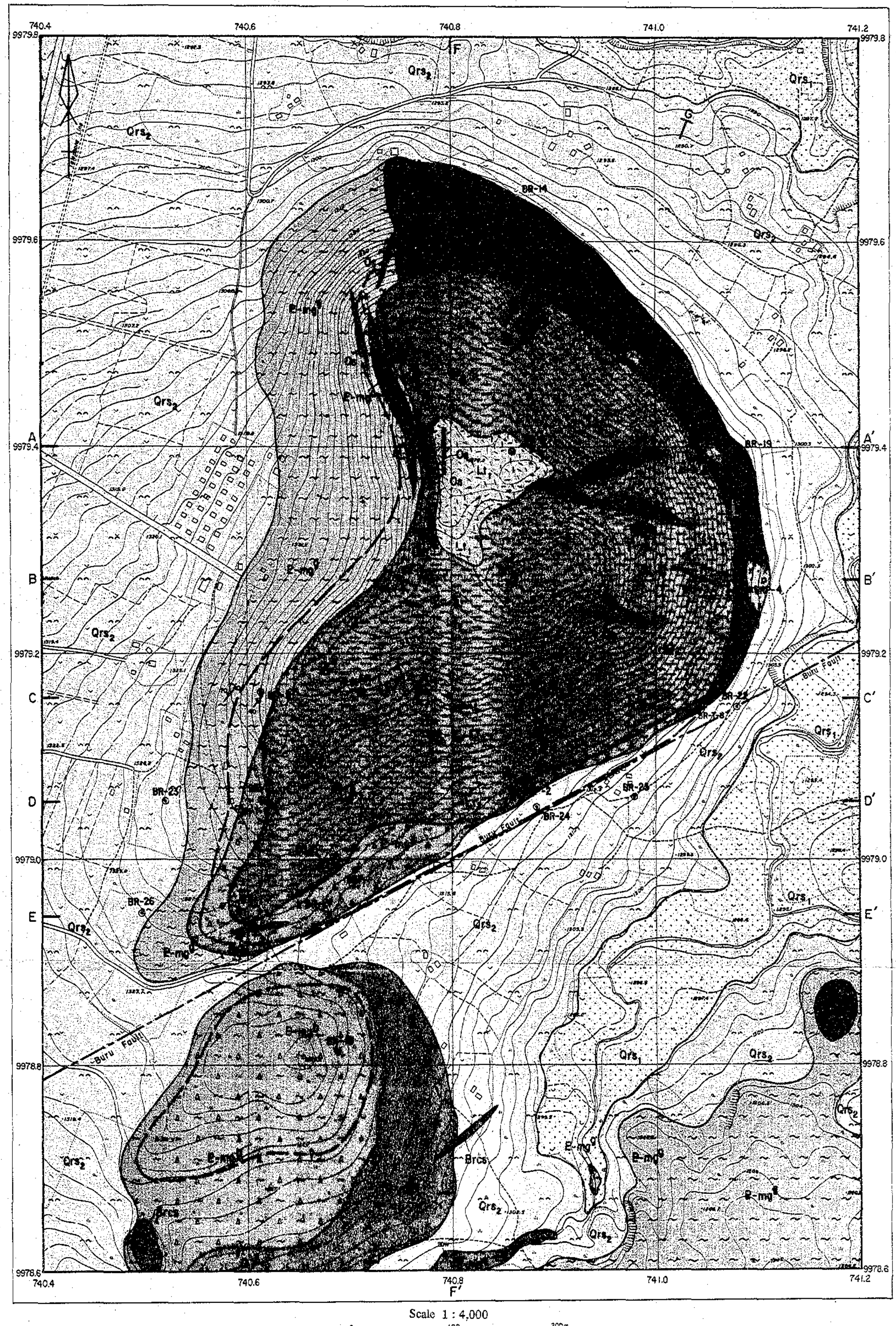
Hard laterite crust is observed in a flat portion close to the crest of the Buru Hill. It is pale brown or orange-coloured, somewhat vesicular, hard and lateritic. It is breakable into block-wise to be used for construction materials.

(15) Colluvial deposits (Qrs_2)

Colluvial deposits are observed on a gentle slope of the Buru Hill environs. They consist of soil materials and boulders of mineralized materials and gneiss derived from Buru Hill.

(16) Alluvial deposits (Qrs_1)

Alluvial deposits are observed in flat lands along the Raragwit River in north-eastern and south-eastern portions of the area. They are composed of boulders, pebbles, sands and silts.



Scale 1 : 4,000

0 100 200m

Fig. II–1–2 Geological Map of the Buru Hill Area

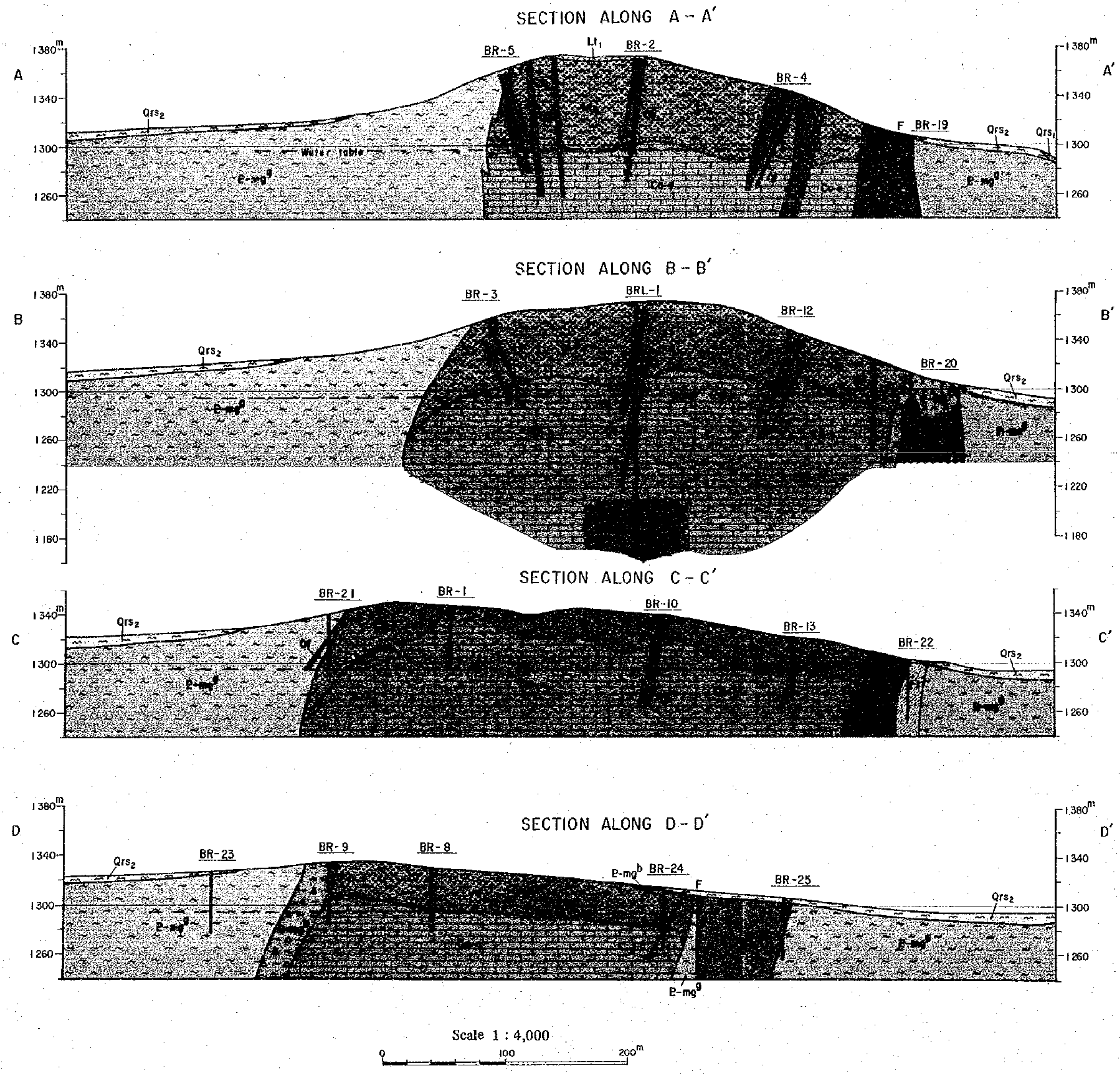


Fig. II–1–3 Geological Sections of the Buru Hill Area – (1)

LEGEND

- Qrs₁ — Alluvium
- Qrs₂ — Colluviul deposits
- Lt₁ — Laterite (hard crust, carbonatite origin)
- Lt₂ — Laterite and earthy rock (carbonatite origin)
- T-vp — Phonolite
- T-vn — Nephelinite, Melanephelinite
- Os — Siliceous ore (dyke, vein)
- Of — Ferruginous ore (vein)
- Cf — Ferrocarbonatite
- Ca-s — Carbonatite (alvikite, sövite)
- Brcs — Siliceous breccia (dyke, plug)
- P-mg^{f} — Fenitized rock (original rock : gneiss or intrusive rock)
- P-mg^{b} — Brecciated, silicified gneiss
- P-mg^{s} — Sheared gneiss
- P-mg^{g} — Granitoid gneiss
- P-mg^{a} — Amphibole gneiss, amphibole bearing gneiss
- Mineralized zone (Plane)
- Secondary enriched zone (Section)
- Strike and dip of foliation
- Strike and dip of vein
- Fault (infered)
- Water table
- Lower limit of strongly weathered zone
- BR- / BRL- — Location of DDH site (BRL-1,2,3 BR-1 to BR-27)
- BR-P- — Location of Pit (BR-P-1 to BR-P-5)
- BR-T- — Location of Trench (BR-T-1 to BR-T-10)
- Portal (inclined shaft)
- A – A′ — Line of section

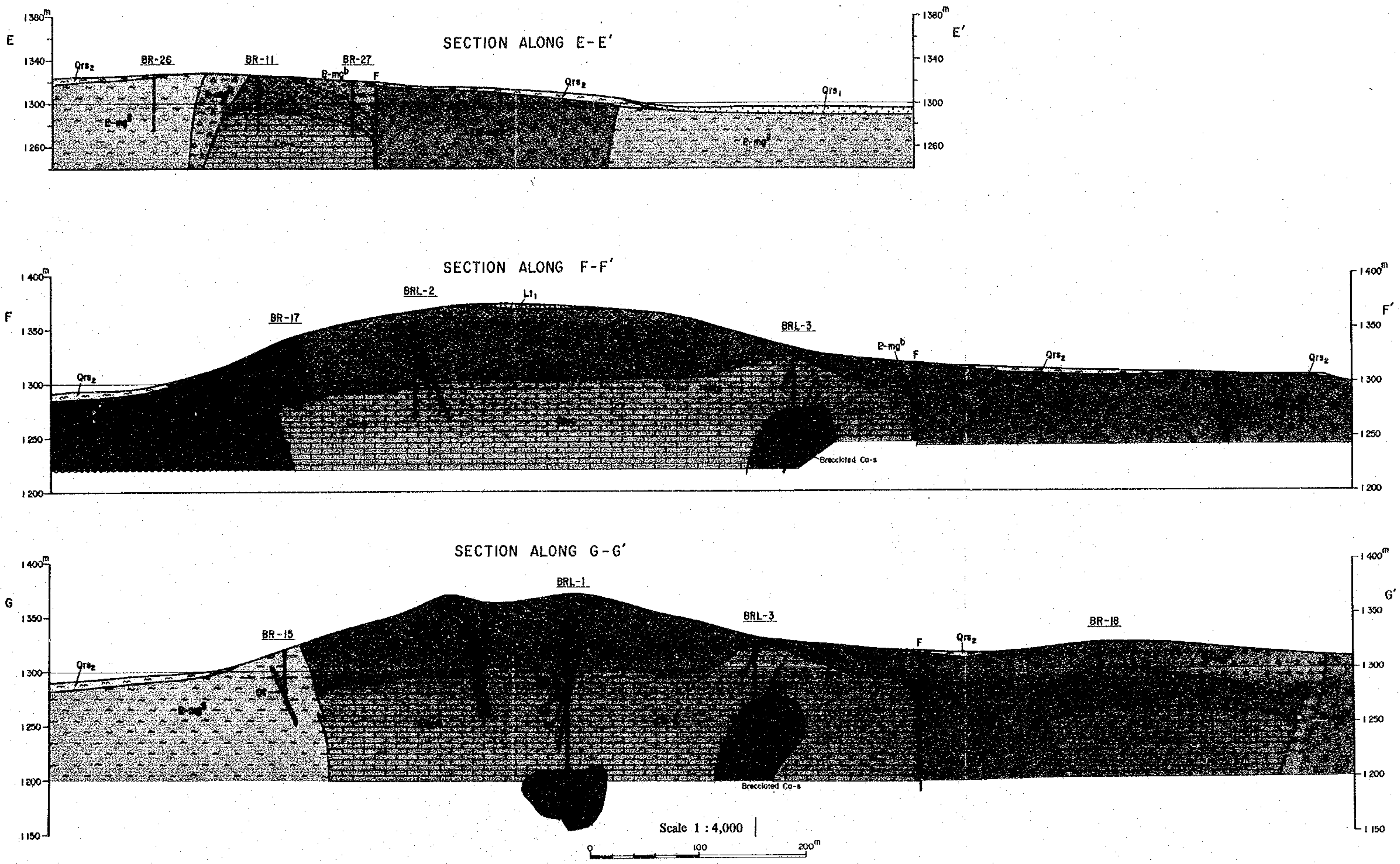


Fig. II–1–4 Geological Sections of the Buru Hill Area – (2)

1-2-3 Geological structure

Buru Hill is a small hill, considered to be geologically formed by a carbonatite intrusion. The Buru Hill carbonatite, delineated by surface mapping and diamond drill exploration works, is a massive body, upper-most portion of which is extremely weathered and lateritized. It is also elucidated that an oxydation by weathering reaches to the level of the current ground water table.

An occurrence of small satellite carbonatite body, underlain by fractured basement rock, has been elucidated to the south. The Buru Hill Fault, which has been initially inferred by a geological interpretation based on that a topographical conspicuousness of the hill and a petrological disparity of gneiss betwen both sides of the inferred fault, has also been firmly estimated by the current diamond drill works.

The Buru Fault has a strike of N60°E trend and is possibly considered to be extending southwestward to the Kendu Fault (Geological Sheet: Kericho; Binge, 1962) or to its branch. The Kendu Fault is considered to be possibly extended toward the Kaniamwia Fault (Report, Phase 1, 1988), which defines the southern demarcation of the Kavirondo Rift.

Based on that, all of the carbonatite-alkaline rock complex in the Homa Bay environs is distributed within the Kavirondo Rift, the Buru Fault is reasonably considerd to be forming a fault in the Kavirondo Rift.

Geological structure of the major rocks observed in the Buru Hill Area is described below:

Gneiss of Basement: It shows a north-south trend in general, steeply dipping toward west or east ununiformly. General trend of the rock shows a structural disturbance by a carbonatite intrusion. It frequently shows a northeast-southwest trend in south-western portion of the area, north by northwest to south by southeast trend in the north. Mylonitic gneiss, observed in south-western portion of the area, geological structure of which is still hardly elucidated, is zonally distributed in southern portion of the Buru Fault. An occurrence of silicified and fractured gneiss, which forms a small hill south-westerly from Buru Hill, is considered to be posing a possible underlying occurrence of separate carbonatite body seated underneath.

Carbonatite: Geological structure of carbonatite in a whole is hardly elucidated resulted from insufficient intersections to carbonatite by diamond drill exploration. Each drill hole, other than the hole BRL−1, has made unsuccessful intersections and/or narrow intersections against upper portion of carbonatite. It is envisaged at present that carbonatite in the Buru Hill area has an irregular surface configuration and shows a cone-shaped massive body being narrow downward. Frequent inclusions of basement rock renmants are observed in carbonatite body. It is possibly considered that an upper portion of carbonatite is mostly formed by swarms of sheets and a massive portion of it may be more or less deeply located.