Report No. 65

GOVERNMENT OF KENYA

MINISTRY OF NATURAL RESOURCES
GEOLOGICAL SURVEY OF KENYA

GEOLOGY
OF THE
SEKERR AREA

DEGREE SHEET 26 N.W. QUARTER
AND 25 N.E. QUARTER
(with coloured geological map)

by

G. J. H. McCALL, B.Sc., A.R.C.S., Ph.D., D.I.C., F.G.S.
Geologist

Twenty-Five Shillings - 1964

FOREWORD

The Sekerr area, north-east of Mount Elgon, is a most interesting part of Kenya in many ways—scenically, geologically, and because of interesting small mineral deposits that it contains. Its geological survey has, however, met with several setbacks. Mapping was begun in 1952, but it was not until the end of 1957 that it could be completed, and then not by the geologist who had started the survey. The present report is the work of Dr. G. J. H. McCall, who took up the survey after it had been started and completed the task. He was, however, able to use little of the preceding work in his compilation.

After the editing of the first draft Dr. McCall left Kenya to take employment in a distant part of the world, which made final editing difficult, and there are some controversial sections in the report. One such section is that on the interpretation of erosional bevels. The author's opinion has here been preserved as he left it in his draft, modified only in the interests of clearer writing, but a series of footnotes and part of a text figure have been added by the writer indicating objections to the conclusions expressed and suggesting lines of alternate thought that, in the writer's opinion, more reasonably fit the facts mapped.

Two other sections are considered as controversial, one on the structures of the Basement System rocks and another on the age of Rift Valley faulting. No comment has been added to the text on the structure, as the map and large structures diagram accompanying the report provide a detailed statement of information available for the interpretation of structures, and those interested can form their own opinion. Footnotes on the age of the Rift faulting have been added by the writer, as the author has drawn conclusions that are not fully based on the facts available.

Dr. McCall deals in considerable detail with the several interesting mineral deposits —notably of gold, chromite, nickel and columbite—that are found in the area. He unfortunately has to conclude that the nickel and chromite deposits are unlikely to be of economic interest, but thinks that there is a future for the gold workings in the Turkwell Valley and for the pegmatites in the north-west part of the area that yield columbite.

Nairobi,
2nd March, 1961.

WILLIAM PULFREY,
Commissioner (Mines and Geology).

CONTENTS

	Page
Abstract	(ix)
I—Introduction and General Information	1
II—Previous Geological Work	4
III—Physiography	5
IV—Summary of Geology	12
V—Details of Geology	16
1. Precambrian Rocks	16
(1) Basement System	16
(*a*) Metasediments	17
(i) Semi-pelitic Gneisses and Schists	17
(ii) Calcareous Rocks	20
(iii) Graphite Schists	21
(iv) Quartzites	21
(*b*) Metavolcanic Rocks— Amphibolitic Gneisses and Schists	22
(2) Major Intrusions into the Basement System	27
(*a*) Ultra-basic and Basic Intrusions	27
(i) Ultra-basic and Basic Intrusions in the Tamau-Kunyao gneisses	27
(ii) Ultra-basic and Basic Intrusions in the Marich-Korpu schists	31
(*b*) Basic and Intermediate Orthogneisses	34
(*c*) Acid Intrusions	38
(i) Granites	38
(ii) Granitoid Orthogneisses	42
(3) Minor Intrusions into the Basement System	43
(*a*) Pegmatites and Microgranites	43
(*b*) Quartz Veins and epidote-bearing veins	44
2. Tertiary Rocks	44
(1) Tertiary Volcanic Rocks	45
(2) Fault-Breccias (of probable Cainozoic age)	45
3. Pleistocene and Recent Deposits	46
4. Metamorphism	47

CONTENTS—(*Contd.*)

	PAGE
5. Structures	51
(1) Orogenic Structures of probable Precambrian Age	51
(2) Probable Tertiary Structures related to the Rift Valley System	57
VI—Mineral Deposits	59
1. General	59
(1) Alluvial deposits	60
(*a*) Gold	60
(*b*) Other Minerals	67
(2) Magmatic Segregations—Chromite	67
(3) Hydrothermal Deposits	70
(*a*) Gold	70
(*b*) Copper	70
(*c*) Kyanite	71
(4) Pneumatolytic Deposits	71
(*a*) Columbite, Samarskite and Mica	71
(*b*) Mica	74
(5) Secondary	76
(*a*) Nickel (Garnierite)	76
(*b*) Anthophyllite Asbestos	78
(6) Miscellaneous	78
(*a*) Building-stone	78
(*b*) Corundum	78
(*c*) Garnet	78
(*d*) Graphite	79
(*e*) Gravel	79
(*f*) Ilmenite	79
(*g*) Limestone	79
(*h*) Magnetite	79
(*i*) Spinel	79
(*j*) Talc	79
(7) Summary of conclusions on the Economic Prospects of the Sekerr Area	79
2. Water Supply	80
(1) Surface Water	80
(2) Ground-water	81
(3) Hydro-electric Power	81
VII—References	82

CONTENTS—(*Contd.*)

LIST OF ILLUSTRATIONS

PAGE

Fig. 1.—Sketch map showing the position of the Sekerr area in relation to localities and features of the surrounding country 1

Fig. 2.—The drainage pattern in the Sekerr area 6

Fig. 3.—Sketch map showing erosion surfaces recognized in the Sekerr area .. 7

Fig. 4.—Section and sketch illustrating physiographic details .. .. .. at end

Fig. 5.—Sketch map showing distribution of ultra-basic and gabbroic intrusions.. 28

Fig. 6.—Diagram illustrating the relation of Regional and Thermal metamorphic effects to structure 47

Fig. 7.—Typical porphyroblast textures from Marich-Korpu schists 49

Fig. 8.—Garnet knotenschiefer from Alamonges River 50

Fig. 9.—Key map of the sections chosen for statistical evolution of structures in the Sekerr area 53

Fig. 10.—Stereographic projection of lineation and poles to foliation in the sections indicated in Fig. 9 54

Fig. 11.—Sketch map of the area held under an Exclusive Prospecting Licence for alluvial gold by S.A. Embleton—Marich Pass 61

Fig. 12.—Sketch map of the area prospected and worked by J. G. Van Wyk under Exclusive Prospecting Licences for alluvial gold—Turkwell river .. 64

Fig. 13.—Section and sketch map of Telot Serpentine lens illustrating the nature of the chromite occurrences 69

Fig. 14.—Pegmatites at Nasolot—formerly worked for "ruby" mica 75

Fig. 15.—Structural map of the Sekerr area .. .. at end

PLATES

Plate I.—Reproduction of an air photograph of the Turkwell Gorge .. at centre

Plate II—

(*a*) Entrance to the Turkwell Gorge .. .. at centre

(*b*) The Turkwell River immediately below the gorge .. .. .. at centre

Plate III—

(*a*) Rodded limestone, Iun Gorge .. .. at centre

(*b*) Thin bands of plagioclase amphibolite, near Futun .. .. .. at centre

Plate IV—

(*a*) Garnet porphyroblasts in amphibolite, Ikilip .. .. at centre

(*b*) Agmatite, Marich Pass .. .. at centre

CONTENTS—(*Contd.*)

PAGE

Plate V—

(*a*) Granitic sheets, contact zone of Marich granite, Marich Pass .. at centre

(*b*) Sigmoid fold in a granitoid sheet, Magaich .. .. at centre

Plate VI—

(*a*) Porphyroblast schist, Aberit River .. .. at centre

(*b*) Minor structures, Iun River .. .. at centre

Plate VII—

(*a*) Recumbent isoclinal folds, Iun River .. .. at centre

(*b*) Lens of amphibolite, Iun River .. .. at centre

Plate VIII—

(*a*) Recumbent isoclinal fold, Iun River .. .. at centre

(*b*) Mullion structures, near Futun .. .. at centre

Plate IX

(*a*) Rodding structures, Turkwell Granite, Alamonges River .. .. at centre

(*b*) Rodding structures, Akeriemet .. .. at centre

Plate X

(*a*) Amphibolite lens showing discordant relations between foliation and that of the enclosing gneiss, Nakuijit River .. .. at centre

(*b*) Amphibolite lenses in a zone of isoclinal folding, Cheperapoi River at centre

Plate XI—

(*a*) Small fracture lines and faults, Kaptolomwa .. .. at centre

(*b*) Interpretative drawing of XI (*a*) .. .. at centre

Plate XII—

(*a*) Shattering of "Basement System" schists in the Sekerr-Turkwell Fault-Zone, Riritian Hill .. .. at centre

(*b*) Coarse alluvial gold from the Turkwell River, Korpu .. .. at centre

Plate XIII—

(*a*) Recovery of alluvial gold from the Turkwell River, Korpu .. at centre

(*b*) Chromite lens in serpentine, Telot .. .. at centre

Plate XIV—

Nickeliferous mineralization of serpentine, Telot .. .. at centre

MAP

Geological map of the Sekerr area (degree sheet 26 N.W. quarter, and 25 N.E. quarter). Scale 1 : 125,000 .. .. at end

ABSTRACT

The report describes the geology of an area of some 1,200 square miles in central-west Kenya. The greater part of the rocks exposed in the area are metamorphosed sediments, including paragneisses, paraschists, crystalline limestones and quartzites of the Basement System, which is of Precambrian age. The System has been invaded by sill-like intrusions ranging from peridotites through gabbros to granitic rocks, some of which have been partly or completely metamorphosed. Tertiary rocks are represented by a few plugs and dykes of nephelinite and alkali basalt, and possibly by some fault-breccias. Quaternary rocks present consist of soils, alluvium, scree and ironstone cappings. A detailed account is given of the petrography, structure, granitization and metamorphism of the ancient rocks, and the tectonic history of the area is described, including the effects of rift faulting, which took place at a late stage in the history of the area.

Several erosion bevels are present in the area, and an account of their succession is given.

Considerable attention is given to the various kinds of economic minerals that occur in the area. Mica, gold and columbite are worked on a small scale, and occurrences of chromite, copper, nickel, samarskite and kyanite are known. No large-scale mineralization has, however, yet been discovered.

(W.P.)

I—INTRODUCTION

The country mapped during the survey covered by this report consists of the quarter degree area bounded by the 1° 30′ N. and 2° 00′ N. latitudes and 35° 00′ E. and 35° 30′ E. longitudes (Directorate of Overseas Surveys Sheet No. 63). In addition a small area west of the 35° longitude and immediately south of the 2° latitude was included to complete the mapping to the Uganda border. The inter-territorial boundary runs east of the 2° longitude before crossing it south of Amudat, and a small part of Uganda thus lies within the quarter degree area covered. The inter-territorial boundary is not marked on the ground, though faint traces of cut lines sometimes show on air-photographs, and the line shown is the nearest approximation that could be made.

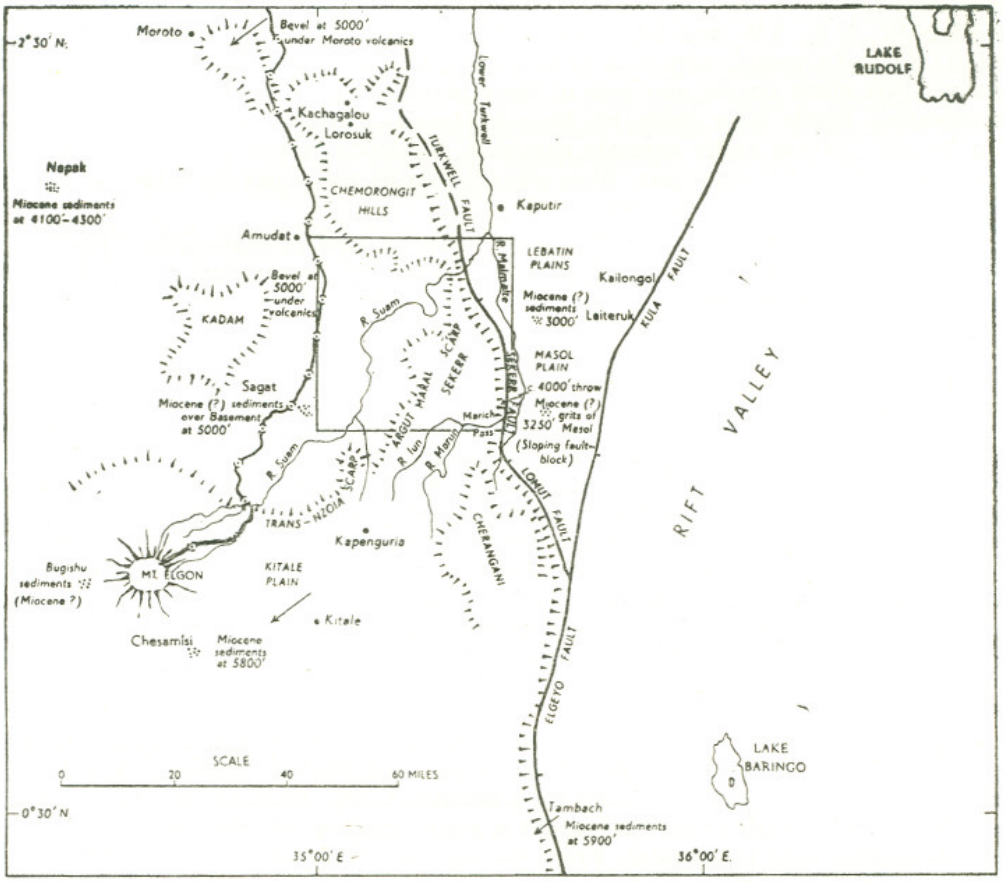


Fig. 1—Sketch map showing the position of the Sekerr area in relation to localities and features of the surrounding country.

The area (see Fig. 1) lies for the most part in the West Suk District of Kenya administered from Kapenguria and Sigor, and in Karasuk which, though part of the Turkana District of Kenya and subject to the Kenya mining laws, is administered from Moroto in Uganda through an Assistant District Commissioner at Amudat. A small part of the area in the north-east lies within the Turkana District and is administered from Lodwar. The area is one in which prospects for gold, nickel, copper, chromite, columbite and mica have been and continue to be explored. Gold in the Turkwell gorge and columbite-samarskite-mica deposits at Kenailmet are the only sources of production at the time of writing (1958). The official geological survey of the area was started by D. L. Searle, who carried out four months' field-work in 1952, but was unable to complete the work. The survey was taken up by the present writer in

December, 1955, the part surveyed by Searle being remapped, as the only material available from his work comprised a set of brief monthly progress reports. The survey was again interrupted by the illness of the writer in February, 1956, and the field-work was not resumed until May, 1957, being completed in November, 1957.

Maps

The original topographic survey of the area compiled in 1912 at the War Office, London, was published on the scale of 1 : 250,000. Modifications were made in respect of the topography, towns, and communications by the 157th (E.A. and S.R.) Base Survey Company, East African Engineers, for a reissue published in 1946 (E.A.F. 1717, scale 1 : 500,000). Preliminary plots on the scale of 1 : 50,000, based on aerial survey flights carried out by the Directorate of Colonial Surveys, comprising sheets North A-36-RI, N.W., N.E., S.W. and S.E. (sheets 62/I-IV Kenya) together with sheet North A-36-QII, N.E., of Uganda, were used as base maps for the present survey. A considerable area was left blank on the east side of these plots owing to a gap in air cover. Later photographic flights were made by Messrs. Harward Maclachlan and Company and Hunting Air Surveys under separate contracts, the latter company covering the whole area. The gap on the preliminary plots was filled in by the writer from the photographs produced by Hunting Air Surveys.

The form-lines on the map are entirely based on field measurements. The lack of adequate control—only one major and three minor trigonometrical points lie within the area, all in Karasuk—militates against any high degree of accuracy in the form-lines. Owing to extreme altitude variations in certain parts of the area the spacing of the form-lines had to be based on 500-foot intervals, so as not to obscure other detail on the map.

The geological map of the area accompanying this report shows the boundaries between the formations as deduced by the writer. Owing to the extremely steep and dissected topography boundaries could seldom be followed for any distance and the mapping had to be carried out mainly by means of traverses across the strike following the few lines of communication. In the time available much detail must inevitably have been overlooked and the boundary lines are not as definite as could be wished, but the map does give a picture of the geological features of the area sufficiently detailed to assess the economic potential. A limited amount of extrapolation from air photographs was used for the mapping of an inaccessible region south-west of Nasolot.

Communications

The nearest railhead is Kitale, 45 miles by road from Kacheliba and 70 miles from the Marich Pass. The main Kapenguria-Lodwar and Moroto highway runs through Kacheliba, where it crosses the Suam on a wooden bridge founded on reinforced concrete. This road though single-track width is maintained by the Ministry of Works and is an all-weather road to Amudat. From the main road branch-tracks run eastwards to Nakuijit on the Suam River, and to Korpu and the Turkwell Gorge (via the Kanyangareng drift, which is not passable in wet seasons, and a dry-weather ford across the Suam at Korpu). From Amudat in Uganda, two further branch-tracks lead eastwards, the first through Lossom to Kasei and the second to the "Bore-holes Road" which runs southwards into the area at Burgich. Access to these tracks across the Kanyangareng is limited to dry weather, the drift becoming impassable after heavy rain.

The eastern half of the area is reached by a completely separate road system branching off the Marich Pass trunk-road. This road, though recently much improved, is narrow and tortuous, and crosses many steep bouldery drifts. It descends from the high ground round Kapenguria (above 7,000 feet) in a series of steep declines, to break through the Cherangani Hills into the Masol Plain (the Rift Valley) at the Marich Pass. At Sigor the altitude is only 3,500 feet. From this road a track diverges at Cheberera and climbs two escarpments in a series of hairpin turns to Chepunyal and Ptoyio. This track is passable only to Land-rovers beyond Tamau. A second track leads off the

Marich road immediately east of the pass, crossing a Bailey bridge spanning the Marun River, and running north some 28 miles to Nasolot. This track is also impassable to anything larger than a Land-rover. From this track a road was being constructed by New Consolidated Goldfields Ltd. (London) at the time of the survey. The intention was to build it up the Sekerr Escarpment to the nickel-chromite prospect at Telot. This road if completed would have also served Mbara, an important location centre now only accessible to porter safaris. Work on it was abandoned, however, after only a mile or so had been completed. Malmalte is reached by a track starting from the far side of the second Bailey bridge over the Wei-Wei River near Sigor Administrative Post, and running through Lotongot to Kaputir (*see* map, Mason and Gibson, 1951).* The road communications in the area are gradually being improved but owing to the dissection of the Sekerr massif, and the abrupt hills around Karikau and Tarakit in the northern part of the area, many parts are accessible only by means of several days of foot safari. The area is, however, laced with cattle-tracks and hill-paths, the latter following the contours and designed to conserve effort—such paths being a speciality of the Suk people. The roads are designed for administrative use only and the narrow tortuous tracks, poorly surfaced and liable to become impassable after rain, are a factor that must be considered in evaluating any mineral deposit found in the area.

Public services are limited to a weekly Somali-owned bus from Kapenguria to Sigor, and numerous Asian-owned and Somali-owned lorries and African bus services along the Lodwar highway.

Climate and Vegetation

The climate ranges from that of cold mountain rain-forest and upland zone to that of the semi-desert of the Rift Valley (Masol). This reflects an altitude variation of over 8,000 feet. The vegetational and climatic types in the area can be divided into:—

(1) Arid semi-desert. Flat and sparsely thorn-covered sandy country.

(2) Dry stony bush-clad hills.

(3) Grassy bush-clad uplands.

(4) Rain-forest and highland meadow country (including cedar forest).

The forests on the Sekerr massif form a dense rain forest-zone. In Karikau and Kaptolomwa there is sparse forest cover composed of large cedar trees set out on the flat grassy table land as if in a park.

The rainfall in the area is summarized in Table I.

TABLE I

RAINFALL IN THE SEKERR AREA

(*Supplied by the Director of the East African Meteorological Department*)

Rainfall (in inches)

Station	1955	1956	1957	Average	No. of years records taken
88.3526 Kongelai	30·56	43·38	20·93	32·35	5
88.3529 Sigor	33·74	31·12	21·88	27·72	6
88.3532 Chepunyal	34·36	38·92	34·26	33·85	5

It will be seen that the rainfall is considerable, the main problem of the area being retention of rainfall and not lack of it.

* References are quoted on pp. 82-84.

Population

The Suk or "Pokot" are semi-Hamitic in origin, and occupy the whole of the West Suk area and Karusuk. They further occupy a large area east of Masol, where they are administered from Baringo. They are divided into pastoral and agricultural groups, but in the area under consideration land cultivation is almost entirely subsidiary to the main occupation of the people, the tending of their humped cattle, together with flocks of goats and sheep. The lack of soil and the waterless nature of much of the area during the six months' dry season militates against any large-scale cultivation. The only substantial areas of cultivation seen during the survey were at Chepunyal, Endoo and along the banks of the Malmalte River. The main crops grown in the scattered *shambas* are matama and maize.

The Suk are primitive people and do not travel much. They are rarely found in the army or in employment outside their territory. They are by nature self-centred and satisfied with their mode of life, primitive as it is, and tend to resent incursions into their country such as mining operations. Otherwise their attitude to visitors is characterized by a peculiar disinterestedness. They are, however, excitable and under the sway of witch doctors and this, together with the existence of scattered cells of a subversive underground movement called Dina Yomut, makes it necessary for outsiders working in the area to exert considerable care and tact in dealing with them. Their attitude to efforts to save the country from soil erosion by grazing control and destocking is not always co-operative, their outlook being to live for the day, and not to provide for the future.

Commercial

The only commercial occupation in the area is trading from small shops run by local Africans or Somalis, and the buying of cattle from the Suk in Karasuk and Uganda by meat-buyers of the Uganda Meat Commission.

Acknowledgements

The writer is indebted to Mr. A. D. Shireff, District Commissioner, Kapenguria, and Mr. A. Mortimer, Assistant District Commissioner, Amudat, for generous assistance given in the course of the survey. His thanks are also due to Mr. C. Chenevix Trench for much help in collecting place-names, and to Messrs. H. Wreford Smith and J. F. van Wyk for valuable information on the Kanailmet and Turkwell gorge deposits, and also for hospitality and help of every kind. The co-operation of Dr. A. F. Trendall of the Uganda Geological Survey in providing information on boreholes, peneplain surfaces in Uganda, and the geology of the nearby portion of Karamoja District was invaluable in the preparation of this work.

II—PREVIOUS GEOLOGICAL WORK

H. H. Austin (1902) carried out a traverse throughout the area on his way from the Sudan to Mombasa. J. W. Gregory (1921, p. 34) mentioned that the "Suk Country" is formed by a "zone of gneisses". So far as is known no geological work of any kind was carried out in the area before V. G. Glenday and J. Parkinson visited the Suk hills (1926, 1927). They traversed the Marich Pass and followed the Suam River to the Turkwell gorge, and visited the Chemorongit and Kateruk areas collecting specimens. They subsequently published a general description of their traverse, providing several invaluable rock descriptions and analyses. They considered that the rocks they had examined were related to the Turoka Series of southern Kenya (Glenday and Parkinson, 1927, p. 797). They used the name Kateruk Series for metamorphosed sediments exposed north of the present area.

R. Murray-Hughes (1933) indicated the main boundary fault of the Rift Valley below the Turkwell Gorge and Marich Pass on a small-scale map of western Kenya.

A. M. Champion in 1937 described the physiography of the region west and south-west of Lake Rudolf. He placed the Turkwell-Sekerr fault in the correct position on his map, but also placed a fault, the existence of which is disproved by the present survey, through the Marich Pass. Further, he described a fracture at the Turkwell Gorge (Champion, 1937, p. 103) which is also disproved. His paper includes much interesting information on drainage patterns and the processes involved in the evolution of the present day land-forms.

F. Dixey (1946A, 1946B, 1948, 1956), treated various aspects of the geomorphology of this part of Africa, and his views are discussed in the section of this report dealing with peneplanation.

The adjacent areas of Kitale, Cherangani and Kalossia-Tiati have been the subject of recent official geological reports (D. L. Searle (1952), J. M. Miller (1956) and P. Mason and A. B. Gibson (1957)).

III—PHYSIOGRAPHY

Topography

The area can be divided into eight major topographical units.

(1) The North-west Suk Hills (Sekerr massif)—(10,910 ft.),
(2) The Cherangani Hills (Yutum spur)—(6,800 ft.).
(3) The Sogho Hills—(about 7,000 ft.).
(4) The Kapchok Hills—(6,867 ft.).
(5) The Tarakit Hills—(8,256 ft.).
(6) The Karikau-Ikilip-Tingiri Hills (rising to about 7,400 ft.).
(7) The Suam Plains (averaging 4,100 ft.).
(8) The Masol-Malmalte-Lebatin Plains (sloping gently southwards from 3,500 ft. at Sigor to 2,500 ft. in the north of the area).

The Sekerr massif forms a large part of the area and rises to 10,910 feet at Mtelo, the highest peak in the area. Yutum is a spur of the Cherangani Hills, which lie south of the Marich Pass, while Sogho is an isolated ridge rising to about 7,000 feet between the Marun and the Iun Rivers. Kapchok is an isolated ridge rising from the flat plain north of the Suam River, while the Tarakit and Karikau Hills form the southern extension of the Chemorongit Hills of Champion (1937, map). The highlands in the area are bounded by two scarps—the great fault-line scarp bounding the Masol Plains on the east, and a scarp believed to be purely erosional in origin which forms a west-facing feature extending from Pungung to Maral, to the north of which it is cut by the Suam valley, continuing northwards as the western scarp of the Karasuk Hills east of Morumeri.

The drainage to a great extent follows the strike of the Basement System rocks and is thus mainly "subsequent" (Fig. 2). The east-west lines of the Marun and Turkwell appear to be related to the end-Tertiary planation, while many streams in the north-west of the area follow straight fracture-lines (e.g., Kokoten River). In parts of the area where dips are low there is little evidence of structural control of the drainage.

The drainage comprises two systems, that of the Marun in the south and the Turkwell-Suam system in the north, together with the streams that flow off the Sekerr and Turkwell escarpments direct into the Malmalte, which connects the Marun and Turkwell. The northward-flowing Malmalte and lower Turkwell are probably fault-aligned rivers related to the north-south trend of the Rift Valley graben.

The small streams whose headwaters are situated in the Burgich Valley form part of a more northerly system flowing eventually into the lower Turkwell via the Kamila River.



Fig. 2—The drainage pattern in the Sekerr area.

Peneplains

The area is situated in a position of key significance with respect to the study of erosion surfaces in Kenya and Uganda. It is surrounded by places where the base of the Miocene is known, so that the shape of the sub-Miocene surface can be estimated, and is part of a larger area in which an extensive flight of bevels can be demonstrated. A considerable amount of work has been carried out in the neighbouring areas both on a broad scale (the work of Dixey and Shackleton) and on a more detailed scale by geologists surveying restricted areas (Searle, Miller, Mason and Gibson). Before describing erosion surfaces recognized in the Sekerr area a brief summary of the conclusions of these writers is given, and a statement of the basis of a difference of opinion between Shackleton and Dixey is made.

Dixey (1946B, pp. 357) considered the "Kitale Plateau", standing at 6,300-6,500 feet above sea-level in the area around Kitale, as pre-Miocene, being bounded on three sides by scarps that antedated the Miocene peneplanation. He indicated that there was a later planation when the main "Uganda" peneplain was formed and that this planation transgressed across disturbed lower Miocene sediments and volcanic rocks. He considered this planation to have terminated probably in the upper Miocene, since it was

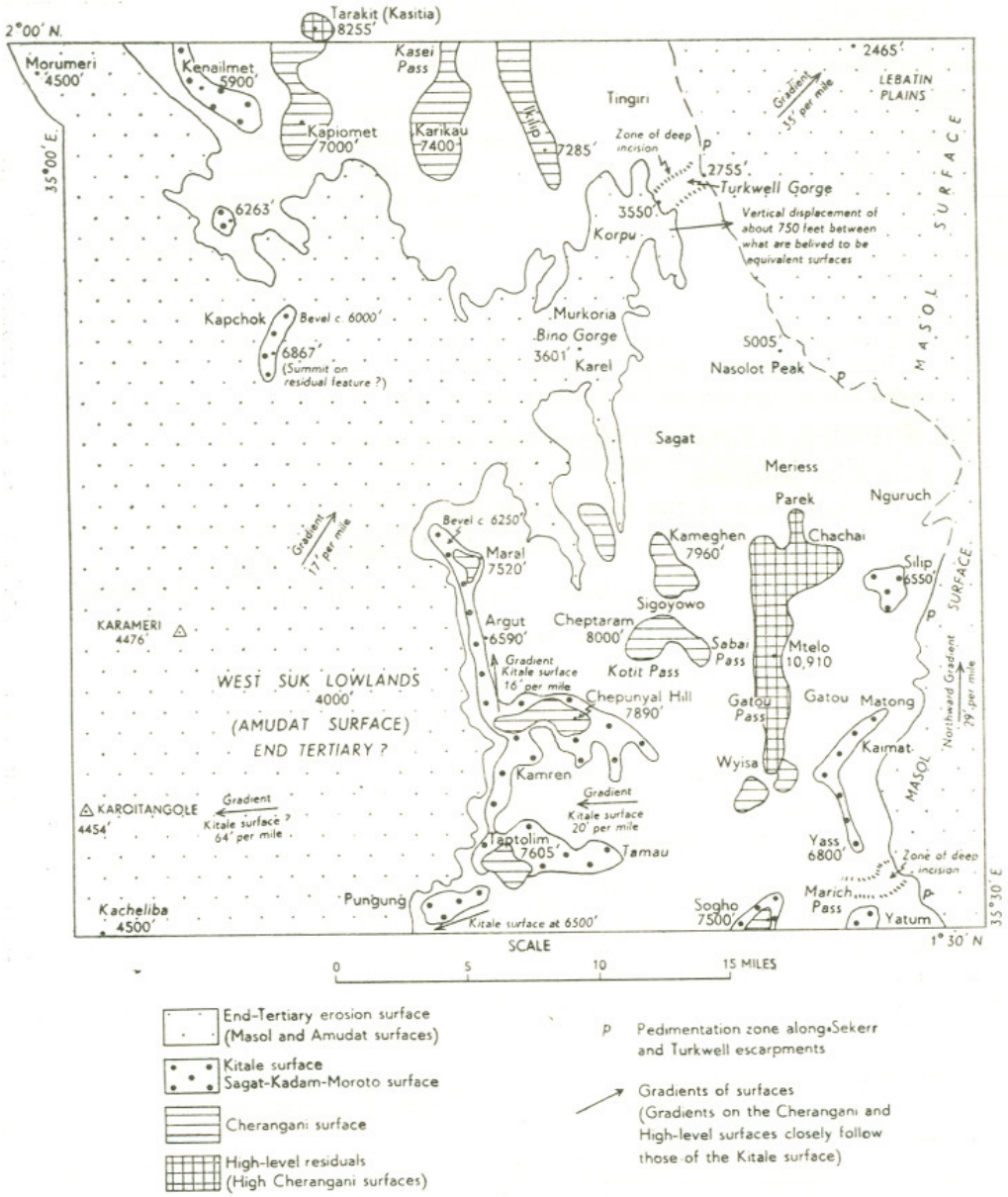


Fig. 3—Sketch map showing erosion surfaces recognized in the Sekerr area.

dissected during a new cycle terminating in the late Pliocene (Dixey, 1946B, p. 353). He further suggested a correlation between the high peneplain of the Cherangani Hills with the end-Jurassic surface of Abyssinia.

In a later paper Dixey (1948, p. 2) distinguished the Cherangani surface standing at well above 7,000 feet; the Kitale surface at about 6,200 feet; an intermediate surface at 5,000 feet under the volcanics of Moroto; the main Uganda surface at around 4,200 feet and extending eastwards to include the flat plain of the Suam Valley (c. 4,000 feet) and some residual features situated in the Turkana plains to the east of the Turkwell River. This surface was stated to show no rise in level towards the Rift Valley, and like the "Uganda" surface was allocated an end-Miocene age. The youngest

surface defined by Dixey was the plain resulting from the end-Tertiary cycle in Turkana, generally occurring some 2,000 feet below the level of the Uganda surface. It is now known that faulting is in part responsible for the magnitude of this interval between the surfaces.

Shackleton (1951, pp. 385-6) did not agree with Dixey, and interpreted the erosional history of the west of Kenya and eastern Uganda as follows. The sub-Miocene (Buganda) peneplain was a vast almost flat surface, with inselbergs and larger residuals rising from it, that was effected by minor warping in the lower Miocene, followed by faulting. The main deformation was interpreted as late Pliocene or earliest Pleistocene, and was thought to have consisted of an upswelling in the vicinity of the margin of the Gregory Rift Valley, and a depression in the Lake Victoria basin. Shackleton provided a contoured map revealing the regular slope of the sub-Miocene surface south-westwards from the Kitale surface near to the margin of the Gregory Rift Valley, to the Kavirondo Gulf. He did not accept the Kitale Plain as a separate entity.

Searle (1952, p. 4) followed Dixey, listing three erosion surfaces:—

(1) 6,700-foot peneplain.
(2) The Kitale Plain—6,200 feet—Pre-Miocene.
(3) The West Suk lowlands—4,300 feet—Mid-Tertiary.

Searle's highest surface was represented only by a spur from the Cherangani Hills.

Miller (1956, p. 5) recognized six erosion surfaces in Cherangani:—

(1) Cherangani Plateau high-level surface—10,800 feet.
(2) Lelon Plateau—9,600 feet.
(3) Cherangani surface—7,600 feet (Cretaceous).
(4) Kitale Plain—6,500 feet (Pre-Miocene).
(5) West Suk lowlands—4,500 feet (Sub-Miocene).
(6) Masol Plain—3,500 feet (End-Tertiary).

Mason and Gibson (1957, p. 10) extended Miller's Cherangani surface to include Kailongol (6,780 feet) and Laiteruk (6,470 feet) east of the Masol Plain, and attributed the discrepancy in level to movements on the Rift Valley bounding fault running along the west margin of the Masol Plain. They identified the Kitale surface with the Masol Hills (5,300 feet) and described the gently northwards-sloping end-Tertiary Masol surface already mentioned by Miller.

Gibson (1954, p. 9) writing on the Broderick Falls area recognized a 7,000-foot surface in the Nandi Hills, the Kitale Plain (6,200 feet), a separate sub-Miocene surface, and an end-Tertiary surface.

The writer favours Shackleton's hypothesis with some modification*, though accepting the six surfaces postulated by Miller with altered dating.

The erosion surfaces in the Sekerr area (Fig. 3) are believed to be of four ages. The oldest high-level residual may be composed of two separate surfaces as distinguished by Miller (1956, p. 5) in the Cherangani Hills.

(1) Cherangani high-level surface ..	10,950 ft.–9,500 ft.	Older than Cretaceous? End-Jurassic?
(2) Cherangani surface	7,900 ft.–7,000 ft.	Cretaceous?
(3) The Sagat-Kadam-Moroto surface..	5,000 ft.	Sub-Miocene or older surface.
The Kitale surface	6,800 ft.–5,000 ft.	
(4) Masol surface	3,500 ft.–2,460 ft.	End-Tertiary.
West Suk lowlands (Amudat surface)	4,500 ft.–4,000 ft.	

* It will be noted on subsequent pages that the modification is profound (W.P.).

The lowest surface, the *Masol surface,* slopes gently from Sigor northwards, dropping from 3,500 feet to 2,460 feet in 35 miles (a slightly greater slope than that described by Mason and Gibson (1957, p. 11) for the same surface further east). The surface consists of a nearly smooth plain, and the tributaries of the Turkwell and Malmalte form a complex system of closely-spaced watercourses with low and narrow interfluves—typical of a peneplain in an advanced stage of planation. The surface is, however, a pediplain and has cut across the line of the Sekerr and Turkwell faults (Plate I) (*see* page 58). The surface must be later than the faulting that caused the striking fault-breccias of Riritian and Orwa thought to be of Tertiary age (p. 45), and is believed to represent the end-Tertiary surface, which was cut back from the coast.

The *Amudat surface* is an even plain dotted by a few residuals, standing a few hundred feet above it. The tributaries of the Suam River form a complex pattern of ramifying streams with narrow and low interfluves—a pattern strikingly similar to that on the Masol Plain. The surface cuts back on the east into the Argut-Murel Escarpment, at the foot of which there is a marked pediment. On the west it is bounded by the low divide* between the Nile and Lake Rudolf drainage systems, which is beyond the western margin of the Sekerr area.

The Amudat surface declines from an altitude of 4,500 feet at the foot of the Trans-Nzoia Escarpment to 4,000 feet west of the Bino Gorge, a gradient of 500 feet in about 30 miles in a north-north-east direction—a gradient comparable with that of the Masol surface, through the latter slopes to the north-east.

The Amudat surface is separated by about three miles from the Masol surface by the Turkwell Gorge (Plates I and IIa), the two surfaces being about 750 feet apart in the vertical sense. A similar deep incision is seen near to the line of the Sekerr Escarpment in the Marich Pass. The deep incision and the displacement of the end-Tertiary surface at the Turkwell Gorge indicates movement along the line of the Sekerr Escarpment subsequent to the end-Tertiary planation.

The Amudat surface truncates volcanics of Mount Elgon west of the Trans-Nzoia Escarpment (verbal communication from Dr. A. F. Trendall). The Trans-Nzoia scarp appears to be an erosional feature continuing the line of the Maral-Argut-Pungung Escarpment westwards. The straightness of this latter feature, however, suggests some tectonic control. No trace of brecciation could be found along the escarpment foot, and if movements have occurred they were clearly minor—possibly a limited flexure of monoclinal style.

The *Sagat-Kadam-Moroto surface* is revealed by bevels situated on residual features. The only one of these features that is close to the present area is Sagat (Searle, 1952, pp. 66-72), situated west-north-west of Kacheliba on the Uganda border. Here sediments underlying volcanic rocks of the Elgon suite rest on a hillock of Basement System rocks rising from the Amudat surface. Searle equates these sediments with the Napak sediments in Karamoja (King, 1949, p. 4) which stands at 4,300 feet. The Sagat sediments stand at 5,000 feet. The sediments are possibly Miocene, but may be younger.

Further north Trendall (1959, p. 2) has recognized a bevel under Kadam, forming a residual feature at about 5,000 feet, standing up from the Amudat surface and north again Dixey (1948, p. 2) has recognized a similar bevel at 5,000 feet under Moroto volcano. Trendall considers this is the sub-Miocene erosion surface and that it slopes towards Napak, further west.

The *Kitale surface,* which Searle (1952, p. 5) described as having an average height of 6,200 feet on the Kitale plain and Miller (1956, p. 5) recognized at 6,500 feet in the Cherangani hills, clearly has a south-westwards slope near Kitale. In the present

* This divide was incorrectly described by Searle (1952, p. 6) as running along the line of hills between Riwa and Nongalitaba. It is further west, on a sinuous line of hills between Riwa and Kadam, and the Kunyao river drains the eastern slopes of Kadam.

area it can be recognized in many hill features, forming distinct bevelled areas either at the top of the hills or as steps beneath summits composed of fragments of the Cherangani surfaces. In the east, near the Sekerr escarpment, it is believed that it lies at 6,800 feet on Yutum and Yass (Fig. 4*b*, at end), further west near Tamau and Ptoyio it stands at 6,500 feet (Fig. 4*a*), on Maral it is slightly below 6,500 feet, and to the north the bevelled shoulders of the marked line of hills of uniform height running through Kapchok and Kudulem at 6,000 feet are also believed to be parts of this erosion surface. In the extreme north of the area, at Kenailmet, an extensive plateau area at 5,900 feet is thought to continue the surface. It is the author's view that this surface is the extension of the Sagat-Kadam-Moroto surface described above. This would involve an east-west gradient of 1,800 feet in thirty-five miles (i.e. 51 feet per mile between Yutum and Sagat (Fig. 4*b*))*. The gradient between Taptolin and Kenailmet is about 18 feet per mile, declining to the north-north-west.

The divergence of opinion on the physiographic evolution of the area east of Mount Elgon has already been mentioned, the main point at issue being whether the Kitale plain is a separate older erosion surface or whether it is an extension of the continent-wide sub-Miocene surface. Pulfrey (1960, p. 7) has supported the first view. He accepted that there was little warping of the sub-Miocene surface until after the end-Tertiary erosion cycle was completed. This means that a generally constant vertical separation of the two surfaces is to be expected, and on a map he drew contour-lines representing the sub-Miocene surface at 4,500 feet at the Turkwell Gorge and 5,000 feet to the south of Kunyao, indicating a north-eastwards slope of 19 feet per mile. If this is true there is hardly a trace of this surface preserved.† The few low residual features on the Amudat surface, such as Karameri and Merul stand too low to fit in with such a bevel and there are no corresponding bevels on the escarpment to the east of the Suam plain.‡ The alternate view propounded by Shackleton (p. 386) must involve the acceptance that large-scale uplift of the sub-Miocene surface occurred between the completion of the sub-Miocene cycle and the initiation of the end-Tertiary cycle.§ The movement suggested was in the nature of an upwarping near to the Rift Valley shoulders.‖ If the Kitale surface is the upwarped equivalent of the sub-Miocene peneplain, in the writer's view major faulting must have been involved along the Sekerr and Turkwell escarpments before the end-Tertiary planation, otherwise the variation of vertical separation between the Kitale surface and the end-Tertiary surface—more than 2,000 feet along the Argut-Merul escarpment, about 1,500 feet at Kenailmet, and only about

* The bevel as indicated by the author is composite, East of Taptolin the gradient is about 20 feet per mile, and between Taptolin and Sagat it is about 70 feet per mile. (W.P.)

† This, of course, is correct. Pulfrey pointed out in his paper that little of the sub-Miocene bevel remains in Kenya, except where it has been preserved under Miocene sediments and lavas. In an area like the West Suk lowlands, where erosion has been intense owing to the rejuvenation at the Turkwell Gorge, it would be remarkable if much of the unprotected bevel remained. (W.P.)

‡ The bevel on Pulfrey's ideas would stand at about 4,700 feet in Karameri. It does not seem unreasonable to regard Karameri (4,476 feet) as a denuded residual of the bevel, especially if it can be considered as never having been protected by Miocene accumulations. The author gives no precise information on Merul and it is not possible to comment. Shelves on the Agut escarpment would not be expected as a rule as it represents the edge of a hill mass that stood up from the Miocene bevel and has been subject to intense erosion. There are, in fact, a few small remnants of the bevel on the angle with the Trans-Nzoia escarpment, south of the Sekerr area. Bevels of about 4,500 feet are prominent at the western end of the Turkwell Gorge. (W.P.)

§ This is a mis-reading of Shackleton. He says quite clearly (Shackleton, 1951, pp 385-6) that in his opinion there were only slight disturbances in lower Miocene times, when shallow lakes were formed, and that the main disturbance of the bevels took place in late Pliocene or earliest Pleistocene times, the main effects being felt along the Rift Valley and the Kavirondo Gulf graben. Shackleton regarded the "Elgon-Kitale plateau" as a normal extension of the sub-Miocene bevel of North Nyanza (*op. cit.* p. 379). (W.P.)

‖ This again is a mis-reading of Shackleton, who did not regard the sub-Miocene bevel as specially warped near to the Rift Valley. The warping he indicated was gentle and continuous from Lake Victoria to the Rift. (W.P.)

500 feet on Sagat and Kadam on the west-cannot be explained. Such a separation is only explicable* if one considers the end-Tertiary surface cutting back through a section of the Rift Valley where, east of the present site of Lake Rudolf, the east wall of the rift was entirely absent (the limited Rudolf depression of the present day being formed at a later date). The separation of the two surfaces would thus be maintained across the area now forming the Rift Valley floor, until an area where Rift Valley movements had already commenced was encountered when the end-Tertiary surface would cut back into a fault-scarp near the line of the Sekerr-Turkwell escarpment. The sub-Miocene surface would have been uplifted west of the fault, consequent on the upward movement of the rift-shoulder area, and the uniform separation between the sub-Miocene and the end-Tertiary surface would be lost.† As the end-Tertiary surface cut back into the area behind the escarpment, through narrow gaps in the hard granite at the Turkwell gorge and the Marich pass, the separation would become gradually less, since the effect of the upwarping of the older surface diminished towards the west, away from the Rift Valley shoulder area. According to this hypothesis the sub-Miocene surface may well be below the end-Tertiary surface in parts of the Rift Valley.‡ This relationship is suggested in Fig. 4b.

The writer favours this second hypothesis and considers that two separate movements along the line of the Sekerr-Turkwell fault have occurred, one before and one after the end-Tertiary planation. Both involved uplift of the shoulder area; the second movement may have been entirely monoclinal, no fault being involved. Further detailed study of erosion surfaces should, however, decide the question: if the first hypothesis is correct, it is clear that the Sekerr area is unusual in that the sub-Miocene surface is virtually unrepresented, and this does not make the Sekerr area one that should be used as a basis for study to decide the issue.§

The Cherangani High-level Surfaces

The plateau surface of Miller (1956, p. 5) at 10,800 feet and his Lelon surface (9,600 feet) are not readily distinguishable in the highly dissected high plateau of Sekerr. There is, however, a pronounced level ridge at about 9,500 feet extending from Chachai to Mtelo. From it, Mtelo, the highest point in the area rises to 10,910 feet (according to the Survey of Kenya, though the writer is rather doubtful about the accuracy of this

---

* The variable separation is also explicable if it is accepted that the Kitale surface is not the extension of the sub-Miocene bevel. Some warping of the Kitale surface before the development of the sub-Miocene bevel would lead to the same result. The remains of the Kitale surface would, of course, later on also be subject to the warping that affected the sub-Miocene bevel. It is significant in this connexion that the author has shown on an earlier page that the Kitale surface is warped in a manner comparable with the warping of the sub-Miocene bevel, though the two bevels are not parallel. (W.P.)

† This would be acceptable if it were the case that the end-Tertiary bevel had been eroded through the Rift Wall. It is not the case, however, as the author shows in his report and map. (W.P.)

‡ This opinion is contradicted by the statement on the development of the bevel earlier in this paragraph. (W.P.)

§ The Sekerr area is not unusual. In many parts of Kenya little remains of the sub-Miocene bevel. The attitude of the surface can be defined by projection from areas where known or presumed Miocene sediments and lavas indicate the lowest level reached in Miocene times. (W.P.)

measurement; it might be somewhat lower). Clearly the high plateau represents dissected residual features derived from the two higher surfaces of Miller or from a single surface if the Lelon surface is merely a local feature. There is a noticeable steady decline in the height of the high-level features northwards—Kameligon (11,400) and Sondhang (10,520), Sekerr (10,910) and Chachai (9,680), Lorosuk and Kachagalou (just below 9,000), which is to be expected since the younger Kitale surface is also warped down to the north, relatively to its level in the Cherangani massif, and the end-Tertiary surface appears also to have undergone some warping-down towards the north.

The *Cherangani surface* is well represented by Chepunyal (7,880 feet), Taptolim (7,605 feet) and Maral (7,520 feet), features which form eminences on the younger "6,500-foot" surface. On Cheptaram (8,000 feet) and Kameghen (7,960 feet) the planed surface is rather higher. The summit of the latter hill appears, however, to protrude several hundred feet above the planed surface. There appear to be residuals of a higher surface in this neighbourhood. There are not enough remnants of this surface to estimate the upward slope towards the Sekerr escarpment in the south of the area, though such a slope appears to exist. Looking southwards from Sekerr towards the Cherangani hills the gradual slope upwards of this surface eastwards from Kapenguria is at once apparent. Also in the north of the area in the southern extension of the Karasuk hills, the tilt is again well seen. There is a well preserved surface on Tarakit, from which the summit of Tarakit rises as a residual feature. Here, the altitude is about 7,000 feet, but further east in Karikau, Ikilip and Kaptolomwa there is a tableland area between 7,200 and 7,400 feet which clearly marks the east-south-easterly extension of this surface. There is thus a slight tilt upwards to the east. Looking northwards over the Karasuk hills from Kapiomet one can see the Cherangani and Kitale surfaces falling steadily northwards. Whatever the age of the Cherangani surface it shows a warp upwards to the Cherangani hills from the north and west, paralleling the suggested warping of the Kitale peneplain.

Other Minor Erosion Surfaces

There is evidence of a bevel on Maral at 5,500 feet, and a series of hills at this height are seen along the Turkwell escarpment, but there appears to be no major erosion surface corresponding with these bevels. There are some minor bevels on the side of the deeply eroded Marun valley marking stages in the down-cutting of the river (mentioned by Miller, 1956, p. 7).

IV—SUMMARY OF GEOLOGY

The Geological History of the Sekerr Area

The sequence of events recognized in this part of the African continental shield is summarized in Table II below. The history is one of marine deposition in a geosyncline during the Precambrian era, followed by a major orogeny. After this there succeeded a comparatively stable period during which only epeirogenic movements occurred, it extended throughout the remainder of the Precambrian, Palaeozoic and Mesozoic eras. In the mid-Tertiary this aeon of uneventful continental history was interrupted by movements, small warps at first accompanied by lacustrine deposition, and later by movements of considerable magnitude accompanied by rifting and vulcanism (the latter very restricted in this area, but of considerable magnitude in East Africa as a whole). These movements at last altered the face of the continent, moulded by erosional processes for at least four hundred million years, and formed the rift valley type of horst and graben topography seen today.

TABLE II

GEOLOGICAL SUCCESSION IN THE SEKERR AREA

Age	System	Formation	Earth movements and erosional phases	Metamorphism
QUATERNARY	Recent	Soils Stone mantles Bouldery screes Outwash fans Murram cappings River alluvium		
	Pleistocene	Calcrete Calcareous boulder breccias in river-beds	Rejuvenation of Rift faulting	
TERTIARY	Pliocene		End-Tertiary-Quaternary surfaces formed (i) Masol Plain (ii) West Suk Lowlands (Amudat Surface)	
	Miocene	Nephelinite plugs Basanitic dykes Fault breccias (Lake sediments of Sagat and Masol Plain deposited)	Faulting (dominantly normal) along the line of the Sekerr and Turkwell escarpments. Minor fracture lines.	Localized low temperature effects leading to formation of muscovite along microfractures
	Oligocene		Gentle warping End of Sub-Miocene peneplanation *(Possibly the Kitale and Sagat Kadam Moroto surfaces)	
	Eocene			
MESOZOIC	Cretaceous		Kitale and Sagat-Kadam Moroto planation completed* Cherangani surface, planation completed?	
	Jurassic Trias		Cherangani High Level surfaces?	

*Alternative hypothesis are given on pp. 9-11.

TABLE II—(*Contd.*)

Age	System	Formation	Earth movements and erosional phases	Metamorphism
PALAEOZOIC	Permian Carboniferous Silurian Ordovician Cambrian			
PRECAMBRIAN	INTRUSIONS	Late pegmatites (tourmaline-columbite-samarskite suite) Granite pegmatite intrusions (Marich, Sogho, Iun, Ptoyio and Kapiomet granites) Granite (foliated granites) (Parek and Turkwell granites) Granitoid sheets and granitoid orthogneisses Ultra-basic and basic intrusions ("ophiolitic") (peridotite and gabbro) Early biotite garnet pegmatites	OROGENY: ↑ Waning Movement continuing OROGENY OROGENY OROGENY OROGENY: Incipient Intense folding	Retrograde metamorphism Knotenschiefer, formed by persistence of thermal effects after main deformation Regional Metamorphism (attaining amphibolite facies grade)
	Basement System	Metavolcanic rocks; basic intrusions and/or lavas possibly derived from submarine eruption ("ophiolitic") in the geosynclinal trough Deposition of sediments in a geosynclinal trough 2. Shallow-sea deposits Limestones Fine silty sediments (some graphitic) 1. Littoral deposits Coarse sandstones Impure sandstones		

Basement System

The greater part of the rocks exposed in the area consists of gneisses and schists of the Basement System, including both paragneisses of sedimentary origin—semi-pelitic gneisses, together with quartzites and crystalline limestones—and orthogneisses of volcanic origin with which orthogneisses of intrusive origin are associated. Semi-pelitic gneisses and amphibolites predominate over all other types. Most of the amphibolites are believed to be of eruptive origin, though coarse-textured orthogneisses accompanying them are believed to be derived from gabbroic and granitoid intrusions, and have been accordingly separated from the Basement System.

The rocks of the Basement System have in part a pronounced north-south regional strike but there are important deviations; dips are predominantly eastwards. Age determinations made on pegmatites that have invaded the system indicate that it is older than Palaeozoic.

Intrusions into the Basement System

Intrusions into the Basement System include ultra-basic, basic, acid, and possibly some intermediate types, some of which have been partly or completely metamorphosed. They are all sill-like bodies. It is suggested that these intrusives may represent an ophiolite suite emplaced in geosynclinal sediments at the beginning of an orogeny. The distinction between the basic intrusions and metamorphosed effusive rocks is obviously not easy to detect in such a metamorphic sequence, although the textures of the little metamorphosed members suggests an intrusive origin. The whole sequence is believed to be of Precambrian age, possibly ranging up to the earliest Palaeozoic.

The rock types included are:—

Ultra-basic ..	Peridotites, pyroxenites and their derivatives—serpentines, talc schists, etc.
Gabbroic	Gabbros and their derivatives—hornblendites, epidiorites, hornblende schists, actinolite schists, chlorite schists.
	Gabbroic orthogneisses.
Granitic	Lenticular bodies of foliated biotite granite.
	Swarms of biotite granite and granite pegmatite sheets. Granitoid orthogneisses.
	Pegmatities; concordant sheets and cross-cutting dykes.

Tertiary Rocks

A few scattered plugs and dykes of nephelinite and alkali basalt are the only Tertiary rocks in the area and they do not cover more than a square mile in total extent.

There are also fault-breccias believed to be of Tertiary age (p. 45) derived from the older metamorphic rocks and restricted to fault-zones associated with major fractures.

Quaternary Rocks

These are restricted to superficial deposits—soils, alluvium, calcified agglomerates in river-beds, scree and murram cappings.

V—DETAILS OF GEOLOGY

1. Precambrian Rocks

(1) Basement System

The rocks of the Basement System in the area appear to consist of a continuous succession younging to the east. This is inferred from structural considerations, though the estimated thickness of approximately 60,000 feet seems excessive for a single geosynclinal sequence. No unconformity has been recognized, however, and it is accepted as an unbroken succession; though it is possible that hidden unconformities or structural discontinuities may be obscured.

Glenday and Parkinson (1927) erected the Kateruk Series further north, and some of the rocks in this area are its equivalents. It was not found possible to extend the Kateruk Series and use Glenday and Parkinson's terminology, as the mapping of the sequence in the Sekerr area was carried up from the south, and as insufficient details were given by these authors, who made only a rapid geological reconnaissance. The succession suggested for the Sekerr area takes into account much detailed structural evidence not available to Glenday and Parkinson. The resemblance of the Kateruk Series to the Turoka Series in southern Kenya noted by Glenday and Parkinson (1927, p. 797) is interesting, but the presence of limestones and other metasediments in both areas cannot be considered a safe criterion for stratigraphic correlation. The writer thus prefers not to correlate the two areas, especially as they are widely separated and it is not possible to trace the rocks of the one area into those of the other.

The succession in the Sekerr area can be separated into four divisions:—

	Estimated Thickness in feet (approx.)
(4) Malmalte Semi-pelitic Gneisses	20,000
(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

The boundaries of the four divisions are rather arbitrarily defined, but the Tamau-Kunyao Gneisses are dominantly semi-pelitic and contain subordinate amphibolite and few limestones, whereas the Chepunyal-Burgich Gneisses are predominantly amphibolitic. The members of the Marich-Korpu Schists are about equally volcanic and sedimentary in origin, while the Malmalte division consists of semi-pelitic gneisses with subordinate amphibolites and a few limestone beds, and closely resembles the Tamau-Kunyao Gneisses.

The extent of paragneisses is far greater than Glenday and Parkinson (1927) supposed. Quartzites occur only among the Tamau-Kunyao Gneisses, while limestones are abundant only in the Chepunyal-Burgich Gneisses and Marich-Korpu Schists. The last-named contain many bands of actinolite and tremolitic schists, presumably derived from impure calcareous sediments.

The sediments from which the metamorphic rocks were derived are compatible with deposition under early littoral conditions near to the foreland, followed by deposition under clearer-water conditions further away from the foreland.

The only marked discordance within the Basement System is a zone of intense shearing, probaly due to squeezing, within the Marich-Korpu Schists, the outcrop of which constricts from a width of twelve miles in the south to a width of only a mile at Ukwaram. The variation in thickness may in part be due to lack of persistence of the volcanic rocks in the succession. Recent mapping north of Ukwaram (Walsh, Karasuk) has shown that the belt continues narrow for many miles northwards before again opening out into a wide belt of amphibolites. The wide belt of limestones at Burgich west of Kasei shows a comparable local thinning, which however is confined to one limb of a fold and appears to be of tectonic origin.

(*a*) Metasediments

(i) *Semi-pelitic Gneisses and Schists*

Semi-pelitic and pelitic Gneisses

The semi-pelitic gneisses form by far the largest part of the Basement System exposed within the Sekerr area. They make up all but a small fraction of the Tamau-Kunyao Gneisses and the Malmalte Gneisses. They also occur as subordinate bands in the Chepunyal-Burgich Gneisses.

The rocks of semi-pelitic origin include.—

Biotite gneisses,
Biotite-muscovite gneisses,
Muscovite gneisses,
Biotite-hornblende gneisses,
Hornblende gneisses.
Garnet-biotite-hornblende gneisses,
Garnet-biotite gneisses,
Garnet-hornblende gneisses,
Biotite-epidote gneisses.

All the gneisses of semi-pelitic composition are flaggy and strongly foliated, the foliation apparently representing the bedding planes of the original sediments, since where psammitic or calcareous bands occur within the semi-pelitic gneisses their margins conform with the foliation structure.

Semi-pelitic gneisses (*Tamau-Kunyao Gneisses*)

Biotite gneisses predominate over all other types. Hornblende gneisses, showing specks of hornblende sparsely distributed through dominantly leucocratic rocks, are common near to the junction with the Chepunyal-Burgich hornblendic gneisses. Biotite-hornblende gneisses are always found near to the small amphibolite lenses which are particularly abundant in the top part of the Tamau-Kunyao Gneisses. Garnet gneisses are not very common but conspicuous developments were found at Chemeroi, on the Kabomba escarpment, and in the bed of the Naburkaina river, near Kasei pass.

In thin section (for example of specimen 26/430* from Tamau) the biotite gneisses show a fine irregular granoblastic aggregate of quartz and felspar with small flakes of brown biotite and a little muscovite. Microcline is the most common felspar, though there is usually some plagioclase showing polysynthetic twinning also present. The biotite is a deep greenish brown variety. Some epidote is present and rare small garnets. Epidote is often present in these leucocratic gneisses, indicating a higher calcareous content than in the simple biotite gneisses. Specimen 26/470 from north of the Tamau river road-crossing is an example containing abundant epidote.

* Numbers prefixed 25/ and 26/ refer to specimens in the regional collection, Mines and Geological Department, Nairobi.

The garnet gneisses are leucocratic gneisses with specks of red garnet scattered through them.

Glenday and Parkinson (1926, pp. 597-598) remarked on the flaggy gneisses at Akker (near Kaptanguss of the present map) and inferred sedimentary origin for them. They calculated the chemical composition on the basis of micrometric analysis.

Semi-pelitic gneisses in the Chepunyal-Burgich Gneisses

Whilst these gneisses are dominantly amphibolitic there is a fine alternation of compositional bands in them. This is well seen in specimens from near Chepunyal camp. Within the space of a few inches there are many alterations between amphibolite, biotite-hornblende gneiss and biotite gneiss. Similar fine alternations are seen in the Tamau-Kunyao Gneisses, and there can be little doubt that the Chepunyal-Burgich Gneisses represent rocks of the same semi-pelitic type as the Tamau Gneisses, but with a greater preponderance of added volcanic material.

In thin section the semi-pelitic rocks from the Chepunyal-Burgich Gneisses are seen to carry epidote and muscovite (26/401 and 404 from Chepunyal). Specimen 26/404 also contains scattered garnets. Plagioclase is much more in evidence than microcline.

Semi-pelitic Gneisses in the Malmalte Gneisses

In the Malmalte Gneisses biotite gneisses outweigh all other rock types. Small lenticular bodies of plagioclase amphibolite are present as are seen in the Tamau-Kunyao Gneisses and hornblendic gneisses and biotite-hornblende gneisses again occur near to the margins of these bodies suggesting migration during crystallization. Such conditions are well seen in the river which runs from south of Agitor to the Malmalte near Lokwiam, and on the old road between Lotongot and Nasolot. In thin section specimen 26/1027, from south of Agitor, is seen to be a biotite-quartz-microcline gneiss with a fine irregular granoblastic mosaic structure. The biotite is a dark brownish green variety as in the rocks already mentioned. There is a little muscovite. Myrmekite is also present.

Muscovite-biotite gneisses and muscovite gneisses predominate in a shear-zone along the foot of the Turkwell escarpment (at Lokwien and Nasolot), but as can be seen in thin sections the muscovite has been produced from biotite as a very late effect, and presumably relates to a late low-temperature shearing episode—the last deformation of the orogeny.

A sheared variety with biotite almost entirely replaced by muscovite is seen in 26/1028 (p. 50) from the Nasolot-Lotongot road east of the Malmalte shearing. The rock has undergone considerable deformation and the primary constituent minerals are difficult to recognize. This kind of texture is also typical of the muscovite gneisses of the shear-zone along the Turkwell escarpment.

Granitoid Gneisses of Kapchok, etc.

A group of coarse semi-pelitic rocks within the Tamau-Kunyao Gneisses west of the Suam river are described here, as they are believed to be derived from more fine-grained semi-pelitic gneisses by soaking by metasomatic agents. They are much coarser than the normal flaggy type of biotite gneisses and have a coarse sugary granitoid texture. They weather to massive bouldery outcrops characterized by a pinkish tint, and magnetite is much more abundant than in the other semi-pelitic types. South of Kapchok they form several broad bands up to a mile in thickness, the band immediately west of the Karameri quartzite being particularly regular and well defined. North-west of Kunyao the Lodwar road crosses a belt of these gneisses of similar thickness.

On Kapchok the granitoid gneisses form a large hog-backed hill, mantled with large boulders resembling granite. The rocks here are coarser than the Karameri and Kunyao types, but bands of less coarse normal biotite gneiss separate the coarse bands, which are certainly only a very coarse development of gneisses similar to those seen west of Karameri. There is a restricted development of similar coarse gneisses on Ngoritun, near Kasei Pass. The regular closely-spaced banding seen throughout these gneisses always follows the trend of the nearby finer paragneisses and it is undoubtedly derived from a bedding structure in semi-pelitic sediments.

In thin section a coarse granitoid gneiss from Kapchock (26/818) is seen to be a coarse granoblastic mosaic of quartz, microcline and subordinate oligoclase. Magnetite and a little hornblende are also present. Another of these gneisses is represented by specimen 26/831 from Futun, four miles north of Kunyao. This is not coarse enough to be strictly classified as granitoid but otherwise is similar to the coarser gneisses of Kapchock. Muscovite is prominent in this rock and garnet is also present.

Specimen 26/786 from Nakuijit turn-off on the Lodwar road south of Karameri is a coarse microcline-oligoclase-quartz gneiss, containing a little myrmekite. Magnetite grains are present, but mafic minerals are represented only by a few wisps of biotite and rare small hornblende grains. A more calcic band is represented by specimen 26/790 from nearby which contains green hornblende, some epidote and abundant sphene. Pink garnets are also present and there are a few flakes of biotite. The felspars are dominantly oligoclase. The Kapchock gneisses were referred to as "granitoid" by Glenday and Parkinson (1927, p. 790).

Semi-pelitic members of the Marich-Korpu schists

Biotite schists are subordinate to actinolitic schists in the Marich-Korpu formation, but bands of semi-pelitic paraschists form a considerable portion of it. They are typically finely fissile grey schists, with fine-grained textures. In composition they do not differ much from the semi-pelitic gneisses, though mica is more common and garnet a very common constituent. In highly sheared zones, as at Korpu, grey muscovite schists largely take the place of biotite schists. This is apparently due to the break-down of biotite to muscovite under low temperature conditions of deformation (*see* p. 49).

Among the Korpu-Marich Schists there are types intermediate between semi-pelitic and amphibolite schists such as biotite-actinolite schists, and actinolite schists with sparse amphibole content, comparable with the gneissose semi-pelitic rocks, and there seems little doubt that both the semi-pelitic gneisses and these intermediate schists were derived from generally similar sedimentary rocks. The differing textural characteristics now seen may be largely due to degree and type of deformation (*see* p. 51). Epidote is widespread in these schists emphasizing the somewhat calcareous composition. Felspar porphyroblasts are not uncommon.

Thin sections of the normal semi-pelitic schists in this formation (26/484, 26/493 from Gatou Pass) show fine-grained granoblastic textures. Flakes of biotite pleochroic in shades of dark brown and yellow are set in a granoblastic mosaic of oligoclase, microcline and quartz. Some large late growths of faint-pink phlogopite mica give the schist a porphyroblastic habit (p. 48). An epidotic schist is represented by specimen 26/875 from the road between Korpu and Nakhang. It also contains a little white mica and the felspars are untwinned. In specimen 26/899 from Tsonguru also most of the felspars are untwinned. Epidote is abundant and muscovite a minor constituent. Several magnetite euhedra are present in the slide of this rock, but on the whole magnetite is a very sparse constituent in the semi-pelitic schists.

In specimen 26/867 from the Kianantuing river (two miles south-south-west of Korpu camp) in addition to biotite there is a great deal of white mica, a feature of all the highly sheared semi-pelitic rocks. Quartz, microcline and oligoclase are present as a rather irregular granoblastic mosaic, and there is some suggestion of felspar porphyroblasts.

In specimen 26/914 from the Nyaparei river, 2½ miles east-south-east of Korpu camp, kyanite is present. The rock also shows retrogressive development of muscovite from kyanite, a metamorphic effect (*see* p. 49). Kyanite schists are also present on Tingiri summit, north-west of the Turkwell gorge. They are cream-coloured highly puckered kyanite-muscovitic schists and retrogressive textures are again evident (p. 49). A third occurrence of kyanite schists occurs in the Kianantuing river (26/965). This rock also contains graphite while chlorite is present in all these kyanite schists. Glenday and Parkinson (1927, pp. 599-606) describe some of these rocks, and noted the occurrence of kyanite. Their identification of cordierite also has since been found to be erroneous.

(ii) *Calcareous Rocks*

The calcareous rocks can be divided into—

Crystalline limestones,

Blue-grey impure limestones,

Calcareous schists (paraschists of dominantly calcareous composition).

Calcareous rocks are widespread in the Sekerr area as is revealed by a glance at the map. They are most abundant among the Chepunyal-Burgich Gneisses and the Marich Schists and are of minor significance in the semi-pelitic formations (Tamau-Kunyao and Malmalte Gneisses), though there is a single important limestone horizon in each of them.

The Crystalline Limestones

The crystalline limestones are for the most part white in colour, coarsely crystalline, and dolomitic in composition (c.f. Miller, 1956, pp. 31-32). Pink coloration is locally seen. Where green silicate minerals such as forsterite, diopside or actinolite are present, a greenish banding may be evident. They commonly show complicated small-scale contortions and rodding (Plate III (*a*)).

A pink crystalline limestone from the Iun gorge (specimen 26/368) is seen in thin section to consist of a coarse mosaic of carbonate containing scattered rounded grains and aggregates of quartz and occasionally quartz and plagioclase. There is some brown mica present. In another specimen (26/503) from the same locality aggregates of talc are present. There is also a little apatite present.

A specimen from the Sergoi escarpment (26/452) is rich in wollastonite, whilst a crystalline limestone (26/682) from within the Marich granite on the west slope of Yutum contains a pale green diopside pyroxene. Actinolite is also sometimes present in the crystalline limestones; for example in specimen 26/1009 from the ridge between Chintakuiki and Maral (identified in crushed grains). Tremolite in sheath-like aggregates is found in the white marble exposed at the Kotit pass (26/367). An unusual mineral found was blue spinel identified in a crushed sample of specimen 26/606. The specimen was collected between Kameschen and Kainoth by Searle and the exact locality is not known. Blue spinel has also been reported from Morumeri by an officer of the Uganda Geological Survey (verbal communication). Graphite is present in a coarse grey limestone from the Kanyangereng drift (26/580).

Impure Limestones

Some blue-grey limestones with fine texture and a non-crystalline appearance occur in the Marich-Korpu Schists on a bluff immediately east of Korpu camp and on Wamgurigwa. They are restricted to minor discontinuous bands.

Calcareous Schists

Some calcareous schists of the Marich-Korpu formation are of sedimentary origin, such as cream-coloured schists from the south-west spur of Wyisa which consist of a fine schistose mosaic of carbonate, felspar, quartz, epidote and clinozoisite, with widely spaced folia containing actinolite porphyroblasts and magnetite (Fig. 7). Tremolite schists, such as fine-textured grey schists (26/898) from the Nyaparei river below Tsonguru, are also clearly derived from calcareous sediments. A band of tremolite schist also occurs at Kotik Pass. It contains a deep green spinel (the magnesian spinel pleonaste?), apatite and iron ore. Similar schists occur in the bed of the Ninyit river in approximately the same stratigraphic position, near to the presumed continuation of the Sinjo limestone.

Such calcareous paraschists certainly form an appreciable part of the Marich-Korpu Schists, but the dominant rocks of this formation, actinolitic schists, are not considered as paraschists and are discussed with the amphibolites on p. 22. J. Walsh (verbal communication) reports that actinolitic schists of similar type pass along the strike into plagioclase amphibolites in the Karasuk area, an observation that supports this separation.

An epidote-rich rock (26/773) from east of Taptolin is a pistachio-green coarsely crystalline rock with weakly developed foliation visible in the hand-specimen. In thin section it is seen to be composed of a coarse aggregate of epidote, which in parts shows lamellar twinning, and felspar which is largely saussuritized, though in a few individuals twin lamellae are preserved from which a calcic andesine composition can be deduced. There are a few flakes of a brown very altered micaceous mineral, resembling vermiculite in appearance. There is considerable quartz visible in the hand-specimen and the rock is probably derived from a calc-silicate band with the right composition for the formation of epidote.

(iii) *Graphite Schists*

The only coarse graphite schists containing a high proportion of graphite in the area occur on Morumeri immediately east of the first limestone outcrop within Kenya. They form a thin band of coarse black glistening rocks. Further north in the Karasuk area similar schists are well developed near Epeiyelel.

A few thin bands of fine-textured black or grey schists were recognized in the Endoo valley and on Kameghen. These schists have the appearance of phyllites, but appear to be rather coarse grained. This coarseness of texture is probably entirely due to recrystallization. They are probably derived from silty detritus. In thin section such a schist (26/967) from one mile north of Kameghen shows a fine aggregate of quartz granules, with a few flakes of mica, the whole being dusted with powdery graphite. There are one or two patches of rather coarser quartz mosaic. Similar schists occur at the confluence of the Endoo river and the Gudwarun river, and on the north-east slope of Kameghen.

Graphitic quartzitic flags are also seen in the Kianantuing river (*see* p. 22).

(iv) *Quartzites*

The main occurrence of quartzites in the Sekerr area is in a belt of coarse muscovite quartzites which extends from the road between Kongelai and Chessera (which loops in and out of the area in the south-west corner) through Moruangai to Karameri. There are two thinner bands to the east of the main band of quartzite,

which has a thickness up to 200 feet. All three bands suddenly disappear in the region of Karameri, but quartzites again outcrop in Uganda just north of Amudat. There is a gradual thinning northwards of the quartzites mapped in the Cherangani area (Miller, 1956, map), though whether this is of depositional or tectonic origin is not known.

The quartzite on the Kongelai-Chessera road (26/568) is a flaggy well foliated muscovite quartzite, with little felspar content. In thin section the rock is seen to be composed of a coarse granoblastic aggregate of quartz, together with many small flakes of muscovite. There is a felspar granule present, which appears to be strained microcline.

A specimen (26/652) from Lokomor, near Nakuijit, contains numerous small granules of cream-coloured kaolinized felspar of much smaller size than the quartz granules. The foliation is rather weakly developed in this specimen.

The quartzite from Karameri (26/581) is highly foliated, contains abundant muscovite, and has clearly undergone extreme deformation. The presence of extremely sheared quartzite near to the point at which the outcrop of the quartzite becomes lost suggests that the thinning may be tectonic in origin, though it is by no means conclusive evidence.

Green Quartzites

Pale green quartzites occur within the Tamau-Kunyao Gneisses in the Iun river due east of Kabomba and to the west of Taptolin summit. They form thin bands, and are muscovite quartzites, with fine sugary textures. In thin section (specimen 26/775, from near Taptolin) they show an irregular granoblastic aggregate of quartz with small flakes of muscovite and small prisms of a colourless amphibole. The maximum thickness of these green quartzite bands is about 20 feet.

Impure Quartzitic Flags

A few beds of impure quartzitic banded flags were noted in the Iun river (east of Kabomba), in the Tamau river east of the road crossing, south of Tarakit, and west of Lossom. All these lie within the Tamau-Kunyao Semi-pelitic Gneisses. They are never more than a foot or so thick. In the Marich-Korpu Schists similar bands were seen near the Iun gorge (26/369) and in the Kianantuing river (26/868). The former consist of finely banded quartz mosaics shot through with minute crystals of colourless garnet, which is closely concentrated in some bands. There is also some green hornblende and iron ore. The latter specimen contains appreciable plagioclase, mica and opaque iron ore, but little hornblende. A nearby band of similar type is shot through with finely powdered graphite (26/868A).

(*b*) Metavolcanic Rocks—Amphibolitic Gneisses and Schists

Plagioclase amphibolites, and amphibolitic schists occur throughout the area. Their mode of occurrence and petrography is first described, and their origin is then discussed (p. 25).

Plagioclase Amphibolites

The plagioclase amphibolites are essentially fine textured and composed of green hornblende and plagioclase. Epidote is a common constituent but is by no means invariably present and clinozoisite is sometimes present.

The plagioclase amphibolites are important members of the Chepunyal-Burgich Gneisses but occur only as small lenses and thin bands within the biotite gneisses of the Tamau-Kunyao (Plates IIIb, VIIb, Xa and Xb) and the Malmalte formations. The lenses are sometimes only a few inches thick but range up to 100 feet thick, though such large lenses are rare. The most common size is not more than about 20 feet long and about six feet thick (Plates Xa and b show the characteristic lenticular habit).

Garnet is not uncommon in the amphibolites and pyroxene has been recognized in some localities. Amphibolites within the Chepunyal-Burgich formation do not as a rule contain any pyroxene. For instance, specimen 26/435 (a plagioclase amphibolite) from the top of the escarpment east of Ptoyio is a granoblastic aggregate of green hornblende and mainly untwinned plagioclase. There is some sphene and epidote present, and quartz in small granules. Another plagioclase amphibolite from one mile north of Chepunyal on the Ptoyio road (26/431) has a slightly coarser texture, and the felspars show prominent polysynthetic twinning. They are oligoclase. In 26/406 from the top of the Chepunyal Escarpment the well-twinned andesine felspar shows peculiar skeletal alteration. Epidote is present and there is a considerable quantity of garnet in the hand-specimen. The hornblende is of the bluish green variety, typical of the epidiorites of the Marich-Korpu Schists. A specimen from the crest of the ridge west of the summit of the Chepunyal Hills and due south of Ptoyio camp shows a "myrmekitic" intergrowth of epidote and andesine felspar.

The amphibolites of the Burgich area resemble those from Chepunyal. Specimen 26/810, a garnetiferous amphibolite from Kenailmet, consists of a granoblastic gneissic mosaic composed of green hornblende and calcic oligoclase, much of which is twinned. Sphene, apatite, and magnetite are accessories, the sphene being unusually abundant.

The amphibolites in the small lenses in the Tamau-Kunyao Gneisses show little difference from those of the Chepunyal-Burgich Gneisses. Epidote is unusually abundant in an amphibolite (26/418) from the escarpment above Kabomba on the Chepunyal road. As in most of the amphibolites a little quartz is present, but it is a minor constituent.

Pyroxenes are rare in the amphibolites of the Chepunyal-Burgich formation, though a little green diopside is present in specimen 26/402 from the Chepunyal Escarpment. Pyroxenes are more common in amphibolites from the Tamau-Kunyao and Malmalte formations, perhaps because the competent nature of the accompanying semi-pelitic gneisses has aided resistance to extreme deformation. It is, however, the exception rather than the rule for pyroxene to be present. In specimen 26/429, a coarse garnet amphibolite from three miles south of the Tamau River drift on the Chepunyal road, light green diopside is present. Green diopside is also present in specimen 26/419, a garnet amphibolite from west of the escarpment above Kabomba. Pyroxenes are seen within green hornblende in specimen 26/561, an amphibolite from between the Nakuijit and Chessera Rivers.

In a fine-grained speckled amphibolite, from two miles south of the Kanyangareng Drift (on the Suam River), a band carrying pyroxene was recognized (26/552). In thin section a pale green to neutral clinopyroxene is seen. The pyroxene is partly enclosed by aggregates of well-formed crystals of green hornblende. The pyroxene, which is weakly pleochroic, is identified as diopside. The felspar is a calcic andesine and shows prominent polysynthetic twinning. There is no quartz in the thin section. This specimen provides an obvious link between the amphibolites and the gabbroic rocks, and the outcrop may be regarded as an amphibolite with bands of metagabbro preserved in it. The specimen is similar to 26/882 from near the Kabyen River and the epidiorites and amphibolites of the outer sheath of the Kapitero gabbro about three to four miles north-east of the Kanyangareng drift.

The basic lenses in the semi-pelitic Malmalte Gneisses of the Lebatin plains in the north-east corner of the area are darker in colour than those in the west of the area, more crystalline in appearance, and often carry pyroxene. A typical pyroxene-amphibole gneiss among these lenses is represented by specimen 26/1025. The rock is a strongly foliated dark green gneiss and under the microscope is seen to be composed of a weakly pleochroic clinopyroxene, neutral in colour and identified as diopside, together with yellowish green hornblende and plagioclase felspar which is mostly untwinned and altering in patches to saussurite.

Garnet Amphibolites

Garnet amphibolites are common in the Sekerr area though they tend to have localized development. They vary from fine-grained amphibolites with small red specks of garnet to coarse rocks with garnet porphyroblasts making up to about 80 per cent of the rock. Some have already been described in previous pages. The fine-grained type is seen in specimen 26/999 from Koduch. Small neutral-coloured garnets are scattered through the rock, and resemble those seen in some of the metagabbros (e.g., specimen 26/925 from the Cheperapoi River). The thin section of the rock contains an unusually high proportion of magnetite aggregated with sphene (cf. epidiorites, p. 26). The garnets have quartz haloes, as do all garnets seen in the amphibolites of the area, demonstrating the use of other dark minerals to form garnet, quartz being left or pushed outwards from the new mineral. A remarkably coarse development of garnets (Plate IVa) on the east scarp of Ikilip shows the surrounds of quartz particularly well.

Amphibolite Schists

The greater part of the rocks of the Marich-Korpu formation are schistose and composed dominantly of the amphiboles actinolite and actinolitic hornblende. The most common rock type is a deep green fine-textured schist with a satin-like sheen, due to the fact that the rock is made up of myriads of minute prisms of amphibole with parallel alignment. In general the textures are much finer than in amphibolite gneisses, leucocratic minerals are often more subordinate and the amphiboles are always crystallized with slender prismatic habit. Many of these schists carry more coarse-grained knots of the amphibole, which is variably actinolitic hornblende or actinolite. For example, specimen 26/599 from the Iun River, has lenticular porphyroblasts of amphibolite set in a fine aligned satin-like aggregate of actinolite prisms. The question of the origin of these porphyroblastic textures is discussed on p. 48. There are several different types of porphyroblastic textures (Fig. 7) superimposed on the original fine-grained schists. There appears also to have been much migration between actinolitic schists and nearby semi-pelitic beds, all intermediate compositions between actinolite schists and chlorite and muscovite schists being found. Thin sections of the amphibolitic schists tend to be monotonous. A few characteristic examples are briefly described below.

A garnetiferous amphibolite schist from the Iun Gorge (26/510) shows in thin section lenses of dark minerals, hornblende and magnetite set in a granoblastic base of felspar and quartz. There is a great deal of granular apatite in the rock, and a little calcite and biotite. The felspar is plagioclase, almost entirely untwinned. Garnet is visible in the hand-specimen but was not cut by the thin section.

An epidote-hornblende schist from Nakhang (26/585) has a banded texture and is strongly foliated. Green actinolitic hornblende, epidote and plagioclase make up the greater part of the rock. The plagioclase is untwinned. There are some small pinkish brown garnets present, as well as a little quartz and magnetite. A flaggy amphibolitic schist from the Sergoi River (26/457) shows a similar texture, though it is less banded. In thin section it is seen to be composed of blue-green hornblende and calcic oligoclase, together with a little magnetite, white mica and quartz. A schist (26/732) from the veterinary crush at Sarmach is similar, but again epidote is abundantly present.

An amphibolitic schist (26/502) from the Iun Gorge shows in thin section a markedly parallel alignment of thin prisms of deep green hornblende. The felspar is only rarely twinned. Apatite, sphene and iron ore are also present. Another schist (26/736), from the north-west slope of Nguruch, contains unusually large skeletal crystals of actinolitic hornblende set in granoblastic felspar and quartz. The felspar is untwinned. There is some iron ore present. In a second specimen (26/736A) a considerable amount of epidote is present. A schist from the Bino Gorge (26/915) contains abundant clinozoisite interbanded with actinolitic hornblende. The felspar is mostly untwinned, but twinned oligoclase was also found.

There are striking schists immediately east of Korpu (specimen 26/873). These schists with their remarkable stellate clusters of hornblende prisms up to two inches long have been described in detail by Glenday and Parkinson (1926, p. 602-3) who also provide a chemical analysis. There is some quartz present besides untwinned felspar. Schists from Tsonguru are almost monomineralic—in specimen 26/895 only a little iron ore is present besides hornblende. In specimen 26/891 from Tsonguru magnetite is abundant.

A massive amphibolitic schist is seen on the west granite contact on Yutum (26/686). It contains green hornblende, calcic oligoclase, iron ore, apatite and a little biotite. The granoblastic texture is rather coarser and less strongly aligned than in typical schists of the Marich-Korpu formation. The schist appears to be to some extent recrystallized, probably due to thermal effects by the adjacent mass of granitoid sheets (*see* p. 40).

The Mode of Origin of the Amphibolites

The amphobolitic gneisses and schists are believed to have been derived from either "ophiolitic" volcanic rocks or "ophiolitic" near-surface intrusions that act as feeders for such volcanic rocks. The phenomenon of ultra-basic intrusion allied to the downwarping of a geosyncline is well known, and to such intrusions the term ophiolites has been given. Further, rootless eruptive rocks of similar occurrence in the alpine geosynclines have been referred to loosely as ophiolites although they are of widely differing composition. Heritsch (1929, p. 56) listed amongst ophiolitic eruptive rocks, spilite, variolite, diabase-porphyrite, gabbro, serpentine and ophicalcite. It is thought that the basic rocks of the plagioclase amphibolite group in the Sekerr area are ophiolitic in this broad sense, emplaced as the geosyncline was warped downwards. They probably represent a complex system of sill-form hypabyssal intrusions and related volcanic rocks, erupted under submarine conditions. Such geosynclinal basic suites have also been described from other geosynclines. Jones and Pugh (1948, pp. 71-94) described intrusions in Radnorshire, and similar suites are also seen in the multiple swarms of epidiorite in the Dalradian metamorphic rocks of the Scottish Highlands and north-west Ireland. In Ireland both lavas and intrusions are recognized (McCallien, 1936). In the weakly metamorphosed Dalradian rocks of north-west Donegal, a stratigraphic sequence upwards from swarms of small lenticular epidiorite sills, often not more than a few feet in diameter, to massive sills of metadolerite, has been described by McCall (1954, pp. 160-1). In both the Donegal and Radnorshire occurrences the small lenticular sills are confined to pelitic host-rocks. Jones and Pugh attribute the lenticular habit to a mechanism of lateral penetration, from vertical feeders, of stiff, moist, muddy sediments along preferred horizons. McCall (1954, p. 161) recognized no feeders and suggested that depth and fluidity of the hot magma may have some control over the formation of such lens swarms. Though the host-rocks are not pelitic in the case of the Sekerr lenses, the mode of origin of the amphibolites may well be the same as in the cases quoted and, if Jones and Pugh are correct, the presence of swarms of lenticular basic intrusives indicates that the amphibolites were emplaced when the geosynclinal sediments that are now represented by paragneisses were still moist and unconsolidated. There is no restriction of the lenticular bodies to the lower part of the succession in the Sekerr area, as there is in Donegal, and Jones and Pugh recognized such lenticulation in the upper part of their succession in Wales. It would seem therefore that there is no control by depth, but that the condition of the host-rock is the main controlling factor during formation.

The possibility of a purely tectonic origin for the lensing cannot be discounted, the lenses being akin to boudins. They occur throughout the whole area of semi-pelitic gneisses, and there appears to be a complete lack of relation to local tectonic style, the lenses occurring both in isoclinally folded rocks (Plate X (*b*)) and in evenly dipping rocks with slight open folding (Plate X (*a*)), though in the second case larger more complex structures might be concealed. The lenses illustrated in Plates VII (*b*) and X show structures suggestive of a tectonic mode of origin.

Although the amphibolites are believed to be derived from basic eruptives, they are too metamorphosed for structures such as pillows and vesicles to be preserved. It is doubtful if there is any criterion by which surface or submarine volcanic rocks can be distinguished from near-surface minor intrusions in a state of metamorphism and deformation equivalent to that seen in the Sekerr area. The writer accepts that there may be surface (or more probably submarine) volanic rocks represented, but intrusive rocks are believed to have formed the parent rocks of the greater proportion of the amphibolites. The features that lead to this conclusion are as follows:—

(i) The lenticular form. The resemblance to the known occurrence of sill-form lenticular minor basic intrusions in geosynclinal sediments is patent, though equally these lenticular forms could be tectonically derived.

(ii) Fairly frequent occurrences of relics of pyroxene. While such pyroxene could be derived from calcareous sediments this is most improbable as the limestones in the area carry relatively little pyroxene or other silicate minerals.

(iii) Where pyroxene is present the felspar is calcic, typical of a basic eruptive. In the completely metamorphosed amphibolites a more sodic felspar is present.

(iv) The presence of small colourless garnets in some specimens (e.g. 26/999) identical with those seen in some metagabbros.

(v) The occasional presence of iron ores with sphene haloes exactly comparable with these minerals in the epidiorites of the Marich-Korpu Schists, which preserve in palimpsest their primary texture and are undoubtedly derived from basic eruptives.

(vi) The presence of metagabbro bands, such as seen in specimen 26/552 from near the Kanyangereng drift, indistinguishable from the sheaths of gabbroic intrusions.

(vii) The absence of any gradation into limestones, as would be expected if they were derived from calcareous sediments.

(viii) Quartz is only present in minute quantities in the relatively unmetamorphosed amphibolites that contain pyroxene. More quartz would be expected in metasedimentary rocks.

The sixth point made is worth enlarging. There is undoubtedly a close relation between these rocks and the major intrusions now preserved as basic or intermediate orthogneisses (p. 34). It seems probable that both are ophiolitic in the broad sense—contemporaneous sill-form intrusions of the geosyncline. The larger intrusions have however preserved more of their primary features and can be readily identified as intrusive in origin—they and the epidiorites have thus been removed from Basement System. The removal of the whole complex suite of amphibolites has not been made, as the origin of by far the greater part cannot be stated with certainty. Part, if not all of the amphibolites, however, should in the writer's view be considered as syn-tectonic eruptives and should more correctly carry a symbol devoid of the X of the Basement System; such a differentiation, however, is unpracticable.

The amphibolitic schists pass along the strike into amphibolitic gneisses in the Karasuk area (verbal communication, J. Walsh) and there can be little doubt that they represent highly deformed rocks of similar origin to the amphibolite gneisses.

Small included lenses a few inches long of amphibolite in the marbles (especially well seen at Burgich and the Iun gorge) are thought to be of tectonic origin, the rocks being highly lineated and crumpled (Plate III*a*). The lenses are believed to be small infolds exposed in section.

(2) Major Intrusions into the Basement System

(*a*) Ultra-basic and Basic Intrusions

The ultra-basic and basic intrusions can be divided into two groups: firstly, peridotites and gabbros which are sufficiently well preserved to be confidently identified, and secondly a suite of orthogneisses from which relics of the original igneous rocks are almost entirely absent, the intrusions now being preserved as gneissose rocks of basic or intermediate composition. The question whether there is one suite of major basic intrusions or two suites, of slightly different age, cannot be finally resolved on the evidence available. There is, however, strong evidence that the two groups are closely related and the division made may be arbitrary, based on differences in metamorphic state alone.

The petrographic evidence given in the succeeding pages reveals that the gabbros have metagabbro, epidiorite or amphibolite selvedges, and that the hornblendic orthogneisses contain relatively fresh patches of metagabbro, similar to the rocks of the gabbro intrusions. The writer accordingly follows Glenday and Parkinson (1927, p. 795) who said "The gabbros are normally crystallized portions of a magma which elsewhere gave rise to certain of the hornblendic schists. The two rock types appear to pass into one another". There is strong petrographic evidence (p. 23) that some, at least, of the amphibolites were derived from gabbros by metamorphism, though other amphibolitic rocks may be derived from lavas. The ultra-basic and gabbroic rocks are sill-form intrusions, possibly emplaced after folding had begun, but most probably at an early stage of downwarping of the geosynclinal sediments. They are sometimes entirely converted to talc schists, serpentine, or epidiorites in zones of extreme shearing. They have certainly undergone at least a large part of the orogenic deformation and metamorphism affecting the Basement System gneisses. Amphibolites of the sheaths of the intrusions are sometimes indistinguishable from the plagioclase amphibolites already described from the Basement System.

There is a distinct grouping of these intrusions into belts, which conform closely to stratigraphic levels in the country rocks. There are two main belts, besides one or two minor belts, and a few isolated occurrences. The ultra-basic rocks, serpentine and peridotite, show a close grouping with the gabbroic rock types. This is particularly evident in the eastern belt where lenticular bodies of both types are seen in juxtaposition on Yutum, Telot, Kameghen and Karel.

(i) *The Ultra-basic and Basic Intrusions within the Tamau-Kunyao Gneisses*

The ultra-basic and basic rocks emplaced in the Tamau-Kunyao Gneisses are never extensive, being usually in the form of lenses up to a hundred feet wide, though often they are only a foot or so wide. The lenses seem to follow certain stratigraphic horizons, being particularly in evidence near to the top of the formation. They were probably derived from sill-form intrusions which have been shaped into lenses or boudins during orogenic movements. These bodies are in general preserved in a comparatively fresh unsheared state, but in several cases sheaths of epidiorite and amphibolite form selvedges to them, and many of them are certainly earlier than at least the last stages of the orogenic movements, and must be regarded as massive residual fragments that have resisted deformation and metamorphism. Some of them appear as remarkably fresh outcrops forming dark features that stand out from the light-coloured gneiss terrain and resemble Tertiary dykes. However, the Kapitero feature is preserved in similar condition, and was in fact at first mapped as a Tertiary plug, but the presence of a sheath of amphibolite gneiss belies that interpretation. There is a lack of any features suggesting alkaline affinities such as would be expected if the intrusions were of Tertiary age.

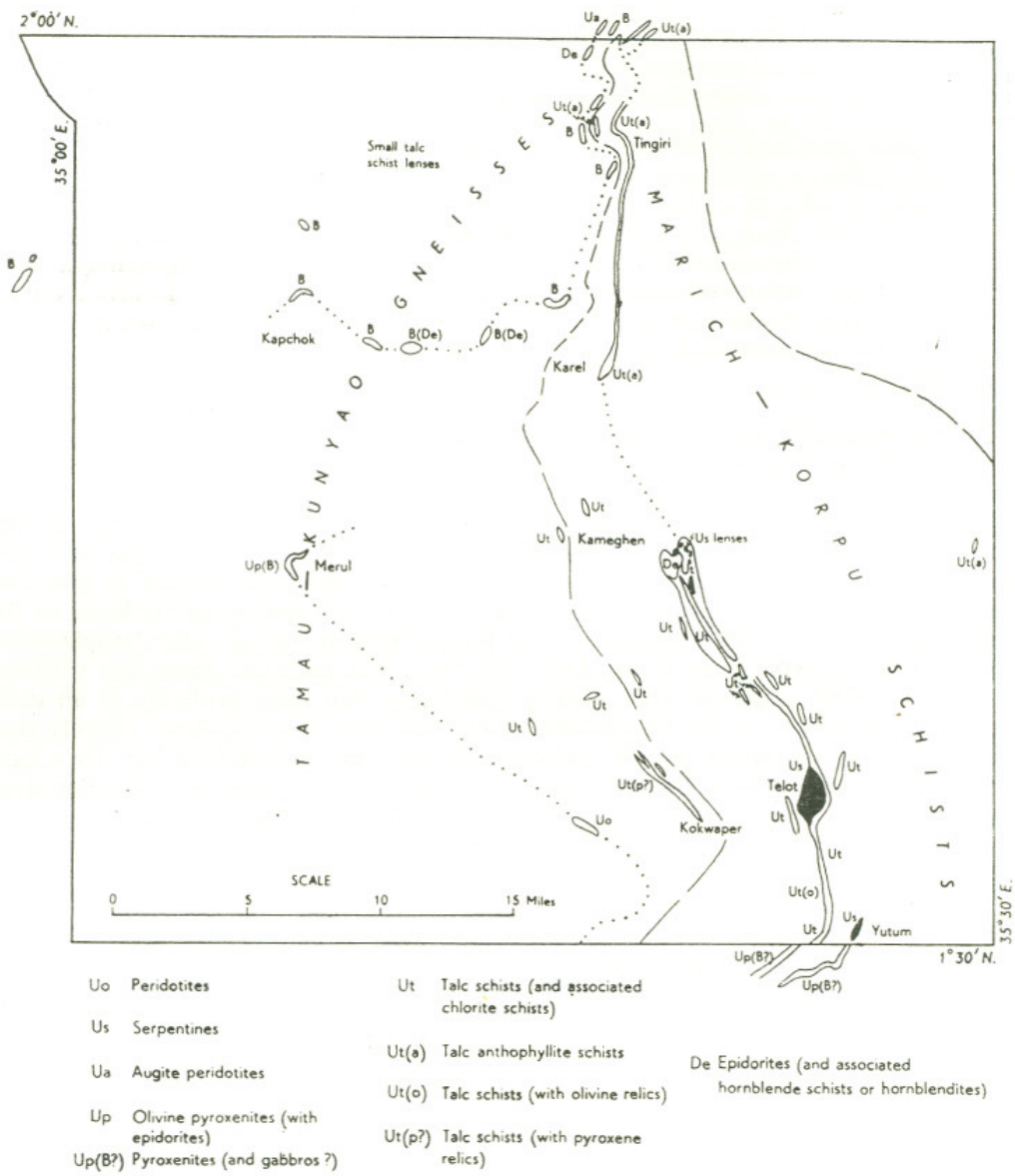


Fig. 5—Distribution of the ultra-basic and gabbroic intrusions and their derivatives, serpentine, epidiorite, hornblendite and hornblende schists, talc, anthophyllite and chlorite schists. The dotted lines show the separation into two distinct belts, one within the Marich-Korpu Schist, largely represented by serpentine and talc, and a belt of less altered intrusions within the Tamau-Kunyao gneisses.

These rocks include the following primary types:—

(*a*) Peridotites,

(*b*) Olivine Pyroxenites,

(*c*) Gabbros.

Peridotites

A peridotite intrusion with the form of a steeply dipping concordant sheet crosses the Chepunyal road a quarter of a mile south of the Tamau river drift. The body is about ten feet wide. It is a coarsely crystalline purplish black rock, showing patches of

green serpentine. In thin section (specimen 26/423) it is seen to contain no felspar or other felsic mineral. Olivine and hypersthene, the former laced by cracks along which alteration to iddingsite and serpentine is evident and the latter skeletal in form and distinctly pleochroic form cores to coronas with dentate fringes of an iron-poor hypersthene with weak pleochroism, and an outer zone of uralite and spinel. There is considerable magnetite in the rock and secondary iron oxides, and much of these are concentrated in patches where the rock consists of dark, opaque, or near opaque iron-stained spheroids that are not easily resolvable into distinct mineral assemblages. The rock is interlaced with serpentine along the cracks.

A peridotite body occurs north-east of Ogwagwat just beyond the northern boundary of the area. It forms a dark bouldery ridge contrasting strikingly with the light-coloured semi-pelitic gneiss country rock. It is composed of a remarkably fresh-looking greenish grey, medium-textured, holocrystalline rock. In thin section (specimen 18/133) it is seen to contain no felspar or other leucocratic mineral, and to be composed of olivine surrounded by dentate coronas of serpentine (two pyroxenes, patchily coloured enstatite and pale grey augite, are also present). Both the serpentine coronas and the augite are surrounded by uralitic coronas, and there is also present some black opaque iron ore (magnetite?) surrounded by a little lepidomelane.

A mile to the south-west near the Cheparapoi river is a similar body (18/134) but it is probably gabbroic as it is altered to an epidiorite composed of felspar pools and green amphibolitic aggregates.

Olivine Pyroxenites

The pyroxenites are characteristically grey to black crystalline rocks, often with a purplish tinge caused by a thin weathered skin. They vary from coarse-textured rocks showing dominantly mafic minerals and a few felspars to finer-textured rocks in which the component minerals are indistinct. Iron ore in the form of magnetite is usually present but not very abundant. Original igneous textures are preserved, and there is no evidence of foliation, though microcope study reveals alteration in varying degrees. Spheroidal weathering is a feature of these rocks.

The best exposed occurrence is seen at the bend of the Suam river, west of Merul. A lenticular body of black spheroidal igneous rock outcrops along the river for about two miles of its course. Outcrops are intermittent and the form of the lens drawn on the map is to a certain extent conjectural. The rock varies in coarseness, the coarser varieties being represented by specimens 26/533 and 26/535 and the finer variety by specimen 26/534. Specimen 26/533 varies patchily from pyroxenite to gabbro. Under the microscope it shows a striking pattern of corona structures. The centres of the coronas consist of relics of the primary minerals—olivine altering along cracks to brown iddingsite, hypersthene with weak to fairly strong pleochroism, and magnetite. The inner coronas consist of weakly pleochroic hypersthene in a dentate fringe of prisms elongated normal to the circumference of the corona. An outer fringe of grass-green uralite associated with many granules of spinel separates the coronas from the coarse mosaic of strongly twinned plagioclase crystals which, in the gabbroic varieties, forms the base in which the coronas are set. The plagioclase is calcic labradorite approximating to a composition of An_{55}. The magnetite is usually associated with a brown mica, which also occurs in the amphibole coronas where there is no magnetite. Hornblende is set in the felspar base.

Stages of the alteration of the Suam river intrusion to an epidiorite are seen in specimens 26/537 and 26/537A which were taken from the same outcrop—a coarse-textured grey and black holocrystalline rock, which is a gabbroic patch in the pyroxenite. A few small red garnets can be recognized in the hand-specimen. In thin section specimen 26/537A contains aggregates of mafic minerals with cores of granular hypersthene together with magnetite surrounded by mosaic aggregates of hornblende crystals,

associated in places with brown mica, which also forms coronas round magnetite. There is far more felspar than in specimen 26/533 varying from coarse individuals to mosaic aggregates of much smaller crystals. It approximates to a composition An_{32}. In specimen 26/537 there is no pyroxene and the amphibole shows a tendency towards a fibrous habit, and is lighter coloured. The felspars are rather more calcic than in 26/537A but have similar habit.

A fine textured specimen from the Suam river intrusion (26/534) is seen in thin section to be partly altered to epidiorite. A few orthopyroxene cores with low birefringence and little or no pleochroism remain. The remainder of the rock consists of a granoblastic aggregate of brownish hornblende and plagioclase with a little iron ore and biotite. A similar rock in which pyroxene has been completely replaced by amphibole is seen in 26/584, collected by Searle from four miles south of Tamau.

Gabbros

The gabbroic rocks show about equal content of mafic and felsic minerals. The largest intrusion of gabbro is that of Kapitero which, unlike the Suam river intrusion, makes a distinct conical hill feature covered with large boulders.

The centre of the Kapitero intrusion (26/953) is composed of dark green and purplish grey moderately coarse, igneous rock showing no signs of foliation. In thin section relic cores of clinopyroxene, neutral in colour and not pleochroic, are seen to be surrounded by various products of alteration including a strong pleochroic orthopyroxene (iron-rich hypersthene?), uralite with spinel, and serpentine. The corona structures are sometimes poorly developed, but distinct rings of brownish hornblende and uralite are seen. The felspars in the rock are cloudy altered plagioclase with ragged outlines and surrounded by alteration products.

A dove-grey moderately fine-grained rock (26/950) from near the outer margin of the Kapitero intrusion shows partial conversion to a schistose rock composed of garnet, amphibole and plagioclase. The hand-specimen shows specks with a greenish tinge with minute pink dots of garnet and white felspar. In thin section abundant relics of a clinopyroxene are seen surrounded by pale brownish green amphibole. The amphibole is optically positive and only weakly pleochroic, the maximum extinction to cleavage parallel to elongate sections being about 20 degrees. It is an unusual type, probably an iron poor pargasite. Scapolite is also present. The felspar is completely fresh, and is clearly recrystallized, no trace of the primary felspar being seen. It shows rather distorted polysynthetic twinning, and is tentatively identified as andesine.

The Kapitero intrusion has an outer sheath of dark green epidiorite with either a poorly defined or a well-marked foliation. The former is seen in specimen 26/952, a dark green moderately fine-textured crystalline rock which on study of the microscope slide reveals an incompletely developed directed texture. The rock consists of ragged hornblende, pleochroic in pale shades of yellow-green, grass-green and blue-green, together with elongate crystals and granules of epidote and plagioclase. The felspar is variably untwinned or polysynthetically twinned and is labradorite (An_{60}). A fully developed foliated texture is seen in specimen 26/951, a dark green crystalline amphibolite. Elongate hornblende crystals make up more than half the bulk of the rock. There are some pale green pyroxenes, together with granules of garnet, scapolite and epidote and lenses of plagioclase crystals that are mostly untwinned, but appear to have a composition in the middle of the labradorite range. The felspars are granoblastic, as is typical of metamorphic rocks.

Altered gabbro intrusions outcrop on the southern face of Serakangetun, and on the Korpu road just east of the drift across the Kabyen river. The latter (26/853) is a moderately coarse dark grey igneous rock with a fresh appearance, though in thin section indications of a considerable degree of alteration are seen. The felspars are

prisms of plagioclase that often have considerable cloudy alteration, and tend to have zones of poorly formed water-clear garnet granules separating them from the dark minerals and forming the outer rims of corona structures. Monoclinic pyroxene much speckled by iron-ore dust forms the cores of the coronas, and there are small skeletal fragments of iron ore that may represent olivine. The felspar preserves its polysynthetic twinning and can be recognized as sodic andesine. Aggregates of granules and fringes of a secondary pyroxene, colourless and non-pleochroic, possibly enstatite, also figure in the coronas. There is much brown hornblende in ragged aggregates, and brown mica. These tend to surround the pyroxenes, the skeletal fragments and magnetite.

A fine grey crystalline rock (26/885) from Serakangetun also contains prisms of sodic andesine. Polysynthetic twinning is preserved but there is considerable alteration to saussuritic material, and fresh garnets similar to those described above are dotted through and around the felspars. Pyroxene is present and was identifiable in one case as clinopyroxene. There are some fresher looking granules of pyroxene as in specimen 26/853. Again, there are brown hornblende and biotite aggregates, predominantly clustered around magnetite.

Two altered pyroxene-bearing intrusions derived from gabbros occur in the country around Kapchok. A body about fifty yards wide and lenticular in form crosses the branch track between the Kanyangareng drift and Kabyen river. It is a fine-grained holocrystalline rock (26/949), greenish black in colour and showing prominent red garnets. In thin section it is seen to contain cores of neutral-coloured clinopyroxene altering along the edges to amphibole, pleochoic in shades of olive-green and greenish brown. There is some brown mica and iron ore (magnetite?). The rest of the rock is composed of aggregates of plagioclase showing some polysynthetic twinning, amphibole and garnets. The felspar is a sodic andesine. The garnets are small, pink in colour and rounded in form.

Another body, north-east of Kapchok, is similar in appearance but it contains strongly pleochroic hypersthene with coronas of hornblende, pleochoic in shades of blue green, deep green and yellow green (26/933). Biotite and large grains of iron ore are associated irregularly with the coronas. The felspar forms a coarse mosaic and is mostly twinned. It is a sodic andesine.

An intrusive rock (18/134) east of the peridotite near Ogwagwat (*see* p. 29) identified as a metagabbro, shows considerable alteration. It is a cream and grey speckled rock with prominent red garnets. In thin section it is seen to consist of a pale green clinopyroxene altering around the edges to a uralitic aggregate and set in a granular mosaic of felspars, hornblende and small rounded, colourless and water-clear garnets. The felspar is a sodic andesine. There is a little biotite and carbonate in the rock.

(ii) *Ultra-basic and Gabbroic Intrusions and Associated Derivatives in the Marich-Korpu Schists*

A belt of ultra-basic and basic intrusives and their derivatives can be recognized in the eastern part of the area, extending from the vicinity of Wakor, through Telot, Kameghen, Karel and Tingiri. Two or more distinct bands can be recognized at some points. The rocks forming the two intrusions at Wakor are the only relatively unaltered igneous rocks preserved in the belt, since to the north metamorphism and shearing increase abruptly. The only representatives of these intrusions on Tingiri are talc-anthophyllite-chlorite schists.

Pyroxenites and gabbros have been described by Miller (1956, pp. 21 and 22) from just south of the present area. The pyroxenites near Wakor are olivine-augite-hypersthene rocks and occur as patches in two sills of gabbro. The relatively unaltered olivine-free gabbro from two miles west of Wakor along the main road to Kapenguria is represented by specimen 26/757, collected just south of the boundary of the Sekerr area. It is a

coarse, greyish black rock in which pyroxene and felspar can be seen in the hand-specimen. In thin section it is seen to be mainly composed of a flesh-coloured, weakly pleochoic augite, together with a little magnetite, and well twinned plagioclase. The latter forms about 30 per cent of the rock and is labradorite. The primary mafic minerals are often surrounded by coronas of uralitic hornblende and spinel. A little secondary carbonate is present.

The rock gives an indication of the nature of the parent intrusives from which some part of the rocks of the eastern belt of intrusions are believed to be derived. This type of rock would be expected to convert to metagabbro or epidiorite under the effects of further metamorphism. The olivine- and hypersthene-bearing ultra-basic patches in the gabbro described by Miller are believed to be the parent rocks from which the talc and serpentine rocks were derived. Whilst no connexion between the relatively unaltered intrusions and the metamorphosed derivatives can be seen on the ground, a glance at the sketch map (Fig. 5) shows that the distribution is beyond the bounds of coincidence.

The main eastern sill shown by Miller (1956, map) can be detected as a thin band of serpentine immediately west of the granite contact on the steep western face of Yutum on the west side of the Marun valley, and three miles south of Wakor. There are also several small lenticular bodies of hornblendite and epidiorite below the serpentine, coarse, dark green, unfoliated or poorly foliated rocks, and similar bodies of hornblendite are found in the granite of Yutum. One of the hornblendite enclaves is represented by specimen 26/687. It shows large crystals of light green diopside partly replaced by vivid green hornblende (cf. Miller, 1956, p. 22), and contains iron ore, sphene, epidote and a considerable amount of apatite in large crystals. There is no felspar in the thin section and the parent rock appears to have been a pyroxenite. Another coarse hornblendic rock (26/513) below the Yutum serpentine, on the side of the main road, shows a poorly developed foliation, and is seen to be composed of green hornblende together with streaky patches of epidote, a little quartz, and accessory sphene. The rock is regarded as a basic epidiorite.

The westerly sill, which cuts the main road west of Wakor, to the south of the southern margin of the Sekerr area, appears to pass northwards into a belt of talc schist which passes over the east shoulder of the Sogho massif and connects up with a band of talc forming a conspicuous bar across the Iun river immediately at the Iun gorge. This talc schist carries olivine (26/511) and is dotted with small octahedra of magnetite (26/616). It is associated with compact, pale green, talc-chlorite-anthophyllite schists carrying specks of magnetite (26/613). The talc belt continues northwards over the Akeriemet river to Telot where there is an abrupt widening into a lens of serpentine associated with talc and chlorite schists and chromite lenses (*see* also pp. 67-70). The form of the lens can be deduced with confidence from schistosity and cleavage structures within the body, and from the shape of its boundaries in relation to the steep dissected topography. Its plan and section are shown in Fig. 13. It forms an almost treeless expanse on the steep east slope of Wyisa, a ridge rising to over 8,000 feet and projecting south from Mtelo. The country rock consists of actinolitic schists of the Marich-Korpu formation. The lens itself is dominantly composed of serpentine together with subordinate chlorite schists and talc schists, and is bounded on the east by a belt of chlorite schists and talc schists several hundred feet thick.

The serpentine is pale green in colour unless nickeliferous, when it is bright green. It consists for the most part of antigorite (26/476), and carries considerable magnetite. It shows surface weathering to a brownish or buff-coloured material which contains some magnesite (26/473). The associated chlorite schists contain talc (26/479, 26/480) and knots of iron ore, and magnetite octahedra. Small granules of apatite are not uncommon in them. The chrome spinel picotite has also been reported from these green schists. Within the schists there are some cross-cutting secondary veinlets of pure white talc in coarse parallel flakes (26/481).

Two distinct bands of talc schist east and west of the Telot lens are also thought to represent highly sheared ultra-basic intrusions.

North-north-east of the Telot serpentine, on the slope between Telot and Mbara, are some bands of hornblende schist whose texture suggests derivation from epidiorites. In thin section (specimen 26/486) they show a highly schistose texture composed of alternating felsic and hornblendic streaks. The hornblende is deep green, pleochoic in shades of blue-green, grass-green and yellow-green, while the felsic streaks contain much epidote and clinozoisite. The felspar is of granular mosaic habit and untwinned. There is some opaque iron ore. The rock is identified as a very sheared epidiorite. Other than these narrow bands, there is no gabbroic or hornblendic rock associated with the Telot serpentine (cf. Kameghen, p. 33).

It is possible that chlorite schist streaks in the serpentine are all derived from hornblendic lenses similar to the epidiorites near the Marich pass (*see* p. 34), and ultimately from gabbros.

North of the Telot lens a belt of sheared talc schists passes over the Gatou and Sabai saddles and connects with the serpentine and epidiorite complex of Kameghen. A specimen of the talc schist from this connecting section is monomineralic (specimen 26/490).

The Kameghen complex contains very varied rock types and only a brief outline can be given here. Detailed mapping is extremely difficult owing to the prevalence of precipitous slopes. The southern end of the complex is composed of two parallel belts of talc schists and chlorite schists, similar to those on Telot. On the summit of the mountain a lenticular patch of greenish black hornblendic rocks occurs, and on the eastern flank there is a string of lenticular bodies of serpentine, forming bare treeless patches on the steep hillside.

Some of the hornblendic rocks are monomineralic hornblendites. Specimen 26/978, for example, is seen in thin section to be composed entirely of deep green hornblende, pleochroic in shades of yellow-green, deep grass-green and blue-green.

The greater part of the rocks of the Kameghen hornblendic body are, however, not monomineralic. For instance a dark blackish green crystalline schist (26/980A) is seen in thin section to contain patches of hornblende, much epidote, granular sphene and opaque iron ore. This rock carries no felspar. Other types are epidiorites and contain felspar. For example, specimen 26/976, a dark green and grey speckled crystalline rock, showing specks of characteristic pistachio green indicative of epidote, contains considerable felspar. It is weakly foliated. In thin section it is seen to consist of green hornblende together with pools of plagioclase showing well-marked polysynthetic twinning. The felspar is identified as labradorite. Prisms of clinozoisite and granules of epidote are scattered in the felspar pools, particularly near their edges. There are also a few small flakes of white mica derived from alteration of the felspar. Iron ore is present in sparse and rather small specks. The rock is an epidiorite, retaining the pattern of the primary texture. The alteration is further advanced in specimen 26/977, a rock of similar appearance. The felspar has been converted from patches of well-twinned plagioclase to pools of recrystallized untwinned plagioclase (probably oligoclase), often with much epidote and clinozoisite. There is some sphene in this rock, sometimes as coronas to the ore, indicating that the ore is titaniferous. As it is strongly magnetic it is probably titano-magnetite. The rock retains the pattern of the primary igneous rock in the pattern of the felsic pools, and is classified as an epidiorite.

There are several lenticular bodies of serpentine aligned in a crescentic pattern on the east slope of Kameghen, below the hornblendic body. Small patches of serpentine were identified within the hornblendite and epidiorite, one being a few yards east of the summit. Some of the hornblendite is interlaced with serpentine (e.g. 26/980C).

The serpentine is pale green and is seen in thin section to be largely antigorite (26/970). No nickel-staining was noticed but there are traces of chromite and magnesite, though no body was identified *in situ*.

Green *chloritic schists* associated with *talc schists* form two distinct broad belts extending south from Kameghen, and the serpentine lenses east of the hornblendic body lie within schists of this type. These schists are similar to those on Telot and unlike any other schists in the Marich-Korpu formation, except those of the anthophyllite belt running north from Karel, which are also believed to be derived from ultra-basic or basic intrusions. They are thought to represent highly sheared members of the intrusive suite on Kameghen. There are outlying bands of talc schists which are also thought to have been derived from small intrusive lenses.

A thin belt of *talc-anthophyllite-chlorite schists* extends from Karel northwards through Korpu to Tingiri saddle, where there are two distinct bands. Anthophyllite schist was again recognized in an extremely thin band north of Ukwaram. There is a consistent relationship to a limestone band throughout, the anthophyllitic rocks being always just east of it, and it is thought that they represent a highly sheared sill-form ultra-basic intrusion. The anthophyllite forms coarse asbestiform aggregates on Karel (26/918), as is also seen near the Tingiri saddle. The economic value of the occurrence is discussed on page 78.

There are several bodies of *talc schists* and *talc-anthophyllite schists* which are outside the well-defined belt described above. Near Kokwaper there is a considerable body of talc-anthophyllite schist and several minor lenses have been noted between there and Chepunyal. In a section of the rock from near Kokwaper (26/494) lineated aggregates of iron ore surrounded by aggregates of anthophyllite suggest derivation from pyroxene with a pronounced parting. Similar schists are seen in small lenses on Chepunyal hill (26/443A, 26/444).

Small talc schist lenses occur on the Chepunyal-Ptoyio road, in the valley of the Chemyabet river, and on Chepunyal. Talc schists form several small lenses in the semi-pelitic gneisses of Karikau, on the escarpment due east of Awannyatun. A lenticular body of talc-anthophyllite schist, presumed to be derived from an ultra-basic intrusion, occurs north of Orwa, near the foot of the Sekerr escarpment. In thin section (26/728) it is seen to contain appreciable carbonate.

(*b*) Basic and Intermediate Orthogneisses

Within the schists and gneisses of the Basement System are found bands of coarse gneissic rocks, devoid of any closely spaced compositional banding, of basic or intermediate composition. The greatest thickness of any of these belts is about two miles, on Choto. Although evidence of intrusive relationships is not preserved, there is evidence in the petrography of the rocks that they are of intrusive origin. They all show sheet form, and it is suggested that they are sheet intrusions squeezed into the gneiss country rock at an early stage in the orogeny. Though it cannot be definitely decided whether they are syn-orogenic or pre-orogenic, the former is by far the most likely (*see* p. 35).

The main occurrences of these intrusions are:—

(1) The Miskon-Chepkopit belt.

(2) The Sigoyowo-Wyisa belt.

(3) The Choto-Mtelo belt.

(4) A cluster of lenses south of the Tamau river.

(5) On the Kenailmet escarpment, facing west to Morumeri.

There is a considerable variation in composition. The Miskon-Chepkopit belt is composed dominantly of orthogneiss of basic composition, while the others are rather of intermediate composition. There seems to be an association between these orthogneisses and the granitoid orthogneisses, and occasionally patches of granitoid orthogneiss are found within the more basic bodies, but whether these are separate intrusions or patches of different composition within a single intrusion has not so far been determined, though the former seems more likely.

Miskon-Chepkopit Belt

A belt of coarse hornblende-plagioclase orthogneisses appears to extend from Miskon northwards to Chepkopit and Cheptanoya where it is thought to underlie Quaternary soils. At the latter locality it is thinning out and no trace of it can be found further north along the strike. To the south of Miskon where several hundred feet of this gneiss are exposed in the cliffs below Kamren, the course of the belt is not known for certain. It probably runs along the foot of the escarpment below Bonong (as tentatively shown on the map). The precipitous Bonong feature was not traversed during the survey and the connexion has not been substantiated with the easterly band of hornblendic gneiss shown by Miller (1956, map). It will be noted that the mapping on the north margin of Miller's map is not followed by the writer since semi-pelitic gneisses occur along the greater part of the boundary adjoining the syncline of basic gneisses marked *Xah* and *Xk* by Miller.

A typical specimen of the gneiss from Miskon is dark green and foliated with white lenticular felspar flecks which make up about 25 per cent of the rock In thin section (26/1006) it is seen to be a coarse granoblastic aggregate of green hornblende and oligoclase-andesine. There is some quartz, sphene and epidote in the slide. A similar rock from north of Merul (26/551) contains more epidote.

The Sigoyowo-Wyisa Belt

A belt of at least three metagabbroic orthogneiss sheets within the Marich-Korpu Schists can be followed southwards from the east slope of the Sigoyowo ridge, southwest of Kameghen, to the middle of the steep slope which drops three thousand feet from Wyisa to the Sergoi river. They are coarse biotite hornblende gneisses of intermediate composition, but may well be derived from more basic rocks such as gabbros. Large lenticular patches of white felspar up to a centimetre in length are conspicuous on weathered surfaces and are believed to represent phenocrysts though recrystallized under the influence of metamorphism. Foliation textures are well developed in these orthogneisses.

In thin section (26/458, from Sergoi) the felspars are seen to be plagioclase and the large individuals show granules of epidote and prisms of clinozoisite inset in them. There is also much granoblastic untwinned plagioclase and quartz which partly surround the large felspar crystals. Hornblende and biotite are present. The felspar granules are sodic-andesine. The epidote and clinozoisite within the felspars suggest that the original felspar was a more calcic plagioclase. There are a few granules of carbonate, probably secondary. The sparseness of iron ore is noteworthy, correlating with the case of the gabbros and associated rocks described on pages 31-34.

Some sphene is present in 26/465, a similar rock from the slope west of Wyisa.

Further examples of orthogneisses from this belt are seen in 26/989 from Sabai and 26/993 from the east slope of Sigoyowo. In the latter, a coarse biotite-hornblende gneiss showing lenticular felsic streaks, felspar makes up 35 per cent of the rock. The texture is seen under the microscope to be coarsely granoblastic. Biotite and green hornblende are present and calcic felspar containing epidote and clinozoisite in small

granules and prisms. This strongly foliated rock has a granoblastic base composed of plagioclase and quartz. The plagioclase, which occasionally shows polysynthetic twinning, is oligoclase. A little carbonate is present in the slide.

In specimen 26/985 from Sabai pass the felspars lack the clouds of epidote seen in 26/993: in contrast much white mica is present in the felspars, and hornblende is very sparse compared with biotite. Magnetite and apatite are accessory minerals.

The Choto-Mtelo Belt

A wide belt of coarse biotite-hornblende orthogneisses extends from Mtelo through Choto to Tingiri, where it becomes so sheared out as to become unrecognizable. Certain coarse mica-felspar schists extending from Tingiri to Ukwaram probably represent the continuation of the belt northwards.

The orthogneisses near Nakhang and on Choto are more leucocratic than those of Sigoyowo, and contain appreciable biotite and quartz. They may either be derived from an intrusion of intermediate composition such as a diorite or from basic rocks which have undergone metasomatism. In them the change seen in the Sigoyowo gneisses seems to have been carried a stage further, with alkali minerals (biotite, oligoclase) replacing calcic minerals (hornblende, calcic plagioclase), and quartz being introduced. The writer's opinion is that they are metasomatically altered basic intrusions, though this cannot be proved and they may have originated in rocks of intermediate composition.

These orthogneisses are seen under the microscope to be coarse biotitic and hornblendic rocks with lenticular patches of felspar which sometimes make up about half the composition of the rock. In thin section (for example specimen 26/904 from one mile west of Nakhang) they show a granoblastic texture. Biotite, a little green hornblende, untwinned oligoclase and quartz are the most common minerals. There are felsic pools crammed with epidote and clinozoisite, and white mica, representing the alteration products of a calcic primary felspar. A single aggregate of a dark brown strongly pleochroic mineral of high refractive index was identified tentatively as allanite.

A felsic patch in the same intrusion at Choto shows biotite in stellate clusters set in a pinkish buff felsic base. A thin section (26/958) shows that the felspars are filled with granules of epidote and clinozoisite prisms. Again quartz is abundant, often in larger granular pools and some white mica is present. One garnet crystal is present in the section.

The orthogneisses of this belt are picked up again on Saula and Mtelo. The exposures in the perennially damp heath-zone above 9,000 feet are very weathered and it is difficult to obtain a good picture of the rocks from the few small outcrops. There are some basic orthogneisses, as described by Glenday and Parkinson (1926, p. 605-6) from the summit of Mtelo at 10,400 to 10,500 feet. These writers concluded that the three specimens which they picked up were heavily saussuritized basic gabbros. They noted that they were garnetiferous. On the summit of Mtelo, however, there are some much more leucocratic rock types, and the only specimen (26/985) examined in thin section is distinctly granitoid, containing microcline and abundant quartz as well as pools of plagioclase containing epidote, clinozoisite and white mica. There is no hornblende present but biotite and muscovite are abundant. The microcline individuals are larger than the other components and appear to have been superimposed on a granoblastic texture, of which they contain inclusions. These granitoid patches in the Choto-Mtelo belt can be explained by invoking a subsequent potassic metasomatism or by assuming various original intrusions.

Searle marked a small "nose" of granite on the summit of Mtelo in a sketch map accompanying a monthly progress report, suggesting that the end of the Parek granite curved round and terminated there. This may be true, but since leucocratic rocks have

been found in the Choto-Mtelo belt further north, the writer prefers to mark the orthogneisses on Mtelo summit as the termination of that belt, though the alternative may be correct. Unfortunately the ground between Mtelo and Chachai could not be mapped in the time available. It is composed of densely forested slopes, harbouring a considerable population of buffalo, and the location of the few exposures likely to be found would take weeks of arduous work.

Lenses of Meta-gabbroic Orthogneisses near Tamau

There are several small lenticular bodies of hornblendic orthogneiss within the Tamau-Kunyao semipelitic gneisses near Tamau. Some are exposed in the bed of the Tamau River, three miles east of the road crossing, while others are exposed on the crest of the high ridge to the south of the river. In an almost unfoliated patch in one of the latter group of lenses, a diopsidic rock giving some clue to the parent rock was found. It is a coarse speckled black and cream rock, mafic patches and leucocratic patches being about equally distributed and each patch having a diameter of about half a centimetre. In thin section (26/768) cores of diopside surrounded by aggregates of green hornblende, biotite and garnet are seen, with a distinct annular pattern, garnet in some parts forming well-defined outside rings. These aggregates of mafic minerals are set in a base of equigranular interlocking crystals of sodic andesine some with straight boundaries and some patches of rather imperfectly developed granoblastic texture in which there is an appreciable amount of quartz. Apatite and magnetite are accessories.

There is a considerable resemblance between this rock and the metagabbro (26/537) described on page 29, which forms part of a gabbroic intrusion. It is considered possible that these sheets and lenses of basic and intermediate composition are derived from sills of gabbro closely related to the basic and ultra-basic rocks of the gabbroic suite already described. Specimens of dioritic orthogneiss (26/673) indistinguishable from those of Wyisa were collected from the Marich-Korpu schists near Akeriemet *duka* close to the belt of serpentine, pyroxenite, hornblendite, and epidiorite intrusions immediately west of Yutum.

South of the Tamau lenses the orthogneisses are attenuated and were not differentiated in the field. This arose partly as that part of the area was surveyed before the rock type had been clearly recognized and the orthogneisses could not then be distinguished from the country rock.

Orthogneisses of the Kenailmet Area

Orthogneisses of the same type outcrop on the Kenailmet Escarpment immediately west of the columbite workings. They appear to form several distinct bands. Petrographically they resemble the more basic Miskon type. A specimen of these basic orthogneisses (26/795) is seen in thin section to be composed of green hornblende, sodic andesine in interlocking twinned crystals, and prisms of a varicoloured green to colourless amphibole of the tremolite-actinolite series. The texture is coarsely granoblastic and there is a patchy distribution of the mafic and felsic components reminiscent of the metagabbro from the Suam River (26/537A, p. 29). There is a trace of biotite in the slide. This mineral is prominent in some bands of orthogneiss on the Kenailmet Escarpment, but hornblende is the dominant mafic component.

An isolated occurrence of orthogneisses was noted immediately west of the ford of the Malmalte River at Chepterr. It resembles an amphibolite in superficial appearance, but a thin section of the rock (26/1023) carries pale green diopside, epidote and green hornblende. The felspar is oligoclase and some quartz is present. Magnetite is present as an accessory. The rock appears to be derived from a basic or intermediate intrusion.

Emplacement of the Orthogneisses

The major bodies of orthogneiss appear to become progressively more leucocratic from west to east, that is upwards in the succession. There are exceptions but the general trend is noticeable. In contrast the minor lenses as represented by the amphibolites retain a constant basic composition. It seems probable that the higher major intrusions of orthogneiss come from magma that had commenced to crystallize at a lower level, and that some of the early crystallizing mafic components have been left behind. The further the magma had to travel the more chance there was that it would undergo metasomatism, including some exchange of constituents with the more siliceous and more alkaline geosynclinal sediments through which it passed. As these orthogneisses are all of sill form upwards penetration may well have been a slow process.

This concept would explain the varied composition of the Choto-Mtelo orthogneisses which contains both basic and granitoid rocks. The resemblance between the granitoid patches in these gneisses and the foliated granite—the rock from Mtelo (26/985) is indistinguishable in the field from some of the Parek granite—is also explained if the granite is the end stage in these two processes of differentiation and metasomatism leading towards the same end-point, but the major granites seem rather too substantial for such a hypothesis to be invoked. There seems to be a strong likelihood that the basic and intermediate major intrusions were derived from a single magma, which as a result of the two processes, differentiation and metasomatism gave rise to a series of igneous rocks ranging from gabbroic composition to intermediate composition, and localized granitoid patches in the latter.

(c) Acid Intrusions

The acid major intrusions are all foliated and are either syntectonic or pre-tectonic, most probably the latter (*see* p. 35). They are divided into—

(1) Foliated granites (and foliated granite sheet complexes).

(2) Granitoid orthogneisses.

Whilst there is little compositional and textural difference between the types, there is a slight difference in colour and texture apparent in the field, and the foliated granites show some traces of cross-cutting relations at their very sharp contacts. All trace of such contacts has been obliterated in the rather more deformed granitoid orthogneisses, which tend to grade into the enclosing schists.

(i) *Granites*

The major intrusions of granitic rocks of the Sekerr area have certainly undergone at least a major part of the deformation and metamorphism associated with the orogeny that affected the Basement System. They can be divided into two groups: —

1. Foliated granites in extensive homogeneous lenses.
2. Foliated granite and granite pegmatite sheet complexes.

Foliated Granite Lenses

Three major masses of foliated granite occur within the area, but two are parts of the same mass separated by a narrow synclinal infold at Sarmach. The two portions are collectively known as the *Parek granite*. The western and larger part forms a broad lentoid mass with abrupt terminations at north and south. The contacts are knife-sharp, this being especially well seen near the veterinary crush at Sarmach where a pavement-like surface forms the upper margin of the granite and is overlain by unaltered schists, whose foliation planes follow undulations in the granite surface. Such sharp contacts are always seen with these granites, and the foliation in the granites always follows that of the enclosing schist formation. This relationship suggests a possible mode of formation of the granite other than by intrusion. The Parek granite, however emplaced, appears to have followed a plane later distorted by fold movements.

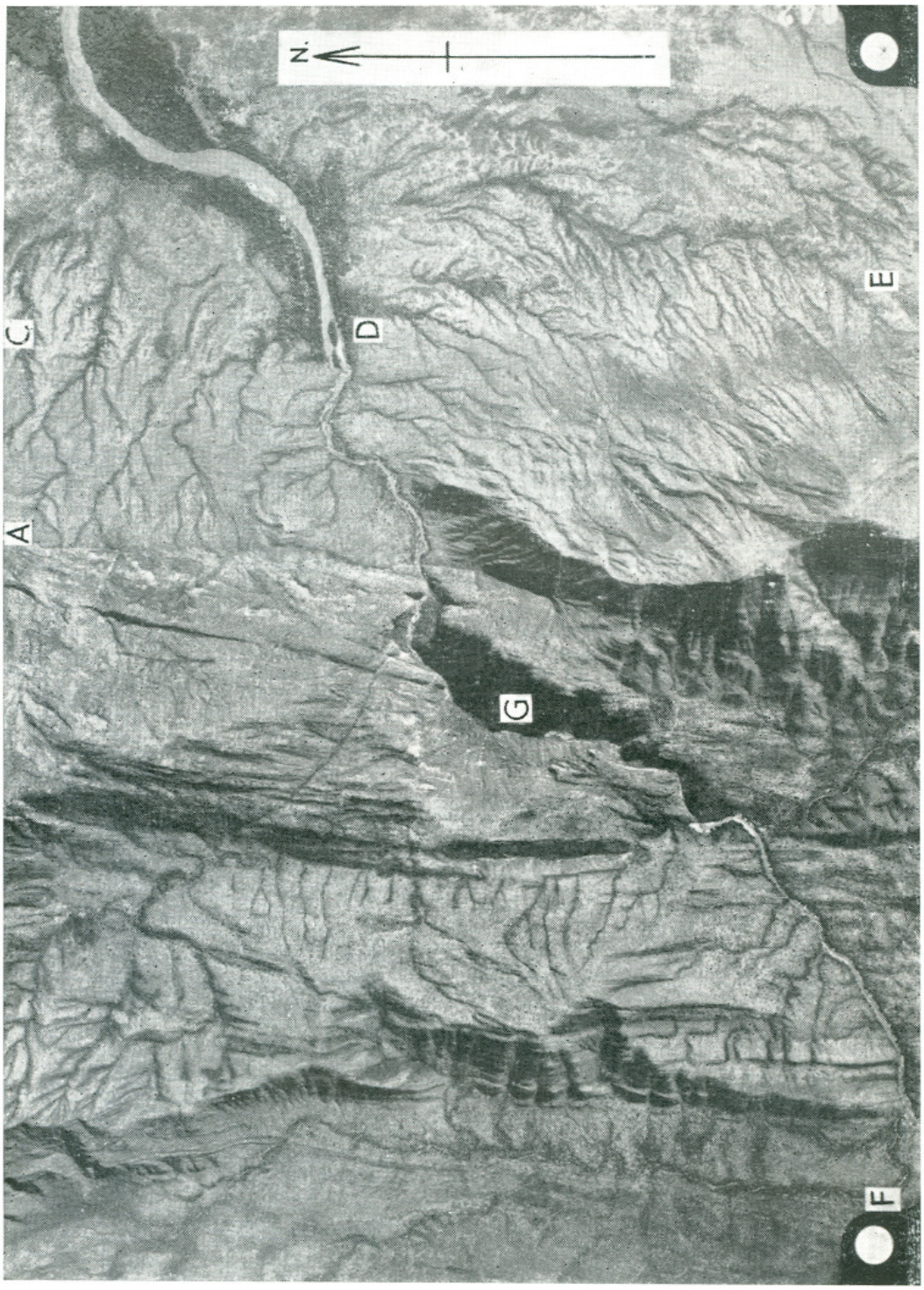


Plate I—Reproduction of a portion of an air-photograph (Contract 15/KE26/042) taken from 26,000 feet (scale approximately 1:55,000). The line of the escarpment (A-B) east of the Turkwell Gorge (G) is seen to be separated by a pediment of gneisses and schists from the fault-zone (C-D-E). To the east of the fault-zone is a flat plain void of exposure of gneisses, even in the bed of the Turkwell river. There is no marked feature along the actual fault-zone. The course of the Turkwell has been deeply incised between Korpu (F) and the foot of the escarpment, where a secondary fault is seen in the northern part of the photograph, 1½ miles west of D.



Plate II—(a) The western entrance of the Turkwell Gorge. The river flows between low banks before meeting the Turkwell granite, situated at the point where the person is standing. The gorge deepens until the walls stand nearly a thousand feet above the river, and ends abruptly at the eastern contact of the granite.



(b) The Turkwell river immediately below the gorge. In the left middle distance the river can be seen tumbling down a narrow rocky channel traversing the pediment of gneisses at the foot of the escarpment. The outcrop of the gneisses, which dip eastwards, can be seen in the foreground. The river changes abruptly to a wide mature stream at the western end of the nearest of the twin islands, and then meanders across the Masol plain. The line of the Turkwell fault is believed to pass immediately underneath the twin islands.

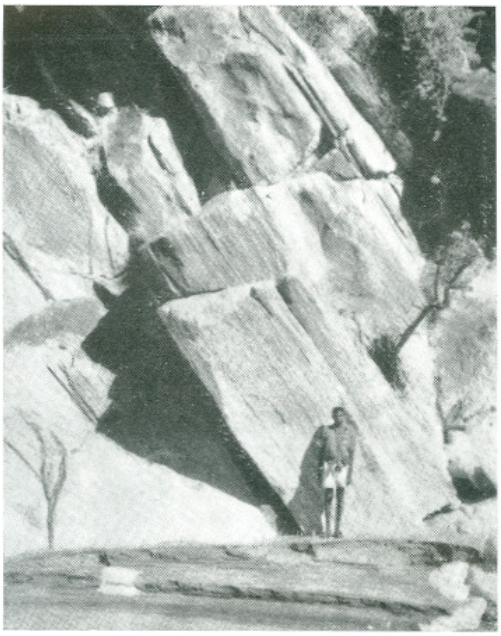
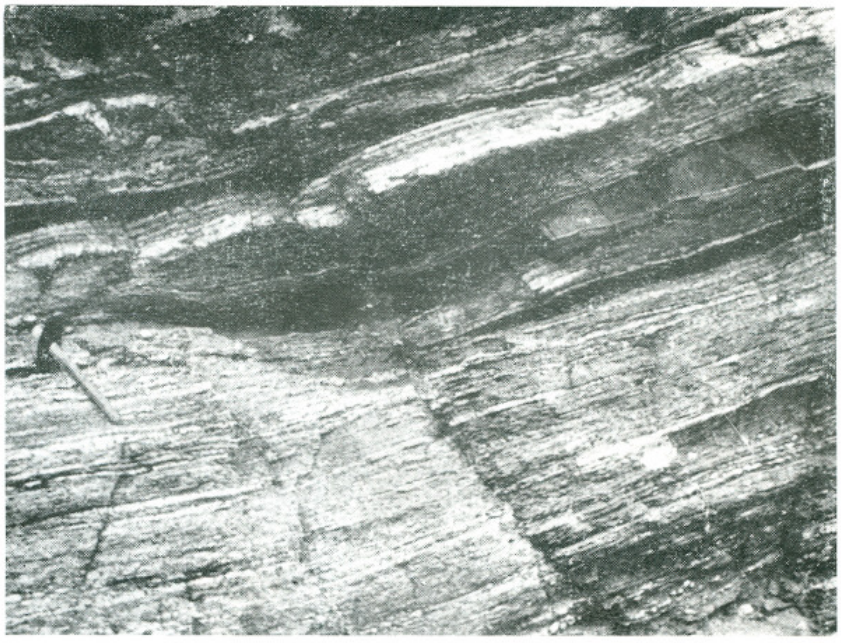


Plate III—(a) Rodded dolomitic limestone in the Iun gorge.



(b) Thin bands of plagioclase amphibolite in semi-pelitic flaggy gneisses of the Tamau-Kunyao formation, one mile due west of Futun. A minor fault displaces the body by about an inch. The semi-pelitic gneisses are invaded by numerous concordant or near-concordant stringers of augen, felspar and pegmatite.



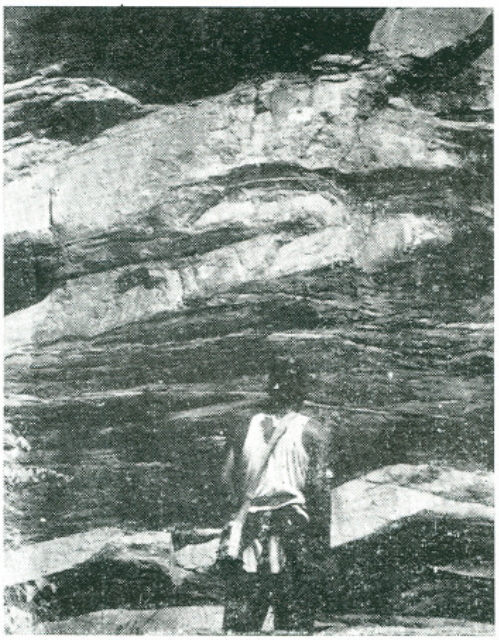
Plate IV—(a) Porphyroblasts of garnet in plagioclase amphibolite, Ikilip. This extremely coarse porphyroblast type forms a recognizable horizon close to the lower contact of the Chepunyal-Burgich formation and appears to owe its existence to some primary compositional characteristic.



(b) Agmatite, Marich pass. Amphibolite or hornblendite of the Marich-Korpu Schists has been invaded by the Marich granite, and preserved as massed xenoliths within a sheet of granite-pegmatite.



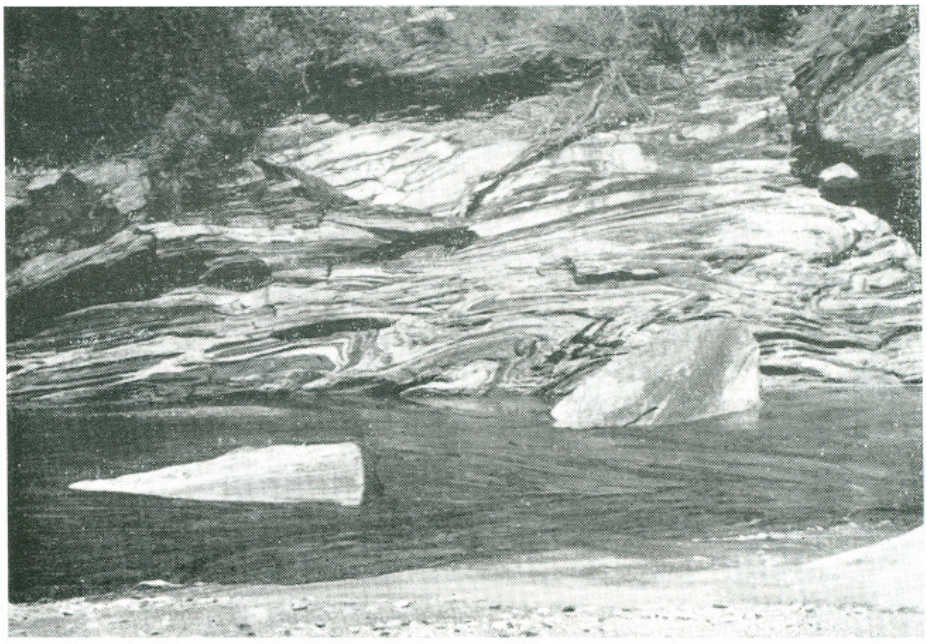
Plate V—(a) Granite pegmatite and granite sheets cutting compact hornfelsed schists of the Marich-Korpu formation in the contact zone of the Marich granite. Slight discordance of the sheets to the foliation of the schists is seen, and the cross-cutting relationship to an earlier minor granitic vein.



(b) A sigmoid fold in a granite pegmatite sheet on the east cliff of Maguich, near Orwa. The sheet cuts schists of the Marich-Korpu formation, which form one of the many country-rock enclaves within the granite sheet complex. The cross-cutting relationship of the granite to the schist country rock can be clearly seen.



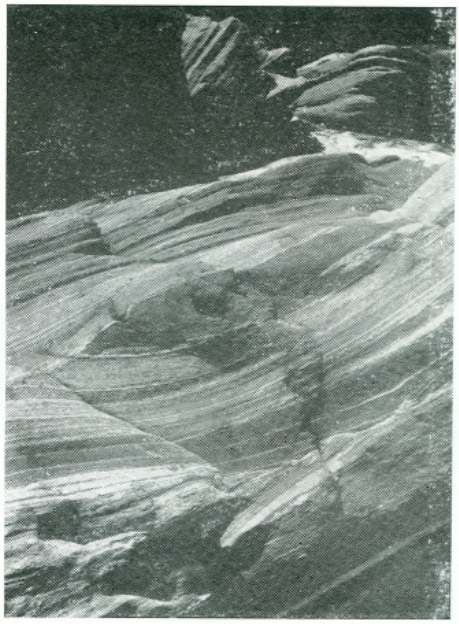
Plate VI—(a) Porphyroblast schist from the Aberit river, Nasolot. Such coarse porphyroblastic texture is common in the Marich-Korpu Schists. The photograph is natural size, and shows prismatic crystals of actinolite and a large garnet crystal, which have prominent quartz coronas and are set in a fine schist base. The porphyroblasts have no pronounced linear orientation.



(b) Minor structures in flaggy biotite gneiss of the Tamau-Kunyao formation, in the bed of the river, due west of the summit of Sogho. The folds and axial lineations plunge to the south-east.



Plate VII—(a) Recumbent isoclinal folds in flaggy biotite gneiss, with the middle limb sheared out, and pegmatitic stringers following the shear planes, Iun river, due west of Sogho summit.



(b) Lens of amphibolite in a semi-pelitic member of the Tamau-Kunyao gneisses, in the bed of the Iun river, due west of Sogho summit. The discordance of the enclosing foliation planes and the folded shape of the lens suggests that there has been considerable movement. The lens is about 12 inches in length.

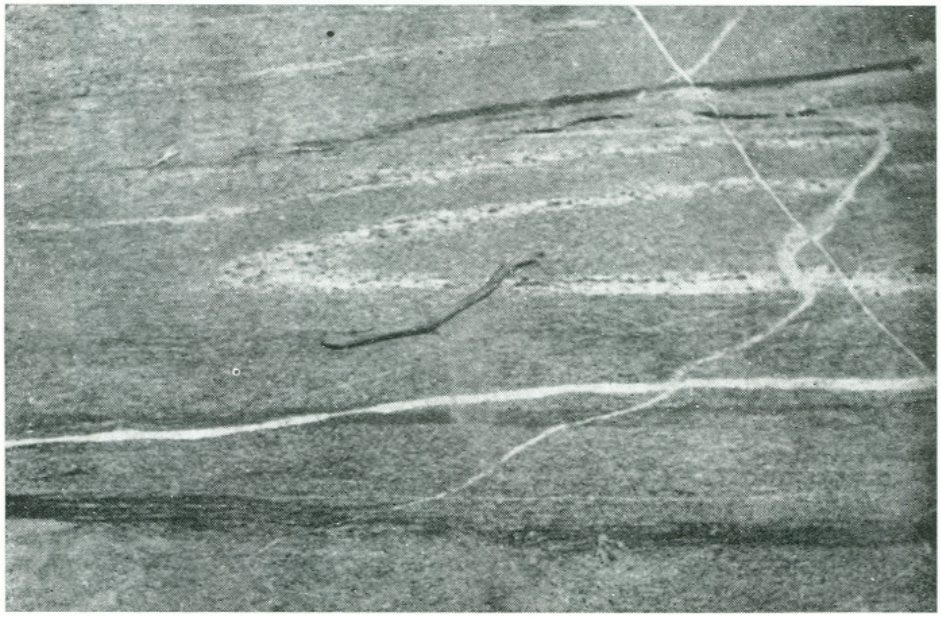


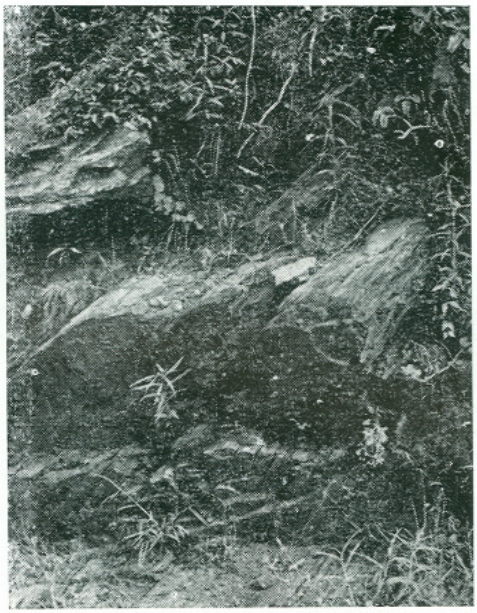
Plate VIII—(a) Recurrent isoclinical fold in hornblende-biotite schists, Iun river, at junction with Tamau river.



(b) Mullion structures in semi-pelitic gneisses (Tamau-Kunyao formation) plunging eastwards in a stream bed one mile west of Futun.



Plate IX—(a) Giant rodding structures in the Turkwell granite, Alamonges river. The rodding structures and related minor folds (seen in the top-centre of the photograph) plunge gently to the south and are typical of such north-south structures in the area.



(b) Mullions and rodding in amphibolite schists, Marich pass road, Akeriemet. The rodding shows the gentle plunge typical of north-south structures in the area. It is one of the rare north-south lineations recognized in the southern part of the area.



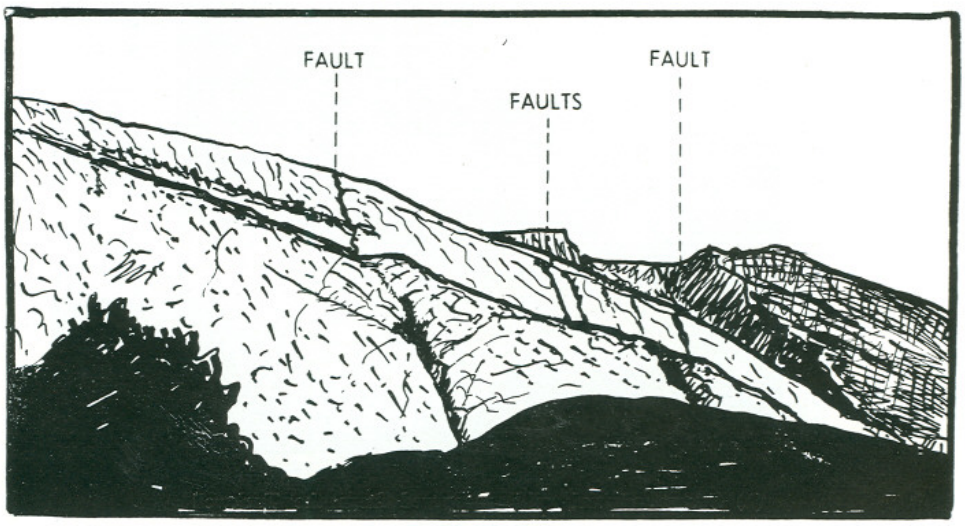
Plate X—(a) Amphibolite lens in semi-pelitic (Tamau-Kunyao gneisses), Nakuijit river. The gneisses have horizontal foliation while the amphibolite has pronounced vertical foliation, discordant to it. Such a discordance is not uncommon in the amphibolite lenses and it is thought that the lens has moved from its original position along a thrust plane which cannot now however be recognized. The lens is four feet high.



(b) Lenses of plagioclase amphibolite in semi-pelitic gneisses (Tamau-Kunyao formation) in a zone of intense isoclinal crumpling on north-south axes, Cheperapoi river. Discordant foliation planes in the lenses are seen left of centre. This is thought to be due to movement along shear-planes in a zone of intense deformation.



Plate XI—(a) Small fracture lines and faults on the west face of Kaptolomwa. Five lines of dislocation, all trending north-west, and throwing down to the south-west, can be seen on the hillside in the foreground and middle distance, while a larger dislocation trending in the same direction and throwing down in the same direction can be seen on the right hand side of the photograph.



(b) Interpretative drawing of Plate XI (a).



Plate XII—(a) Muscovite schists of the Basement System (sheared biotite gneisses) shattered into equidimensional fragments by later movement along the fault-zone immediately north-east of Riritian hill. The shattering is on the downthrow side of the breccia zone on Riritian hill itself, suggesting that this is possibly the moved block in relation to the rocks of the escarpment.



(b) Coarse alluvial gold, recovered from the Turkwell river at Korpu.



Plate XIII—(a) The recovery of gold from bouldery gravels in the Turkwell river at Korpu.



(b) Lens of massive chromite ore in sheared and foliated serpentine, Telot.



Plate XIV—Nickel mineralization (Telot). A boulder of nickeliferous serpentine in which the dark area is unmineralized grey serpentine, and is surrounded by a zone carrying stringers of green garnierite (showing as black selvedges to the white thread-like veins). The garnierite impregnation of this intermediate zone shows in the photograph as grey patches (green to the eye) between the veins. The light outer zone is a weathered brown crust from which all minerals but iron oxide have been leached out. (Photo about half natural size.)

The Parek granite is marked by an almost complete absence of pegmatitic material within it. There are some large dyke-like muscovite pegmatites near its margin at Nasolot (*see* p. 74) and these may be late phases of the granite, though this is not certain. There is also an almost complete lack of xenoliths. The granite is typically non-porphyritic or finely porphyritic. Specimens were collected from the main body at Sarmach (26/735) and from the smaller crescentic eastern body north-east of Nguruch (26/738). They are moderately coarse-textured, greyish cream rocks with no marked mineral banding, but showing well developed foliation. The first mentioned specimen contains small but distinct felspar phenocrysts, while the second is non-porphyritic.

In thin section specimen 26/735 is seen to be composed of a granoblastic aggregate of quartz and oligoclase with a pronounced directed texture, together with large crystals of muscovite, and magnetite altering to hematite. The muscovite has grown across the mosaic texture of the rest of the rock and clearly is a late mineral in the paragenesis. It is associated with patches of amorphous brown iron ore, which suggests derivation from biotite. Biotite is commonly seen in the Parek granite but amphibole is extremely rare. The thin section of specimen 26/738 shows microcline about three times as abundant as the oligoclase. There is a little myrmekite and a small amount of pink garnet. A few small crystals of biotite are also present.

The *Turkwell granite* forms an elongated lens and shows more or less apparently concordant contacts: it cannot be appreciably disturbed by folding, since it lies in a series of consistently eastward-dipping schists. It shows westerly foliation dips of about 75 degrees along its western margin near Nakhang, but elsewhere dips are eastward and correspond closely with those of the country rock. The mapping around the south end suggests a discordant contact, as certain bands in the enclosing schists appear to be cut off abruptly by the granite. The contacts are knife-sharp, pegmatite is not seen in the granite body, and there are few xenoliths. In appearance it closely resembles the Parek granite, and in thin section (26/877, from Nakhang) it shows similar petrography, with microcline dominant, oligoclase altering to saussurite and both muscovite and biotite, the former stained with iron oxide along the cleavage planes. The same rock was described by Glenday and Parkinson who noted the rather weak foliation in hand-specimen (1926, p. 606 and Plate XLI, 1).

The Turkwell granite near Nakhang is rodded (Plate IX (*a*)), leaving no doubt that it has undergone strong deformation.

In view of the lack of compositional variety, the absence of amphibolitic enclaves and the apparent cross-cutting relations of the Turkwell granite, the writer regards the Parek and Turkwell granites as intrusions that represent mobilized products of granitization, moved upwards into the schistose rocks overlying the zone of granitization. The evidence as to their mode of origin is not, however, as conclusive as one would wish.

Granite Pegmatite Sheet Complexes

There are five masses of foliated granite pegmatite sheets—the Marich granite, the Sogho granite, the Iun granite, the Ptoyio granite and the Kapiomet granite. Of these the Marich granite is by far the largest, forming an elongated more or less parallel-sided mass 15 miles long and two miles broad, and projecting southwards for a mile or so into the Cherangani area (Miller, 1956, map). The Sogho, Iun and Ptoyio masses are much smaller and lenticular in form, whilst the Kapiomet mass has an irregular outline. These masses are called sheet complexes as they consist of a concentration of concordant and slightly cross-cutting sheets of foliated granite characterized by abundant pegmatitic material. The granitic material far outweighs other rock types in proportion, but numerous screens of country rock between the individual sheets are always present. The mapped outlines of these inhomogeneous masses are arbitrary and were generally drawn at the point where granitic material is more abundant than other rock types.

There are many thin discreet sheets of sheared granite and pegmatite in the area, especially between the Ptoyio mass and the Iun mass, but they are too small and too numerous to be shown on the map. Narrow sheets of foliated granite and pegmatite are seen between the granite hills of Yutum and Sogho, becoming more numerous as the contact of each granite mass is approached.

An excellent section of the *Marich granite* is seen in the Marich pass where the road has been excavated along the steep wall of the defile. Between the shop at Akeriemet and the Marich granite there is a belt of extreme shearing, the schists being converted to soft rubble, in which fragments of contorted granitoid gneiss and pegmatite are enclosed. The western contacts on Yutum show the rubble zone and hornfels zone as at the Marich pass. On the Kaimat ridge the hornfels zone is seen but the rubble zone, if present, is obscured by soil cover. In the shear-zone in the Marich valley a band of compact massive hornfelsed schists invaded by undistorted and gently cross-cutting foliated granitoid and pegmatoid sheets (Plate V (*a*)) separates the rubble belt from the granite proper. The granite itself is seen to be composed of a complex mass of sheets separated by screens of country rock. Towards the centre of the granite hornblendic rocks in these screens have been disrupted to form agmatites (Plate IV (*b*)). The dip of the foliation and the individual sheets is steep at the west contact and becomes gentler to the east. At the Marich Bailey bridge the granite is in thinner sheets invading schists which are compact and to some extent hornsfelsed, and it is reasonable to assume that this is near the east contact, though the contact cannot be seen as it is obscured by superficial cover.

Enclaves of limestone and schist together with hornblendite and other basic rocks occur on Yutum, and the presence of the latter is fairly conclusive evidence that the granite intrusion post-dated the ultra-basic and gabbroic suite, since the petrography of the enclaves closely matches that of the hornblendite and epidiorite west of the granite contact (p. 32) and of the pyroxenite described by Miller (1956, p. 22). North of Yass another traverse of the granite yielded evidence of enclaves of the Marich-Korpu Schists, becoming more numerous to the east. Further enclaves are seen on Magaich, where one of the granitoid sheets is folded into a sigmoid flexure (Plate V (*b*)), leaving no doubt that these acid intrusions have undergone deformation.

There are many variants of foliated granitoid rocks seen within the Marich granite and bands of garnet-muscovite granitoid schist (e.g. specimen 26/676 from the Marich pass) are typical of the shear-zones. Garnets are common throughout the granitic body but are restricted to certain bands. There are some peculiar hybrids near to the hornblendic enclaves and agmatites containing coarse crystalline patches of epidote and hornblende (e.g. 26/649). A thin section of a typical well-foliated garnetiferous sheet from the Marich pass (26/679) shows, it is estimated, about 5 per cent garnet and biotite, while the leucocratic content is made up of felspar (70 per cent) and quartz (25 per cent). The felspar includes microcline and oligoclase in about equal proportion. There is a little of a prismatic mineral (possibly mica) of moderate refractive index and birefringence showing straight extinction situated close to the garnet. There are also some minute needles also showing straight extinction which are probably sillimanite. The texture is granoblastic but the variation in size of individual granules is marked. A coarser foliated pegmatoid sheet (26/656) has microcline about four times as abundant as oligoclase. The biotite has a few minute flakes of muscovite aggregated around it and there is evidence of cataclasis in the presence of microfractures traversing patches of crushed rock and infilled with muscovite.

The *Sogho granite* is the continuation of the belt of granitoid gneisses of Kalapot and Moribus described by Miller (1956, p. 20). It appears to the writer to be a swarm of intrusive sheets. Granitoid gneiss of the type described by Miller has not been recognized in the Sekerr area, unless it is what the writer prefers to call "foliated granite" (Parek and Turkwell intrusions).

It appears that the "granitoid gneisses" of Cherangani must pass northwards into mobilized phases as suggested by Miller (1956, p. 21), but whether these phases are cores of the granitized zone is open to doubt. It seems more likely they represent mobilized material squeezed upwards into a crustal level above the zone of granitization, which has not here been exposed by erosion.

The western half of the Sogho granite body is difficult of access and the mapping carried out was limited to the eastern half (the western boundary being put on to the map from air photographs). On the east side the field relationships match those of the Marich granite, sheets of foliated granite and granite pegmatite becoming more numerous until they form the greater part of the rock exposed. Bands of schist and limestone form numerous screens between these granite sheets. There are some cross-cutting contacts between the granitoid sheets and the schists.

The Sogho granite is a biotite granite with abundant pegmatoid material associated with it and its petrography appears to match that of the Marich granite.

A small lenticular body of foliated granite, the *Iun granite,* is cut by the Iun River immediately east of its confluence with the Tamau River. It is a pink highly deformed granitoid schist (26/500) and in thin section is seen to be composed of microcline, oligoclase and quartz with a little muscovite. Biotite is present in nearby exposures but is not seen in the slide.

Between the Iun granite and the Ptoyio granite there are numerous thin sheets of foliated pegmatite and granite. These are discrete and frequently show cross-cutting relationships. They must be considered as minor intrusions of mobilized granite which have been subsequently deformed. They are pink-tinted coarse foliated granites. Thin sections (26/411 from Tamau, 26/434 from Chepunyal, 26/463 from Sergoi and 26/498 from Kokwaper) all show microcline, oligoclase and quartz. Muscovite is more abundant than biotite, and all the specimens show evidence of strong deformation. Except for the grouping seen at this locality these minor intrusions cannot be distinguished from the scattered foliated microgranite and pegmatite minor intrusions referred to on page 43.

The *Ptoyio granite* is a lenticular mass. The field relationships are similar to those described from the Marich and Sogho granites, the granite being composed of a closely-spaced swarm of sheets, which are mostly concordant to amphibolite country rock, but cross-cutting relationships can be detected on close field examination. Pegmatoid material is not uncommon and the mineral assemblages are similar to those already described.

The *Kapiomet granite* forms the ridge of Kapiomet, which projects northwards from Tarakit summit and is composed dominantly of granitoid sheets. These tend to follow the foliation of the amphibolite country rock but cross-cutting relationships are frequently seen. The area in which granitoid material predominates has a Y-shaped outline. The eastern arm of the Y is formed by a gentle north-westerly-dipping concordant sheet of granite pegmatite which appears to be tapering as it passes northwards into the Karasuk area. The western arm is formed by a series of easterly-dipping sheets running up to Sinchulul in the Karasuk area, where the granitoid rock forms a towering rounded feature. The southern part of the granite—the stem of the Y—is difficult to delineate accurately owing to the precipitous topography, but the area in which granitoid rocks predominate has been roughly outlined. There are some small lenses of similar granite pegmatite in the escarpment west of Kenailmet, and the granite may taper and curve round with the strike of the amphibolites, and continue as a series of minor lenses. There are many screens of amphibolite, biotite gneiss, and limestone within the Kapiomet granite. It is a pinkish or cream-coloured biotite granite, showing well marked foliation. Microcline and oligoclase are both present in varying proportions. A white pegmatoid foliated granite from below Tarakit summit in thin section (26/839) shows oligoclase, quartz and a little microcline. Biotite is abundant in the hand-specimen.

(ii) *Granitoid Orthogneisses*

The granitoid orthogneisses are concordant sheets of acid gneiss within the Marich-Korpu Schists. There are two main belts:—

(1) The Murkorio belt.

(2) The Cheptaram belt.

Some small bands of similar gneiss are also seen in the Choto-Mtelo basic orthogneiss belt between Korpu and Nakhang. There are similar sheets at the Kotit Pass and near the top of the Sergoi Escarpment.

The granitoid orthogneisses are all biotite, microcline and oligoclase-bearing granitoid gneisses. Epidote is not uncommon, but may be derived by contamination with the enclosing calcareous schist country rock.

The Murkorio Belt

A thin belt of biotite-microcline orthogneiss can be traced from Ukwaram over Morulem and Tingiri summit to Murkorio, where it widens out and forks into several distinct bands. The same rock can be traced on Wamgurigwa, and on the west side of Kameghen where it has tapered to a series of narrow discontinuous lenses. It is not seen south of Kameghen. The belt is almost entirely composed of coarse pinkish buff biotite schist, showing prominent yellowish lentoid felspar phenocrysts. Muscovite is also common. A patch of hornblendic orthogneiss was seen within this granitoid orthogneiss on the south-east slope of Karel, but it is otherwise strikingly uniform in composition. It has the form of a concordant sheet.

In a thin section of a specimen (26/907) from the Seruach Valley, the rock is seen to be composed of an irregular aggregate of sub-angular crystals of microcline, quartz and oligoclase—the last much subordinate to the microcline, the granules of which are in general larger than those of the other minerals. Muscovite, and a few biotite flakes are aligned along the foliation planes. A little magnetite is also present.

A much more highly sheared example is seen in specimen 26/876 from Korpu, which has well-developed banding of quartz and felspar granules separated by folia of muscovite with a little biotite. The felspar, much of which is very strained, is dominantly microcline, though some oligoclase is present. Glenday and Parkinson (1926, p. 601) came to the same conclusion about the intrusive origin of this rock. They described a specimen from the Bino Gorge and calculated a chemical analysis from micrometric determinations. They considered it to be derived from the same magma as the Turkwell granite, but in the writer's opinion though they are very similar there is some reason to believe that the Murkorio intrusion may be slightly older than the Turkwell granite.

The Cheptaram Belt

A belt of granitoid gneisses extends between the Sergoi River and the Ninyit River, forming a marked cliff feature at the crest of the Cheptaram Escarpment. This gneiss, which is white to buff and has pronounced foliation, is identical in type with the Murkorio gneiss. Micas, both biotite and muscovite, are abundantly concentrated along the foliation planes. Phenocrysts are not as common as in the Murkorio gneiss.

In thin section, specimen 26/992 from the Ninyit River is seen to have a rather fine highly foliated texture composed of granoblastic microcline, oligoclase and quartz. together with abundant muscovite and a little biotite along the foliation planes. The plagioclase is sometimes twinned, and the microcline occurs as porphyroblasts, showing strain effects. Epidote granules, grains and lenses are scattered through the rock.

In the Sergoi Valley the belt of acid gneisses appears to pass southwards into several minor bands. Similar acid gneisses are seen in lesser bands at Kotit and on the Sergoi Escarpment.

(3) Minor Intrusions into the Basement System

(*a*) *Pegmatites and Microgranites*

A great number of small bodies of pegmatite and microgranite have invaded the gneisses and schists of the Sekerr area. They can be divided into two groups:—

(1) Thin segregations, mostly concordant to the foliation, often associated with strings of augen felspar (Plate III (*b*)).

(2) Larger sheet-form bodies with numerous irregular and cross-cutting contacts.

The members of both these groups are dominantly biotite or biotite-garnet pegmatites, are often folded, and from the field relations and degree of directed texture are clearly syn-orogenic or pre-orogenic segregations and intrusions. They contain microcline and plagioclase and are associated with minor intrusions of finer-textured microgranite. The pegmatite bodies are petrographically indistinguishable from the sheet complexes forming the large granites of Marich, Sogho, etc., and a close relationship must exist between the larger groups of acid intrusions and the scattered minor bodies.

There are two further groups of intrusions which are characterized by a much more pronounced dyke form and less well developed directed textures:—

(1) *The Nasolot Pegmatites.*—Muscovite-garnet pegmatites with plates of white or pale pink muscovite, up to eight inches in diameter, which form a swarm near Nasolot and Sarmach. They contain white felspars which are predominantly plagioclase. Further details are given on page 74.

(2) *The Kenailmet Pegmatites.*—These carry plates of green muscovite and resemble the Sebit pegmatites of the Cherangani area (McCall, 1957A). They contain a suite of minerals similar to those of the pegmatites of Nacholo (Baragoi) and Tura (north of Nanyuki)—tourmaline, columbite, samarskite, green fluorite, xenotime, magnetite and garnet are present in prominent crystal growths, while biotite and vermiculite occur in the form of small flakes along the margins. Corundum has also been reported from Kenailmet. The felspar is predominantly microcline. They form a series of north-south orientated zoned bodies with complex structure cutting abruptly across the folded amphibolites and limestones of the Burgich syncline. At the time of writing three mineralized dykes have been located. Further details of the Kenailmet occurrences are given on page 71.

Similar muscovite pegmatite dykes have been noted near Lossom a few miles south of Kenailmet, south of Kapitero, near the Suam river north-west of Merul and on the ridge running east from Taptolin. No significant mineralization other than mica and tourmaline has, however, been seen in them, and the mica crystals are small. A prominent pegmatite on the Sergoi escarpment carries tourmaline, garnet and large flakes of green muscovite. It is red stained owing to hematitic inclusions in the quartz and felspar. No large mineral-bearing body has so far been located at Sergoi, but the occurrence clearly forms a link between the Sebit pegmatites of the Cherangani area (McCall, 1957A) and the pegmatites of Kenailmet.

Minor intrusions of microgranite were reported by Hitchen (1942) associated with the Nasolot pegmatites and a small boss of microgranite appears to continue the line of the largest of the Kenailmet pegmatites northward. It is a pink, fine-grained, foliated rock with abundant small aligned flakes of muscovite. The presence of foliation suggests that the Kenailmet pegmatite suite has possibly undergone some orogenic deformation, but that the coarse massive texture of the pegmatites has not had a preferred orientation impressed on it like the finer rocks. No crushing was noticed but it might be recognized on more detailed examination. A thin section of the microgranite (26/808) shows that microcline is the only felspar present in any notable quantity.

(b) Quartz Veins and Epidote-bearing Veins

Veins of quartz varying from an inch or less in thickness to dyke-like bodies several feet wide are numerous throughout the area, and are considered with the minor intrusions for convenience. In the main the larger ones are unrelieved masses of white quartz and what the prospector calls "hungry looking". In two cases copper minerals have been found in small quantities in such quartz segregations and in one case gold (pp. 70-71), but these occurrences are of purely academic interest. Other types of quartz veins seen are quartz-pyrite veins (in the Iun river), quartz-ilmenite veins (on the west slope of Wysia), and quartz-chlorite-hematite (specularite) veins which are common near the Parek and Turkwell granites. Quartz-magnetite veins are common throughout the area, but there is a marked development of foliated sheet-like bodies of quartz and magnetite associated with the Kapchok gneisses. Segregations of garnet and an unusually pleochroic epidote (26/822) with subsidiary quartz or garnet, diopside and minor quartz (26/785) also accompany these quartz magnetite bodies. Quartz-tourmaline veins are common on Sogho, Telot and in the Endoo valley. They are also seen between Tingiri and Terekondich.

Foliated flaggy quartz bodies exposed in the Tamau river about two miles east of the Chepunyal road drift are believed to be sheared concordant quartz segregations rather than quartzites, as there is no suggestion of clastic texture and they have a very white colour. There is a similar occurrence of foliated quartzose flags east of the Marich Bailey bridge. Again evidence of clastic texture is lacking, and the white colour and uniformly coarse granulose texture suggest derivation from a large vein of quartz. These quartz bodies contain wisps of green hornblende.

Minor epidotic vein segregations associated with quartz veins are particularly noticeable on the ridge connecting Taptolim with the escarpment above Kabomba, near Nakuijit, in the Marich pass and between Nakhang and Korpu. These epidote-rich rocks are of hydrothermal origin. Specimen 26/878 from a large knot of epidote-rich rock one mile west of Nakhang, in the bed of the Turkwell river, is representative. In hand-specimen coarsely crystallized carbonate and chlorite aggregates are associated with finely crystallized epidote and quartz. Epidote forms the greater part of the rock. In a thin section finely granular epidote, subordinate carbonate, quartz, felspar and a few crystals of muscovite were found—there being no chlorite in the part of the specimen sliced. The epidote-rich segregations near the Marich pass and Nakuijit are essentially similar in texture and mineral content.

2. Tertiary Rocks

The great span of some five hundred million years between the Precambrian and the Tertiary eras is not represented by any rock formations in the Sekerr area, and the only traces of any kind dating from this time are the high-level erosion surfaces (*see* p. 11), which provide clues to the physiographic history of the continental shield during this period.

Tertiary rocks are but meagrely represented in the area and there are no Tertiary sediments, though sediments bearing plant remains occur on Sagat (Searle, 1952, pp. 51-52, and p. 1 of this report), five miles west of Karoitangole (*see* Fig. 1). Sediments bearing fossil wood also outcrop on the Masol plain eight miles east of the Marich pass and five miles east of Nasolot. All these sediments are dominantly grits and material of non-volcanic origin, and they have been tentatively referred to the Miocene—in the case of Sagat by Searle and in the case of the Masol sediments by Mason and Gibson (1957, pp. 17-24) who correlate them with the Turkana Grits.

(1) Tertiary Volcanic Rocks

The Tertiary volcanic rocks consist of two small nephelinite plugs at Sabirit near Nakuijit, and on the east bank of the Suam river, south of Nakuijit, a few basalt dykes near the Kunyao-Kacheliba road, and an altered dyke in a fault-zone running along the bed of the Kokoten river.

Sabirit is a well-marked conical hill some 200 yards in diameter, composed of dark green nephelinite carrying prominent phenocrysts of greenish black pyroxene. The contact with the surrounding gneisses is abrupt but is poorly exposed and no distinct evidence of chilling can be recognized. In thin section (26/1000) the rock is seen to be composed of phenocrysts of light green and faintly pinkish pleochroic augite set in a granular base of smaller individuals of a similar pyroxene and nepheline. There is a considerable magnetite content in the form of opaque crystals and granules. The rock from east of the Suam river is a mela-nephelinite (26/558). It does not form any conspicuous feature, but it is thought to be a small plug rather than a dyke. It is vesicular, the vesicles being infilled with zeolite and carbonate.

A compact black dyke-rock (26/848) was collected from the bed of the Kokoten river in the fault-breccia zone. It is seen in thin section to be composed of neutral-coloured non-pleochoic augite and olivine together with a confused aggregate of alteration products. There are some criss-cross palimpsests suggesting felspar. The rock is probably a very altered basanite but it is too altered to be identified. From the situation in which it was found, it is believed to be a Tertiary dyke intruded along the fracture-line of the Kokoten fault. It is cut by a set of closely spaced micro-fractures.

A few small dykes of compact black basalt or basanite cut the gneisses of the Tamau-Kunyao formation in the vicinity of Nongalitaba and Moruangai. The dyke near Nongalitaba shown on the map is never more than a foot or so in width. The presence of dykes on Moruangai is indicated by float specimens picked up by the writer. Searle also collected a specimen of basalt from this ridge, though whether it was *in situ* or float is not known.

The compact rock from near Nongalitaba (26/997) is a dense fine-textured feebly porphyritic rock, greenish black in colour. Specks of water-clear felspar can be detected with the naked eye. In thin section augite and a little olivine, together with black opaque iron ore are seen to be set interstitially to prisms of well-twinned sodic labradorite (An_{52}). The rare small phenocrysts are felspar and augite. There is a little nepheline present. The rock is a basanite.

(2) Fault-Breccias (of Probable Cainozoic Age)

Fault-breccias derived from the older metamorphic rocks occur at Orwa and Riritian along the line of the major faults bounding the Masol plain on its west side. They are impregnated with iron oxides, and thus readily recognized by their brown colour.

Pyritic breccias are also seen along the Kokoten fault. These breccias are, in the writer's view, probably of Tertiary age. They were formed during fault movements preceding the end-Tertiary erosion cycle—the end-Tertiary (Masol) plain extends across the breccia zone with no topographic feature disrupting the plain. The fault may, however, be older than Tertiary.

At Riritian, where the best exposure of breccias can be seen, and near Nasolot a great deal of iron-staining affects the amphibolite gneisses. Riritian hill itself is composed of brown iron-stained breccias of various types, all showing a distinct planar structure dipping at 30° to 60° north-east, concordant with the dip of the Basement System gneisses and schists. The most common type is a rough-textured brown to

cream-coloured breccia (26/748) seen under the microscope to consist of angular fragments of gneiss, showing cataclastic textures and set in a very fine matrix of spongy iron oxides. Some seams of white mica fill cracks. Contrasting with this angular type of breccia is a laminar ironstone (26/745) which consists of narrowly spaced lentoid laminae of finely milled iron-stained material, streaked brown, yellow and cream. This rock appears to be mylonitic. A third type of breccia consists of a brown slightly carious reddish-brown porcellaneous rock. In thin section the fine porcellaneous material is seen to be spongy and composed of iron oxides. Some of the cavities are filled with radial aggregates of silica. This rock is certainly an alteration product and it is difficult to say whether it was derived from a tuff or a clay gouge. The latter seems more likely. Below Riritian hill highly sheared derivatives of Basement System schists are exposed (26/752, 26/753), bleached and shattered to such an extent that they break off into minute angular fragments (Plate XII (*a*)) on being touched. In thin section the schists are seen to be composed of highly sheared mosaics of quartz, felspar and mica interlaced with cracks filled with white mica and minute siliceous fragments. Iron-staining similar to that seen near Riritian and Nasolot is also seen north of Lokwien, in amphobolite bands in the gneisses and schists, and provides confirmatory evidence that the faulting zone continues northwards from Riritian to the Turkwell escarpment.

North of Orwa, half a mile east of the road, there are small hills of cataclastic breccias composed of angular fragments of white and brown-stained sheared granite set in a grey matrix of finely milled siliceous fragments (26/1012). South of Orwa, immediately east of the road there are some small hills of cream-coloured cataclastic breccia (26/724) composed of fragments of quartz and oligoclase in a very fine matrix of siliceous crush fragments, showing some iron-staining. There are some veinlike segregations of carbonate cutting these breccias.

Immediately east of the Marich Bailey bridge there are some white foliated quartz rocks, carrying a little green amphibole (26/707-8). They have the appearance of a quartzite flag, but are unusually white and coarse textured, and are more probably sheared quartz veins. They are intensely shattered, and provide evidence of the proximity of the Sekerr fault to the eastern end of the Marich pass.

A breccia (specimen 26/849) from the Kokoten river is a pink, grey and green rock, speckled with pyrite and traversed by an irregular network of quartz stringers. In thin section cataclasis is apparent, and biotite has been converted to chlorite, indicating retrograde metamorphism localized in the fault-zone.

3. Pleistocene and Recent Deposits

The superficial deposits of the area include:—

Stony soils, forest soils, alluvial soils.
River gravels.
Calcareous cemented boulder conglomerates.
Murram and laterite.
Calcrete.
Boulder screes.

The river gravels occur as patches of reddish gravel with sparse stony content and abundant calcareous concretions. They are of limited extent and were not differentiated except along the lower course of the Marun river where they form a series of low flat hillocks. They are also of widespread occurrence along the Suam and Kanyangareng and their tributaries. Searle reported a series of river terraces along the Tamau river, but these were not investigated by the writer.

Calcareous cemented boulder conglomerates are found in some of the deeply incised valleys, near to limestone outcrops in the Basement System rocks. They are particularly noticeable in the Iun and Sergoi river beds (26/456).

Murram is of restricted occurrence near Kacheliba, Nakuijit and near Lossom. It forms thing cappings on biotite gneisses and it is of no economic significance. Calcrete cappings are also occasionally found near limestone bands in the Basement System. Stony and lateritic soils cover the gneisses of the lowlands, while forest soils occur in the forested areas on the high ground. Alluvial soils occur in small flat areas near the bigger streams, but such soils suitable for cultivation are scanty except along the Malmalte river.

Artifacts

Piles of scrapers and flakes shaped out of obsidian, mauve "cherty" lava (rhyolite?), and quartz are common along the line of the old K.A.R. wagon-road. At Lossom and near Kunyao they are particularly numerous.

4. Metamorphism

The metamorphism of the Basement System and associated rocks can be divided into three processes (Fig. 6):—

(1) Regional metamorphism.
(2) Thermal metamorphism.
(3) Retrograde metamorphism.
(Late low-temperature effects.)

The description of the metamorphism that follows must be considered as no more than an outline. Much more petrological study is called for in this field.

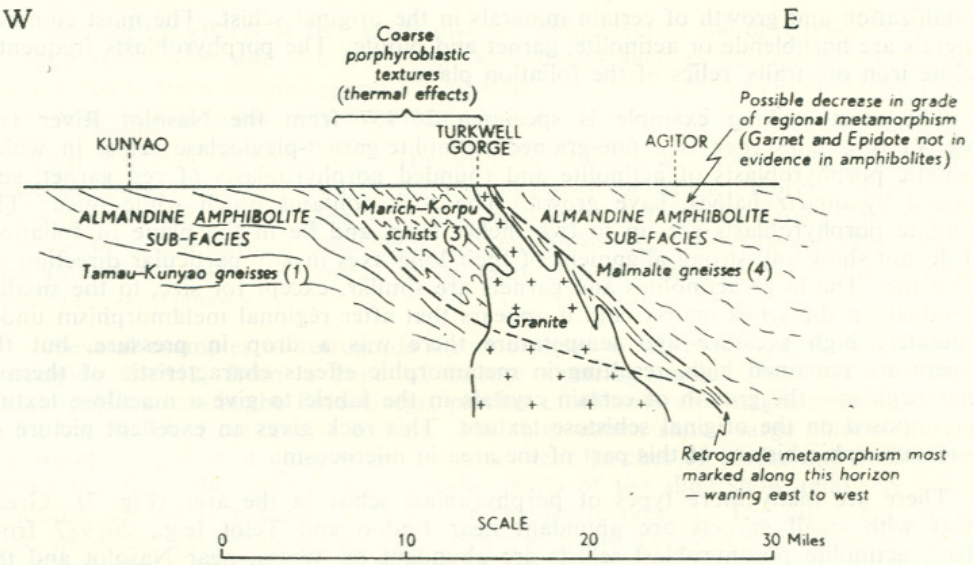


Fig. 6—Diagram illustrating the relation of regional, thermal and retrograde metamorphic effects to the structure of the Sekerr area. An increase in zonal index-minerals from garnet to sillimanite can be recognized in the semi-pelitic rocks from west to east.

Regional Metamorphism

The gneisses and schists of the Sekerr area include little pelitic material and Barrow's zonal classification based on index material in pelitic rocks is only of restricted use in determining the grade of regional metamorphism. A more recent basis for classification of regional metamorphism was suggested by Eskola (1939) and elaborated by

Turner (1948), a revision being made by Fyfe, Turner and Verhoogen (1958). According to Turner's (1948, p. 87-88) classification the metamorphosed basic rocks of the area might well fit into the almandine-diopside-hornblende subfacies of the amphibolite facies. The mineral assemblages seen closely follow those listed by Turner. The expanded system propounded by Fyfe, Turner and Verhoogen includes an almandine-amphibolite facies, corresponding to the high-grade zones of progressive regional metamorphism of Barrovian type (middle of the garnet zone, staurolite, kyanite and sillimanite). Almandine-bearing amphibolites are restricted to this facies, though many of the amphibolites in the facies contain no almandine; this condition is matched throughout the Sekerr area, where almandine-bearing amphibolites are widespread (except in the north-east corner) but are associated with almandine-free amphibolites. The facies contrasts with the lower-grade green schist facies, of which the epidote-amphibolite facies is considered to be a sub-facies by these writers, in the absence of albite. Albite was not found in any rocks from the present area.

The almandine-amphibolite facies is believed by Fyfe, Turner and Verhoogen (p. 228) to be representative of higher pressure than the green schist facies. Hydrous silicate (amphiboles, micas) predominate, indicating high water pressure.

Rocks of this facies commonly grade into migmatites, veined with granitic minerals (indicating temperatures up to 700° C.), but in the Sekerr area such a gradation does not seem to be developed to any significant extent.

Thermal Metamorphism

Unusually large porphyroblasts are of widespread occurrence in the Marich-Korpu Schists. The rocks are essentially fine-textured schists in which there has been a recrystallization and growth of certain minerals in the original schist. The most common minerals are hornblende or actinolite, garnet and biotite. The porphyroblasts frequently enclose iron ore trails, relics of the foliation planes.

The most striking example is specimen 26/957 from the Nasolot River (*see* Plate VI (*a*)). This rock is a fine-grained actinolite-garnet-plagioclase schist in which prismatic porphyroblasts of actinolite and rounded porphyroblasts of red garnet, surrounded by quartz haloes, have grown. The rock contains much white mica. The actinolite porphyroblasts are up to two inches long, and lie in the plane of foliation, but do not show any strong alignment of their long axes in any particular direction on that plane. The large actinolites and garnets are similar, except for size, to the smaller individuals in the schist matrix, and it appears that after regional metamorphism under moderately high pressure and temperature there was a drop in pressure, but the temperature remained high, resulting in metamorphic effects characteristic of thermal metamorphism—the growth of certain crystals in the fabric to give a maculose texture superimposed on the original schistose texture. This rock gives an excellent picture of the metamorphic history of this part of the area in microcosm.

There are many more types of porphyroblast schist in the area (Fig. 7). Green schists with small garnets are abundant near Endoo and Telot (e.g., 26/987 from Sabai); actinolite porphyroblast schists are abundant on Wyisa, near Nasolot and the Turkwell Gorge (e.g., 26/702, Wyisa and 26/872 near Nakhang); hornblende porphyroblasts are common at Nakhang, in the Sergoi Valley and near the Iun Gorge (26/612). Large pinkish brown phlogopite porphyroblasts are of common occurrence in the Marich-Korpu Schists.

Retrograde Metamorphism and Late Low-temperature Effects

The Marich-Korpu Schists and the Malmalte Gneisses close to them show considerable evidence of retrograde metamorphism. The schists appear to be rocks that have reached a grade of regional metamorphism equivalent to the rest of the area, but have later undergone shearing.

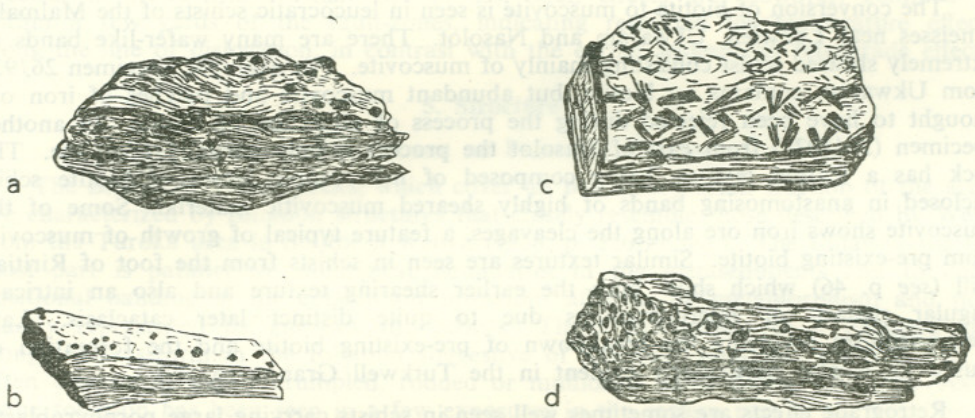


Fig. 7—Typical porphyroblast schists from the Marich-Korpu Schists:—

(a) Specimen 26/505, Iun gorge. Garnet knots in garnet-biotite schist. Note the pushing out of the foliation planes around the porphyroblasts, which are about three millimetres diameter.

(b) Specimen 26/987, Sabai. Green schist with small well-formed red garnets (one millimetre diameter), here grown across the foliation planes.

(c) and (d) Specimen 26/612, Iun gorge. Hornblende porphyroblast schist. The porphyroblasts grow obliquely to the dark amphibole rich bands in the schist, but there is also some displacement of the banding due to the pushing aside by the growing crystals.

Among the effects of retrograde metamorphism seen is the development of chlorite from garnet and biotite. Certain other relationships such as the apparent development of muscovite from biotite suggest a similar process, but cannot be considered as effects only seen in retrograde metamorphism.

Chlorite (together with muscovite) appears to increase in development as the visible shearing effects increase towards the north end of the Marich-Korpu Schists outcrop. This development is well seen around Korpu and the Turkwell gorge. This suggests a strong connexion between retrograde metamorphism and late shearing. The retrograde metamorphism does not appear to be related to the faulting along the Sekerr and Turkwell escarpments.

Several examples of retrograde metamorphism were recognized in thin section. In specimen 26/912, from a zone of intense shearing immediately east of the talc-anthophyllite lens in the Bino Gorge, patches of chlorite and magnetite have developed in a biotite schist containing garnets. The thin section shows large chlorite aggregates in which the plates of chlorite enclose small relic patches of biotite and zoisite crystals preserved from the original schist. Other parts of the slide show relatively unaltered biotite-epidote-zoisite schist, with a little muscovite present. The outcrop from which the specimen was taken is six miles from any major fault—a fact which confirms the lack of relation between the widespread retrograde metamorphism and the fault movements along the Turkwell Escarpment.

A good example of retrograde metamorphism is seen in specimen 26/945 from Tingiri summit. The rock, a puckered muscovite schist, carries skeletal relics of kyanite sparsely distributed through the thin section. These kyanite crystals are surrounded by pools of later crystallized muscovite. In another specimen (26/914) from Nyaparei, kyanite is present in a virtually unaltered state, but the biotite is partly converted to chlorite. In yet a third specimen carrying kyanite (26/865 from the Kianantuing River) much of the muscovite and chlorite present appears to be derived from the kyanite and biotite.

The conversion of biotite to muscovite is seen in leucocratic schists of the Malmalte Gneisses near Lokwien, Ukwaram and Nasolot. There are many wafer-like bands of extremely sheared schist consisting mainly of muscovite. For example, specimen 26/927 from Ukwaram contains no biotite, but abundant muscovite and patches of iron ore thought to have been rejected during the process of alteration of biotite. In another specimen (26/1028) from east of Nasolot the process is only partially complete. The rock has a lentoid texture, being composed of microscopic lenses of biotite schist enclosed in anastomosing bands of highly sheared muscovitic material. Some of the muscovite shows iron ore along the cleavages, a feature typical of growth of muscovite from pre-existing biotite. Similar textures are seen in schists from the foot of Riritian Hill (*see* p. 46) which show both the earlier shearing texture and also an intricate angular pattern of micro-fractures due to quite distinct later cataclasis. Late metamorphism involving the breakdown of pre-existing biotite and the formation of muscovite is also particularly evident in the Turkwell Granite (p. 39).

Retrograde effects are sometimes well seen in schists carrying large porphyroblasts. In specimen 26/892 from the Alamonges River, south of Nakhang, the development of chlorite around a large garnet porphyroblast is attributed to late shearing which caused the rotation of the porphyroblast (Fig. 8). The porphyroblast is unbroken, which suggests that the temperature at which this late movement took place was not so very low. In specimen 26/957 (Plate VI (*a*)) there is much late muscovite extending into the quartz coronas of a garnet and the amphibole porphyroblasts, indicating its formation during a late stage of metamorphism under low temperature conditions.

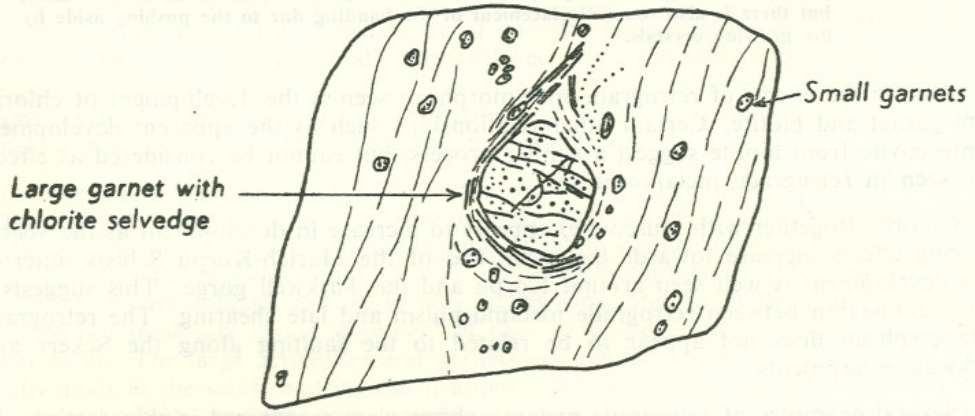


Fig. 8—Garnet porphyroblast schist from the Alamonges river, specimen 26/892. Two generations of garnet are seen, the second much larger than the small garnets scattered through the fine schist. The large garnet shows evidence of retrograde metamorphism in the form of a sheath of chlorite on the left side, and the texture suggests rotation during a late shearing episode as the last stage in the formation of this polymetamorphic rock, the chlorite being formed during this later deformation.

There are some wafer-like amphibolite lenses in schists of the Malmalte formation on the escarpment west of Lokwien. These are entirely converted to actinolite-epidote schists (26/928). Retrogression cannot be demonstrated here but the schists are thought, on account of the field relationships, to be amphibolite lenses which have adopted a lower-grade mineral assemblage under the influence of the extreme shearing which has affected the enclosing leucocratic schists.

Late Metamorphism Associated with the Fault-zones

Metamorphic effects are seen in the fault breccias; chlorite in the breccia along the Kokoten fault (26/849) has clearly been derived in a process of retrograde metamorphism from the biotite, and the growth of muscovite along cracks is a feature of the

breccias at Orwa and Riritian (*see* p. 45). Such effects are, however, confined to within a few yards of the fault-zones, indicating restricted low-temperature effects along the line of dislocation, in contrast with the earlier widespread retrograde effects.

5. Structure

(1) Orogenic Structures of Probable Precambrian Age

The Basement System rocks, which cover all but a very small fraction of the area, are characterized by foliation structures that closely resemble those described by Weiss from the Turoka area in Southern Kenya (1958, p. 126 *et seq.*). The foliation for the most part is parallel to lithological boundaries in the metasediments and to compositional banding in the concordant intrusions affected by metamorphism and now mainly represented by gneisses and schists. There is evidence of a flattened and elongated lens-form in the foliation suggestive of extensive boudins. The foliation is often obscure in highly crumpled, rodded or mullioned rocks (Plate VIII (*b*)). Axial plane foliation has been seen in a few exposures in the eastern part of the area, being particularly well developed at the junction of the Iun and Tamau Rivers (Plate VIII (*a*)). It is invariably seen at the closures of isoclinal folds. There is no evidence of widespread secondary foliation.

Minor Fold Structures

The minor structures have been studied in the field on a megascopic scale in sufficient detail to reveal their general characteristics. The folds are predominantly of the flexural-slip type characterized by sharp hinges and appressed limbs (Plate VI (*b*)). The axial surfaces of the smaller folds are usually planar and are often steeply inclined. The profiles (Plates VII (*a*), VIII (*a*)) are uniform and cylindroidal. A feature of the minor structures is the occurrence of small tectonic "fish" derived from more competent bands in the gneisses (Fig. 9 (*a*), Plate VII (*b*)).

Lineations include minor folds, striated surfaces and elongated mineral grains. Rodding and mullion structures (Plates VIII (*b*), IX (*a*), IX (*b*)) are parallel to the locally predominant minor fold trends and may be considered as congenetic.

Major Folds

Several major folds have been delineated (*see* structural map, Fig. 15, at end) by plotting the foliation structures and the relations of the various formations within the succession. In the north of the area large-scale anticlinoria and synclinoria running from north to south are seen in the region of Karikau and Tarakit, and an anticlinorium further west of this which appears to continue southwards as the Karita anticline within Uganda. Yet another major synclinal structure appears in the extreme north-west corner of the area. In the southern half of the area easterly-trending major folds are seen, the Merul-Maral syncline and the Tamau-Marich anticline. In all these structures an open style characterized by antithetic foliation dips predominates, but east of Karikau a more complicated structure runs from north to south from Morulem through the Endoo Valley. At Morulem the structure is an open syncline characterized by gentle antithetic dips; it tightens southwards, becomes overturned near Korpu, and passes into a tight open syncline near the Endoo Valley. Further south it is believed to pass once again into an overturned synclinal structure of isoclinal form. Of the easternmost structures recognized the Chachai anticline and the Nguruch anticline are open but the intervening Sarmach syncline is tightly folded, approaching isoclinal in style. North of these north-south-trending structures a distinct cross-flexure, the open Eremai anticline, is recognized but north of this, at the Turkwell Gorge section, dips are uniformly east and affected by gentle flexures running north to south. It is believed that the axis of an overturned anticline runs through Nakhang camp, extreme deformation suggesting an axial zone, but this fold cannot be demonstrated with certainty. It is possible that overturned isoclines running north to

south also pass through the Marich Pass area in the south-east corner of the area, but the evidence for them is based entirely on the presence of linear zones of north-south lineations suggesting axial zones. In general the major fold pattern is one of open structures trending in two directions approximately north-south and east-west and passing into tight overturned folds. In the east of the area near Sarmach the structures resemble those mapped by Joubert (report to be published) in the Loperot area, north-east of the Sekerr area, where canoe-shaped north-south folds are arched by minor cross flexuring. It seems from a study of Miller's report on the Cherangani Hills (Miller, 1954) that south of the Marich road the open folding characteristic of the Sekerr area gives way to overturned and recumbent folding and a similar change in style appears to be evidenced in the Karasuk Hills area to the north (Walsh, report to be published) but Walsh has recognized open north-south folding superimposed on recumbent east-west folds in the extreme south of that area (verbal communication).

The Orientation of the Fold Structures

The trend of the minor structures in any part of the area closely follows that of the major structures described above, the minor folds occurring for the most part in localized zones of crumpling. These crumple-zones occur paralleling the trend of both sets of major folds and rarely both trends of minor folding are seen within the limits of a single outcrop. The best example of this is seen at Akeriemet at the eastern entrance to the Marich Pass. The crumple-zones are separated by long stretches of country in which few minor folds are seen, as between Ptoyio and Maral. The plunge of north-south structures, both major and minor, is gentle and shows rapid variation from north to south, but the east-west structures plunge mostly to the east matching the dip of the foliation planes. In the Endoo syncline and south of Mtelo mountain sharp reversals of plunge are seen in these lineations following concertina folds affecting the foliation as well and there can be no doubt that here refolding has occurred. In the main it is believed, however, that the two systems of folding are congenetic and that the east-west system is related to cross-ripples affecting an inconstantly trending north-south orogenic belt where north-south folding is the dominant style. The type of structure envisaged is a rather accentuated pattern comparable with the Braemore-Droma structure of the Scottish Highlands (Clifford, Fleuty, Ramsey, Sutton and Watson, 1957, p. 7). The evidence for the conclusion drawn is partly derived from field studies and partly from statistical analysis.

Field Evidence on the Relative Age of the Structures

(1) Minor folds, rodding and mullions are all of the same style and scale.

(2) Minor folding is concentrated in definite localized zones of crumpling in which both trends sometimes occur closely intermingled.

(3) The minor structures do not interfere with one another.

(4) There is, however, locally seen a gentle arching of the minor structures suggestive of slight cross-flexure. This arching variably follows either main trend, often yielding gentle dome structures or canoe-shaped folding. Gentle arching is particularly noticeable in the west of the area where dips are very low. It is paralleled in the Loperot area to the north-west.

(5) Secondary foliation is never seen (compare with cross-fold structures involving refolding described by King and Rast from Cowal (1956, p. 189)). No secondary strain-slip cleavage is seen.

(6) In any part of the area the major and the predominant minor structures show a close correspondence.

These facts suggest that the area is mainly one of cross-folding of congenetic type. Evidence for refolding is limited to the concertina attitudes of east-west folding in the Endoo syncline. Here refolding of east-west minor structures on north-south axes is

clearly present and a limited refolding comparable with the much stronger refolding described by Walsh (report to be published), from the Karasuk Hills must be postulated. It is thought that the axial zones of north-south lineation in the Endoo syncline represents a structure of the Tarvie type (Clifford, Fleuty, Ramsay, Watson and Sutton, 1957, p. 11). There is support for this in the apparent deflection of the cross-lineations on the flanks of this structure and it is probable that this refolding is present throughout the steep-dipping zone extending from the Turkwell Gorge through Endoo to the Marich Pass. Though well-defined aligned zones of north-south lineation may represent axial zones of north-south refold structures the cross-structure as a whole is not believed to be formed in this way. There is no evidence for the relation of older north-south and younger east-west structures as described by Glenday and Parkinson (1927, p. 797) who, however, provided little evidence for their supposition.

Statistical Analysis

Though monoclinic symmetry is seen in the field in the case of minor folds, no area of complete homogeneity could be found by statistical analysis. An approach to monoclinic symmetry was, however, attained in limited sub-areas. The sub-areas analysed are shown in Fig. 9. Even in the first small area to be considered there is a considerable degree of inhomogeneity but there is an approach to a monoclinic symmetry shown in

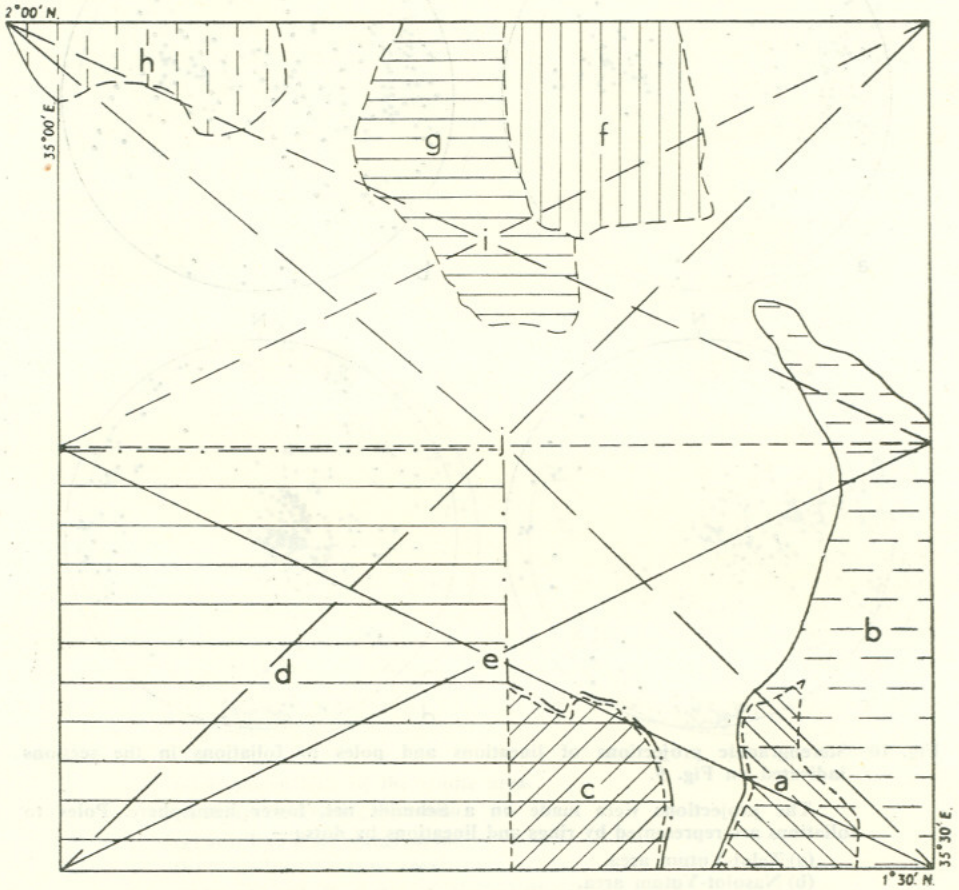


Fig. 9—Key map of the sections chosen for statistical evaluation of structures in the Sekerr area.

the distribution of the poles to the foliation planes (Fig. 10 (*a*)). The lineations concentrate around a maximum direction of about N. 67° E. The pitch is steep, corresponding with the steep dips of the foliation planes in this sector of the area. Three north-south lineations with characteristic very slight plunge southward are strongly anomalous to the general pattern. In the plot for the area between Nasolot and Yutum (Fig. 10 (*b*), which includes the Telot-Yutum area), the distribution of the foliation planes shows less definite form than that for the smaller areas, but the contrasts between shallow-plunging meridional lineations, and those plunging at a much steeper angle on an average of N. 67° E., is strikingly demonstrated. The two sets of folds are clearly reflected in this diagram.

The third section considered is a small area near Tamau and Chepunyal (Fig. 10 (*c*)), which is characterized by low dips and variable strikes. Most of the folds which can be seen are small open arching structures, complicated by minor crumpling and plunging eastwards. The much greater scatter of the foliation orientation corresponding with the variable strike direction is seen. It will be noted that in this section only easterly-plunging lineations were noted.

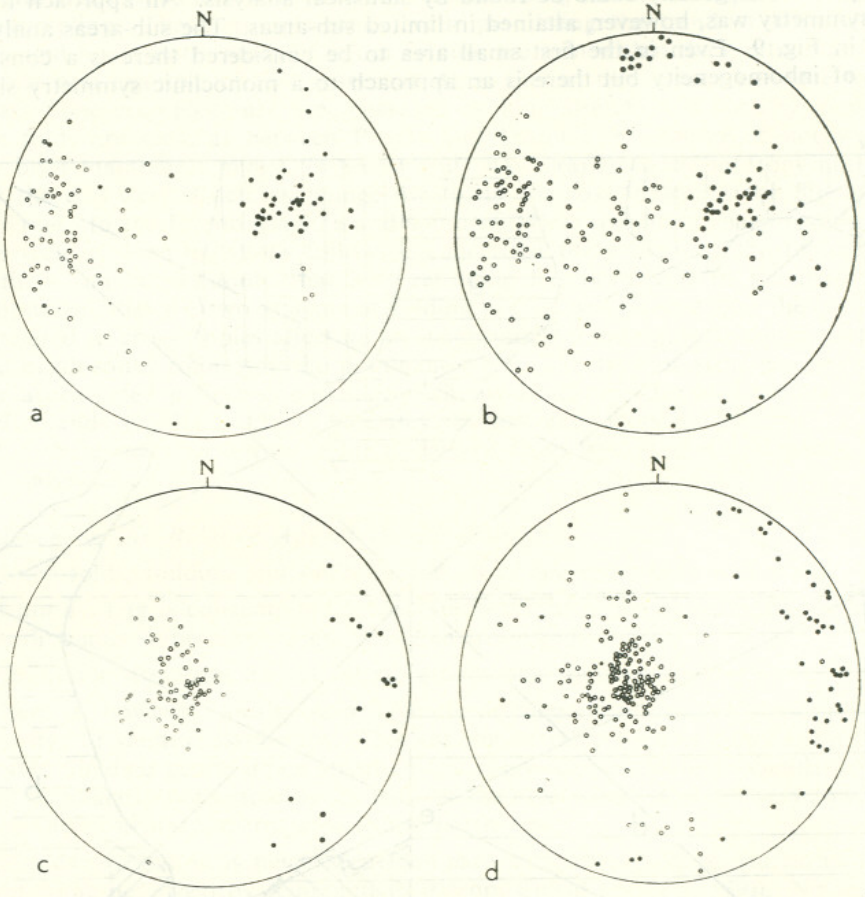
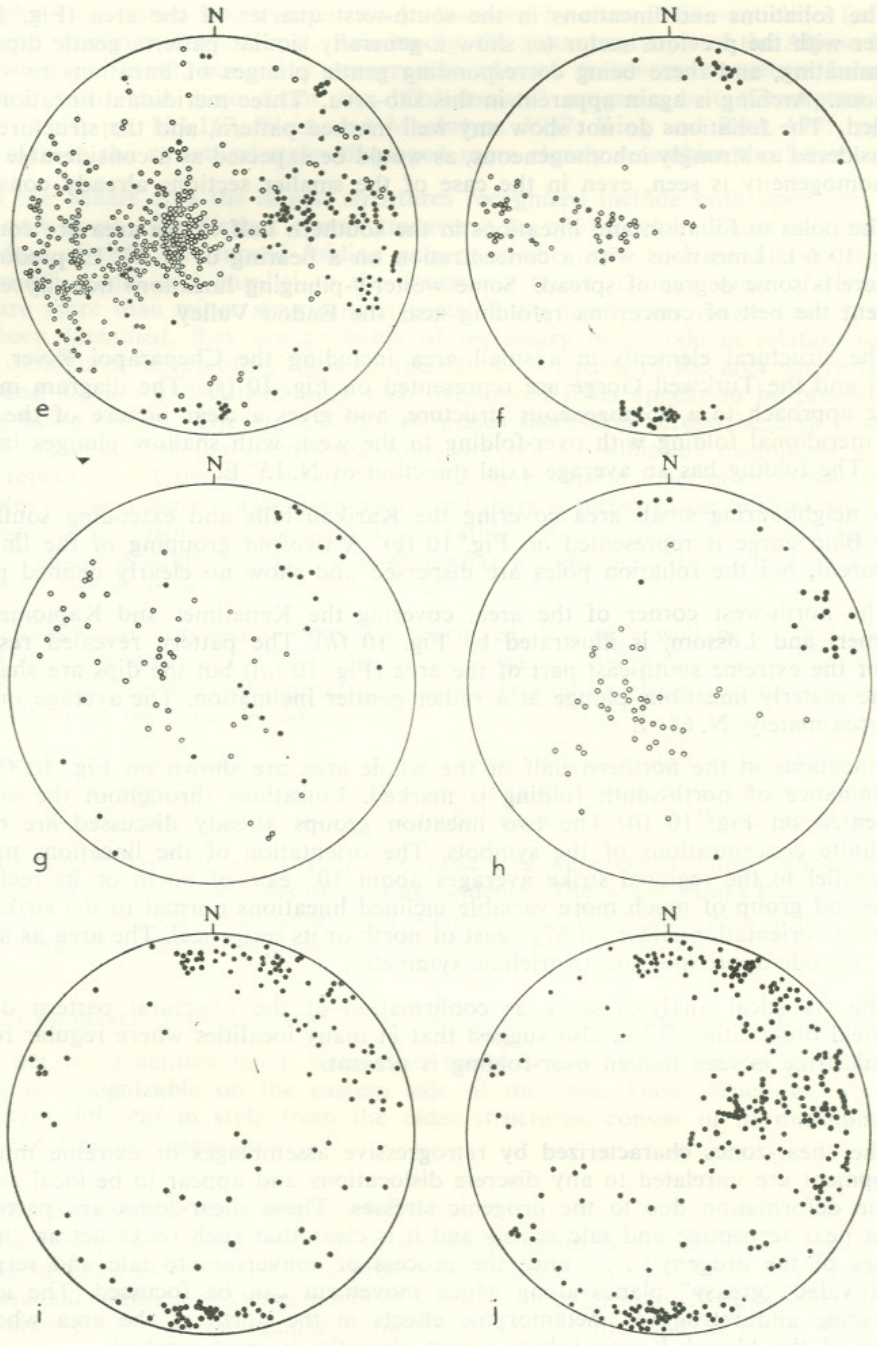


Fig. 10—Stereographic projections of lineations and poles to foliations in the sections indicated on Fig. 9.

The projections were made on a Schmidt net, lower hemisphere. Poles to foliations are represented by rings and lineations by dots:—

(a) Telot-Yutum area.
(b) Nasolot-Yutum area.
(c) Tamau-Chepunyal area.
(d) South-west quarter of the whole area.



(e) Southern half of the whole area.
(f) Ikilip-Turkwell gorge area.
(g) Karikau-Bino gorge area.
(h) Kenailmet-Lossom area.
(i) Northern half of the whole area (lineations only).
(j) The whole area (lineations only).

The foliations and lineations in the south-west quarter of the area (Fig. 10 (*d*)), together with the previous sector (*c*) show a generally similar pattern, gentle dips again predominating, and there being corresponding gentle plunges of lineations to variable directions. Arching is again apparent in this sub-area. Three meridional lineations were recorded. The foliations do not show any well marked pattern, and the structures must be considered as strongly inhomogeneous, as would be expected as a considerable degree of inhomogeneity is seen, even in the case of the smaller sections already considered.

The poles to foliation and lineations in the southern half of the area are combined in Fig. 10 (*e*). Lineations with a concentration on a bearing of N. 67° E. predominate but there is some degree of spread. Some westerly-plunging lineations now appear and represent the belt of concertina refolding near the Endoo Valley.

The structural elements in a small area including the Cheparapoi River, Ikilip, Tingiri and the Turkwell Gorge are represented on Fig. 10 (*f*). The diagram indicates a close approach to a homogeneous structure, and gives a clear picture of the north-south meridional folding with over-folding to the west, with shallow plunges in either sense. The folding has an average axial direction of N. 15° E.

A neighbouring small area covering the Karikau hills and extending southwards to the Bino gorge is represented on Fig. 10 (*g*). A twofold grouping of the lineations is apparent, but the foliation poles are dispersed and show no clearly defined pattern.

The north-west corner of the area, covering the Kenailmet and Kapiomet hills, Morumeri and Lossom, is illustrated by Fig. 10 (*h*). The pattern revealed resembles that for the extreme south-east part of the area (Fig. 10 (*a*)) but the dips are shallower, and the easterly lineations plunge at a rather gentler inclination. The average direction is approximately N. 68° E.

Lineations in the northern half of the whole area are shown on Fig. 10 (*i*). The predominance of north-south folding is marked. Lineations throughout the area are represented on Fig. 10 (*j*). The two lineation groups already discussed are marked by definite concentrations of the symbols. The orientation of the lineations more or less parallel to the regional strike averages about 10° east of north or its reciprocal. The second group of much more variable inclined lineations normal to the strike show an average orientation either on $67\frac{1}{2}°$ east of north or its reciprocal. The area as a whole shows a crude approximation to triclinic symmetry.

The statistical analyses serve as confirmation of the structural pattern deduced from field observation. They also suggest that in many localities where regular regional dip and strike is seen hidden over-folding is present.

Shear-Zones

The shear-zones characterized by retrogressive assemblages or extreme muscovite development are unrelated to any discrete dislocations and appear to be local zones of extreme deformation due to the orogenic stresses. These shear-zones are particularly evident near serpentine and talc schists and it is clear that such rocks act as "the ball bearings of the orogeny" . . . once the process of conversion to talc and serpentine has provided "greasy" planes along which movement can be focussed. The increase in shearing and retrograde metamorphic effects in the north of the area where the outcrop of the Marich-Korpu Schists tapers abruptly, is most marked.

General Conclusions on the Orogenic Structures

In an area including two distinct axial trends, the question arises whether there were two separate orogenies, or two episodes in a single orogeny, or whether there is a system of cross-folds of more or less simultaneous origin. The existence of such a two-fold system might be taken to indicate two orogenies, but early in this century the Alpine geologists, led by Argand (1912) defined "tectonic segmentation" dividing

the Alpine fold system into a series of arcs bounded by cross-folds—anticlines (culminations) and synclines (depressions). Admittedly, the recumbent style of the Alpine folding is not seen in Sekerr, but many occurrences of such transverse structures have been described since that time from the "Caledonian" orogenic belt (Crampton, 1913; McCall, 1954; pp. 163-167, Weiss and MacIntyre. 1957; King and Rast, 1955, pp. 243-266) which in the structural styles displayed more closely resembles the Sekerr area.

In the Sekerr area the largest structures recognized include both open and closed folds, and show two distinct trends transverse to one another. There is certainly a great deal of tight overturned folding present in the area, both parallel to the main north-south trend, and parallel to the transverse trend. Though some of these tight folds are more than minor structures in parts of the area where major open structures have been identified, they are probably of secondary magnitude in relation to these largest structures representing folds on their limbs. In parts of the area where regional strike and dip are undisturbed only such overturned folds appear to be present, open folding being absent. The apparently continuous succession across the area from west to east suggests that the overturned folds are not of sufficient magnitude to cause major repetitions of the succession. Segmentation produced a series of cross-structures as ripples across a main north-south trend, and there is some reason to think that where these occur the north-south structures are rather more weakly represented than elsewhere. The north-south trend is also somewhat inconstant, a fact which provides an additional complication.

Refolding on north-south lines has occurred, but may well be of localized and limited development, as for example in the zone of steep dips extending from the Marich pass to the Turkwell gorge. It is certainly well developed in the Karasuk hills to the north of the area (Walsh, report in preparation).

The minor folds form crumple-belts following both fold-trends. The transverse crumples are related to the segmentation and may represent piled up east-west trending overfolds or recumbent folds similar to those recognized by Weiss (1958, p. 62).

The question of to what extent the structures were synchronous cannot be conclusively answered on the basis of existing evidence. The writer thinks that only limited subsequent folding on north-south axes occurred, but the Sekerr area is one in which further detailed structural investigation is needed.

(2) Probable Tertiary Structures Related to the Rift Valley System

A set of structures much later than those already described for the Basement System is recognizable on the eastern side of the area. These structures, which are completely different in style from the older structures, consist of normal faults and rectilinear fracture patterns.

The Sekerr, Turkwell and Associated Faults

The escarpment facing east on to the Masol plain is a fault-line scarp following the line of a series of faults. The presence of faulting is manifested by the presence of prominent breccias at Orwa, north of Orwa, and at Riritian (Plate XI (*b*)) and by a large outcrop of shattered quartz immediately east of the Marich Bailey bridge. No breccias along the Turkwell fault have been recognized north of Riritian only iron-staining (p. 46), but the country there is difficult of access, and it was not possible to carry out a detailed examination of the foot of the escarpment. The Turkwell escarpment is, however, considered as the continuation of the waning westernmost bounding fault-line scarp of the Rift Valley. The Masol plain is not strictly speaking the floor of a graben, but a faulted-down step, probably tilted upward to the east, where a second fault scarp bounds the Rift Valley graben proper to the east of Kalossia (*see* Fig. 1, Mason and Gibson, 1957, pp. 28-32).

The nature of the faulting can be deduced from the fault breccias (p. 45). For the most part their textures indicate simple cataclasis compatible with a tension fault. In one case, however, at Riritian the breccia is mylonitic and is probably a result of compression.

The Age of the Faulting

The age of this faulting is important, as it has a bearing on the controversy as to the physiographic evolution of north-west Kenya (p. 5).

The fact that the end-Tertiary surface traverses the breccia-zone without interruption, and forms a pediment cut into hard rock between the breccia-zone and the line of the escarpment, is considered to be proof of faulting along this line before the end-Tertiary planation*. The fault east of the Marich pass passing southwards becomes the Elgeyo fault, which displaces sediments accepted as Miocene at Tambach (Shackleton, 1951, p. 371). It does not seem improbable that the faulting on the east side of the area occurred during the Miocene, and before the end-Tertiary erosion cycle commenced, but there is no proof that it is not older†. From the physiographic evidence (p. 10) subsequent movement limited to monoclinal warping associated with uplift of the area immediately west of the Sekerr and Turkwell escarpments is believed to have occurred.

The writer considers that the form of the escarpments favours the existence of a Tertiary valley rather than that the escarpments were produced by Pleistocene faulting, since no cliff fault-scarp akin to the known Pleistocene scarps of the central Rift Valley (McCall, 1957 B, p. 4, and Nakuru-Thomson's Falls-Lake Hannington report) are seen in the area. The degree of dissection closely matches that seen on the Laikipia escarpment and the Elgeyo escarpment, and the writer has recently recognized (Nakuru-Thomson's Falls-Lake Hannington report) that such escarpments represent the oldest of three successive episodes of major faulting in the central Rift Valley, the youngest of which preceded middle Pleistocene deposition.

The absence of any volcanic rocks along the line of faulting is striking, but provides no evidence as to age, since faulting without vulcanicity is a well-known feature of parts of the Rift Valley System.

Control of the Fault Structures by Older Structures

The Sekerr and Turkwell faults follow a zone of extreme shearing in the ancient gneisses and schists. There are serpentine bodies derived from ultra-basic intrusions near the line of the Tertiary faulting, and a chain of foliated granite lenses closely following the same line. There thus appears to be a close relationship between the late faulting and a much older structural zone of weakness marked by shearing and eruptivity. Such relationships have been described from many rift-faulted areas by Dixey (1956).

Minor Faults and Fracture Lines

A network of minor faults and fracture lines (Plates XI (*a*) and (*b*)) makes its appearance in the north-east corner of the area, having considerable effect on the

* It will be appreciated from Plate II (*b*) that, if the Masol plain and the pediment both form part of the end-Tertiary bevel, the bevel is faulted. The lip of the bevel has been removed by erosion subsequent to the faulting, so that eventually the top of the breccia appears as one with the degraded bevel. If the faulting followed the bevelling, at no stage of its evolution would the breccia stand at a higher level than the bevel. (W.P.)

† The evidence at Tambach indicates that the faulting seen is post-lower Miocene and the displacement of the end-Tertiary bevel at the Turkwell gorge indicates that it (or some component of it) is post-mid Pliocene. There is certainly no proof that part of the faulting is not pre-Miocene, but no evidence has yet been adduced to support that suggestion. (W.P.)

drainage pattern (p. 5). There are several trends, the most common being north-east—south-west, north-north-east—south-south-west, north-west—south-east, north-north-west—south-south-east and north-south. Most of the faults are merely fracture lines marked by vertical or near vertical jointing, and causing no appreciable displacement.

The Kokoten fault, however, shows some evidence of displacement and brecciation (p. 45). A small dyke of basic composition was noted in the bed of the Kokoten River (p. 45). The Orwa fault shows evidence of a small downward displacement to the south.

The date of these minor faults is not known. They occur near to the eastern zone of major faulting, which bounds the Masol Plain on the east, and could be of Cainozoic age.

VI—MINERAL DEPOSITS

1. General

The Sekerr area is one in which a number of mineral deposits are known, but there appears to be no deposit likely to be of great economic importance—though the alluvial gold deposits in the Turkwell River, and possibly the Marun River, are likely to contribute a small but steady flow of money to the country.

Nickel and chrome deposits found so far, though interesting, are insignificant, and copper showings are of no economic value. No other base metal deposits are known and in the writer's opinion none are likely to be uncovered in the future.

Production of columbite, samarskite and mica is limited to one pegmatite deposit workable on a small scale at a restricted profit margin. Other pegmatitic deposits may be found but there is no large number of suitably mineralized pegmatites, and such deposits can never be more than minor undertakings.

Asbestos (anthophyllite) and kyanite are known but neither is present in any great quantity, though concentration of quartz-kyanite veins near Nasolot might conceivably be worthy of an examination by an expert with knowledge of working kyanite. It is doubtful, however, if the kyanite could be mined economically at the present time.

The mineral deposits of the area are divided into the following groups:—

(1) Alluvial deposits.
   (*a*) Gold.
   (*b*) Other minerals.

(2) Magmatic segregations—Chromite.

(3) Hydrothermal deposits.
   (*a*) Gold.
   (*b*) Copper.
   (*c*) Kyanite.

(4) Pneumatolytic deposits.
   (*a*) Columbite-samarskite-mica deposits.
   (*b*) Mica deposits.

(5) Secondary deposits.
   (*a*) Nickel.
   (*b*) Anthophyllite asbestos.

(6) Miscellaneous.

(1) Alluvial Deposits

(a) *Gold*

The presence of gold in the rivers of West Suk and Karasuk has been known for many years. The large rivers flowing in an easterly direction into the Masol Plain and the lower Turkwell valley—the Marun and Iun, the Turkwell (Suam) and the Kateruk —carry appreciable quantities of alluvial gold in restricted sections of their courses near to their emergence from the incised gorges which conduct them down to the lowlands. The exact source of the gold is not known. Gold has, however, been found in a gully in the Telot serpentine and in one small stream flowing off the west flank of Murkorio into the Suam and this suggests that the source is in such tributary deposits derived from gold disseminated in the Marich-Korpu Schists. This important problem is discussed in more detail with the Turkwell deposits about which most information is available.

Assays carried out on actinolite schist and serpentine from Wyisa and Telot, near to the occurrence of gold referred to above, show that there is a slight but significant content of gold in these rocks (Table III). There must be quartz-stringers carrying greater percentages within the schists and serpentine but their location is likely to present a problem of great difficulty to prospectors.

TABLE III

Gold Content of Some Basic Rocks in the Sekerr Area

No.	Rock Type	Locality	Au-dwt./ short ton
28067 (26/702) ..	Actinolite schist	Wyisa	0·2
28070 (26/1031) ..	Nickeliferous serpentine	Telot	0·2
28071 (26/1032) ..	Serpentine	Telot	trace

Anal: W. P. Horne, 23–4–58

Gold in the Marich River

Interest in the possibilities of the alluvial gravels in the Marich River was at its peak in 1951-52. In 1952 there were three claims being operated by J. J. de Jager, C. J. de Jager and by Mrs. I. McNaughton and A. P. S. de Bon. Prospecting and working appears to have been carried out intermittently during the next three years. No great quantity of gold was recovered—figures are given in Table IV below—and by 1957 when S. A. Embleton took out an exclusive prospecting licence (No. 122) over an area of 0.7 square miles of the river-bed and banks between Wakor and the eastern end of the Marich Pass (Fig. 11) all the claims mentioned had lapsed.

TABLE IV

Gold and Silver Production in the Marich River

(*fine ounces*)

		1951	1952	1953	1954	1955
J. J. de Jager ..	Gold	15·13	41·28	119·23	—	—
	Silver	0·62	2·08	5·21	—	—
C. J. de Jager ..	Gold	—	8·36	—	—	—
	Silver	—	0·39	—	—	—
I. McNaughton ..	Gold	2·40	—	—	—	—
	Silver	0·08	—	—	—	—
A. P. S. de Bon ..	Gold	2·40	—	—	—	43·92
	Silver	0·09	—	—	—	0·62

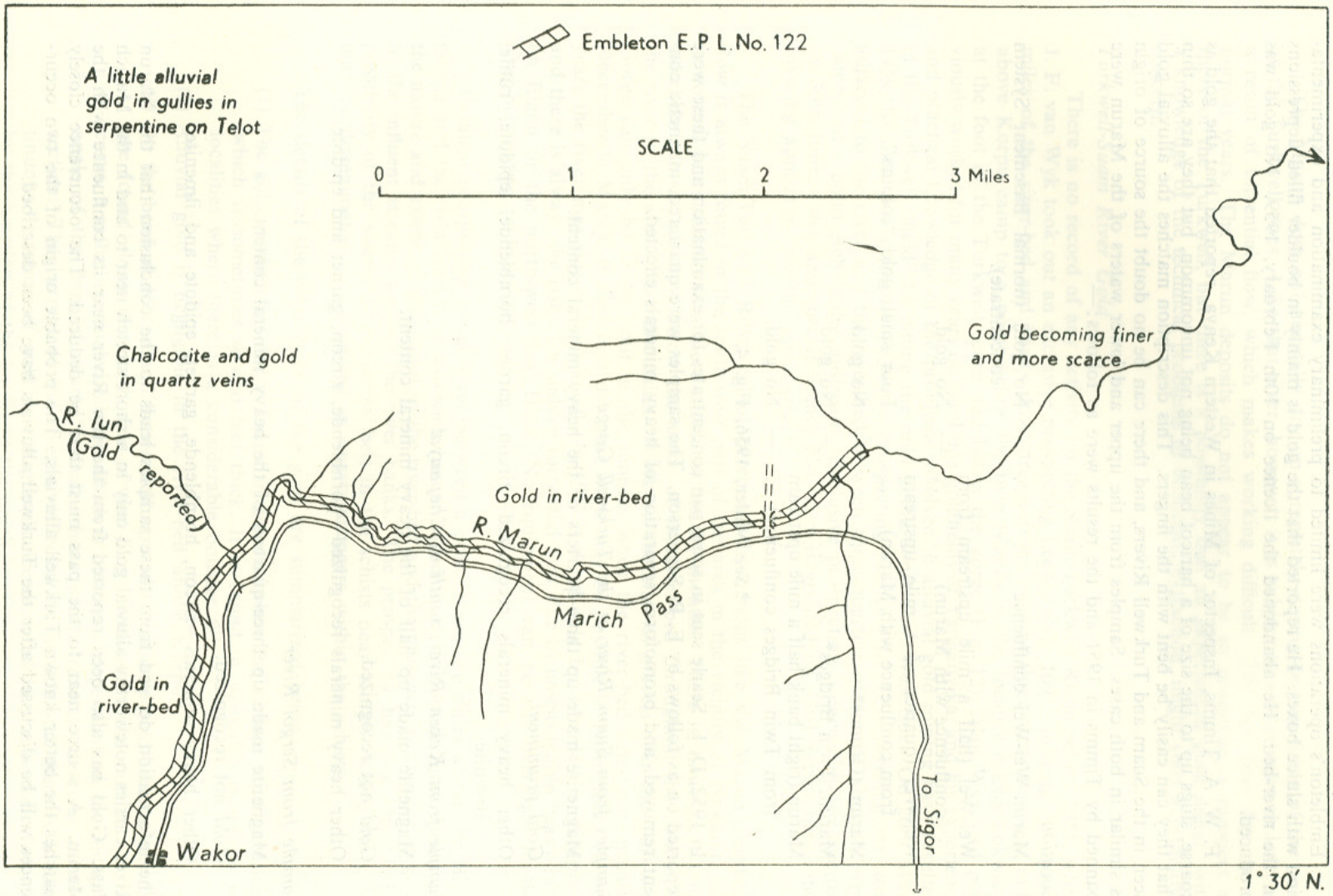


Fig. 11—Sketch map of the area in the Marich pass held under exclusive prospecting licence No. 122 between February 1957 and February 1959 by S. A. Embleton.

Embleton's operations were limited to preliminary examination and experimentation with sluice boxes. He reported that the gold is mainly in boulder filled depressions in the river-bed. He abandoned the licence on 10th February, 1959. No gold was produced.

F. W. A. Timms, Inspector of Mines in Western Kenya, reported that the gold is coarse, slugs up to the size of a haricot bean being not uncommon, but they are so thin that they can easily be bent with the fingers. This description matches the alluvial gold seen in the Suam and Turkwell Rivers, and there can be no doubt the source of origin is similar in both cases. Samples from the upper and lower waters of the Marun were panned by Timms in 1951 and the results were as follows:—

Location		
Marun-Wei-Wei confluence	—	No gold (normal Basement System concentrate).
Wei-Wei (half a mile upstream from confluence with Marun)	—	No gold.
Wei-Wei (quarter of a mile upstream from confluence with Marun) ..	—	Four small gold "colours".
Marun (Ortum)*	—	No gold.
Marun, Twin Bridges*	—	No gold.
Marun (right bank half a mile upstream from Twin Bridges confluence) ..	—	No gold.

* *See* Miller, 1956, Fig. 4.

In 1952, D. L. Searle sent in some pan concentrates for examination and these were reported on as follows by E. P. Saggerson. The samples were quartered, magnetic content removed, and bromoform separation of heavy minerals effected.

Samples from Suam River at the Turkwell Gorge

Magnetite made up three-quarters of the heavy mineral content.

Gold prominent.

Other heavy minerals recognized—zircon, garnet, hornblende, epidote, rutile, ilmenite.

Sample from Keken River, south of Chepunyal

Magnetite made up half of the heavy mineral content.

Gold not recognized.

Other heavy minerals recognized—hornblende, zircon, garnet and epidote.

Sample from Sergoi River

Magnetite made up three-quarters of the heavy mineral content.

Gold not recognized.

Other heavy minerals—zircon, hornblende, garnet, epidote and ilmenite.

The information derived from these samples leads to the conclusion that the Marun River carries noteworthy alluvial gold only in a short stretch near to and in the Marich Pass. Gold has also been reported from the Iun River near its confluence with the Marun. A source near to the pass must thus be deduced. The occurrence closely matches the better known Turkwell alluvials. The probable origin of the two occurrences will be discussed after the Turkwell alluvials have been described.

The Marun does not normally dry up completely during certain times of the year as the Turkwell does. Like that river, however, it is subject to abrupt rises in level as a result of torrential flow, which makes working difficult. The Iun does dry up in normal years. The Marun deposits do not appear to be so promising a prospect as those of the Turkwell, but there is a possibility that an experienced gold miner, with a knowledge of the technical problems of economic extraction, might start a profitable concern.

Turkwell-Suam River Gold

There is no record of any activity on the Suam-Turkwell River before 1955, when J. F. van Wyk took out an exclusive prospecting licence (No. 109), covering 0.8 square miles of the river-bed and banks downstream from a point three quarters of a mile above Korpu camp to a point below the twin islands at the locality called Lokwien, at the foot of the Turkwell scarp and below the gorge (Fig. 12). Van Wyk had previously worked for many years on the Lupa goldfields of Tanganyika, and his experience and practical knowledge of the problems involved in alluvial gold mining have resulted in the Turkwell "field" becoming the only going concern in West Suk. On 26th May, 1958, he took out a further exclusive prospecting licence (No. 129) covering the area adjacent to the river and the river-bed between three-quarters of a mile above Korpu camp and a point eight miles upstream. Exclusive prospecting licence No. 109 expired on 30th June, 1960, and special licence No. 11 was granted on 23rd September, 1960, covering approximately the same area.

The Suam-Turkwell River is not perennial throughout like the Marun. Surface flow is always found in the south-west part of the area in the vicinity of Nakuijit, but in normal years shrinks to a mere trickle in the dry months. There is, however, a considerable sub-surface flow below the sands of the river-bed throughout the course of the river in the area under discussion. Work on the alluvial gravels near the Turkwell Gorge can only be carried out in the months when the river-bed dries out, usually December to March, though in a dry year work may be possible in November. In wet years the river may not dry out at all—in 1957 it dried only for two days at Korpu—and there is always the risk of a sudden torrential flow due to unseasonable heavy rain on Elgon or the north-west Suk Hills. No equipment can be left overnight in the river-bed owing to this risk.

Detailed prospecting of the river between a point some two miles above the Bino Gorge and the twin islands at Lokwien has provided much important information on the nature and extent of the gravel in the river-bed and the presence or absence of gold in the influent streams and on the river banks. The prospecting has also limited the possibility of the source to a narrow belt in the schists near Korpu, where the gold may be disseminated or distributed in quartz stringers within the schists.

The details of the occurrence of the gold are summarized below:—

(1) The gold in the river-bed is found in gravels below the surface sand covering, which is sometimes several feet thick. It is found in workable quantities in localities where there is a considerable boulder fill.

(2) Alluvial gold is negligible in the river-bed above Korpu.

(3) On the bend at Korpu and between Korpu and Nakhang gold-bearing gravels are found along the north side of the river. This is on the outside of the curve, a rather unusual condition which is obviously dependant on the oblique angle of the bars of nearly vertical schists which traverse the river in this section. The current of the river is deflected to the left and there is a continuous accretion of gold in the gravels accumulated in the pockets formed by the junction of the bars and the north bank.

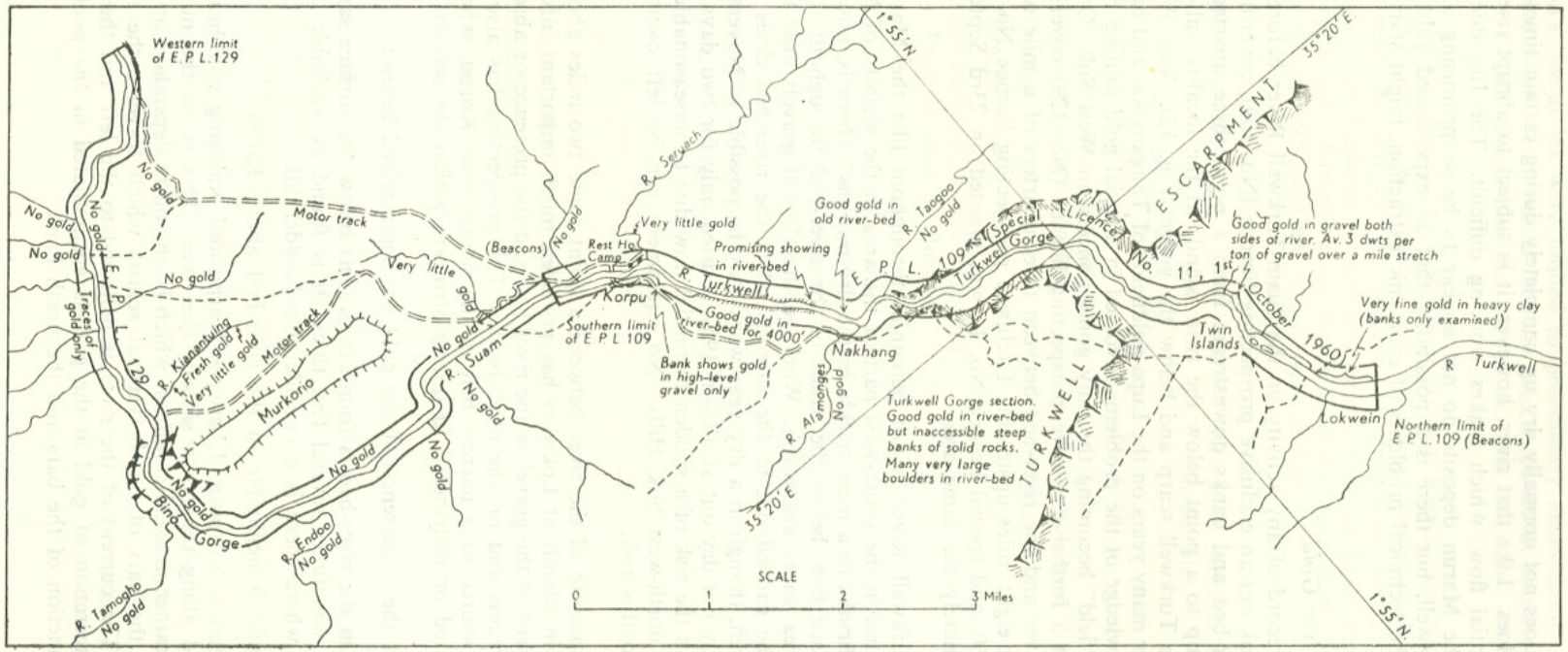


Fig. 12—Sketch map of the area prospected and worked by J. F. van Wyk under Exclusive Prospecting Licences Nos. 109 and 129—Turkwell river.

There are good showings of gold rather patchily distributed from Korpu to Nakhang. On the banks there are a few high-level gravels with gold. The banks around Korpu yield a little gold on panning.

(4) There is an old river channel on the right bank at Nakhang. Good showings of gold were reported here but it has subsequently proved disappointing. Fine gold is present in the soil but little in the coarser gravels.

(5) There is good gold in the river-bed in the gorge itself but it is difficult of access and the boulders are large. The banks are steep and composed of rock.

(6) Below the gorge there is good gold-bearing gravel on both sides of the river, averaging three pennyweights per ton* for over a mile.

(7) From the last rock outcrops to Lokwien the river banks are composed of very clayey material and the gold is very fine. The river-bed has not recently dried out in this section so it has not been possible to examine the gravels in the bed of the stream.

(8) The gold (Plate XII (*b*)) is of the type called "pea-milled" by some prospectors. It occurs in the form of lenticular flecks flattened into a thin wafer. These flecks are found up to a centimetre in length at Korpu. The grain size becomes gradually finer downstream to Twin Islands. The gold at Korpu is coarser than the gold in the Kianantuing River above the Bino Gorge and this led Mr. van Wyk to suspect another source but the coarser grain size may be entirely due to extension of the grains in the process of flattening by abrasion in the bouldery stream bed.

The Suam-Turkwell Tributaries

The streams influent to the Suam-Turkwell have been carefully prospected by van Wyk in an endeavour to locate the source of the gold. The results have been for the most part surprisingly negative. No gold has been found in tributaries near to the Turkwell granite (Taogoo and Alamonges), thus virtually ruling out a source in or adjacent to this granite lens. The tributaries between Korpu camp and Nakhang show no gold whatever. The influent stream immediately upstream of Korpu camp contains no gold, while the stream further up on the west bank has yielded a small amount of gold. No gold was found in the streams between here and the Bino Gorge, including the Endoo and Tamogho. Upstream of the Bino Gorge minute traces of gold were found in the series of small tributaries south of the river but on the north side a good showing of unworn gold was discovered for a distance of more than a mile in the bed of the Kianantuing stream, which drains a short length of catchment about two miles in extent from north to south on the west side of the Murkorio Hills. The unworn gold was found in bouldery hollows in the river-bed. All the tributaries of the Kianantuing come from the east, i.e. down from the steep scarp of Murkorio, and all carry a few grains of gold, though the main showings are always in the main stream-bed. The stream traverses a series of highly sheared schists and crystalline limestones. The rock types seen included:—

Kyanite schists	(Marich-Korpu Schists)
Actinolite schists	
Hornblende-actinolite schists	
Muscovite-chlorite schists	
Actinolite-epidote schists	
Crystalline limestone (dolomitic)	
Quartz-biotite-felspar schists	
Impure flaggy quartzite (thin bands)	
Sheared and foliated aplite sheets	

* In 1959 Van Wyk prospected below the gorge. He found evidence of considerable variations in the river-course in the past. The top soils near the river carry fine gold but the coarser gravels are barren. The gold is so fine and flattened in the top-soil that it cannot all be trapped in sluice boxes and more can be collected by panning. There is gold in the gravels in the existing stream-bed, but it was unworkable owing to the strong flow of the river that year.

The only quartz veins seen consist of minute lenses of quartz averaging about two inches in length, which are particularly noticeable in the sheared aplites. The Murkorio Hills consist of a widening in a sheet of felspathic granitoid gneiss, believed to be derived from a pre-metamorphic granitoid intrusion. The gold may thus be either:—

(*a*) disseminated in the Murkorio sheet;

(*b*) disseminated in the schists near their contact with this sheet;

(*c*) in small lenses of quartz in the schists.

The Kianantuing is the only stream in which evidence of a source of the gold can be detected. Further upstream in the Suam River no gold can be found either in the river-bed or the tributaries and the Kanyangareng carries little or no gold. The Kianantuing is not workable as the river-bed is highly porous and holds water only for about an hour after heavy rain. The showings indicate that about 30 ozs. could be extracted in a month if the water problem was overcome. The rise from the nearest source of water, the Suam, to the top of the gold-bearing section is about 150 feet in a mile and this would require a heavy outlay on pumps and piping.

Assays of schists from the Kianantuing River and other sources near Korpu were carried out with the following results:—

TABLE V

ASSAYS FOR GOLD, KORPU AREA

Laboratory No.	Specimen No.	Rock type	Locality	Gold content
27,333 ..	(26/864)	Aplite sheet	Kianantuing river	1·5 dwt/short ton
27,347 ..	(26/861)	Hornblende-actinolite schist		Trace
27,348 ..	(26/862)	Actinolite schist		0·3 dwt/short ton
27,349 ..	(26/865)	Tremolite schist		Trace
27,350 ..	(26/866)	Epidote-actinolite schist		Trace
27,351 ..	(26/864)	Flaggy biotite schist		Trace
27,352 ..	(26,907)	Murkorio-type granitoid orthogneiss	Seruach river	Trace Anal: J. Furst, 8–1–58
28,068 ..	(26/917)	Murkorio-type granitoid orthogneiss	Bino Gorge	Trace.
28,069 ..	(26/918)	Talc-anthophyllite schist		Trace. Anal: W. P. Horne, 23–4–58

The above results point to a small to almost negligible gold content in the schists, with a rather higher concentration in the sheared aplite with small quartz lenses. The concentration of gold on the west side of Murkorio may be related to the body of felsic orthogneiss, and it might be worth while to pan the streams lying to the west of similar features on Wamurigwa and Cheptaram in the Tamoglio and Sinjo Valleys. It might also be worth while to dig two or three short trenches across the contact of the felsic orthogneiss on the west side of Murkorio, to see if there is any marked auriferous horizon.

Production of Gold from the Suam-Turkwell Valley

So far mining operations have been limited to the section of the river between the southern beacons of Exclusive Prospecting Licence No. 109 and the entry to the gorge just below Nakhang. Using manual labour (up to 150 labourers during the dry

months) the gold-bearing gravel has been removed from the river-bed and passed through sluice boxes (Plate XIII (*a*)). A maximum of two sluice boxes can be operated satisfactorily. The removal of the sand overburden, often six feet deep, has been a drawback, but a hoist and mechanical scraper have been purchased and the sand cover should now be removable speedily, leaving the labour force free to concentrate on the exploitation of the gravel.

The highest production so far recorded was 219.8 oz. in 1955 but this can certainly be bettered with the improved equipment now available. A figure of about 80 oz. a month is considered a reasonable target and with luck production may range up to 200 oz. Early in 1958 80 oz. were recovered in three days working. No bottom to the gold-bearing gravels has been found, except where prominent rock bars cross the river-bed and there may be at least locally considerable thicknesses of workable gravel. The reserves appear to be high, though they cannot be calculated, and even if no extension of the field comes to light there is a prospect of many years of limited operation in the river-bed.

Production figures since the start of operations in 1953 are given below.

The figures of production for 1953-59 must be considered as low in relation to the production that might be expected in a succession of normal years, as the period consisted of abnormally wet years, in which the river never dried out completely.

TABLE VI

GOLD PRODUCTION FROM THE SUAM RIVER

Producer	Year	Gold	Value of gold	Silver	Value of silver
		(*Fine ounces*)		(*Ounces*)	
			£		£
J. F. van Wyk	1953	89·48	1,146	3·73	1
	1954	138·40	1,735	6·82	2
	1955	219·98	2,756	10·16	3
	1956	203·30	2,543	9·43	3
	1957	125·06	2,236	6·05	3
	1958	153·78	1,920	7·10	2
	1959	111·70	1,396	5·30	1
	1960	119·16	1,502	5·79	2
TOTALS		1,160·86	15,234	54·38	17

(*b*) *Other Minerals*

Examination of heavy mineral concentrations indicates that there is little likelihood of the occurrence of other minerals of value in the alluvials of the Sekerr area.

(2) MAGMATIC SEGREGATIONS—CHROMITE

Chromite Deposits of Telot

Chromite was first discovered on Telot, a bare grassy hillside in the Sekerr massif, by G. W. Ulyate, to whom an exclusive prospecting licence was issued on 28th March, 1956. This Licence, No. 115, covered an area of approximately 140 square miles between the Marich and Turkwell Rivers; it was withdrawn on 19th January, 1959, and a new licence, No. 133, issued on 20th January, 1959, which in turn was abandoned on 21st December, 1959. A small part of the area covered by Ulyate's exclusive prospecting licence was being investigated under option by New Consolidated Goldfields at the time the field work for this report was carried out, but the option was relinquished in 1959.

An attempt was made to investigate these deposits by a Government prospector in early 1956, but abnormal rains and difficulties in obtaining labour hindered work. The writer paid a visit to the chromite occurrences in May, 1957, and a brief report was compiled as a result of two days' work mapping the structures in the serpentine lens and examining the chromite in surface exposures, float, and preliminary trench excavations. R. G. Dodson visited the occurrence in November, 1957, when pitting and trenching had proceeded further (Dodson, 1957).

The chromite occurs in the form of small lenses lying within the Telot serpentine body. They are arranged *en echelon* and appear to be discordant to the country rocks. The present serpentine is less than two miles long and has a maximum width of outcrop of three-quarters of a mile. The pattern of the schistosity and cleavage structures seen within this body leave no doubt as to its form and limitation in depth (Fig. 13). It can be seen to taper abruptly north and south, continuing in each direction along the strike in the form of narrow parallel bands of talcose schist. In depth also it tapers abruptly where it emerges in section on the steep hillside which forms the south end of the bare grassy alp of Telot, and the general picture is of a rather shallow lenticular widening in a narrow steeply dipping belt of talc schists, derived from an ultra-basic intrusion (*see* p. 31).

The lenses of chromite occur in the waist or widest part of this serpentine lens. Nine lenses were identified by the writer, the largest being some 20 feet wide and not more than 50 yards long (Plate XIII (*b*)). Excavation of three of these lenses suggests that they die out within a few feet of the surface. Such lenticular deposits in serpentine are almost universally accepted as early magmatic segregations. Results of various assays of the ores are given below:—

TABLE VII

ASSAYS OF CHROMITE ORES FROM TELOT

	1	2	3	4	5	6
	%	%	%	%	%	%
SiO_2	—	—	2·52	—	—	—
Al_2O_3	—	—	6·03	—	—	—
Fe	—	—	10·56	9·19	14·50	31·62
MgO	—	—	15·51	—	—	—
CaO	—	—	0·38	—	—	—
Loss on Ignition..	—	—	2·78	—	—	—
TiO_2	—	—	0·18	—	—	—
P_2O_5	—	—	0·11	—	—	—
S	—	—	Nil	—	—	—
Cr_2O_3	54·63	—	56·24	44·00	45·00	31·76
NiO	—	0·22	—	—	—	—

1. Lab. No. 25207. Anal: W. P. Horne, 3–7–56.
2. Lab. No. 25972. Anal: W. P. Horne, 3–7–56.
3. Lab. No. 26563. Anal: J. Furst, 26–4–57. Cr/Fe ratio 3·64. (Assuming that the chromite conforms with the general formula of the spinel group it was calculated that Fe_2O_3 = 8·08 and FeO = 6·33 per cent. The loss on ignition was corrected on this basis, assuming that FeO would be completely oxidised to Fe_2O_3)*.
4. Lab. No. 26856. Anal: J. Furst, 23–7–57. Cr/Fe ratio 3·28 (Cr = 30·11 per cent).
5. Lab. No. 26858. Anal: J. Furst, 23–7–57. Cr/Fe ratio 2·15 (Cr = 31·14 per cent).
6. Lab. No. 26859. Anal: J. Furst, 23–7–57. Cr/Fe ratio 0·69 (Cr = 21·73 per cent).

*For Nos. 3–6 the analytical methods and calculations were based on "Composition of some chromites of the western hemisphere" by R. E. Stevens, *American Mineralogist*, vol. 29, 1944, pp. 4–6.

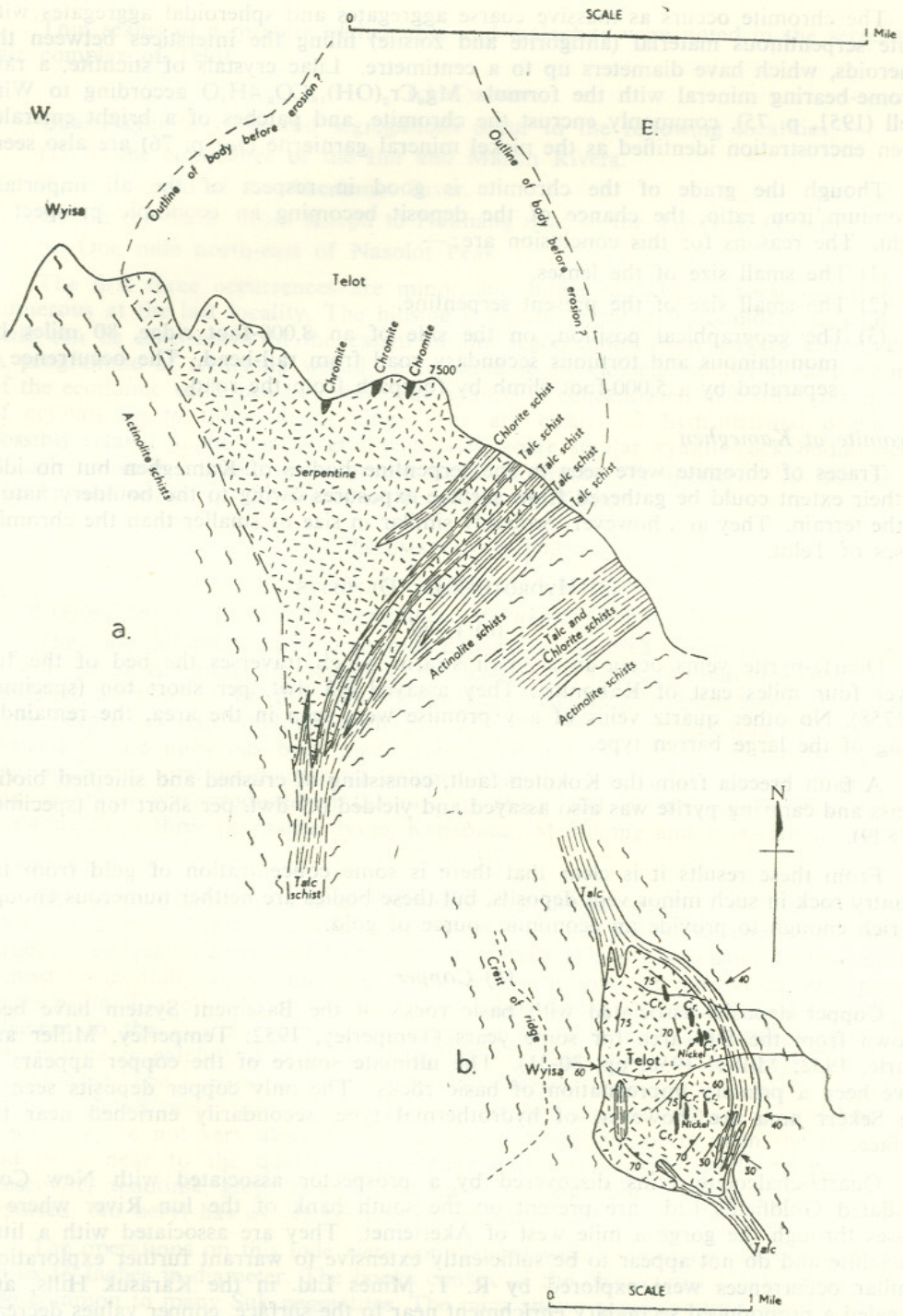


Fig. 13

(a) Idealized section showing the probable structure of the Telot serpentine lens.
(b) Sketch-map of the Telot serpentine lens.

The chromite occurs as massive coarse aggregates and spheroidal aggregates with white serpentinous material (antigorite and zoisite) filling the interstices between the spheroids, which have diameters up to a centimetre. Lilac crystals of stichtite, a rare chrome-bearing mineral with the formula $Mg_6Cr_2(OH)_{16}CO_3 \cdot 4H_2O$ according to Winchell (1951, p. 75), commonly encrust the chromite, and patches of a bright emerald-green encrustration identified as the nickel mineral garnierite (*see* p. 76) are also seen.

Though the grade of the chromite is good in respect of the all important chromium/iron ratio, the chance of the deposit becoming an economic prospect is slight. The reasons for this conclusion are:—

(1) The small size of the lenses.

(2) The small size of the present serpentine.

(3) The geographical position, on the side of an 8,000-foot ridge, 80 miles by mountainous and tortuous secondary road from rail-head. The occurrence is separated by a 5,000-foot climb by footpath from the road.

Chromite at Kameghen

Traces of chromite were seen in the serpentine bodies of Kameghen but no idea of their extent could be gathered from surface exposures owing to the bouldery nature of the terrain. They are, however, probably similar in size or smaller than the chromite lenses of Telot.

(3) Hydrothermal Deposits

(*a*) *Gold*

Quartz-pyrite veins occur in a small swarm which traverses the bed of the Iun River four miles east of Kabomba. They assayed 0.3 dwt. per short ton (specimen 26/758). No other quartz veins of any promise were seen in the area, the remainder being of the large barren type.

A fault breccia from the Kokoten fault, consisting of crushed and silicified biotite gneiss and carrying pyrite was also assayed and yielded 0.9 dwt. per short ton (specimen 26/849).

From these results it is clear that there is some concentration of gold from the country rock in such minor vein deposits, but these bodies are neither numerous enough or rich enough to provide an economic source of gold.

(*b*) *Copper*

Copper deposits associated with basic rocks of the Basement System have been known from the Suk area for some years (Temperley, 1952; Temperley, Miller and Searle, 1952; Miller, 1956, pp. 30-31). The ultimate source of the copper appears to have been a primary impregnation of basic rocks. The only copper deposits seen in the Sekerr area are, however, of hydrothermal type, secondarily enriched near the surface.

Quartz-chalcocite veins discovered by a prospector associated with New Consolidated Goldfields Ltd., are present on the south bank of the Iun River where it passes through the gorge a mile west of Akeriemet. They are associated with a little malachite and do not appear to be sufficiently extensive to warrant further exploration. Similar occurrences were explored by R. T. Mines Ltd. in the Karasuk Hills, and revealed a pronounced secondary enrichment near to the surface, copper values decreasing very rapidly in depth (verbal communication, J. Walsh). Some minor occurrences of malachite were seen immediately west of Nakhang in the Turkwell River. They are associated with quartz veins of hydrothermal origin. The copper is present in small and sparsely distributed nodes and there is no likelihood of any economic deposit in this locality.

Thin seams of a mixture of hematite and malachite were noted in the serpentine-talc complex of Telot.

(c) *Kyanite*

Quartz-kyanite veins and segregations occur in the following localities:—

(1) At the confluence of the Iun and Marun Rivers.

(2) In the bed of the Akeriemet River.

(3) On the track from Korpu to Nakhang near to the Turkwell Gorge.

(4) One mile north-east of Nasolot Peak.

The first three occurrences are minor, but bodies of kyanite rock appear to be numerous at the last locality. The hillside is much obscured by bouldery detritus and little can be determined of the extent of the segregations from surface examination. A programme of trenching would be required to be carried out before any estimate of the economic value can be made. The kyanite is concentrated in bluish grey patches of crystals up to three inches long. They are clearly of hydrothermal origin and possibly related to the nearby granite masses where similar kyanite-rock bodies occur, though no such relationship to granite exists at Murka (Temperley, 1953, pp. 31-39), The kyanite schists (p. 20) are of no economic significance.

(4) Pneumatolytic Deposits

(a) *Columbite, Samarskite and Mica Deposits*

H. Wreford-Smith's Claims at Kenailmet, Morukong and Kokusan

The only columbite-samarskite-mica deposit in the area which is actively worked is situated at Kenailmet in Karasuk, nineteen miles from Amudat and near to the southern termination of the "Bore-holes road" at Burgich bore-holes. The claims were pegged by H. Wreford-Smith in 1955 and limited production of columbite, samarskite and mica has been made during the last five years, entirely by opencast methods.. The total production of columbite up to June, 1960, was under five tons and cut mica was produced at the rate of about 100 lb. per month. The deposits are situated in three pegmatite dykes, Kenailmet, Morukong and Kokusan.

Kenailmet

This is an exceptionally large pegmatite of complex structure cutting amphibolite gneiss and crystalline limestone country rock. The pegmatite shows a complex structure of quartz cores and flanking zones. Excavations reveal some zones running almost horizontally across the dyke, while others follow the normal pattern, parallel to the walls. Large books of biotite or vermiculitic biotite are concentrated immediately adjacent to the quartz zones, with a few set as if in gash fractures within them. Tourmaline is patchily distributed along the areas marginal to the quartz cores but is abundant. The mineral is a brownish black variety and occurs in perfect prismatic crystals. Small well formed red garnets are associated with it. Columbite and samarskite are not very abundant in the cut sections, but occur with the tourmaline and mica near to the quartz cores. Other minerals include white felspars, green muscovite, xenotime, green fluorite and traces of magnetite. Corundum has also been reported. No beryl has as yet been found at Kenailmet.

The operations on this lode were commenced with the recovery of books of mica up to 16 inches in diameter. The books consist of the characteristic pale green muscovite common to many Suk pegmatites. The mica shows some spotting, especially where near to lumps of samarskite, but many clear sheets are recovered. The mica near to the surface tends to be bent and cracked, but this condition becomes less marked below the surface. Cross graining is common, and results in much wastage. The patchy and rather poor quality of the surface mica was responsible for an early cessation of working of this mineral, and all available resources were transferred to recovery of columbite from the top soil. This has so far resulted in the sale of less than five tons to

buyers in England. The top soil, which is only a few inches thick, is rich in lumps of columbite, samarskite and magnetite The latter is separated by magnet, and the samarskite by use of a ratemeter.

In July, 1957, the clearing of the topsoil was continuing and mica was once again being recovered.

In 1958 green fluorite was found in lumpy aggregates within the pegmatite. This closely resembles the occurrence at Lake George, Colorado, described by Glass, Rose and Over (1958). The presence of xenotime in association with the fluorite is a further resemblance to the Colorado occurrence. The xenotime is light brown and forms radiating aggregates of tetragonal crystals, with well marked pyramid faces. The specific gravity is 4.1, the maximum refractive index 1.80, and the hardness 5-6. In thin section it is seen to be optically positive. There are ragged water clear isotropic, or near-isotropic inclusions within the xenotime crystals, which have a micro-granular appearance, and show a moderate birefringence. The identity of the xenotime was confirmed by spectrographic analysis.

In 1959, the dyke itself was being worked; it was found very hard to work, but the amount of columbite and samarskite was increasing.

Morukong

The pegmatite at Morukong is narrower than the Kenailmet lode. It carries the same general mineral assemblage but the samarskite is not accompanied by columbite. Samarskite has been proved in float for a mile along the strike and will eventually probably be recovered. There is some large mica at the north end, and the structure observed suggests that Morukong may be the top of a large lenticular body comparable with Kenailmet, in which case it might be possible to prove a large quantity of mica in depth.

Kokusan

The westernmost dyke in the Kenailmet area contains a rather fine-textured intergrowth of columbite and samarskite; the intergrowth has been proved over a length of half a mile at the north end of the dyke. The grain size is a handicap and, as the samarskite is not separable, the product can only be sold as rather low-quality columbium ore, owing to the lower percentage of columbium in the samarskite than in the columbite. Working on this lode is proceeding, but it looks probable that excavation of the actual pegmatite may present difficulties, and the soil mantle is not promising.

Columbite of the Kenailment Lode

The columbite has an appreciable tantalum content. Analyses of samples have given the following results:—

	1	2	3	4
	%	%	%	%
Ta_2O_5	16·44	71·8	74	68·5
Nb_2O_5	55·52			
SiO_2	Tr	—	—	—
TiO_2	1·70	—	—	—
MnO	4·48	—	—	—
FeO	15·58	—	—	—

1. Shipment sample, March 7th, 1956, dried at 100°C. Anal: B. Kitto.
2. Lab. No. 26039. Anal: W. P. Horne, 11–8–56. The specimen analysed was non-magnetic and non-radioactive.
3. Anal: P. G. Jeffrey (Geological Survey of Uganda).
4. Anal: B. Kitto.

Samarskite of the Kenailmet Area

Mineralogical details on the samarskite at the three lodes have been supplied to Mr. Wreford-Smith by the Atomic Energy Division of the United Kingdom Geological Survey.

The mineral is black when fresh with bright vitreous lustre and conchoidal fracture. The hardness is 6. In thin flakes it is pale brown to reddish brown. Weathered surfaces are grey to brown. Crystals are flat prismatic, possibly with orthorhombic symmetry, and sometimes in parallel growth. The mineral is weakly magnetic.

Radiometric assays gave the following results:—

	eU_3O_8
Kenailmet	16.8
Morukong	15.5
Kokusan	13.5

With an aluminium screen between the specimens and the radiation counter the radioactivity recorded is almost halved, showing that it is almost entirely due to uranium and not thorium.

X-ray diffraction photographs gave no pattern before heating showing that the specimen is metamict (devoid of crystalline structure as a result of bombardment of atoms by alpha particles and recoil nuclei). On heating to 1,000° C. for over 12 hours all three specimens gave a pattern similar but not identical with a standard specimen of samarskite treated the same way.

Spectrographic examination of the Kenailmet material proved that the element outstandingly present is niobium, with some uranium, titanium, yttrium and iron. Tantalum was not detected but may be present in very small quantity. The detection of thorium was doubtful and, if present, it is a minor or very minor constituent. Trace elements detected included manganese, lead, zirconium, aluminium and silicon. The Morukong samarskite is similar to that from Kenailmet, but contains slightly more iron, and thorium was not detected. An additional trace element detected in it was calcium. The samarskite from Kokusan is again like the Kenailmet material but contains rather less uranium. Tantalum was detected in small quantity. The tests allow the classification of all the specimens as titancolumbates of uranium, yttrium and iron, and they were provisionally identified as samarskite.

Analyses of samples gave the following results:—

	1	2
	%	%
Nb_2O_5	43·34	46·8
Ta_2O_5	2·70	
Fe_2O_3	—	20·0
TiO_2	3·14	1·0
SnO_2	0·07	—
MnO	—	0·4
CaO	—	2·9
Rare Earths and Thorium Oxides	—	15·0
U_3O_8	—	14·3
		100·4

1. Samarskite, Morukong. Anal: Benedict Kitto, April, 1957.
2. Samarskite, Kenailmet. Anal: Industrial Research Organization, Nairobi.

Conclusions on the Wreford-Smith Claims

This small undertaking has enough reserves for limited working for several years and it is possible that further prospecting may reveal extensions of the mineralized pegmatite swarm. In 1957 the first shipment of columbite was sold for £400 a ton (its price, has, however, dropped since then) and the intergrown ore commands a rather lower price owing to the lower columbium content. There should be a considerable quantity of workable mica to uncover before the claims are exhausted. The samarskite cannot at present (1960) be sold for its uranium content, since no process of extraction from the extremely refractory ore has yet been evolved, but interest has recently been shown by an American firm in the possibility of extracting rare-earths from this ore.

Age Dating from Samarskite

Three specimens from Morukong, Kenailmet and Kokusan "lodes" were tested by the Atomic Energy Division, Geological Survey of Great Britain. The ages deduced in millions of years were*:—

	Pb_{207}/Pb_{206}	Pb_{206}/U_{238}	Pb_{207}/U_{235}	Pb_{208}/U_{232}	Chemical
Morukong ..	652	636	639	642	640
Kenailmet ..	613	544	557	533	560
Kokusan ..	617	469	495	464	500

The Pb_{207}/Pb_{206} values are all in close agreement, but the Pb_{206}/U_{238} value for Morukong is considered the most reliable. All the Morukong values agree with the dating 636 $\pm$ 20 m.y. The low values for Kenailmet and Kokusan are attributed to lead loss, and the dykes are considered to be of the same age as Morukong. The age 636 $\pm$ 20 m.y. indicates a late Precambrian age for the pegmatites.

Reported Occurrence at Karameri

An application was received by the Mines and Geological Department in June, 1957, from J. L. Coulthard for an exclusive prospecting licence covering a small area south of Karameri, where he reported columbite and samarskite. The writer visited the area in question. There seems little doubt that Coulthard was under the impression that the hydrothermal veins carrying magnetite associated with the Kapchok gneisses were columbite deposits. The area is traversed by a swarm of pegmatites, but these were found to carry only magnetite. White mica and tourmaline are extremely scarce, but a few pieces of rather fresh columbite together with a little samarskite were recovered on the surface. It must be accepted that there is a little columbium in the pegmatites, though appearances are against it. Certainly working the pegmatites could never be profitable, and the geological and topographical conditions rule out any possibility of major eluvial or alluvial concentrations as suggested by Coulthard.

(b) Mica Deposits

Mica of a quality that justifies consideration as a possible economic deposit is found in two localities within the area—Nasolot and Kenailmet. The deposits at Kenailmet have already been described (*see* p. 71).

The Nasolot occurrence was first worked by P. G. Franz Willberg, a German prospector, who discovered the deposit in 1928. The mica was passed through the Imperial Institute to Hart, Mayland and Co. for a trade assessment. They reported on it as being "of very desirable character and readily saleable in large quantities".

The mica occurs in a swarm of large pegmatites of rather unusual dyke-like form (Fig. 14) closely comparable in size and form with the Kenailmet pegmatites. There

* A. G. Darnley *et al.* "Ages of some uranium and thorium minerals from East and Central Africa", Mineralogical Magazine, 1961.

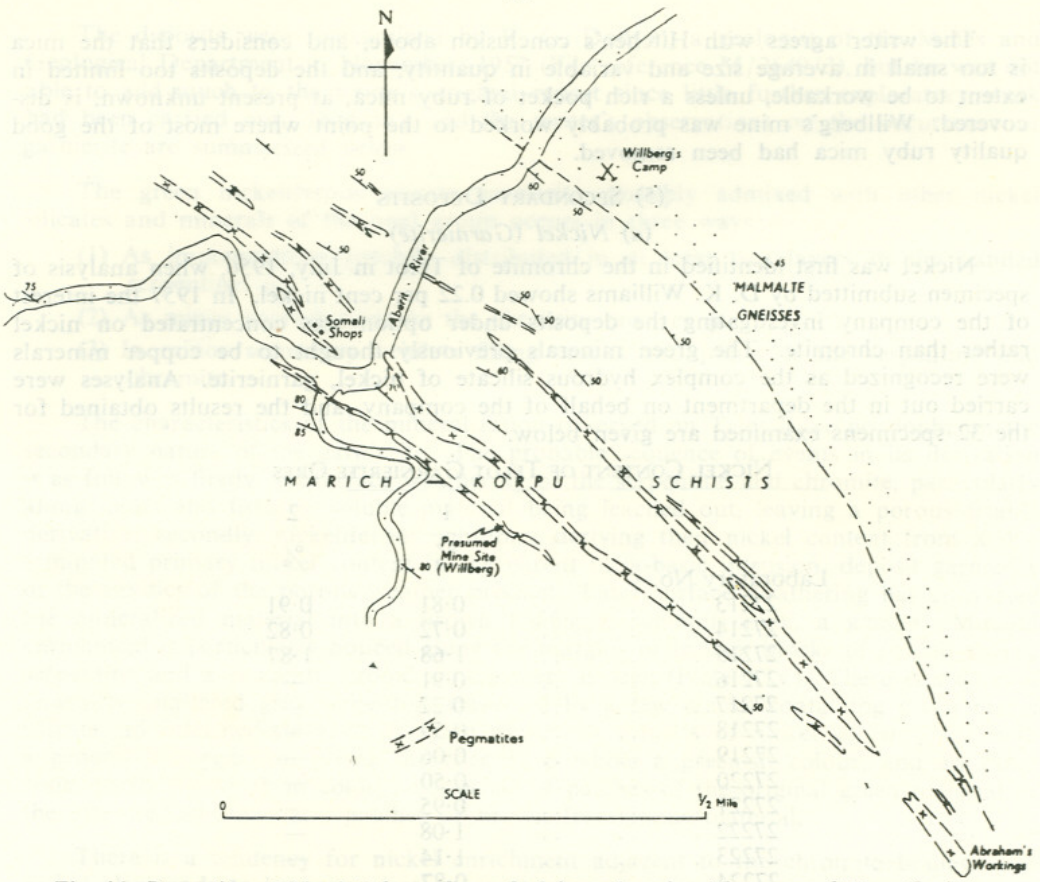


Fig. 14—Pegmatites at Nasolot, formerly worked for ruby mica. The swarm follows the line of strike but appear to consist mainly of steep wall-like bodies and not concordant intrusions. (After C. S. Hitchen, 1942.)

are several small dyke-like bodies of leucogranite associated with them (cf. micro-granite at Kenailmet), which suggests they may be late phases of the Parek granite mass, the contact of which lies about a mile to the south of the swarm.

The swarm is about a quarter of a mile wide and consists of about four or five major dykes of variable composition. Sometimes only quartz and felspar are seen. There are no very well-marked zonal structures or quartz cores. Mica is sometimes present in the body of the pegmatite, but mostly it is of poor quality. Willberg mined the mica in a restricted locality, where good quality No. 4 size grade (6-10 square inches) ruby mica was recovered. His workings extended only to 30 feet according to C. S. Hitchen who reported on the prospect in 1942. The exact mine site is not now known, and one suspects that Hitchen was unable to examine the working face, since he was unable to decide if the mica was worked out or still continued in depth. The information that follows was taken from Hitchen's report (File T.16/1, Mines and Geological Department).

Willberg worked the mica from 1928 to the end of 1929. The only other record of mica production from Nasolot is half a ton of poor quality mica by B. G. Abrahams in 1929. Hitchen was of the opinion that the mine was never an economic proposition, quoting Willberg's production figures for 1929—raw mica mined, 36,450 lb. from 17,986 tons of rock; cut mica, 3,645 lb. sold at Sh. 6/20 a pound. This means that a ton of pegmatite yielded only 0.2 lb. of mica, representing a return of Sh. 1/24. Even with labour costs as low as they were in West Suk, the undertaking could never have been profitable.

The writer agrees with Hitchen's conclusion above, and considers that the mica is too small in average size and variable in quantity, and the deposits too limited in extent to be workable, unless a rich pocket of ruby mica, at present unknown, is discovered. Willberg's mine was probably worked to the point where most of the good quality ruby mica had been removed.

(5) Secondary Deposits

(*a*) *Nickel* (*Garnierite*)

Nickel was first identified in the chromite of Telot in July, 1956, when analysis of specimen submitted by D. K. Williams showed 0.22 per cent nickel. In 1957 the interest of the company investigating the deposits under option was concentrated on nickel rather than chromite. The green minerals previously thought to be copper minerals were recognized as the complex hydrous silicate of nickel, garnierite. Analyses were carried out in the department on behalf of the company, and the results obtained for the 32 specimens examined are given below.

Nickel Content of Telot Garnierite Ores

	1	2
	%	%
Laboratory No.—		
27213	0·81	0·91
27214	0·72	0·82
27215	1·68	1·87
27216	0·91	—
27217	0·22	—
27218	0·59	—
27219	0·06	—
27220	0·50	—
27221	0·95	—
27222	1·08	—
27223	1·14	—
27224	0·87	—
27225	0·78	1·01
27226	0·84	—
27227	1·13	—
27228	0·54	—
27229	0·46	—
27230	0·50	—
27231	0·26	—
27232	0·35	—
27233	0·91	—
27234	0·57	—
27235	1·56	1·72
27236	1·15	—
27237	1·61	—
27238	1·11	—
27239	1·19	—
27240	1·01	—
27241	1·14	—
27242	1·70	—
27243	0·69	—
27244	1·74	1·81
Average	0·89	

Anal: W. P. Horne.

1. Results obtained by dissolution in acid, followed by precipitation of the nickel from the filtrate.
2. Total nickel in the samples, combining that obtained by acid solution and that determined in the residue after fusion.

The deposits were re-examined by R. G. Dodson, a geologist of the Mines and Geological Department in November, 1957 (File reference M/2649/3), but he was not able to add much to the writer's original report since little further exploratory work had been carried out. Dodson's and the writer's observations on the occurrence of garnierite are summarized below.

The green nickeliferous silicate garnierite, possibly admixed with other nickel silicates and minerals of the opal group occurs in three ways:—

(1) As impregnations patchily distributed in at least two layers in the banded serpentine.

(2) As minor encrustations on the chromite ore (*see* p. 70).

(3) In minor secondary veinlets filling cracks and joints in the serpentine and chromite.

The characteristics of the mineralization observed on Telot leave no doubt on the secondary nature of the garnierite. The probable sequence of events in its derivation is as follows: firstly, subsurface weathering of the serpentine and chromite, particularly along joints and fissures, soluble material being leached out, leaving a porous friable derivative; secondly, nickeliferous solutions, deriving their nickel content from a disseminated primary nickel content in the parent ultra-basic intrusion, deposit garnierite in the cavities of the porous weather product. Later surface weathering has converted the mineralized material into a brown friable ferruginous rock, a gossan. Mineral enrichment is particularly noticed along the margins of broken blocks of friable altered serpentine and a concentric zonal arrangement is seen (Plate XIV). There is a core of relatively unaltered grey serpentine traversed by a few cracks containing green nickel silicate, an intermediate zone carrying numerous veinlets of nickel silicates and with a general impregnation giving the rock as a whole a greenish colour, and an outer zone, partly brownish in colour, composed of patches of the original green material of the intermediate zone and patches of brown ferruginous material.

There is a tendency for nickel enrichment adjacent to the chromite bodies. The nickel also tends to be concentrated near to more compact serpentine bands.

The mineral garnierite is not of as widespread occurrence as the other nickel ore-minerals, pentlandite and niccolite. Its main occurrence is in New Caledonia where it occurs in extensive bodies of serpentinized peridotite. This is the second largest nickel field in the world, but of late has suffered some recession owing to the increasing difficulty in competing economically with the richer Sudbury ores of Canada (Lindgren, 1933, p. 372). Garnierite is a nickeliferous serpentine. Winchell (1951, p. 379) considered the mineral as a nickeliferous chrysolite, with a little admixed opal or another hydrous nickel silicate, since the analysis invariably reveals an excess of silica. The mineral is usually apple green, though more rarely it is yellowish in colour. The Telot garnierite appears to be rather lighter in colour than specimens from New Caledonia. The New Caledonia deposits extend to 25 or 35 feet in depth (Bateman, 1950, p. 239). The depth of enrichment in the Suk is not yet known. The ore now smelted in New Caledonia averages 5 to 5.5 per cent nickel and the parent serpentine covers 2,500 square miles (Lindgren, 1933, p. 372). The deposits have been classified into:—

(*a*) Vein-like deposits.

(*b*) Brecciated deposits.

(*c*) Impregnations.

(*d*) Earthy masses.

This classification might be applied on Telot, though breccia deposits were not noted. It is found that the brown surface-weathered material, the "chocolate ores" of New Caledonia, contain nickel in workable quantity, but the brownish crust on Telot is not appreciably nickeliferous.

The conclusion cannot be escaped, weighing the evidence available at the time of writing, that the Telot nickel is not an economic proposition. The reasons for this conclusion are:—

(1) The 32 samples tested average 0.89 per cent NiO and the highest grade in any specimen was 1.74 per cent. It is not, moreover, certain that the samples were not to a certain extent hand-picked on a basis of promising colour. The figures compare unfavourably with the New Caledonia figure of 5-5.5 per cent nickel.

(2) The deposits are situated at about 8,000 feet above sea-level, and 80 miles from railhead along a mountainous and tortuous secondary road.

(3) The deposits are not extensive and the area of the parent serpentine is inconsiderable in comparison with the 2,500 square miles of serpentine in New Caledonia.

(4) The mineralization is patchy and dispersed in the serpentine.

(5) The likelihood of mineralization extending to any depth is small.

(6) No trace of primary nickel ore has so far been discovered and, if found, it is likely to be disseminated and in small quantity.

(*b*) *Anthophyllite Asbestos*

Anthophyllite asbestos has been noted in small quantities in the amphibolitic schists, particularly in the Marich-Korpu formation (*see* p. 34). It is often associated with talc, and is believed to be derived from ultra-basic and basic intrusions. The only appreciable concentrations are on Karel immediately south of the Bino Gorge, and near to Orwa. On the north face of Karel there are many narrow seams of asbestos in talc-chlorite-actinolite schists, but they do not appear to be of sufficient extent to warrant exploitation. The anthophyllite is red in colour and in appearance bundles of fibres resemble slivers of wood—hence the prospector's name "cedar asbestos". The individual crystal fibres are several inches long.

(6) Miscellaneous

(*a*) *Building-stone*

The white dolomitic marble, of which many bands are seen in the area, especially near to the Iun and Sergoi Rivers and Burgich can be used as building-stone without dressing. The stone comes out of the quarry in flattened slabs of irregular outline, which are fitted together in a mosaic by hand and bonded with mortar. The church and houses at Ortum (ten miles west of Wakor in the Cherangani area) provide a pleasing example of this manner of building. There is no doubt that quartzite and siliceous gneiss slabs could be used the same way, but there is little demand for such material, nor is there likely to be such a demand. There is no soft building-stone suitable for hand-dressing into rectangular blocks within the area.

(*b*) *Corundum*

Corundum has been reported from the Kenailmet pegmatites, and a few crystals of corundum were observed in float at Lossom and on the Turkwell Plains north-east of Lokwien. There is at present no indication that there is any likelihood of workable deposits. The corundum seen is not of gemstone quality.

(*c*) *Garnet*

Garnets are widespread throughout the area but those in the metamorphic rocks are invariably cracked, distorted and full of inclusions. On the narrow ridge between the Endoo River and the Gudwarun River, superficial stony float is seen to be almost entirely composed of garnets up to two inches in diameter. The garnets are full of inclusions. Many preserve rhombic dodecahedral form. They are derived from porphyroblast schists of the type illustrated in Plave IV (*a*). They do not appear to have any economic value.

(d) Graphite

Graphite schists occur on Morumeri, and a little graphite was noted in some of the Marich-Korpu schists, but no deposits of the mineral of economic significance were seen in the area.

(e) Gravel

There are pockets of alluvial gravel along the Suam and Kanyangareng Rivers and their tributaries, and several small gravel hills flank the Marun River below the pass. The gravels are of earthy type with sparse pebbles, and are not of any economic importance.

(f) Ilmenite

Some quartz-ilmenite veins were noticed near the Iun Gorge and east of the Sergoi River. A little ilmenite is also associated with the Kapchok gneisses. Samples of this mineral are frequently collected by prospectors from West Suk and Karasuk, but it is of no value. Ilmenite must be found in vast and easily workable deposits to be worth extraction.

(g) Limestone

Limestone occurs in many parts of the area. It is usually a white crystalline iron-poor dolomitic limestone. Though suitable for lime production, the lack of communications in West Suk makes the possibility of exploitation extremely unlikely. It is not suitable for the production of cement owing to the high magnesia content. There may conceivably be localized patches with magnesia below 2 per cent, but this does not seem likely as all the samples tested by the writer showed considerable dolomite content.

(h) Magnetite

Magnetite is abundant in the Kapchok gneisses and is also commonly found in the granitoid sheets of Ptoyio, Sogho and the Marich Pass. Segregations of magnetite are not uncommon in the plagioclase amphibolites, and the peridotite, pyroxenite, dolerite, epidiorite, serpentine and talc bodies all carry it as an accessory. It sometimes occurs in the form of martite i.e., hematitic pseudomorphs after magnetite. The magnetite is never concentrated in large bodies, and although often conspicuous in gullies and in float, is of no economic value.

(i) Spinel

Blue spinels occur in the crystalline limestones on Morumeri, and near the Sabai saddle. They are not of any economic value.

(j) Talc

The south-east part of the area is characterized by many occurrences of talc schists. In the Iun Gorge and on Telot there are considerable bodies of talc, and there are some hydrothermal veins of pure white talc cutting the talc schists immediately east of the Telot serpentine.

(7) Summary of Conclusions on the Economic Prospects of the Sekerr Area

The alluvial gold deposits of the Turkwell River should provide a steady yield for many years to come. The chance of the possibility of discovering a workable band in the schists is, however, not high. The Marich gold is less promising. Large boulders and perennial flow make recovery of the gold a matter of extreme difficulty.

There is no likelihood of any new gold deposits being discovered west of the two known areas, but prospecting on the valley floor east of the Marich Pass and Turkwell Gorge might reveal deposits in old river channels along the meandering courses of the big rivers. There might also be hidden fans of gold-bearing gravels where the Marich and Turkwell debouch over the fault-line, but to prove this would require sub-surface exploration.

The kyanite rock at Nasolot is worth prospecting further. The chromite, nickel and copper occurrences are, however, not likely to be of any economic importance—nor is the asbestos. While the types of deposits seen are varied, only the gold is worked or likely to be worked in the foreseeable future. The field will, in all probability remain small, though energetic prospecting might lead to considerable extensions.

2. Water Supply

(1) Surface Water

The area has a comparatively high rainfall (*see* table, p. 3) but owing to the six months' long dry season (September-March) all but the high country on Sekerr and Karikau undergo considerable periods of drought. The Suam (Turkwell) River dries out below Nakuijit in a normal year (in dry years it sometimes dries out to a point well above the Chessera confluence) but there is always a flow below the sand in the river-bed as far as the point where it leaves the area. A loss of 0.7 cu. secs. per mile between Kacheliba and Korpu has been estimated by Underhill (1955), but he appears to ignore the considerable sub-surface flow in the lower reaches. There can be no doubt, however, that the Suam is a tapering river, losses being almost entirely due to evaporation. Most of the rivers of the Sekerr area taper, and are of the sand-river type in their lower reaches, and permanent streams and springs are only seen on the high ground of Sekerr, Chepunyal and Karikau. The Marun and Malmalte are permanent rivers fed from the extensive well-watered Cherangani Hills, and the Masol Plain is thus well supplied with water. The sand-rivers contain flowing water for only short periods after storms and during the wet months, but water can often be found in the dry season by digging shallow holes in the river-beds. Such holes are the main source of water for the native population and their livestock in the areas distant from permanent water.

The concentration of herds along the Suam in dry weather is the cause of much soil erosion in the lowlands of West Suk and Karasuk. Much of the lowland plain has lost all its soil, and is now a stony surface whose only vegetation is the hardiest of thorn trees and aloes.

Deforestation on the escarpments has caused considerable drying up of the head-waters of the rivers, and decrease in spring activity in the last few years. Rehabilitation of these deforested areas is a matter of urgent necessity. After heavy rainstorms almost the entire increment runs off, converging in torrents often faced by a wall of water and carrying with it boulders and tree trunks and a great deal of what meagre soil is left. The Chessera and Nakuijit provide a terrifying spectacle when in flood. All this run-off is channelled through the Turkwell Gorge and soon lost on the Turkana plains. Thus, we have an area in which there is abundant surface flow, but little run-in. What surface flow there is is of little use in providing water-supply, and is a powerful tool of the process of ruination of the land by soil erosion.

Because of this concentration of the run-off in flood flow, and the consequent difficulties in engineering, small-scale dams are not practicable and irrigation except by flood inundation is also not possible.

(2) Ground-water

From the summary of surface water conditions given it will be realized that water-supply problems in this area are considerable. Ground-water utilization is, however, the subject of two contrary opinions held by the Administration in West Suk and that in Karasuk. The District Commissioner of West Suk considers that boreholes only provide new areas of stock concentration and consequent foci of soil erosion. The Karasuk Administration favour the use of boreholes, and has drilled some 11 holes with success. It is clear from these results that ample supplies of ground-water are available in the lowland country, but whether any long-term benefit accrues to the population from boreholes is questionable. The boreholes drilled are all relatively shallow (*see* Table VIII). They were drilled with percussion rigs and installed with hand pumps. Siting was done by the Uganda Geological Survey without the aid of resistivity depth probes. The general principle of siting appears to be location within well-marked drainage lines.

TABLE VIII

Water Bore-holes in the Sekerr Area*

No.	Locality	Depth	Depth to which water rose	Yield
		(*feet*)	(*feet*)	
CD 1521 ..	Koduch (S)	499	285	Adequate for watering stock
CD 987 ..	Koduch (N)	550	305	,,
CD 1548 ..	Chepukatina	450	200	,,
CD 1503 ..	Kunyao	460	322	,,
CD 267 ..	Kunyao	675	100	,,
CD 147 ..	Kunyao	575	100	,,
CD 854 ..	Burgich (N)	370	300	,,
CD 841 ..	Burgich (S)	720	190	,,
CD 814 ..	Karemeri (S)	836	182	,,
CD 825 ..	Karemeri (N)	205	140	,,

*Information concerning bore-holes in Karasuk was supplied by the Deputy Director, Uganda Geological Survey.

(3) Hydro-electric Power

In such a sparsely inhabited pastoral region the only possibility in developing hydro-electric power is a large-scale scheme benefiting the country as a whole. The drop of 1,000 feet at the Turkwell Gorge appears on first sight promising, but the river dries out below the Chessera River confluence in normal years and storage in a large reservoir would be required to support any scheme. Silt and debris carried by the flow into the reservoir would present a serious problem. There is, however, each year an enormous volume of water plunging down the gorge to waste itself in the arid and empty Lake Rudolf basin, and it is possible that a dam across the Bino Gorge, a rocky defile a few hundred feet across, could impound sufficient storage to cover the three months in which there is no flow.

The Marich River has a smaller drop at the margin of the Masol Plain, and the valleys behind the pass are steep and narrow. The river, however, has perennial flow and could certainly be utilized for the production of hydro-electric power, though probably several fairly small installations would be necessary rather than generators worked from a single large dam.

VII—REFERENCES

*Argand, E., 1912.—"Sur la Segmentation Tectonique des Alpes Occidentales", *Bull. Soc. Vaud. Sc. Nat.*, 5th Ser., Vol. XLVIII, pp. 345-356.

Austin, H. H., 1902.—"A Journey from Omdurman to Mombasa via Lake Rudolf." *Geog. Jour.*, Vol. XIX, pp. 669-690.

Bateman, A. M., 1950.—"Economic Mineral Deposits."

Champion, A. M., 1937.—"Physiography of the region to the west and south-west of Lake Rudolf." *Quart. Jour. Geol. Soc.*, Vol. LXXXIX, pp. 97-118.

Clifford, P., M. J. Fleuty, J. G. Ramsay, J. Sutton and J. Watson, 1957.—"The development of lineation in complex fold systems." *Geol. Mag.*, Vol. XCIV, pp. 1-24.

*Crampton, C. B., 1913.—"The Geology of Cowal." Memoir of the Geological Survey of Scotland.

Dixey, F., 1946A.—"The relation of the main peneplain of Central Africa to sediments of Lower Miocene age." *Quart. Jour. Geol. Soc.*, Vol. CI (for 1945), pp. 243-248.

————, 1946B.—"Erosion and tectonics in the East African rift system." *Quart. Jour. Geol. Soc.*, Vol. CII, pp. 339-379.

————, 1948.—"The Geology of Northern Kenya." Report No. 15, Geol. Survey, Kenya.

————, 1956.—"The East African Rift System." Colonial Geology and Mineral Resources, Bulletin Supplement No. 1.

Dodson, R. G.—"Report on a visit to the mineralized Serpentine on Telot, below Wyisa Ridge, West Suk." Report filed at the Mines and Geological Department, Nairobi.

*Eskola, P., 1939.—"Die metamorphen Gesteine" in T. F. W. Barth, C. W. Correns and P. Eskola, "Die Entstehung der Gesteine".

Fyfe, W. S., F. J. Turner and J. Verhoogen, 1958.—"Metamorphic reactions and metamorphic facies." Memoir No. 73, Geol. Soc. Amer.

Gibson, A. B., 1954.—"The Geology of the Broderick Falls area." Report No. 26, Geol. Survey Kenya.

Glass, J. J., H. J. Rose and E. Over, 1958.—"Notes on the Mineralogy of an Yttrium-bearing pegmatite near Lake George, Park County, Colorado." *Amer. Min.*, Vol. XLIII, pp. 991-994.

Glenday, V. G., and J. Parkinson, 1926.—"The Geology of the Suk Hills." *Quart. Jour. Geol. Soc.*, Vol. LXXXII, pp. 586-614.

————, 1927.—"The Kateruk Series and associated rocks of the northern Suk Hills." *Quart. Jour. Geol. Soc.*, Vol. LXXXIII, pp. 790-800.

Gregory, J. W., 1921.—"The Rift Valleys and Geology of East Africa."

Heritsch, F., 1929.—"The Nappe theory of the Alps."

Hitchen, C. S., 1942.—"Report on mica production in West Suk." Report filed at the Mines and Geological Department, Nairobi.

* References marked with an asterisk were not consulted in original.

Holmes, A., and L. Cahen, 1955.—"African Geochronology." *Colonial Geology and Mineral Resources,* Vol. V, No. 1, pp. 3-38.

Jones, O. T., and W. J. Pugh, 1948.—"The form and distribution of Dolerite masses of the Builth-Llandrindod Inlier Radnorshire." *Quart. Jour. Geol. Soc.,* Vol. CIV., pp. 71-94.

Joubert, P., 1957.—"The Geology of the Namanga-Bissel area." Report No. 39, Geol. Survey Kenya.

————.—"The Geology of the Loperot area." Report Geol. Survey Kenya (in preparation).

King, B. C., 1949.—"The Napak area of Southern Karamoja, Uganda." Memoir No. V, Geol. Survey Uganda.

King, B. C., and N. Rast, 1955.—"Tectonic styles in the Dalradian and Moines in parts of the Central Highlands of Scotland." *Proc. Geol. Assoc.,* Vol. LXVI, pp. 243-266.

————, 1956.—"The small-scale structures of south-eastern Cowal, Argyllshire." *Geol. Mag.,* Vol. XCIII, pp. 185-195.

Lindgren, W., 1933.—"Mineral Deposits."

Mason, P., and A. B. Gibson, 1957.—"The Geology of the Kalossia-Tiati area." Report No. 41, Geol. Survey Kenya.

McCall, G. J. H., 1954.—"The Dalradian Geology of the Creeslough area, Co. Donegal." *Quart. Jour. Geol. Soc.,* Vol. CX, pp. 153-175.

————, 1957A.—"Report on F. C. Daniel's claims at Sebit, West Suk." Report filed at the Mines and Geological Department, Nairobi.

————, 1957B.—"Geology and Goundwater conditions in the Nakuru area." Technical Report No. 3, Ministry of Works, Kenya.

————, 1958.—"The Geology of the Gwasi area." Report No. 45, Geol. Survey Kenya.

————, B. N. Temperley and C. M. Bristow.—"The Geology of the Nakuru-Thomson's Falls-Lake Hannington area." Geol. Survey Kenya (in preparation).

McCallien, W. J., 1936.—"A note on Dalradian pillow lavas, Strabane, Co. Tyrone." *Proc. Roy. Irish Acad.,* Vol. XLIII, Section B, No. 2, pp. 13-22.

Miller, J. M., 1956.—"The Geology of the Kitale-Cherangani hills area." Report No. 41, Geol. Survey Kenya.

Murray-Hughes, R., 1933.—"Notes of the Geological Succession, Tectonics and Economic Geology of the western half of Kenya Colony." Report No. 3, Geol. Survey Kenya.

Pulfrey, W., 1960.—"The shape of the sub-Miocene Bevel in Kenya." Bull. No. 3, Geol. Survey Kenya.

Saggerson, E. P., 1952.—"The Geology of the Kisumu District." Report No. 21, Geol. Survey Kenya.

Searle, D. L., 1952.—"Geology of the area north-west of Kitale Township (Trans Nzoia, Elgon and West Suk)." Report No. 19, Geol. Survey Kenya.

Shackleton, R. M., 1951.—"A contribution to the Geology of the Kavirondo Rift Valley." *Quart. Jour. Geol. Soc.,* Vol. CVI, pp. 345-389.

Temperley, B. N., 1952.—"The Twin Bridges Malachite Occurrence." Report filed at the Mines and Geological Department, Nairobi.

————————, 1953.—"Kyanite in Kenya." Memoir No. 1, Geol. Survey Kenya.

Temperley, B. N., D. L. Searle and J. M. Miller, 1952.—"The Kipkomo Malachite Occurrences." Report filed at the Mines and Geological Department, Nairobi.

Trendall, A. F., 1959.—"Topography under the northern part of the Kadam Volcanics and its bearing on the correlation of the peneplains of south-east Uganda and the adjacent parts of Kenya." Records, 1955-56, Geol. Survey Uganda.

Turner, F. J., 1948.—"Mineralogical and Structural evolution of the metamorphic rocks." Geol. Soc. Amer., Memoir No. 30.

Underhill, H. C., 1955.—"Report on the Suam River Hydrological Investigation." Hydrological Report No. 35, filed at the Hydraulic Branch Ministry of Works, Nairobi.

Walsh, J.,—"The Geology of the Karasuk area." Report Geol. Surv. Kenya (in preparation).

Weiss, L. E., 1958.—"Structural Analysis of the Basement System at Turoka, Kenya." Overseas Geology and Mineral Resources, Vol. XVII, pp. 3-35 and 123-153.

Weiss, L. E., and D. B. McIntyre, 1957.—"Structural Geometry of Dalradian Rocks at Loch Leven, Scottish Highlands." *Jour. Geol.* Vol. LXV, No. 6, pp. 575-602.

Winchell, A. N., 1951.—"Elements of optical mineralogy."

G.P.K. 3084—1m—11/61