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GOVERNMENT OF KENYA

MINISTRY OF NATURAL RESOURCES
GEOLOGICAL SURVEY OF KENYA

GEOLOGY OF THE MARA RIVER–SIANNA AREA

DEGREE SHEET 50, N.W. and S.W. QUARTERS

(with two coloured geological maps)

by

L. A. J. WILLIAMS, B.Sc., F.G.S.
Geologist

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FOREWORD

The most important geological feature that has emerged from the mapping on a regional geological scale of the Mara River-Sianna Area, is the convincing demonstration by Mr. Williams of two periods of folding of the Basement System rocks.

Full use has been made of the fact that hill-ranges occur in well-separated localities thus defining natural, more easily understood units, while the most prominent rock type quartzite, provides well-defined bands due to resistance to weathering, which greatly assisted structural interpretation.

Without doubt, further modifications will be made to the structural history presented here after more detailed mapping has been accomplished, but this will not detract from the value of the present work.

From an economic point of view, the results of the survey are disappointing as they demonstrate that gold-bearing rocks west of the area described in some earlier Departmental reports, have yet to be recognized east of the Siria escarpment. This discontinuation is probably due to another structural feature, a major thrust-movement. Further, the possibilities of diamonds occurring at an alleged old working are shown to be remote.

These negative results, which lessen the possibilities of mining, could be important for the preservation of wild animal life, as abundant game occurs over much of the area.

This report has been edited with the approval of Dr. W. Pulfrey, Commissioner (Mines and Geology).

Nairobi,
17th November, 1961.

N. J. GUEST,
Chief Geologist.

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ABSTRACT

The report describes an area of approximately 1,640 square miles in south-western Kenya, enclosed by longitudes 35° 00′ E. and 35° 30′ E., by latitude 1° 00′ S. on the north and by the Kenya-Tanganyika boundary on the south. The country lies almost entirely within the Narok district of the Southern Province.

Relics of an ancient land surface, believed to be of late Cretaceous age, are preserved on the summits of the highest hills while the sub-Miocene peneplain carries a thin but extensive lava sheet.

Much of the area is underlain by intensely folded Basement System rocks of presumed Archaean age, representing an original sedimentary succession that included psammitic, semi-pelitic, pelitic and semi-calcareous rock types. The metamorphic sequence is dominated by prominent bands of highly resistant massive quartzites.

The post-Archaean rocks include a biotite-hornblende granite that underlies the Siria plateau which is provisionally referred to the Precambrian, and a Tertiary phonolitic lava resting on the peneplained Basement System rocks across the centre of the area. A mantle of Pleistocene to Recent reddish brown sandy soils, dark clayey soils and alluvium frequently mask the underlying rocks.

The petrography of the various rocks is presented in detail and a brief account is given of the processes of metamorphism and granitization that have affected the Basement System. Complex structures in the Basement System are attributed to two phases of folding along axes more or less at right-angles.

The Mara river and its headstreams, together with a number of small springs, provide water supplies. No mineral occurrences of economic importance were discovered during the survey.

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The report describes an area of approximately 1,840 square miles in south-western Kenya, enclosed by longitudes 35° 00' E. and 35° 30' E., by latitude 1° 00' S. on the north and by the Kenya-Tanganyika boundary on the south. The country lies almost entirely within the Narok district of the Southern Province.

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GEOLOGY OF THE MARA RIVER-SIANNA AREA

I—INTRODUCTION

The area described in this report covers approximately 1,640 square miles and lies largely within the Narok District of the Southern Province of Kenya. It is bounded by the meridian 35° 00′ and 35° 30′ E., the parallel 1° 00′ S. to the north, and the Kenya-Tanganyika boundary on the south, comprising the north-west quarter of degree sheet 50 and that part of the south-west quarter which lies within the Colony. These correspond to the Directorate of Overseas Survey sheets Nos. 145 and 158, respectively. The area includes a small portion of the Kericho District of the Nyanza Province, separated from the Masai country to the south by the Amala river and a continuous fence-line that extends from the Amala-Mara confluence to the trigonometrical beacon on Abossi hill (several miles north of the present area).

Most of the field-work was carried out between March and October, 1957, with additional traverses into the country around the Mara river in February, March and June, 1958.

Maps.—The north-west quarter of degree sheet 50 is covered by preliminary plots on a scale of 1 : 50,000 and these were used during field-work in conjunction with aerial photographs. Although a large part of the country south of latitude 1° 30′ S. had been surveyed in 1904 during the demarcation of the Anglo-German boundary, it was found more convenient to prepare a 1 : 50,000 base-map from aerial photographs using the adequate existing ground control. Preliminary plots became available after completion of the geological maps but, as there is generally close agreement between the topographical detail of the two sets of maps, replotting of the geological information was not warranted. As expected, the maximum distortion occurs in the extreme south-eastern corner of the geological map of degree sheet 50 S.W.

In the southern part of the area, many of the form-lines have been modified from the Anglo-German boundary maps. Elsewhere form-lines have been drawn from spot-heights obtained from aneroid readings corrected for diurnal variation.

Place names were obtained from local guides, but alternative names frequently exist for many of the hills and streams. On the other hand, many of the names shown on the older published maps are apparently no longer recognized by the inhabitants of the areas.

For convenience, the geological map is divided along the parallel 1° 30′ S. and is published in two sheets. The northern part is referred to in this report as the Mara River Area, the southern section as the Sianna Area.

Communications.—The northern part of the area is traversed by the Narok-Lolgorien road, crossing the Mara river by a concrete bridge. Apart from the somewhat rough descent into the Mara valley, the road is suitable for all traffic in dry weather, the distance from Ngorengore to Nairobi being some 130 miles and about 100 miles from the railway at Longonot and Lumbwa. At Ngorengore on the eastern border of the area a good earth-road branches to Sotik and Kericho, while a track from the Sotik district also enters Masai territory and ends at a foot-bridge that crosses the river at Mara prison. A temporary road-bridge had been erected originally near the prison to afford easy access from the settled areas to the north but this was destroyed by flood waters in 1957, necessitating a detour to cross the Amala river by a ford at Ungulot.

South of the Narok-Lolgorien road a dry-weather track links the Tsetse Survey and Control camp on the Talek river with Aitong. Tracks to the Olchorro Orogwa cattle ranch, the Tsetse Survey and Control station at Kipleleo and to the old Mara prison also branch northwards from the Narok road, the best approach being by the route that circles round the northern end of Kipleleo hill. All other tracks, including those serving the Sianna area, are poorly defined in parts and may be difficult to follow through long grass.

Mara prison was closed and demolished in 1958 and it is doubtful whether the airstrip nearby has been maintained.

Population.—A striking change in population density and land development occurs at the boundary between the Narok and Kericho districts. To the north, widespread cultivation is carried out by members of the Kipsigis tribe, whilst southwards across the game-filled plains and hills roam the nomadic, pastoral Masai. The traditional circular thorn-fenced villages (*manyattas*) of the Masai are widely spaced and are frequently abandoned by the owners during periodic migrations in search of fresh grazing for their stock. Generally speaking, the Masai inhabit only that part of the area near the northern groups of hills with an occasional migration towards the Talek river during the drier months of the year. Between the Talek and the Tanganyika border the country is largely uninhabited owing to the grave danger of infection of stock by tsetse flies. In the extreme south-eastern corner of the area permanent Masai settlements around Ol Pusi Moru and Ol Koroi are on the fringes of the more habitable Loita Hills area.

There are several small trading centres, a number of Government stations (established to investigate and control the tsetse fly menace), and there was a prison situated on the Mara river. The trading centres are at Ngorengore, Lemek and Olentutu (at the eastern end of the Ol Kinyie hills). Tsetse Survey and Control stations are situated at Kibosek (in the Kericho District), Kipleleo and Aitong. An experimental scheme was carried out near the Talek river to study the relationship between the migration of tsetse flies and the movement of game animals; the Talek station has now been abandoned. In the north, bush-clearing is being carried out along the Mara river in an effort to control the spread of the flies. A Veterinary Department experimental ranching scheme was established at Olchorro Orogwa with the object of investigating the effects of anti-trypanosomiasis drugs on cattle living in fly-areas.

Game.—The country surrounding the Mara river offers one of the finest selections of wild life in Kenya and, in an attempt to preserve the fauna, much of the area covered by this report is at present closed to shooting.

Climate and Rainfall.—Rainfall figures (obtained from records of the Veterinary Department and the E.A. Meteorological Department) recorded from a number of localities in and around the area are shown in Table I. The heaviest falls occur in March-April and again in December-January though, compared with many other parts of the Colony, there is a less well-defined seasonal distribution of the rainfall. A wide temperature variation is demonstrated by figures presented in Table II, from recordings made at the Tsetse Survey and Control station, Talek.

TABLE I

RAINFALL IN AND AROUND THE MARA RIVER-SIANNA AREA

Station	Years recorded	Average total rainfall (*inches*)
Kipleleo (Tsetse Survey and Control Station)	1955–1958	35·58
H.M. Prison, Mara	1956	47·43
Kibosek (Tsetse Survey and Control Station)	1955–1956	38·01
Ngorengore	1950–1951	33·56
Talek (Tsetse Survey and Control Station)	1958	34·57
Kilgoris*	1948; 1953–1957	44·43

*Beyond the present area and 27 miles west of Kibosek.

TABLE II

MEAN MONTHLY MAXIMUM AND MINIMUM TEMPERATURES, TSETSE SURVEY AND CONTROL STATION, TALEK

Year	January		February		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1957	–	–	–	–	–	–	–	–	–	–	–	–
1958	88	52	88	52	85	–	85	–	79	–	82	58
1959	83	57	83	58	83	59	83	57	83	–	83	53

Year	July		August		Sept.		October		Nov.		December	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1957	–	–	87	53	92	52	93	54	81	54	80	54
1958	81	55	83	56	86	57	85	58	88	57	82	59
1959	82	54	–	–	–	–	–	–	–	–	–	–

Acknowledgements.—The author wishes to acknowledge the hospitality and assistance received from officers of the Veterinary and Prisons Departments who were stationed in the area during the period of field-work. Particular thanks are due to Mr. A. Y. S. Patrick (former Livestock Officer, Olchorro Orogwa cattle ranch) and Mr. J. A. Smith (former Field Officer, Tsetse Survey and Control, Talek).

II—PREVIOUS GEOLOGICAL WORK

Although considerable interest has been shown in the gold-bearing rocks that outcrop to the west of the present area, little published geological work has been carried out in the country east of the Mara river.

G. E. Smith, who commanded the British section of the Anglo-German Boundary Commission travelled across the southern part of the Sianna area in 1904. He mentioned (1907, p. 255*) the north-easterly trending Isuria† escarpment defining the western side of a wide valley occupied by the Mara river (Engare Dabash), and its seasonal tributaries; it was appreciated that water could be obtained by digging in the dry beds of the eastern tributaries.

A report by Murray-Hughes, published in 1933, gave a brief account of the geology of the Lolgorien area, including a portion of the present area near the Mara. In it he mentioned (1933A, p. 2) the "Longaria Granite" which he showed on a sketch-map accompanying the report as outcropping in the escarpment (Old Loongarya, i.e. Ol Loongarya, the Siria escarpment) to the west of the Mara river, stating that the rock contains quartz, orthoclase, hornblende, biotite, sphene, epidote and pyrite. Lava ("nepheline phonolite") is shown overlying the granite above the escarpment and was also mapped east of a NE-SW fault (the Siria fault of the present survey) where the underlying rocks were marked as gneiss and quartzite. In the same year Murray-Hughes produced a second report, this time on the geology of the western half of Kenya. He described (1933B, p. 3) "a red granitoid rock and a highly jointed quartzite containing authigenous tourmaline and green mica" extending south-eastwards from

* References are quoted on pp. 46 and 47.

† This feature is incorrectly referred to in previous literature as "Isuria"; the escarpment takes its name from the Siria section of the Masai tribe, and Siria is used in this Report.

the Nyangoris scarp in the Sotik district, and showed on his geological sketch-map undifferentiated Basement Complex over much of the Mara river area with volcanic rocks near the Nyangoris fault as described above.

Sir Albert Kitson (1934) published an account of reconnaissance geological traverses carried out in the Colony in 1932 in which (*op. cit.*, p. 59) he commented on a journey from Sotik to Nairobi that took him through the north-eastern corner of the present area. His observations were recorded in the form of brief notes relating to the various rock-types seen from the road, and from near "Ngori Ngori" he reported grey and yellow calcareous clays, believed to represent an old lake-bed.

Rock specimens collected by B. A. Brannstrom, a Government prospector, during traverses into the present area were examined and commented on by Shackleton (1946, p. 8) in a report on the geology of the Migori Gold Belt. Brannstrom collected muscovite quartzites from the hills around Loldobaith (Loldobaih of the present survey); other metamorphic rock specimens included injection gneiss, augen gneiss, quartz-microcline-biotite gneiss, granitoid gneiss, garnetiferous mica schist and clinozoisite schist. Shackleton compared a granite specimen with the newer granites of the gold-fields. Brannstrom recorded strikes varying from NNW-SSE to NE-SW, with a predominantly easterly dip, so Shackleton suggested that a series of variable schists and gneisses probably dip eastwards beneath a quartzite zone that extends from the "Lemeck Hills" to Loldobaih. Brannstrom reported lavas on the Lorogoti plains (presumably north of Loldurugi) and on both sides of the Mara river between Moggone and Omarti Hill (i.e. between Ol Doinyo Lolamutiek and Loldurugi of the present survey).

Shackleton (*op. cit.* p. 7) himself carried out a reconnaissance of the "Lemeck Hills, near the Lologorien-Narok road about ten miles east of the Mara Bridge. . . . ", probably referring to the hills now mapped as Kipleleo, Oliopa and Ol Doinyo Lalagalesho. He found there " . . . massive whitish quartzites, highly metamorphosed and with pegmatitic segregations". He also noted a considerable variation in the strike directions within short distances. In a later chapter, reference was made (*op. cit.*, p. 48) to the geological section exposed in the Isuria (Siria) escarpment on the road from Lolgorien to Mara bridge (meaning the old iron bridge, that previously crossed the river some ten miles upstream from the present concrete structure). Shackleton mentioned that the "Isuria" fault is crossed about three miles west of the bridge where Tertiary lavas are faulted against the granitic gneisses forming the escarpment. He also recognized the eastward extension of the phonolite to the foot of the "Lemeck Hills, which stood out above the flood of lava".

Schoeman (1949) surveyed the Sotik area, which lies immediately to the north of the Mara River area. Apart from a number of massive quartzites and an occurrence of hornblende gneiss near the Nyangoris river, Basement System rocks were undifferentiated on the geological map accompanying the report. They were said to comprise granitized metamorphic rocks with granitic intrusions. The same author (*op. cit.*, p. 29) examined phonolite exposed near the new Mara bridge and commented on the coarser nature of the groundmass compared with that in the Sotik lavas. In view of this and other minor petrographic differences, he concluded that the "Isuria" phonolite is unlikely to represent a direct southward extension of the Sotik flows.

III—PHYSIOGRAPHY

1. Topography

A glance at the geological maps will show the strong influence exerted by the main rock types on the topography of the area. With the exception of the Siria escarpment and occasional minor lava hills, massive quartzites and associated muscovite quartzites form all the important topographical features by virtue of their high resistance to erosion. In detail, individual ranges of hills are often composed of prominent parallel ridges of hard rock with intervening valleys produced by the differential erosion of less resistant bands in the succession. Generally speaking, the metamorphosed semi-pelitic and semi-calcareous sediments, together constituting a large proportion of the Basement System rocks in the present area, give rise to gently undulating well-drained country, while flat plains with occasional rocky scarps are underlain by the Tertiary phonolitic lavas. Above the Siria escarpment, which is a fault feature extending from a point near the northern boundary of the present area to beyond the Tanganyika border, an intrusive granite mass outcrops in low rounded tors across the featureless plateau lying at about 6,000 feet above sea-level. An originally extensive lava cap that must have flowed in this region across a flat surface west of the Mara river, judging by the remarkably level profile of the scarp (Plate II (*a*)), is now only represented by two isolated phonolite sheets on that part of the Siria plateau covered by the present work. The escarpment rises some 850 feet above the level of the river at Mara Bridge but dies to a barely discernible feature at the Masai-Kipsigis fence-line near the northern boundary of the present area.

East of the Mara river the dominant hills fall into two ranges, a northerly group with ridges lying on either side of the Ngorengore-Aitong road and a southerly group (Plate I (*a*)) stretching from the headwaters of the Talek river to the Tanganyika border. Prominent summits in the former group are those of Ol Doinyo Lolialaram (Lemek trigonometrical beacon, 7,437 feet), Ol Doinyo Lalagalesho (7,230 feet), Kipleleo (7,199 feet), Ol Kinyie (Eregero beacon, 7,462 feet) and Bardamat ridge near Koyage (over 7,000 feet). In the southerly range, subdivided by the Sianna plains and Longaianiet river, the highest summits are Sianna (7,285 feet, *see* Plate III (*a*)), Mwigwarrur (over 7,000 feet), Ol Olojigoshi (6,852 feet) and Ol Opelagonya (6,825 feet, Plate III (*b*)), north of the Longaianiet; Ol Koroi (7,412 feet), Olentoroto (7,212 feet, Plate II (*b*)) and Losemodu (7,118 feet) form a group of hills between the Sianna plains and the Tanganyika border whose summit levels fall gradually in height from east to west.

In the north a lava-capped plain, ranging from 5,600 to 5,800 feet above sea-level, slopes gently down to the Mara from the steep western scarp of Kipleleo. In the western half of the Sianna area the dissected Metta plains also slope down to the Mara from an elevation of 5,400 feet and bear a thick soil cover with occasional accumulations of quartzite pebbles on the higher ground. To the east and rising above the Metta plains are prominent ranges of hills decreasing gradually in summit height from east to west.

2. Drainage

The area is well drained by the Mara river (Plate I (*b*)) and its three main tributary systems, the Olorok-Lemek-Jagartiek, the Talek-Ngwelali and the Longaianiet (better known as the Sand river—Plate I (*c*)). The chief rivers and streams are shown in Fig. 1.

Three factors appear to have controlled the drainage pattern:—

(1) The present network of south-westerly and westerly flowing seasonal streams developed on a lava cover, the surface of which now lies approximately parallel to the slope of the underlying sub-Miocene bevel. The present slope of the lava surface is about 1 : 100 to the south-west. Schoeman (1949, p. 6) noted similar drainage directions in streams traversing the Mau lava sheets in the Sotik district to the north of the present area.

(2) The disposition of the various Basement System rock types, the resistant quartzites in particular, has also influenced the drainage although in many cases stream patterns already established on the lavas, were superimposed on the underlying surface of Basement System rocks following erosion and stripping of the volcanic cover. Hence, many streams (for instance the Ololorok) now cut directly across the strike of the older rocks with only slight lithological control. There are, however, innumerable examples of rivers and streams having their courses dictated entirely by differential erosion of bands in the Basement succession.

Fig. 1—Physiographical map of the Mara River-Sianna Area.

(3) There is some evidence in the area of late westward tilting of an original south-westerly sloping surface, perhaps related to the movement along the Siria fault. The westward-flowing Talek and Longaianiet streams are deeply incised and right-angled bends in the courses of the Oldorotua-Ololorok and the Jagartiek-Motorogie are strongly suggestive of river capture. The Lolongabulu (a tributary to the Talek) perhaps represents the beheaded remnant of a stream that originally drained the western slopes of the Bardamat hills.

In the neighbouring area to the west, Shackleton (1946, p. 53) records a rejuvenation of the westerly portion of the Migori river that presumably occurred in post-end-Tertiary times.

3. Erosion Surfaces

The phonolitic lava mapped in the present area is part of a more extensive sheet already described in the Migori and Sotik areas. The surface on which the lava rests, considered by Shackleton (1946, p. 52) to be of Miocene age, provides a useful physiographic level, since he established that the projection of the base of the Isuria lavas meets the sub-lava surface of the Gwasi volcanic rocks exposed near Karungu Bay on Lake Victoria. The Gwasi volcanics overlie fossiliferous deposits of lower Miocene age (Oswald, 1914). Shackleton (1946, p. 52) has shown that the Miocene land surface slopes gently towards the lake with a gradient of about 1 in 150 and that it has been down-faulted some 1,200 feet to the east by the Siria fault. West of the fault, the sub-lava surface is said to be even and broken only by occasional residual hills. In the present area, though the overall slope of the sub-lava surface is evidently about 1 in 150 (35 feet per mile) to the south-west (judging by the fall in the lava base from 6,400 feet inferred on the plains south of Ngorengore to 5,000 feet near the Mara river at Loldobaih), there is evidence to show that in detail, levels of the base of the phonolite around the Bardamat hills are not co-planar, the uneven nature of the base being due to irregularities in the original surface in the neighbourhood of pre-existing large hill masses. Lava base levels are co-planar throughout the western half of the area where the surface slopes to the WSW at approximately 1 in 160 (33 feet per mile). On the south side of the Lemek valley, phonolite boulders are mixed with quartzite scree near Olentutu at an elevation of about 6,600 feet and grey calcareous soils were found near Ngorengore at about the same altitude. These occurrences are clearly too high to be related to the sub-Miocene peneplain (which, if developed, would lie at an elevation of about 6,100 to 6,300 feet between Olentutu and Ngorengore), and they probably represent local levels of the lava base where the volcanic rocks rested on residual hill masses remaining on the peneplain.

Pulfrey (1960, Fig. 3) shows the approximate slope of the sub-Miocene erosion bevel over most of the present area to be 28 feet per mile in a direction a little south of west, and the slope of the bevel above the Siria escarpment to be about 20 feet per mile to the WNW, increasing to 41 feet per mile towards Lake Victoria. Between Narok and the Loita hills, the slope is shown as approximately eastwards at 47 feet per mile. This warping of the sub-Miocene peneplain along a north-south axis has been described in the Loita Hills area (Saggerson, report in preparation), where main deformation of the surface preceded extrusion of late-Tertiary lavas and is believed to have occurred during the Miocene. Pulfrey (1960, p. 8) summarizes evidence in Kenya demonstrating slight disturbance of the sub-Miocene bevel before and during the lower Miocene, with the main warping occurring during post end-Tertiary times. In the present area, it is suggested that Miocene phonolites flowed across a south-westerly sloping surface (*see* p. 30), so that at least some warping of the sub-Miocene bevel must have taken place before extrusion of the lavas, with possibly additional tilting of the peneplain and lava cover during the late-Tertiary.

The accordant summit heights of the highest hills in the area mark the relics of an ancient land surface that is correlated with the "Kisii Highlands Peneplain" described by Shackleton (1946, p. 52) in a report on the Migori area, and later recognized by

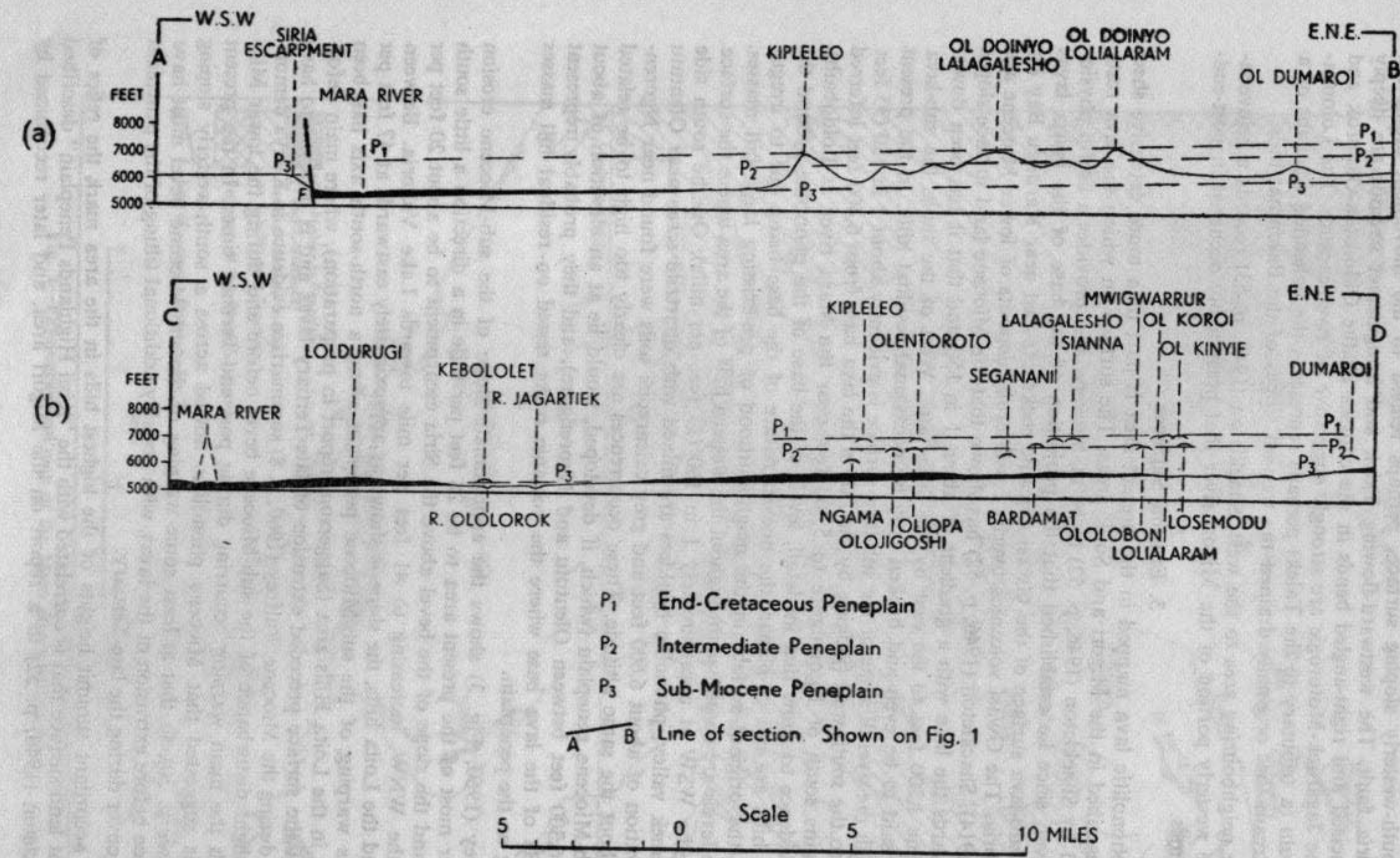


Fig. 2—Sections illustrating erosion bevels in the Mara River-Sianna area. Tertiary phonolite is marked in black. The lines of sections are indicated in Fig. 1.

(a) Section A-B, through Ol Doinyo Lolialaram and Kipleleo showing the "Kisii Highlands Peneplain" (P_1), the sub-Miocene Peneplain (P_3) and a possible intermediate surface (P_2).

(b) Section C-D through the centre of the area. The summits of the more prominent hills have been projected on to the line of the section.

Shoeman (1949, p. 5) and Huddleston (1951, p. 4) in the Sotik and Kisii districts respectively. Remnants of the peneplain (Fig. 1) occur in the neighbourhood of Lemek where the grass-covered summits of the Ol Kinyie hills, Ol Doinyo Lolialaram, Ol Doinyo Lalagalesho and Kipleleo, all stand at between 7,200 and 7,450 feet above sea-level. Further south the surface is represented by the highest points of Ol Koroi, Sianna and Olentoroto. The age of this peneplain has not yet been conclusively established, but it has been suggested (Shackleton, *op. cit.*, p. 52) that it forms part of a Cretaceous bevel noted elsewhere in Kenya. As in the Migori area, the surface stands some 1,300 feet above the sub-Miocene peneplain and has a marked westward tilt (Fig. 2 (*a*) and (*b*)).

Base-levelling in the area at several periods between Cretaceous and mid-Tertiary times is suggested by accordant summits between the level of the "Kisii Highlands Peneplain" and the base of the lavas. Similar intermediate erosion levels were reported by Shackleton (op. cit., p. 52) who noted one at about 600 feet and a second at some 250 feet above the sub-Miocene peneplain. In the present area, the most prominent intermediate surface stands at some 900 feet above the sub-Miocene peneplain.

IV—SUMMARY OF GEOLOGY

The rocks of the Mara River-Sianna area fall into four groups:—

1. Metamorphic rocks of the Basement System (Archaean).
2. Kilgoris granite (Precambrian).
3. Tertiary volcanic rocks.
4. Superficial deposits of Pleistocene to Recent age.

1. Basement System

The Basement System in the Mara River-Sianna area comprises gneisses, schists and amphibolites together with intercalated massive quartzites. The succession undoubtedly represents for the greater part an original sedimentary sequence that has subsequently undergone at least one phase of intense regional metamorphism, accompanied by granitization. The sediments were predominantly impure argillaceous rocks with widespread interstratified arenaceous horizons and occasional calcareous beds. No bands of marble were encountered during the present survey and limestones were apparently absent from the original sedimentary succession.

Garnetiferous mica schists are probably the metamorphosed equivalents of original shales but they apparently form only a very subordinate part of the Basement succession, although the schists might well be more widespread than the isolated exposures suggest.

A group of variable metamorphosed semi-pelitic sediments is far more common and includes a thick series of biotite gneisses exposed in the central parts of the area. The latter frequently show a gradation into migmatitic rocks as a result of their susceptibility to granitization; augen gneisses mark an intermediate stage in this process of alkali metasomatism. Garnetiferous para-gneisses and para-granulites, muscovite-biotite gneisses and part of a group of poorly exposed quartz-muscovite schists are all regarded as regionally metamorphosed sandy shales.

Massive quartzites dominate the psammitic group, their sedimentary origin being confirmed by the preservation of ripple-marks and current bedding. They form prominent ranges of hills extending southwards from the Sotik District, through the area and across the border into Tanganyika.

Hornblende-rich rocks that probably represent metamorphosed calcareous sandstones are extensively developed in the Mara river and its two tributaries, the Talek and the Longaianiet. They apparently grade laterally into a series of biotite-muscovite-epidote schists while diopside-epidote gneisses are locally developed. Lenticular segregations of epidotite are common throughout the group of meta-calcareous rocks.

Gneisses that outcrop along the Siria fault-scarp vary in composition from amphibolites to rocks having a granitic appearance, but all are marked by mylonitic textures and saussuritization of plagioclase. These gneisses are referred to the Basement System since in mineral composition they compare closely with rocks collected from east of the Mara river.

2. Kilgoris Granite

West of the Mara river the Siria plateau is underlain by a mass of biotite-hornblende granite representing an easterly continuation of the Kilgoris intrusion, and is hence provisionally referred to the Precambrian. The age of the Kilgoris granite has been established as post-Kavirondian and pre-Bukoban.

Along the Siria escarpment the granite is conspicuously xenolithic and is intrusive into mylonitized gneisses of the Basement System. The eastern margin of the granite is not clearly defined, the granite itself having suffered a phase of shearing and mylonitization. Where a foliation has developed, it was found to be parallel to the contact and the escarpment.

3. Tertiary Volcanics

Extensive flows of Tertiary phonolitic lava with very minor developments of tuff overlie the Basement System rocks east of the Siria escarpment, the cover being best preserved across the centre of the area. There is evidence to show that the lava flowed from the north-east, forming an extension of the Mau Volcanic Series. Isolated remnants of similar lava overlie the granite above the escarpment, admirably demonstrating the age and movement of the Siria fault.

4. Superficial Deposits of Pleistocene to Recent Age

Wide expanses of the area are mantled by a cover of superficial deposits. Overlying the Basement System rocks two soil types are commonly encountered. Reddish brown, sandy soils surround the outcrops of quartzites and muscovite-quartzites; darker, clayey soils overlie the metamorphosed pelitic, semi-pelitic and semi-calcareous sediments. The latter are frequently indistinguishable from the black-cotton soils found over the phonolite.

Sands, gravels and silts occupy many of the river beds and watercourses.

V—DETAILS OF GEOLOGY

1. Basement System

It should be emphasized that owing to the degree of structural complexity existing in this area, a complete interpretation of the stratigraphical succession in the Basement System is not possible on the evidence at present available and further detailed mapping is required. Similarly, any assessment of the thickness of lithological bands, calculated from the width of outcrop, must be regarded as approximate only; in most instances these figures are probably exaggerated as a result of intense folding.

Rocks that probably represent the oldest members of the Basement System in the region mapped outcrop west of Sianna, between the Ngama hills and Oloiboisoit. These gneisses and schists are apparently overlain by a thick group of metamorphosed semi-calcareous sediments that are exposed north-westwards towards Loldurugi. The succession in the south-western part of the area is believed to be as follows:—

Locality	Lithology	Approx. Thickness
		(*feet*)
Talek river, Loldurugi, Loldobaih and Kebololet	12. Plagioclase amphibolites, amphibolites, hornblende-biotite-epidote gneisses and schists, biotite - muscovite - epidote schists, diopside-epidote gneisses and epidotites	15,000+
	11. Biotite gneisses	1,000–3,500
	10. Quartzites and muscovite quartzites	500–1,000
	9. Biotite gneisses	800–5,000
Ngama, Olchorro Loromon and Oloiboisoit	8. Hornblende-biotite gneisses	0–1,000
	7. Muscovite quartzites	0– 700
	6. Quartzites	800
	5. Muscovite quartzites	0– 300
	4. Garnetiferous para-gneisses	0–1,800
	3. Muscovite-biotite gneisses	0–3,500
	2. Quartzites	800
	1. Quartz-muscovite schists	7,000

At Ol Koroi, in the south-eastern part of the area, the following succession was mapped:—

Lithology	Approx. Thickness
	(*feet*)
5. Muscovite quartzites	700
4. Quartzites	1,500
3. Muscovite quartzites	800–1,000
2. Hornblende-biotite gneisses with lenticular epidotites	500
1. Biotite gneisses	5,000

It is possible that the biotite gneisses at Ol Koroi are equivalent to similar rocks (11) in the Loldurugi-Ngama succession, in which case the semi-calcareous meta-sediments overlying these gneisses display a striking westward thickening from 500 feet at Ol Koroi to over 15,000 feet at Loldurugi.

South-west of Ol Koroi, the Basement succession between Olentoroto and Losemodu is probably as follows:—

Lithology	Approx. Thickness
	(*feet*)
7. Biotite gneisses	3,000+
6. Muscovite-biotite gneisses	2,000
5. Quartzites	400–2,500
4. Quartz-muscovite schists	600
3. Hornblende-biotite gneisses	0–1,800
2. Muscovite-biotite gneisses	3,000
1. Biotite gneisses	2,000+

The quartzites at Olentoroto and Losemodu are probably correlatable with the Ol Koroi quartzites, in which case the total thickness of the exposed Basement System rocks in the Sianna area is about 40,000 feet.

Outcrops in the north-eastern part of the Mara River area suggest the following succession:—

Lithology	Approx. Thickness
	(feet)
4. Quartz-muscovite schists	1,200+
3. Muscovite quartzites	0–2,500
2. Quartzites	500–1,200
1. Muscovite quartzites	1,000–1,300

Between the Siria fault and Kipleleo, quartzites are probably underlain by amphibolites and mylonitic gneisses as indicated in the following succession:—

Lithology	Approx. Thickness
	(feet)
5. Muscovite quartzites and quartz-muscovite schists	5,000+
4. Quartzites	800–1,000
3. Muscovite quartzites and quartz-muscovite schists	4,000
2. Amphibolites	6,800
1. Mylonitic gneisses with lenses of amphibolite, quartzite and epidotite	8,000–17,000

The thickness of the mylonitic gneisses is undoubtedly greatly exaggerated by folding, shearing and faulting. The amphibolites are probably to be correlated with the semi-calcareous meta-sediments of the Loldurugi-Ngama succession.

The local successions described above suggest the following broad subdivision of the Basement System rocks in the Mara River-Sianna area:—

3. Semi-pelitic and pelitic gneisses with intercalated quartzites and muscovite quartzites.

2. Amphibolites and associated semi-calcareous meta-sediments.

1. Semi-pelitic and pelitic gneisses with intercalated quartzites and muscovite quartzites.

Massive quartzites and muscovite quartzites have been mapped in the Kitale-Cherangani Hills area of north-western Kenya (Miller, 1956), in the Kitui area of south-central Kenya (Sanders, 1954), and in the Namanga-Bissel area in the southern part of the Colony (Joubert, 1957). In the latter area quartzites and accompanying crystalline limestones form part of the Turoka Series, named and described by Parkinson (1913), and bands of marble also occur in north-western and south-central Kenya. Though no crystalline limestones were found in the Mara River-Sianna area, their place in the succession is probably occupied by metamorphosed semi-calcareous sediments, the facies change perhaps representing an approach towards the western shore-line of the basin of deposition.

For descriptive purposes, the Basement System rocks are classified as follows:—

(1) Metamorphosed semi-calcareous sediments—

(*a*) Plagioclase amphibolites and amphibolites;

(*b*) Hornblende-biotite-epidote gneisses and schists; hornblende-epidote gneisses and granulites;

(*c*) Biotite-muscovite-epidote schists;

(*d*) Diopside-epidote gneisses;

(*e*) Epidotites.

(2) Metamorphosed pelitic sediments—

(*a*) Quartz-muscovite schists (in part);

(*b*) Garnetiferous mica schists.

(3) Metamorphosed semi-pelitic sediments—

(*a*) Biotite gneisses;

(*b*) Biotite augen-gneisses;

(*c*) Garnetiferous para-gneisses and para-granulites;

(*d*) Muscovite-biotite gneisses;

(*e*) Quartz-muscovite schists (in part).

(4) Metamorphosed psammitic sediments—

(*a*) Quartzites;

(*b*) Muscovite quartzites.

(5) Mylonitic and granitoid gneisses of the Siria escarpment.

(6) Migmatites.

(7) Pegmatites.

The pegmatites (7) include a number of intrusive dykes of post-Basement System age, but for convenience these are described with the Basement System rocks.

(1) Metamorphosed Semi-Calcareous Sediments

Although crystalline limestones frequently form distinct bands in the basement succession in many parts of Kenya, no occurrence of rocks even approaching the composition of marble were encountered during the present survey. There are in the area, however, bands of quartz-bearing amphibole-rich rocks and micaceous epidote schists with rare occurrences of diopsidic gneisses; these rocks appear to exhibit a lateral gradation into typical meta-sedimentary gneisses and schists and are believed to be metamorphosed equivalents of semi-calcareous sediments. Small lenticular masses of epidotite with the meta-calcareous rocks are too small and too numerous to permit differentiation on the geological maps but the main occurrences and possible modes of origin are discussed (p. 17).

(*a*) Plagioclase Amphibolites and Amphibolites

The principal outcrops of amphibolite are found at Loldobaih in the south-western corner of the area where they form a broad belt followed for some distance by the Mara River. The rocks, which are well exposed in both the Mara and its tributary the Longaianiet (the Sand river), are typically poorly-foliated, fine-grained and greenish grey with a hackly fracture. In hand-specimens the rocks have a somewhat silky lustre due to minute prisms of hornblende. Felspar and quartz form thin lenses shot through with needles of hornblende, or are disseminated throughout the rocks so as to impart a gneissose structure. Rarely, calcite occurs in lenticular masses up to two and a half inches long. A thin section of specimen 50/217* from the Longaianiet river shows

* Numbers fixed by 50/ refer to specimens in the regional collections of the Geological Survey, Nairobi.

abundant actinolitic hornblende having a maximum extinction angle of 18° measured from the cleavage. The prisms are arranged in a decussate texture and are partly or completely enclosed by crystals of quartz and plagioclase, the proportion of quartz exceeding that of plagioclase. The plagioclase has a composition between oligoclase and andesine. Occasional subhedral, colourless garnets are present together with accessory apatite, the latter occurring as minute inclusions in quartz. In similar amphibolites (e.g. 50/219) exposed near the confluence of the Mara river and the Olcherro Loldobaih water-course the hornblende is seen partly altering to biotite, and sphene appears in granular aggregates and as inclusions in the amphibole. Accessory minerals include apatite, iron ore and reddish brown rutile.

Mottled, melanocratic amphibolites are interbanded with hornblende-biotite gneisses and epidotites in the Longaianiet river south-west of Ol Koroi. A thin section of specimen 50/229 shows the hornblende in the early stages of alteration to brown biotite. Andesine and quartz are accompanied by granular to subhedral epidote (with subordinate clinozoisite) which occurs both as inclusions in the amphibole and as rims about an ore mineral that, from its appearance as skeletal crystals, is probably ilmenite. Rutile and apatite are accessory.

Between Losho hill and Ol Koroi, hornblendic rocks intercalated in biotite gneisses, have fine-banding imparted by thin felspathic layers and lenticular segregations rich in epidote. The amphibolitic portion contains anhedral to subhedral crystals of hornblende together with oligoclase, quartz, microcline and abundant sphene as shown by specimen 50/211. Accessory minerals include rutile, apatite and epidote. Seven miles to the north, pyroxene is an essential constituent in a thin band of coarse diopside amphibolite exposed near Olobilitai ridge. A thin section of this rock (50/208) shows pale green diopside closely associated with abundant hornblende, within which the pyroxene occasionally forms cores; sphene is a common accessory mineral.

Near the northern boundary of the area coarse greenish black amphibolites are exposed in the Nyangoris river at Kibosek. A thin section of specimen 50/244 is composed of large poikiloblastic crystals of hornblende enclosing quartz, clear andesine, epidote and trains of granular sphene. Magnetite is developed along cleavages in the amphibole. The same minerals form an interstitial mosaic together with rare grains of rutile. The amphibole in this rock shows the initial stages of alteration to biotite. In a specimen of fine-grained amphibolite (42/693), collected from the Nyangoris river three-quarters of a mile north of the Mara River area (where the river is crossed by the Bomet-Sotik road), brown biotite becomes an essential constituent.

(b) *Hornblende-Biotite-Epidote Gneisses and Schists; Hornblende-Epidote Gneisses and Granulites*

Hornblende-biotite-epidote gneisses and schists are believed to be metamorphosed semi-calcareous sediments, the gneisses probably representing original calcareous sandstones, the schists original marls. In some cases the hornblendic rocks could conceivably be the metamorphosed equivalents of igneous rocks of intermediate composition but, on the whole, field relations (with a common gradation into para-gneisses and schists) accompanied by compositional and textural features seen in thin section suggest a sedimentary origin. This evidence is discussed in a later section of the report (p. 15).

Hornblende-biotite-epidote rocks are principally exposed at two localities—near the confluence of the Mara and Talek rivers and again in the south-eastern corner of the Sianna area near Ol Koroi. Minor occurrences, found in thin lenticular bands, are largely confined to the country within a few miles of the Tanganyika border. Typical of the group are the hornblende-biotite-epidote schists exposed in the Ololorok stream at Angata Oldurorai, where the rocks probably represent a repetition of hornblendic gneisses that outcrop in the Mara river. The schists are flaggy greenish grey rocks, a preferred orientation of hornblende crystals on foliation planes often imparting a distinct lineation. Small quartzitic lenses containing concentrations of epidote are not uncommon. A thin section of specimen 50/174 from the Ololorok stream shows porphyroblastic hornblende riddled with inclusions of quartz and epidote; small flakes of biotite are scattered throughout a granoblastic matrix composed dominantly of sodic andesine and quartz. Hornblende, epidote, magnetite, garnet, apatite and interstitial calcite are accessories.

South of Ol Koroi, hornblende-biotite-epidote gneisses and schists are exposed in the Longaianiet river where they are often closely interbanded with minor developments of amphibolite and granular epidotite. The rocks contain varying proportions of essential hornblende, biotite, quartz, plagioclase (typically sodic oligoclase) and epidote. A gradation from biotite gneisses into amphibolites is illustrated by two specimens that represent intermediate stages. Specimen 50/234, collected from the Longaianiet near the Ngorika fault, is a dark highly sheared biotite-rich schist with no obvious epidote in thin section and only subordinate hornblende, whereas 50/230 from an exposure two miles to the north-west in the same stream shows obvious amphibole in hand-specimens. The latter rock encloses lenticular masses of epidotite and grades into an amphibolite (p. 13).

A band of hornblendic gneiss, cut through by the Mara a mile to a mile and a half up-stream from its confluence with the Talek, is typically biotite-free and represents a gradational rock adjacent to a typical amphibolite band, and is probably the lateral equivalent of the hornblende-biotite-epidote schists at Angata Oldurori. In hand-specimen (50/169), the finely banded gneiss shows occasional small pink felspar porphyroblasts, which are found in thin section to be calcic oligoclase, The porphyroblasts are set in a mosaic consisting of elongated grains of quartz and sodic andesine with abundant small, well-orientated prisms of hornblende and scattered grains of epidote.

An unusual hornblende granulite was found intercalated in muscovite-biotite gneisses at Olare Sambu, south of the Bardamat hills. The rock (50/132) is grey, compact, fine-grained and resembles a dark quartzite in hand specimen; under the microscope small shreds of actinolitic hornblende display a marked alignment throughout a fine granular mosaic of quartz with subordinate, largely untwinned plagioclase having a composition near andesine. Abundant epidote is associated with the amphibole. Apatite and sphene are accessory, the latter occasionally bearing inclusions of rutile.

Origin of the Amphibolites and Hornblendic Gneisses

Amphibolites and hornblende gneisses are known to form by:—

(1) Medium- to high-grade regional metamorphism of:—

(i) Intermediate and mafic igneous rocks.

(ii) Marls, calcareous hybrid tuffs, quartzose sediments containing dolomite and kaolinite, or calcite-chlorite-quartz sediments.

(2) Metasomatism of carbonate rocks.

It is frequently difficult to deduce the origin of a particular rock but Heinrich (1956, p. 255) quotes a number of features that are useful in distinguishing ortho-amphibolites and hornblende ortho-gneisses from similar meta-sediments.

The amphibolites and hornblendic gneisses of the present area show no signs of relic eruptive rock textures or pyroxene cores in hornblende, both of which are regarded as diagnostic of an igneous origin. The rocks do contain abundant quartz, and biotite is a common constituent of the more gneissose varieties. The field relationships also point to a sedimentary origin. The bands show a conformable transition into semi-pelitic gneisses and near the Tanganyika border the amphibolites of the Mara river apparently grade eastwards into diopside-epidote gneisses. At Loldurugi, there is evidence of lateral gradation from amphibolite through hornblende-biotite gneisses into biotite-muscovite-epidote schists. Banding is common within individual exposures of the amphibolites and hornblende-biotite gneisses. In the Longaianiet river at Oloiboisoit, felspathization has enhanced the banding in a hornblende-biotite gneiss (Plate V (*a*)) and even more striking are the bands of epidote seen in many exposures of the amphibolites.

(*c*) *Biotite-Muscovite-Epidote Schists*

A series of micaceous epidote-bearing schists are largely confined to the lower reaches of the Talek river where they are assumed to represent the metamorphosed equivalents of calcareous shales and are possibly in part the lateral equivalents of the amphibolites mapped along the Mara river further to the south-west. In hand-specimen the rocks are typically biotite-rich schists carrying subordinate white mica and varying proportions of quartz, and invariably tinged green by epidote that occurs both as finely distributed grains or in impersistent, thin lenticular segregations. Exposures are often characterized by the appearance of mullion structures, with individual "rods" having a roughly rectangular cross-section and a somewhat coarse fibrous texture in place of the normal well-defined foliation.

In a thin section of specimen 50/110 from the Lolongabulu stream (a tributary of the Talek), felspar and quartz form a granoblastic texture with conspicuous biotite and subordinate muscovite, both minerals showing a strong preferred orientation. Abundant granular epidote is accompanied by grains and subhedral crystals of sphene, while a sprinkling of opaque iron ore and an occasional colourless garnet also occur together with minute crystals of apatite. When twinned, the felspar is seen to have the composition of oligoclase; the biotite partly encloses grains of epidote, and is locally replaced by shreds of muscovite. Similar schists (50/147) are exposed in the Talek itself, a mile and a half up-stream from the ford. In thin sections they have an inequigranular, sutured texture with sodic oligoclase, quartz, biotite and magnetite as the essential constituents, the last-named mineral often being rimmed by granular epidote. The biotite is occasionally replaced by large flakes of muscovite, and rare colourless garnets bear inclusions of iron ore. Calcite occurs in interstitial plates with sphene and apatite present as accessories.

Three and a half miles downstream from the ford across the Talek, greenish grey schists, similar to those described above, show the development of quartz-rich lenticles and here the rocks display rodding particularly well. Less than a mile to the west the river cuts through a prominent band of white quartzite intercalated with the schists.

Rocks varying little in appearance and essential composition from those exposed in the Talek were mapped in the Ololorok and Jagartiek streams. In specimen 50/176, collected from the Ololorok three-quarters of a mile south of the margin of the phonolite sheet, abundant brown biotite (occasionally showing alteration to muscovite) is accompanied by aggregates of pale green epidote, sphene, iron ore and a few rounded, colourless garnets. In addition to quartz, both microcline and plagioclase are present, the latter having a composition between albite and oligoclase.

Dark grey fissile micaceous rocks overlie the amphibolite mapped in an inlier beside the Mara river at Loldurugi and a thin section of the schist (50/168) shows abundant biotite together with andesine, quartz and clinozoisite. Garnet and epidote are present and also rare grains of zoisite, the latter having a small optic angle and anomalous interference colours.

(*d*) *Diopside-Epidote Gneisses*

These rocks are apparently only rarely developed in the present area, the only mapped occurrence being south-west of Kebololet hill, where green compact, finely banded, diopsidic gneisses are exposed as intercalations in biotite gneisses in the Longaianiet river. Small lenses of glassy quartzite up to 2½ inches long enhance the felspathic banding in specimen 50/222 from this locality. In a thin section of the rock, subhedral diopside and closely associated granular to subhedral epidote are seen to be set in a granoblastic mosaic of quartz, microcline and sodic-oligoclase together with accessory sphene, apatite and small colourless garnets.

It is thought that these lenticular masses of diopsidic gneiss represent lime-rich concretions and the zone in which they occur constitutes a gradation from biotite gneisses to the amphibolites exposed further downstream in the same river.

(*e*) *Epidotites*

In the present area, epidote is a common mineral in the metamorphosed semi-calcareous sediments and in the mylonitic gneisses of the Siria escarpment and often occurs as an accessory mineral in the biotite gneisses and biotite augen-gneisses. Lenticular masses of green epidote-rich rock are frequently encountered within the amphibolites, hornblende-biotite gneisses and less commonly in the mylonites. Occurrences are too sporadic to indicate on the geological map. Flawn (1951, p. 775) favoured the non-genetic term epidotite to describe "a compact, massive rock composed mostly of epidote (or zoisite) with minor amounts of amphibole, pyroxene, felspar, chlorite, quartz, sphene, calcite, vesuvianite, garnet, etc." The term epidosite used to describe rocks composed essentially of epidote and quartz and of secondary origin is not applicable to rocks in this area. The epidote content is not strictly limited by Flawn's definition, but he (op. cit., p. 776) noted that the rocks assume a typical compact, waxy, yellow-green appearance when epidote forms more than 60 to 70 per cent of their composition.

The epidotite (50/252) developed in mylonitic gneisses exposed in the Sogororovei stream near the Masai-Kericho District fence-line is a fine-grained, compact, yellowish green rock containing visible prisms of hornblende. In thin section subhedral crystals of bluish green hornblende are scattered throughout a granular groundmass consisting of anhedral epidote with microcline, quartz, plagioclase, interstitial calcite and iron ore. More granular epidotites (50/231) occur as thin lenticular segregations in hornblende-biotite gneisses that outcrop in the Longaianiet river south of Ol Koroi, where the epidote-rich lenses grade imperceptibly into more normal gneisses. Epidotites developed within plagioclase amphibolites exposed near the Mara river at Loldobaih display similar gradational contacts. Flawn (1951, p. 775) mentioned a gradation from amphibolite through epidote amphibolite to epidotite in meta-sedimentary rocks of the Van Horn area in Texas.

Several processes have been envisaged to explain the formation of epidotites. Harpum (1954, p. 1078) noted lenticular segregations of epidote in albite-epidote amphibolites of Ukinga in Tanganyika and believed that they were formed by a process of mechanical segregation in a rock that had developed banding due to metamorphic differentiation accompanying dislocation. Widespread epidote, and occasional epidotites, in the Siria mylonites probably owe their origin to dislocation and the high degree of shearing stress that accompanied the movements.

Small segregations of epidotite (50/186) in biotite augen-gneisses exposed in the Olositan stream in the south-central part of the Sianna area, probably developed by localized lime metasomatism. Lime expelled by an influx of potash may have reacted with plagioclase felspars to give epidote.

(2) Metamorphosed Pelitic Sediments

These are probably widely developed but are poorly exposed and comprise:—

(*a*) Garnetiferous mica schists.

(*b*) Quartz-muscovite schists (in part).

Since the only distinction between pelitic and semi-pelitic quartz-muscovite schists lies in the proportion of quartz, these rocks are described together on p. 20.

(a) *Garnetiferous Mica Schists*

Mica schists containing megascopic garnets are not common in the area but where exposed they provide useful marker bands. The rocks are typically greenish silvery schists, sprinkled with numerous small reddish brown garnets and occasionally bearing quartzitic lenticles flattened in the plane of foliation. In specimen 50/139, collected from the Talek river south-west of Ol Doinyo Loi-ip, these lenses of quartzite often reach a length of 6 inches and are conspicuous on weathered surfaces. In thin section, the schists from this locality display a lepidoblastic texture with rounded, colourless or very pale pink garnets set in a mass of muscovite, quartz and turbid plagioclase. Each garnet is surrounded by a kelyphitic border of green chlorite. Accessory minerals include greenish brown biotite, iron ores including hematite, and idioblastic crystals of tourmaline (pleochroic from grey to pale brown).

In specimen 50/136 from similar schists exposed in a small stream-bed crossed by the Talek-Loldurugi track, the porphyroblasts of pale pink garnets up to 3 mm. in diameter are riddled with inclusions of quartz, chlorite, rutile and iron ore arranged in a helical pattern indicative of rotation of the host crystal during growth. In the kelyphitic borders around garnet, biotite is seen altering to chlorite, but elsewhere biotite is replaced by a colourless mica having a very small optic axial angle. Accessory minerals present include plagioclase, rare grains of deep amber-coloured rutile and a few idioblastic crystals of pleochroic tourmaline which probably represent recrystallized detrital grains.

Friable muscovite-chlorite schists containing small dull reddish-brown garnets are exposed in the Mara river about a mile above its confluence with the Talek, and below the junction a more compact garnetiferous rock (50/225) has, in addition to abundant biotite and chlorite, accessory slate-blue tourmaline, magnetite, calcite, apatite and secondary sericitic mica. Plagioclase present has the composition oligoclase-andesine.

On the south side of the Regero stream, where it separates the Bardamat and Ol Kinyie hills, fissile green quartz-muscovite-chlorite schists (50/29) are cut by thin pegmatitic veins. Small subhedral garnets are only visible under the microscope set in a mosaic of oligoclase, microcline, quartz, myrmekite, pale green muscovite and aggregates of chlorite. The quartz occurs in elongated grains having highly sutured margins. Magnetite, clinozoisite and tourmaline are accessory.

(3) Metamorphosed Semi-Pelitic Sediments

(a) *Biotite Gneisses*

Biotite gneisses that are thought to represent metamorphosed semi-pelitic sediments are widely distributed throughout the area, and are best exposed in the upper stretches of the Talek river and its head-streams, southwards across the Sianna plains to Ol Pusi Moru and along the Tanganyika border between Kebololet and Oloiboisoit. In contrast to the more psammitic bands in the Basement System succession, the gneisses have less influence on topography and are generally confined to tracts of monotonous scrubland, where the rocks are seen as discontinuous outcrops in the dry stream-beds and forming isolated flat-lying or rounded exposures on interfluves.

The gneisses are typically dark-weathering, highly felspathic grey rocks of medium to coarse grain, with biotite normally imparting a distinct foliation, and with directional orientation of the mica flakes often giving rise to a lineation on foliation planes. In thin sections, oligoclase, quartz, and varying proportion of microcline are seen to form a sutured mosaic with flakes of biotite lying in roughly parallel alignment and frequently accompanied by a small quantity of muscovite. Epidote is common in these rocks and occurs in aggregates of rounded grains, often closely associated with the biotite. Other accessory minerals are magnetite, apatite, sphene and clinozoisite. Invariably the microcline replaces plagioclase and quartz, as in specimen 50/190, from a tributary to the

Talek, north-west of Seganani, in which xenoblastic crystals of the potash felspar are seen lobing into and enclosing oligoclase. Occasionally a rim of albite separates the oligoclase and microcline. In a lens of well-foliated pink biotite gneiss (50/79) exposed along the northern flank of a quartzite ridge at Ol Doinyo Lalagalesho near Lemek, small porphyroblasts of oligoclase often show idioblastic outlines but are partly replaced by microcline. The biotite is concentrated into distinct folia, accompanied by grains of epidote and iron ore. Scattered aggregates of muscovite have partly replaced the biotite while other accessories include minute, colourless rounded garnets and small crystals of apatite, the latter mineral occurring as inclusions in the plagioclase.

Occasionally the biotite gneisses grade into finer-grained granulitic rocks with more evenly distributed biotite. In a specimen of grey gneiss (50/150), collected from the Talek river a mile up-stream from the small tributary known as Ol Losogon, very finely spaced foliation planes are only apparent on close examination. In the thin section of this specimen, brown biotite exhibits a subparallel orientation throughout a granular mosaic of oligoclase, quartz and microcline, the potash felspar again showing a replacing relationship towards plagioclase and quartz. Small flakes of muscovite are associated with the biotite and apatite is present in rare small grains.

(b) *Biotite Augen-Gneisses*

Coarse-grained biotite-rich rocks with prominent felspar augen up to 2 inches long are exposed in the Longaianiet river between Ol Olojigoshi and Ol Koroi. A thin section of specimen 50/194, from the Ol Olaimutiek stream near its confluence with the Longaianiet river, shows a coarse mosaic with microcline replacing quartz and sericitized oligoclase. Biotite can be seen partly altered to chlorite while epidote and sphene are common accessory minerals. When traced eastwards, the augen gneisses grade into granitoid and migmatitic rocks by a marked accession of felspar. The migmatites are described in a later section (p. 25).

Similar rocks, bearing thin *lit-par-lit* pegmatitic veins, are exposed in the Longaianiet river west of Ol Olojigoshi, and specimen 50/188, shows pink microcline augen occasionally reaching 1½ inches in length developed in biotite gneiss. In the inequigranular mosaic seen in thin section, quartz and oligoclase are partly replaced by microcline with brownish-green biotite exhibiting a roughly parallel alignment. Accessories include granular epidote, apatite, ilmenite and pleochroic sphene in idioblastic rhombic sections and irregular grains.

A lenticular band of augen gneiss is developed in biotite gneisses exposed in the Talek river at Loldurugi, a mile and a half from its confluence with the Mara river. Specimen 50/173 from this locality exhibits markedly inequigranular texture in thin section with porphyroblasts of microcline set in a finer sutured mosaic of plagioclase, quartz, microcline and myrmekite. Muscovite occurs in ragged flakes accompanied by subordinate brown and greenish biotite, with scattered grains of epidote and apatite present as accessories.

At Olare Samburu friable biotite augen-gneisses are exposed in the Ol Sabukiai stream (Plate IV (*b*)). In addition to biotite, oligoclase, microcline, quartz and myrmekite, a thin section of specimen 50/135 shows accessory epidote, sphene, apatite and green hornblende.

(c) *Garnetiferous Para-Gneisses and Para-Granulites*

Occurrences of garnetiferous para-gneisses and para-granulites are few in the present area. Small inliers of garnetiferous gneisses were mapped on the lava plains four miles south-west of Doinyo Iringa, where flat-lying pavements of gneiss are cut by thin veins of pegmatite. Specimen 50/95 from the northern exposure at this locality is a well-foliated grey, biotite-rich rock with no garnets visible in hand-specimens. A thin section of the rock shows a sutured mosaic of quartz, oligoclase and microcline, the last-named mineral frequently replacing plagioclase. Straw-brown and greenish biotite is present in distinct folia, being partly replaced by very pale green muscovite. Pleochroic, lozenge-shaped crystals and rounded granules of sphene are confined to the micaceous bands. Small, colourless, rounded garnets are rare, and accessory minerals include magnetite, calcite and possible epidote. Red garnets are clearly visible in specimen 50/97, taken from coarse-grained gneisses at the contact with a thin cross-cutting pegmatite, half a mile south of the above locality. In thin section, porphyroblasts of shattered pink garnets enclosing quartz are set in an inequigranular mosaic of quartz, oligoclase, microcline and myrmekite. Apart from the enclosed quartz, the garnets are free from inclusions but are surrounded by incomplete kelyphitic borders of pale green chlorite.

Garnetiferous biotite gneisses, cut by thin garnet-bearing pegmatites, are exposed in the Longaianiet river north of Olentoroto. A thin section of specimen 50/198 shows rare, small, rounded, colourless garnets set in a sutured mosaic of oligoclase and quartz, both the last two minerals being partly replaced by microcline. Quartz also appears as myrmekitic intergrowths with plagioclase. Biotite is occasionally replaced by muscovite pleochroic from very pale green to colourless. The muscovite is, in turn, partly replaced by oligoclase.

(*d*) *Muscovite-Biotite Gneisses*

Although muscovite is a common accessory mineral throughout the biotite gneisses described above (p. 18), white mica occasionally becomes an essential component of these rocks, producing bands of leucocratic gneiss. For convenience, biotite-free rocks (that are otherwise similar in composition and texture) and muscovite para-granulites have been included in this group since rapid gradations are often seen in the field.

The muscovite-biotite gneisses are best developed at Eserusopia, south of the Ngama hills, where they are typically coarse, pink, leucocratic quartzo-felspathic rocks containing finely disseminated muscovite and, occasionally, a sprinkling of biotite. In addition, subordinate thin bands of biotite-rich gneiss are intercalated in the succession. In the more granulitic rocks foliation becomes poorly defined. A thin section of a virtually biotite-free gneiss (50/214) exposed near Olchorro Loldugai at Eserusopia, shows a coarse, sutured mosaic of quartz, untwinned felspar and very pale green muscovite with accessory magnetite and a few small grains of rutile. Two miles to the north, muscovite-biotite gneisses develop garnetiferous bands in the vicinity of *lit-par-lit* pegmatitic veins.

At Oloiboisoit near the Tanganyika border, leucocratic muscovite-biotite gneisses containing rare garnets are cut by thin veins of quartz and pegmatite, the latter bearing greenish muscovite in flakes up to 1 inch in diameter. A thin section of the gneiss (50/182) shows both microcline and oligoclase in addition to quartz and the two micas.

A sequence in the Ol Sabukiai stream at Olare Sambu exposes thin bands of pink muscovite and muscovite-biotite gneisses associated with hornblende granulites, biotite schists and quartzites. Microcline, oligoclase, quartz and muscovite are the essential minerals in specimens 50/131 and 50/133 from this locality.

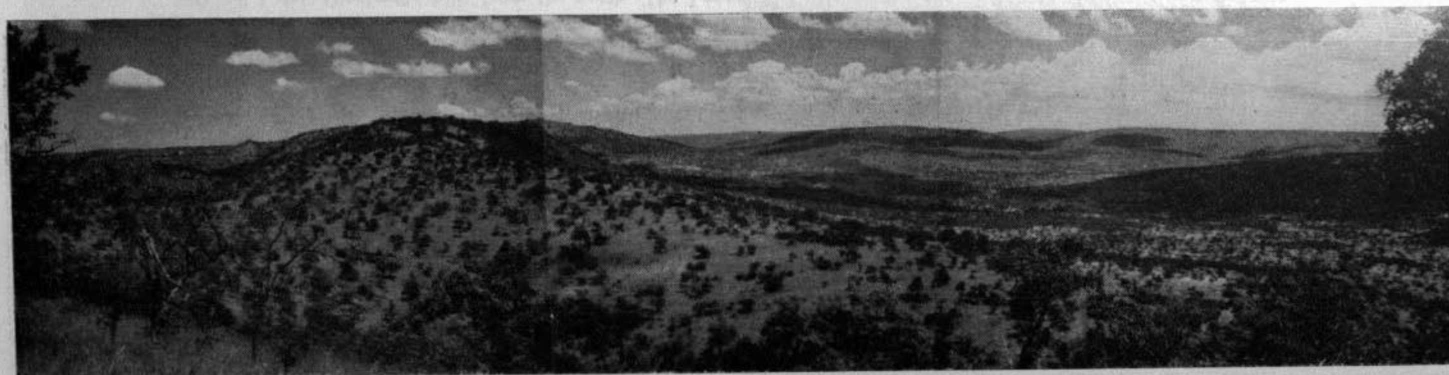
At a drift where the Loldurugi-Talek track crosses the Jagartiek stream, flaggy, well-foliated, pink muscovite-biotite gneisses (50/142) and muscovite granulites (50/141) are intercalated among muscovite-biotite schists and thin quartzites. In a thin section of specimen 50/141 quartz, microcline, plagioclase and occasional flakes of muscovite display a fine granulitic texture with a sprinkling of iron ore and rare rounded grains of epidote.

Muscovite-biotite gneisses, containing rare garnetiferous bands, outcrops near Ol Doinyo Geri in the south-eastern corner of the area.

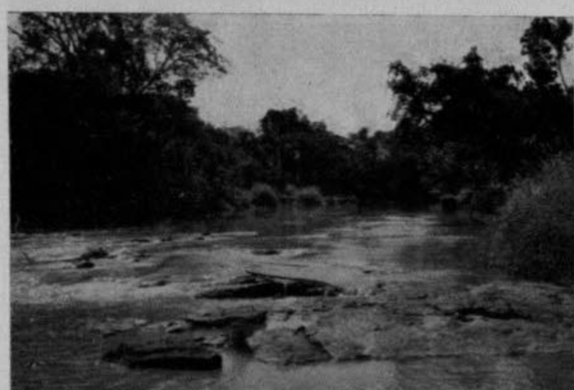
(*e*) *Quartz-Muscovite Schists*

Occurrences of mica schists are probably far more widespread than are indicated on the geological maps of this area but, being here the least resistant members of the Basement System succession, they are rarely well exposed. Isolated outcrops were seen

PLATE I



(a) View south from Seganani. Sianna hill left middle distance; eastern end of Ngama hills on the right; Olentoroto visible in the background.



(b) The Mara river looking up-stream from the site of the old bridge.

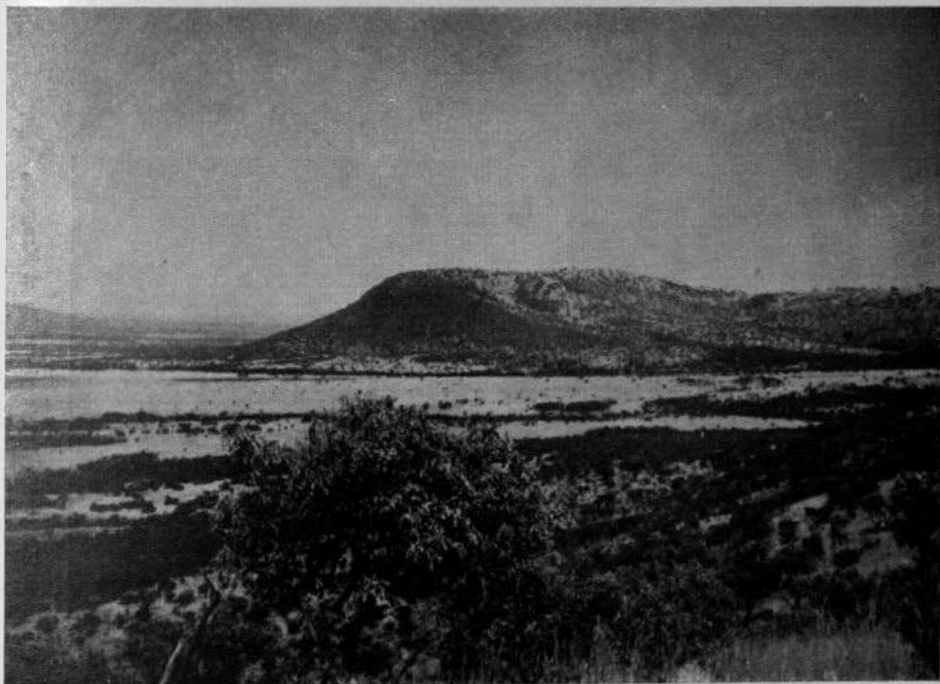
(c) The Longaianiet (Sand river) south-east of Ol Olojigoshi.

PLATE II

(a) The Siria escarpment and Mara valley from Lolomei.

(b) Ol Lalata-Olentoroto hills from the north. The Longaianiet runs across the photograph in the middle distance.

PLATE III



(a) Sianna hill from Mwigwarrur.

(b) Ol Opelagonya from the Sianna plains.

PLATE IV

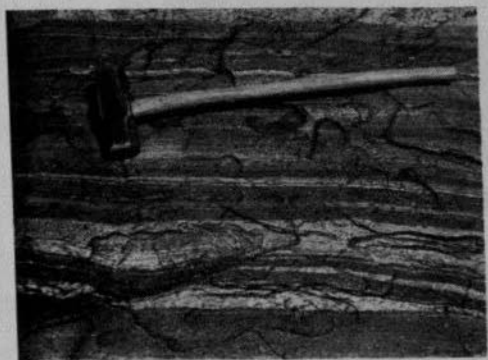
(a) Ripple-marks in quartzite, Ol Koroi.

(b) Biotite augen-gneiss, Ol Sabukiai stream at Olare Sambu.

(c) Pegmatite cutting biotite schists, Ol Sabukiai stream at Olare Sambu.

(d) Spheroidal weathering in phonolite at Nengugai, near Mara Bridge.

PLATE V



(a) Banded hornblende-biotite gneiss, Longaianet river near Oloiboisoit.

(b) Quartzo-felspathic ptygmatic and *lit-par-lit* veining in biotite gneiss, Longaianiet river west of Ol Koroi.

(c) Migmatitic biotite-gneiss, Longaianiet river west of Ol Koroi.

PLATE VI

(a) Small recumbent fold in quartzite, Longaianiet river.

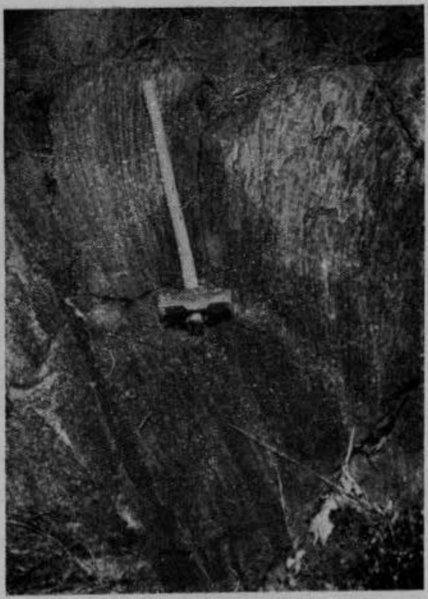
(b) Recumbent folding in quartzite, Longaianiet river near Ol Olojigoshi.

(c) Shallow-plunging folds in quartzite between Medeketa and Ol Doinyo Narasha.

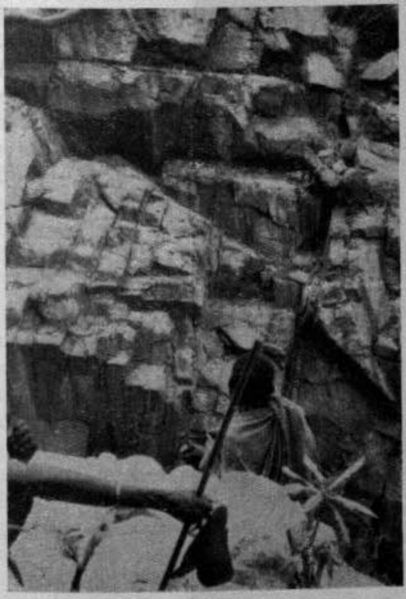
(d) Gentle NE-SW folding in biotite-muscovite-epidote schists, Talek river near Tsetse Survey and Control camp.

PLATE VII

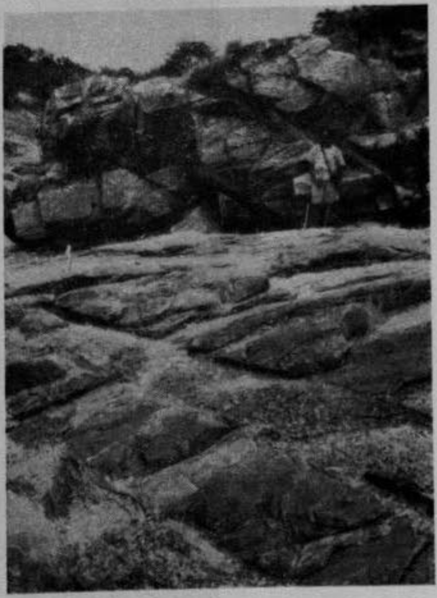
(a) Isoclinal folding in quartzite, Regero stream.



(b) Curved lineation in quartzite, Ol Koroi.

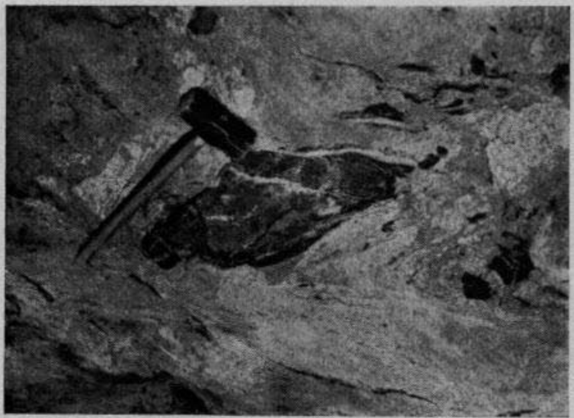


(c) Jointing in quartzite, Bardamat hills.

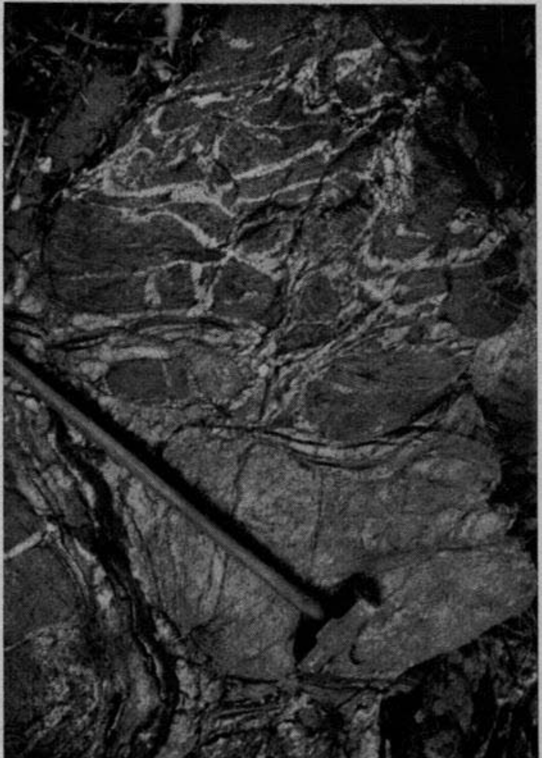


(d) Small pegmatite-injected thrusts in quartzite, Longaianiet river at Ol Olojigoshi.

PLATE VIII



(a) Amphibolitic xenolith in granitoid gneiss, Siria.



(b) Veined amphibolitic xenoliths in granitoid gneiss, Sabaringo stream near Oloololo.

in the hills bordering the Ngorengore-Aitong road and it is not unlikely that similar rocks occupy the broad Lemek valley. Further south, unexposed muscovite schists were mapped from float in the core of the Ngama fold and also south-eastwards towards Ol Opelagonya and Sianna. Traces of quartz-muscovite schists were found underlying quartzites at the western end of Olentoroto ridge near the Tanganyika border. Here the suggestion is that schists (possibly intercalated with muscovite quartzites) occupy the lower slopes eastwards to Ol Lalata.

For convenience, both semi-pelitic quartz-bearing rocks and rarer pelitic schists are described together in this section and similarly, no separation has been attempted on the geological maps. The only petrographic difference appears to lie in the quartz content and, not unnaturally, there exists a complete gradation: pelitic muscovite schists → quartz-muscovite schists → muscovite quartzites → micaceous and massive varieties of quartzite. Part of this gradational series, from semi-pelitic to psammitic rocks, is well demonstrated by specimens 50/94, 50/123, 50/44 and 50/105 described below. Greenish silvery schists at Ol Doinyo Masereji (50/94), show a herring-bone structure in hand-specimen due to small-scale contortions. Under the microscope, large flakes of pale green, slightly pleochroic muscovite exhibit a decussate arrangement and have opaque ore minerals developed along the cleavages; quartz occurs sporadically in inequigranular, highly sutured grains. Schists exposed in the Ol Kinyie hills show a relatively higher proportion of quartz and, in addition, as in specimen 50/44, contain kaolinite and altered felspar. Epidote appears as a minor constituent in specimen 50/123. Muscovite schists (50/105), exposed between Ol Doinyo Olenabala and Ol Dumaroi contain more quartz than mica while retaining a degree of fissility not found in the muscovite quartzites proper. Occasionally bands occur in which greenish and brownish green biotite, accompanied by magnetite and amorphous iron ore, largely supersedes muscovite, as in schists (50/55) that outcrop north of Eregero trigonometrical beacon in the Ol Kinyie range.

Of some interest although of very limited occurrence, are tourmaline-bearing schists encountered in the north-eastern ridge of Kipleleo (Kilaleoni) hill. Specimen 50/81 is a friable, greenish muscovite schist containing rounded "knots" up to 25 mm. in diameter, consisting of small crystals of dark iron-tourmaline and quartz, around which the enclosing schist displays a flow structure. In thin section prominent subhedral crystals of grey and pink pleochroic tourmaline, with common curving cross-fractures, are set in a coarse mosaic of quartz grains showing strain polarization. The host-rock is composed of abundant flakes of white mica and small quartz grains together with angular magnetite and possibly a little kaolinite. The origin of tourmaline in these rocks is discussed on p. 26.

(4) Metamorphosed Psammitic Sediments

(a) *Quartzites*

East of the Mara river, pure massive quartzites are responsible for the main topographical features, the quartzites are normally found outcropping along conspicuous ridges and demonstrate the essential structure of the area. Where foliation dips are high, the quartzites, being the most resistant rocks in the succession, invariably occur as central bands exposed only along the summit of the ridges and forming thick screes that frequently obscure the flanking formations. While every attempt has been made to indicate the true or inferred width of the quartzite bands on the geological maps, it is not unlikely that some degree of exaggeration still remains as a result of both the paucity of exposures and the fact that, in most cases, the quartzites grade imperceptibly into less resistant micaceous varieties.

Variations in colour and texture of the quartzites frequently occur even in individual exposures, but these characters were found to be valueless for correlation purposes. The quartzites are typically white or pale grey, compact and coarsely crystalline and often stained brown by iron oxides on exposed surfaces. Emerald-green translucent varieties outcrop at a number of localities while pink, iron-stained quartzites are exposed at Ol Doinyo Iringa (west of the Bardamat hills) and at Dagurugurueti (near Aitong). The quartzites are composed of anhedral grains, reaching 10 mm. in diameter in the case of a coarse variety found on Sianna hill; more commonly the component quartz grains measure up to 3 mm. across. Small flakes of muscovite were found in all the quartzites examined, the most prominent development being along foliation planes, and with an increasing proportion of mica the rocks grade into muscovite quartzites. Sanders (1954, p. 20) reported fibres of sillimanite among the mica in massive quartzites mapped in the Kitui area, and suggested that much of the muscovite is secondary after sillimanite. In the present area, however, the muscovite can probably be regarded as a primary constituent of the original sediment.

Evidence of the sedimentary origin of the quartzites is provided by the existence of perfectly preserved ripple-marking at a number of localities. At the northern end of the Bardamat hills large fallen blocks of white quartzite display ripple-marks while at Ol Koroi, near the western boundary of the Sianna area, an iron-stained quartzite found *in situ* shows similar sedimentary structures (Plate IV, (*a*)). The evidence of the structure in the ripple-marks indicate that, locally, the succession is the right way up. Recrystallization has generally destroyed all evidence of graded-bedding and current-bedding that might have been present in the original sandstones, but faint suggestions of these structures were seen in the Bardamat and Ol Kinyie hills. The preservation of sedimentary structures in competent bands belonging to a succession that has undergone intense deformation may be explained by assuming that the deforming movement has been concentrated within neighbouring incompetent layers (Weiss, 1958, p. 15).

Jointing is common throughout the quartzites. In massive quartzites foliation planes are usually marked by muscovite flakes. When mica is absent it is not easy to decide whether a plane is foliation or jointing, as sometimes joints parallel foliation (*see* Plate VII (*c*)).

In thin sections, the quartzites show a simple sutured mosaic of quartz with the individual grains invariably exhibiting undulatory extinction due to strain. Minute flakes of muscovite are nearly always present; the mica is largely intergranular in habit but flakes frequently cut across the boundaries of the quartz grains or are completely enclosed by them. Dusty inclusions in the quartz possibly represent carbonaceous material although, apart from a float fragment from the Lemek stream at Musweni, no graphitic quartzite was seen during the present survey. Magnetite is not uncommon (e.g. 50/191, from Seganani) and tourmaline was found in small quantities in the quartzites at several localities, notably in the eastern Ngama hills and at Ol Opelagonya. Where the original sandstones were locally felspathic, quartzites are sometimes found bearing a little fresh untwinned felspar (as in specimen 50/109, from the eastern end of the Ol Kinyie hills); more commonly the rocks contain finely disseminated kaolin and small clusters of sericitic mica, as in specimen 50/57, from the central part of the Ol Kinyie hills.

Mineralogically, the green quartzites differ essentially from the white and grey varieties in the composition of the accessory mica. The colour was found to be due to the presence of fine flakes of the chromium-bearing mica fuchsite, the identification of which was confirmed by a qualitive chemical analysis of specimen 50/101, from the roadside near Ol Dumaroi. The green colour in quartzites mapped north of Luanji in the Namanga-Bissel area by Joubert (1957, p. 21) was also attributed to fuchsite. In another specimen (50/63) collected at Ol Doinyo Lolialaram, in addition to pale green mica, rutile, epidote and apatite are present as accessories.

Rose-pink quartzites exposed at Ol Doinyo Iringa (50/49) and Dagurugurueti (50/69), owe their colour to abundant amorphous and granular iron ores that fill many of the intergranular spaces. Kyanite was identified in thin sections of both specimens.

(*b*) Muscovite Quartzites

Although a small quantity of mica is ubiquitous throughout the massive quartzites, an increase in the proportion of muscovite gives rise to more friable rocks which often assume a flaggy appearance in the field. These muscovite quartzites are commonly found flanking the more resistant central ribs of the main topographical features. Exposures are seldom good and in most cases mapping of the continuation of muscovite quartzite outcrops is based on topography. The rocks often grade vertically into quartzites on the one hand and into quartz-muscovite schists on the other. Similarly, a gradation is often seen from quartzite to muscovite quartzite along the strike of psammitic bands.

In mineral composition, the muscovite quartzites differ little from the associated quartzites. Original felspar, now represented largely by interstitial kaolinite, is more common and on the whole iron staining is more pronounced. Foliation planes are well defined and probably parallel original bedding.

Specimen 50/57, from the Ol Kinyie hills is a mauve, flaggy, quartzitic rock containing abundant white mica and small patches of kaolinite. A thin section shows a mosaic of interlocking quartz grains; muscovite ($-2V=c.15°$) and interstitial kaolinite are prominent. Another muscovite quartzite (50/46), from the Ol Kinyie hills has a fine granular texture and, in addition to quartz and muscovite, contains rare flakes of greenish brown biotite. Interstitial kaolinite is abundant and magnetite is accessory. Muscovite is also accompanied by a few flakes of greenish biotite in specimen 50/195, from the Longaianiet river south-west of Ol Olojigoshi.

Kaolinitic muscovite quartzites (50/82), exposed in the north-eastern part of Kipleleo hill bear thin bands of dark tourmaline and grade into quartz-muscovite-tourmaline schists (p. 21).

Muscovite quartzites (50/104) containing abundant magnetite are exposed on the northern flanks of Ol Doinyo Olenabala. In addition to quartz, pale green mica and magnetite, a thin section reveals acicular crystals of an unidentified yellow-green mineral having a radiating or interlocking habit.

(5) Mylonitic and Granitoid Gneisses of the Siria Escarpment

Rocks that outcrop in the vicinity of the Siria scarp although differing widely in composition from one another are here grouped together for descriptive purposes since they are all to some extent mylonitized. Shackleton (1946, pp. 8-9) described briefly mylonitic gneisses forming a zone which parallels the fault-scarp west of the Mara river and referred them to the Basement System in view of the presence of large, shredded flakes of muscovite (a mineral which he rarely encountered in mylonitized Nyanzian rocks in the granite contact zone along the southern margin of the Migori gold belt). The present survey confirms Shackleton's opinion regarding the age of the Siria mylonites, since they are in many respects lithologically comparable to Basement System rocks mapped east of the Mara river, where cataclastic textures are less pronounced.

The rocks exposed in the spectacular fault-scarp extending from Oloololo to Marrti (at the Masai-Kericho district fence line) are essentially mylonitized, biotite-muscovite granitoid gneisses with subordinate sheared amphibolitic bands and lenses of epidotite, a notable feature being the widespread saussuritization of plagioclase felspar. The gneisses typically exhibit coarse, rough surfaces caused by the differential weathering of angular quartzitic patches. Common accessory minerals are epidote, sphene, garnet and iron ore. The strike of all rocks in the zone is more or less parallel to the escarpment, the foliation dipping consistently south-eastwards at angles of from 50° to 85°, the steeper dips occurring near the northern boundary of the area.

A specimen of highly sheared mylonitic gneiss (50/246), from the Ol Mutii stream in the Marrti district shows typical mortar structure in thin section, with small lenses of intensely sutured, elongated quartz grains having irregular extinction. These lenticular aggregates are surrounded by ragged flakes of muscovite and biotite, saussuritized plagioclase, granular sphene and abundant epidote. Fine-grained granitoid gneisses are exposed in the Marrti stream and display in thin section (50/247), small shreds of biotite and muscovite with grains of epidote and rare colourless garnets set in a fine granular matrix of microcline, quartz and subordinate oligoclase. Microcline is also a prominent mineral in leucocratic mylonitic gneisses (50/239), that outcrop in the Siria scarp west of the Moyan stream. The potash felspar forms an inequigranular mosaic together with quartz, saussuritized oligoclase, shreds of biotite, myrmekite and grains of epidote.

The following rocks were encountered during a descent of the escarpment at Digirr Osirigon some five and a half miles NNE of Mara Bridge:—

(*a*) Mylonitic biotite-gneisses.

(*b*) Thin band of mylonite and quartzite with at least one amphibolitic layer.

(*c*) Coarse mylonitic biotite-gneiss.

(*d*) Thin band inferred from a line of grey mylonite boulders.

(*e*) Mylonitic granitoid-gneisses.

The amphibolite (*b*) is highly sheared and conspicuously banded by the presence of felspathic layers. In thin section (50/241) corroded poikiloblastic crystals of hornblende are seen, riddled with inclusions of epidote, rutile and colourless garnet. The amphibole is set in a matrix of fine granular epidote and amorphous iron ore. In the leucocratic bands, associated with the amphibolite, plagioclase felspar has a composition near oligoclase and is highly saussuritized. The rough weathering, highly sheared mylonitic gneisses (*e*) exposed in the lower slopes, are biotite-bearing rocks of granitic composition. A slide (50/242), shows a cataclastic structure with sutured aggregates of quartz, anhedral crystals of sodic oligoclase and microcline set in a base of crushed minerals; the potash felspar which often has distorted twin lamellae occurs both in prominent grains exhibiting a marked replacive relationship towards quartz and plagioclase and also as antiperthitic intergrowths in plagioclase. Biotite, muscovite, epidote, magnetite and myrmekite are largely confined to the finer-grained, pulverized portions of the rock.

The rocks forming the escarpment at Oloololo near Mara Bridge are essentially muscovite-biotite gneisses, all having a mylonitic texture. Specimen 50/128 from this locality, contains porphyroblastic pink microcline, while large white subhedral crystals of felspar visible in specimen 50/254, were identified as oligoclase. Local cracking of the porphyroblasts results in slight displacement of the twin lamellae. The plagioclase in specimen 50/254 is partly replaced by microcline, and potash felspar also occurs in a finer matrix that includes muscovite, biotite, epidote and occasional garnets.

Although this zone of mylonitized gneisses closely follows the Siria escarpment, a fault feature of post-Miocene age (*see* p. 42), the width of outcrop of the mylonites and the degree of shearing observed in the field, supported by the extreme cataclastic textures seen in thin sections of the rocks, suggest a more profound structural break. Furthermore, since the Siria mylonites separate Basement System gneisses, schists, amphibolites and quartzites described in the present area from rocks of totally different aspect mapped in the Migori area by Shackleton (1946), the mylonitized rocks are thought to have formed during large-scale thrusting, described on p. 41.

An interesting specimen of fault-breccia (49/1) collected by the writer from the foot of the escarpment outside the present area, some 19 miles south-west of Mara Bridge and two miles north of the Tanganyika border, contains angular fragments of phonolite similar to the Tertiary lava seen above and below the escarpment and very fine whitish mylonite, all the fragments being set in a silicified matrix. This suggests that the formation of the mylonite preceded the last phase of faulting.

(6) Migmatites

The term migmatite is applied to a visibly hybrid rock that originated by the admixture of a granitic component and a metamorphic host-rock. Both mechanical injection and metasomatic replacement of the host-rocks have been postulated as processes resulting in the production of migmatites, a stage in the progressive conversion of metamorphic rocks to types having texture and composition indistinguishable from intrusive granites. In some cases it is claimed that migmatization has taken place by the development *in situ* of the granitic component by a process of metamorphic differentiation.

In the present area, the semi-pelitic gneisses were apparently particularly susceptible to migmatization, microscopic evidence indicating that alkali metasomatism is widespread in these rocks. Injection gneisses are common, being particularly striking in the more melanocratic rocks where the *lit-par-lit* emplacement of quartzo-felspathic material often produces a banded appearance. The demarcation of migmatites in a regional map presents no small problem and, during the present work, only a single zone of more intense migmatization (in the Sianna area) has been shown. Between the Ol Olojigoshi and Ol Koroi hills granitization has locally tended to obliterate the metamorphic fabric and a gradation exists from felspathic biotite-gneisses through augen gneisses to leucocratic granular migmatites.

Specimen 50/204 from the Longaianiet river is a grey augen-gneiss showing felspathic banding and occasional prominent microcline porphyroblasts. In thin section the rock is composed mainly of a granoblastic mosaic of oligoclase, microcline and quartz. Brown biotite occasionally encloses colourless garnet and rutile, and the mica is often enclosed by sphene. In specimen 50/205 from the same locality, only a few scattered flakes of biotite are present; muscovite is rare and the plagioclase contains small rounded inclusions of glassy quartz. Biotite is partly altered to muscovite in specimen 50/206, again from the same river section, and the rock also contains euhedral to subhedral opaque iron ore, probably magnetite.

Further up-stream, near Ol Koroi, migmatitic biotite-gneisses retain the original foliation but are characterized by the widespread development of highly contorted *lit-par-lit* and ptygmatic quartzo-felspathic veins (Plate V (*b*) and (*c*)). A three dimensional aspect of the contortions is provided in river exposures. A thin section of a specimen (50/227) of typical migmatitic biotite-gneiss from the Longaianiet river at Ol Koroi, shows the replacive habit of microcline towards plagioclase and quartz.

(7) Pegmatites

Pegmatites in the area occur both as lenticular, concordant auto-segregations in the migmatized rocks and as discordant, intrusive bodies. The former predominate and are found commonly in the semi-pelitic gneisses where granitization has reached an advanced stage. The pegmatites are too numerous and generally too small to indicate on the geological maps; frequent developments occur throughout the muscovite-biotite gneisses between Olchorro Loromon and Oloiboisoit where the pegmatites occasionally bear small books of muscovite up to an inch square. Northwards, towards the Ngama hills, pegmatitic segregations also occur in the garnetiferous para-gneisses.

Cross-cutting, intrusive pegmatites are not common. A small example mapped at Olare Sambu is well exposed in the Ol Sabukiai stream where the discordant nature is clearly displayed (Plate IV (*c*)). A coarse white pegmatite encountered in the Longaianiet river near Ol Koroi is probably a discordant body but the flanking rocks were not seen. In an exposure of garnetiferous para-gneiss beside the Aitong-Talek track three miles south-west of Ol Doinyo Iringa, garnet-bearing biotite pegmatite (50/98) cuts obliquely across the foliation. Microcline, biotite, muscovite, garnet and magnetite are readily distinguished, in addition, oligoclase and myrmekite were seen in a thin section of the rock.

During the present work, no encouraging mineralization was seen accompanying the pegmatites.

(8) Metamorphism and Granitization

The rocks of the Basement System in the Mara River-Sianna area have been subjected to at least one phase of regional metamorphism and the effects of granitization are widespread, being best appreciated in the semi-pelitic gneisses. Indications of retrogressive metamorphism are discussed later.

The grade of metamorphism attained evidently corresponds to the almandine-amphibolite facies for although the zone mineral sillimanite was not recorded during the survey, diopside gneisses are sporadically developed. Kyanite was only encountered at two localities, in quartzites at Ol Doinyo Iringa and Dagurugurueti. The apparent absence of sillimanite and rarity of kyanite, is not necessarily indicative of failure to reach the higher-grades of metamorphism, since metamorphosed pelitic sediments are rarely well exposed in the area, and the Basement System succession is dominated by the existence of originally arenaceous rocks which are not unduly sensitive to changes during metamorphism. Almandine garnet is however, not accompanied by kyanite in the poorly exposed pelitic schists examined. The quartzites and associated rocks lack sufficient impurities to be able to yield characteristic high-grade minerals during metamorphism. In the purer quartzites there has merely been a complete recrystallization, much of the white mica present undoubtedly representing muscovite in the original sandstones and grits. Some sericitic mica might have formed during the breakdown of original grains of potash felspar. Ferruginous cement has occasionally yielded magnetite during metamorphism, as in the muscovite-magnetite quartzite developed locally at Ol Doinyo Olenabala. The formation of tourmaline in meta-sediments is often regarded as proof of the introduction of boron from igneous sources, but recently Frondel and Collette (1957) have questioned the invariability of the process. Having synthesized tourmaline by the reaction of a water solution of NaCl and H_3BO_3 on minerals containing Si, Al and Fe, they claim that tourmaline may often have formed during metamorphism from boron present as an original constituent in argillaceous sediments. In support of the argument, Frondel and Collette note that some recent marine clays are enriched in boron. The presence of tourmaline in some of the purer quartzites is indicative of the pneumatolytic introduction of boron; in contrast, tourmaline seen in some semi-pelitic schists and muscovite quartzites might have formed by the reaction suggested by Frondel and Collette, solutions rich in boron having been derived *in situ* from the argillaceous parts of the sediments (p. 21). Rare grains of epidote in the green quartzites probably originated by the reaction of kaolin and occurrence of the green mica fuchsite indicates that chromium was present in the sediments.

In the semi-pelitic gneisses and schists the mineral assemblages are dependent largely on the proportion of alumina present in the original sediments. Biotite and muscovite are prominent throughout and garnet is not uncommon.

The metamorphosed semi-calcareous sediments are characterized by actinolitic hornblende in association with quartz, oligoclase, epidote and occasionally garnet. Diopside is only sporadically developed.

Retrogressive Metamorphism.—Mineralogical changes due to diaphthoresis were observed in many of the rocks examined. Examples of mineralogical adjustment include:—

Garnet ——— chlorite
Biotite ——— muscovite
Biotite ——— chlorite
Sericitization of oligoclase

These changes often occur in response to a gradual decline in temperature following regional metamorphism and may be controlled by subsequent variations in stress.

Metamorphic Facies.—The concept of metamorphic facies depends on the recognition of critical mineral assemblages in metamorphic rocks of varying types that have reached internal equilibrium.

In the pelitic schists, the folowing typical mineral assemblage conforms to the almandine-amphibolite facies (staurolite-almandine sub-facies) as defined by Turner and Verhoogen (1960, p. 545):—

Quartz-garnet-muscovite-biotite-plagioclase (-epidote).

The plagioclase in these rocks has the composition of oligoclase or oligoclase-andesine, occurrences of the more calcic felspar perhaps indicating a local transition towards the kyanite-almandine-muscovite or sillimanite-almandine-muscovite subfacies (Turner and Verhoogen, 1960, pp. 548-549).

The following mineral assemblages were found in the metamorphosed semi-pelitic sediments:—

(*a*) Quartz-oligoclase-biotite (-microcline-epidote).

(*b*) Quartz-oligoclase-biotite-muscovite (-microcline).

(*c*) Quartz-oligoclase-biotite-muscovite-garnet (-microcline).

The mineral associations in (*a*) and (*b*) indicate a grade of metamorphism equivalent to the staurolite-almandine subfacies. The presence of garnet in (*c*) suggests that locally the sediments were more argillaceous so that the critical mineral assemblage is similar to that seen in the pelitic schists.

Typical assemblages in the amphibolites are:—

(*a*) Hornblende-quartz-plagioclase-epidote.

(*b*) Hornblende-quartz-plagioclase-garnet.

The plagioclase ranges from oligoclase to andesine, and felspar of similar composition characterizes the hornblende-biotite-epidote gneisses in which the following mineral association is typical:—

Hornblende-biotite-quartz-epidote-plagioclase (garnet-calcite).

All the above three mineral assemblages conform to the staurolite-almandine subfacies though it should be noted that Turner and Verhoogen (1960, p. 546) regard the amphibolites as derivatives of basic igneous rocks; evidence found during the present work suggests that the amphibolites and hornblendic gneisses have a sedimentary origin (*see* p. 15).

Schists that are believed to represent metamorphosed marls show the following mineral association:—

Biotite-muscovite-epidote-garnet-plagioclase (quartz-calcite).

As expected, the assemblage is closely related to that found in the pelitic schists.

From the above review, it will be seen that the Basement System rocks examined may indicate the lowest grade of metamorphism within the almandine-amphibolite facies which covers a temperature range of some 550° to 750° C. and pressures normally between 4,000 and 8,000 bars (Turner and Verhoogen, 1960, p. 553). There is some possibility of a local transition to the high-grade part of the greenschist facies (that now includes the former albite-epidote-amphibolite facies redefined as the quartz-albite-epidote-almandine subfacies) but this is not confirmed by the composition of plagioclase in the rocks.

Granitization.—Alkali metasomatism is widespread in the area, the process being convincingly demonstrated by the replacive habit adopted by microcline throughout the semi-pelitic gneisses in particular. Augen gneisses mark a stage in the conversion of biotite gneisses to rocks approaching a granitic composition, the transformation apparently having taken place without the intervention of a magmatic phase. The injection of granitic material in some of the other gneisses and in the migmatites shows that locally a mobile stage must have been attained, as opposed to the bodily conversion of a rock such as the augen gneiss.

The metamorphosed psammitic rocks evidently escaped felspathization, and felspar, when present, assumes a habit indicative of a detrital origin. Sanders (1954, p. 37) found it difficult to visualize a complete resistance to granitization in the coarsely crystalline quartzites of the Kitui area and suggested an origin by a process involving differential re-fusion. In the present area, however, the preservation of sedimentary structures is not easily reconciled with a process of differential re-fusion.

2. Kilgoris Granite

The mylonitized gneisses that outcrop along the full length of the Siria escarpment are followed to the west by biotite-bearing granitic rocks underlying the plateau. Near the scarp, the granite is sheared and mylonitized so that it is impossible to define accurately the boundary between the intrusive rocks and the Basement System gneisses, but along the line shown on the map there exists a zone marked by the appearance of occasional dark amphibolitic xenoliths (Plate VIII, Figs. (*a*) and (*b*)) that probably occur near the granite-gneiss contact.

The potash felspar in the granite is invariably clear microcline or less commonly microcline-microperthite; no confirmed orthoclase was identified in the slides examined. Quartz often shows strain polarization, particularly in specimens collected near the escarpment, and many of the rocks exhibit mortar structure in thin section. Plagioclase felspar usually has a composition near oligoclase and is characterized by varying degrees of saussuritization; and commonly occurs as euhedral crystals enclosed by the potash felspar. The dominant mafic constituents of the rocks is a brownish green biotite, often accompanied by a variable proportion of green hornblende; accessory minerals include sphene, magnetite, apatite and rarely garnet.

Near the western boundary of the area the granites are typically porphyritic biotite-hornblende varieties with phenocrysts of microcline reaching a length of 1½ inches. A thin section of specimen 50/237, collected near the Mutui stream at Laitigo, shows anhedral quartz, with saussuritized oligoclase present in excess over microcline in the groundmass; ragged flakes of brownish green biotite, occasionally having cores of pale green pyroxene, are associated with granular epidote and a little magnetite. Hornblende occurs only sparingly and rhombic sections of leucoxene apparently represent pseudomorphs after sphene.

Rather similar rocks are exposed in the Sosiot stream near the escarpment but there the granite is less markedly porphyritic and on the whole contains a higher proportion of hornblende than the type from the western outcrops. In addition to hornblende and subordinate biotite, accessory minerals in specimen 50/235 include sphene, colourless garnet, apatite, epidote, and black iron ore.

Less than a mile downstream the granite encloses small amphibolitic xenoliths that in thin section (50/238) are seen to be composed of abundant subhedral green hornblende commonly showing alteration to brown biotite. Fine granular epidote is developed around the margins of individual grains and also along cracks and cleavages. The plagioclase is albite with anhedral sphene and rounded, colourless garnets as accessory minerals. In similar dark xenoliths enclosed in the sheared gneissose granite exposed in the Sabaringo stream west of Mara bridge, microcline was also seen in thin section (50/125). At this locality the xenoliths are larger and less completely assimilated, although the amphibolite is intimately veined with granitic material (Plate VIII (*b*)). The host granitoid gneiss (50/126) contains small shreds of biotite but is apparently free of hornblende.

The granite underlying the Siria plateau represents a continuation of the Kilgoris mass described by Shackleton (1946, p. 25) in the Migori area. There the age of the granite has been established as post-Kavirondian since it is intrusive into the Kavirondian boulder conglomerate north of Lolgorien. In the same area, the Kilgoris granite is overlain by rocks of the Kisii Series (Bukoban System) of suggested Palaeozoic age, but regarded by others as upper Precambrian.

3. Tertiary Volcanic Rocks

Nearly a quarter of the Mara River-Sianna area is covered by at least two main flows of phonolitic lava resting on a surface considered by Shackleton (1946, p. 52) to be of Miocene age. The northern limits of the lava are uncertain and the boundary shown on the map should be treated with some caution. Between Aitong and the Bardamat hills there are no exposures across the plains and an arbitary line has been drawn indicating the limit of phonolite boulders seen in the black soils. South of the Ol Kinyie hills float fragments of weathered tuff were seen near the inferred edge of the phonolite sheet. Similar tuff was exposed during the investigation of the alleged underground workings at Loldurugi near the Mara river (p. 45). Schoeman (1946, p. 27) reported occasional poorly exposed ash beds containing abundant pumice interbanded with the phonolites in the Sotik District, but the absence of tuffs in the Migori area led Shackleton to postulate fissure eruption without explosive action. Though phonolites are exposed close to the eastern boundary of the Mara river area (principally in the Kaimurunya watercourse near Ol Doinyo Narasha), subsequent mapping of the adjacent Narok area (Wright, report in preparation) has shown that ash beds and volcanic soils largely obscure the underlying rocks across the Loita plains so that the eastern extent of the phonolite is unknown.

The phonolite is strikingly uniform in appearance and composition throughout the area, typical specimens being medium grey and markedly porphyritic with common euhedral prisms of felspar up to an inch or more in length, together with smaller greenish grey waxy phenocrysts of nepheline. The groundmass is invariably finely crystalline. Occasionally the lava is highly vesicular, the spherical to ovoid vesicles being infilled with white zeolitic material or calcite. The direction of flow of the lava is indicated by the pear-shaped vesicles produced by distortion during movement. Spheroidal weathering of the lavas (Plate IV (*d*)) is common, resulting in the production of extensive boulder fields in black-cotton soils that cover parts of the plains underlain by phonolite. In contrast, flat pavement-like exposures of phonolite with exfoliation resulting in the separation of surface skins of weathered rock are usually encountered in the water-courses. Individual flows are seldom recognizable in the field, but a double scarp, separated by a two-mile wide plain, probably marks the edge of two phonolite flows that are crossed during the descent into the Talek valley along the Aitong-Talek track. The lava is apparently thickest at the foot of the Siria escarpment but this might be explained by a number of small undetected step faults. Elsewhere it is probably not more than 200 feet thick. Several inliers of Basement System rocks were mapped within the phonolite outcrop, some standing out as small hills when the older rocks are quartzitic. Less resistant inliers, for instance the garnetiferous gneisses and pegmatite exposed beside the Talek track 7½ miles south of Aitong, are topographically insignificant. A boulder of phonolite was recorded at an altitude of approximately 6,250 feet in the valley between the double quartzite ridges forming Aitong hill, some 400 feet above the lava mapped on the plains south of Daguruguruеti. Phonolite boulders were also found on the southern side of the Olduroto Labardamat valley (Bardamat hills) at an elevation of 6,400 feet, in the Ol Kinyie hills near Olentutu at 6,600 feet, and on Ol Doinyo Narasha at about 6,500 feet. Although there is no evidence proving local extrusion of phonolite above the level of the sub-Miocene surface, an alternative explanation of the above boulder occurrences involves postulating widespread erosion of between 150 and 300 feet of lava. The latter is considered unlikely in view of the present-day topography of the area.

The phonolite from widely scattered localities shows little variation under the microscope. Euhedral crystals of untwinned felspar and abundant glassy nepheline constitute the main phenocrysts in a pilotaxitic groundmass of felspar displaying Carlsbad twinning, together with purplish brown sub-ophitic kataphorite, subhedral green soda pyroxene, dark brown to red semi-opaque cossyrite, nepheline, apatite and a sprinkling of magnetite. The interstitial base material is frequently isotropic or weakly birefringent analcime or zeolite.

Both phenocryst and groundmass felspars in the phonolite were identified as sanidine. The typical fine cross-hatched twinning characterizing anorthoclase was not seen in any of the slides examined and estimated optic axial angles ranging from about 10° to 30°, and optic planes perpendicular to 010, suggests felspars transitional to the high sanidine series (*see* MacKenzie and Smith, 1956, p. 406). Shackleton (1946, p. 49) identified as sanidine both the phenocrysts and groundmass felspars in the Isuria lavas; on the other hand anorthoclase was reported as phenocrysts in the phonolites of the Sotik area (Schoeman, 1949, p. 28).

The pyroxene has a variable composition and in the groundmass markedly pleochroic bluish green aegirine frequently occurs as an overgrowth on a pale green slightly pleochroic diopsidic variety. Diopside also forms occasional microphenocrysts.

Chestnut-brown, strongly pleochroic biotite is a rare constituent of the lavas and when present adopts an unusual ophitic texture. A single flake having a bronzy lustre was seen in a float specimen (50/53) collected near the Oldorotua stream south-west of Aitong. Chlorite and glassy isotropic crystals of analcime were doubtfully identified in a thin section of the same specimen.

The felspar phenocrysts often exhibit a preferred orientation and a number of measurements were recorded from reliable exposures in an attempt to ascertain the direction of flow of the phonolites. In several cases, the observations were supported by examination of the orientation of pear-shaped vesicles. The evidence suggests that the lava flowed generally south-westwards and westwards (Fig. 3), a direction that coincides with the present slopes of the sub-Miocene peneplain (p. 7). In the western part of the Mara River area the lava evidently flowed across, and partly infilled an irregular surface before reaching the sub-Miocene peneplain west and south-west of Bardamat.

Correlation.—Shackleton (1946, p. 48) commented on the similarity between the lavas found underlying the Isuria plateau, east of Lolgorien, and those seen in the present area and concluded that they form parts of the same sheet. A more detailed examination of the phonolites from the Mara River area shows that, although slight mineralogical differences do exist (notably the presence of biotite and the apparent absence of olivine in the phonolites east of the Mara), the lavas undoubtedly belong to the same suite. In spite of the claimed difference in felspar composition, it is believed that the Mara and "Isuria" lavas can be directly correlated with the Sotik and Mau phonolites especially since the evidence suggests that flow direction into the present area was generally from the north-east.

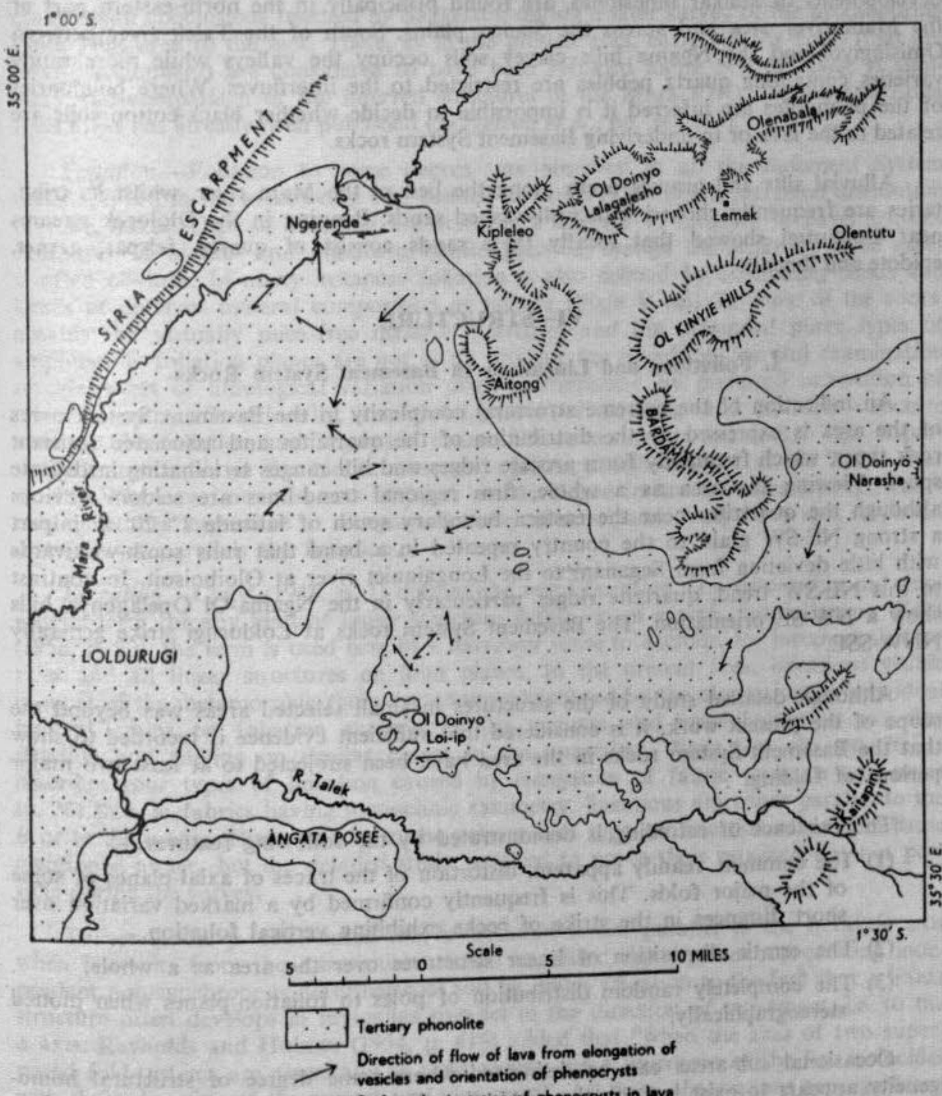


Fig. 3—Flow directions in the phonolite lavas of the Mara River area.

4. Superficial Deposits of Pleistocene to Recent Age

Reddish brown gravels and sandy soils invariably form an apron to the hills of quartzite and muscovite quartzite, grading into coarse quartzite scree as the outcrops are approached. The soils offer a good all-weather surface for roads and tracks, marred only by a tendency to develop gullies during wet weather as a result of the heavy surface run-off from the flanking high ground. The road from Ngorengore to Aitong takes full advantage of the sandy soil.

Brown, grey and black clayey soils frequently mask the underlying geology and are considered to be derived from Basement System rocks other than quartzites and muscovite quartzites. These soils, which are occasionally accompanied by minor developments of kunkar limestones, are found principally in the north-eastern part of the Mara river area and across the Sianna plains. South of the Talek river between Omisingiyoi and the Ngama hills clayey soils occupy the valleys while more sandy varieties containing quartz pebbles are restricted to the interfluves. Where boundaries of the phonolites are inferred it is impossible to decide whether black-cotton soils are related to the lava or to underlying Basement System rocks.

Alluvial silts and gravels occur along the bed of the Mara river, whilst its tributaries are frequently choked with well-washed sands. Panning in the Ololorok streams near Loldurugi showed that locally these sands consist of quartz, felspar, garnet, epidote and ilmenite.

VI—STRUCTURE

1. Foliations and Lineations in Basement System Rocks

An indication of the extreme structural complexity in the Basement System rocks of the area is expressed by the distribution of the quartzites and associated resistant rock types, which frequently form arcuate ridges and hill ranges terminating in digitate spurs. Viewing the area as a whole, firm regional trend-lines are seldom obvious although the quartzites near the eastern boundary south of latitude 1° 20′ S. impart a strong NE-SW grain to the country repeated in a band that runs south-westwards with little deviation from Seganani to the Longaianiet river at Oloiboisoit. In contrast to this NE-SW trend, quartzite ridges particularly in the Ngama-Ol Opelagonya hills show a NW-SE orientation. The Basement System rocks at Loldurugi strike generally NNW-SSE.

Although detailed study of the structures in small selected areas was beyond the scope of the present work, it is considered that sufficient evidence is recorded to show that the Basement System rocks in the area have been subjected to at least two major periods of folding.

The existence of refolding is demonstrated by the following features:—

(1) The common, readily apparent, distortion of the traces of axial-planes of some of the major folds. This is frequently confirmed by a marked variation over short distances in the strike of rocks exhibiting vertical foliation.

(2) The erratic disposition of linear structures over the area as a whole.

(3) The completely random distribution of poles to foliation-planes when plotted stereographically.

Occasional sub-areas can be delineated where some degree of structural homogeneity appears to exist but, on the whole, insufficient data precludes subdivision into small enough units to confirm statistically the form of structures suggested by a stratigraphic approach, and stereograms which were constructed are therefore not included in this report.

A suggestion of refolding in Basement System rocks was reported for the Sotik district immediately to the north of the present area (Schoeman, 1949, p. 34). In a discussion of the structure of the Sotik region Schoeman stated: "The dominant trend of the fold pattern is in a north-east to south-west direction with overfolding to the south-east suggesting that the directed pressure was active in a north-west to south-east direction. In addition the change in disposition of the fold axes towards an almost east-west direction over certain distances may indicate deforming forces applied in the opposite quadrant possibly coming into effect when the main folding was completed."

Many of the opinions formed by the writer in the course of the present work agree closely with conclusions reached by Saggerson during a later survey of the neighbouring Loita Hills area to the east. There, as in the present area, early NE-SW folds (that are locally recumbent) are considered to have been refolded along NW-SE axes. A summary and comparison of the inferred structures in the Mara River, Sianna and Loita Hills areas has already been published (Saggerson *et al.*, pp. 341-343).

Foliation.—Foliation to some degree was observed in all the Basement System rocks mapped in the area, being best defined in bands exhibiting a preferred orientation of mica flakes. Dips of foliation are sometimes difficult to measure in pavement-like exposures of biotite- and muscovite-biotite gneisses, though the strike in some cases is often obvious. In many instances foliation is also defined by alternating bands and lenses of different mineral composition or texture (Plate V (*a*)). In some of the rocks, notably the virtually mica-free massive quartzites and the unbanded purer types of amphibolite, foliation planes are not at all obvious but invariably, careful examination reveals traces of lithological variation often accompanied by preferred orientation of mineral grains. Occasionally, the development of rodding and mullion structure obscures the foliation and imparts a coarse fibrous texture to the rocks. This is particularly noticeable in the biotite-muscovite-epidote schists exposed in the Talek river (p. 16). Where two or more sets of joints are developed in massive mica-free quartzites it is sometimes impossible to recognize foliation planes, particularly when it is suspected that jointing parallels the foliation.

Lineation.—Cloos (1946, p. 1) defined the word lineation as a descriptive and non-genetic term for any kind of linear structure within or on a rock, but following Weiss (1958, p. 20), the term is used here in a narrower sense to exclude, for instance, slickensides and all linear structures on joint planes. In the present area, lineations visible in most of the metamorphic rocks are commonly caused by the elongation of individual mineral grains on foliation surfaces in the gneisses and amphibolites or are fine striation and ribbing on similar planes in the quartzites. Weiss (*op. cit.*, pp. 20-21) describes four types of lineation caused by elongation of fabric elements and notes (p. 26) that, in fabrics having monoclinic symmetry, lineations are either parallel to the *B* or to the *a* axis. There may be in the present area types of lineation other than those mentioned above, but the detailed study required to prove their presence was not possible during the survey.

Turner (1948, p. 180) noted that a lineation is not parallel to the *b* fabric axis when it results from the intersection of two unrelated slip surfaces representing independent non-synchronous deformations, and he draws attention to the fact that a linear structure often develops in mylonites parallel to the direction of movement, i.e. to the *a* axis. Reynolds and Holmes (1954, p. 418) added that "when the axes of two superposed fold-systems are essentially at right angles, the *b* lineations of the first coincides with the *a* direction of the second, and vice versa". All these observations are significant in a consideration of the structure in the present area, where two periods of folding are recognized and a broad zone of mylonites was mapped. The resulting complex lineation pattern will only be interpreted successfully by more detailed statistical work in small sub-areas.

2. Folds in the Basement System rocks

The inferred major structural features in the area are shown in Fig. 9; lineations and minor fold structures recorded during the survey are presented in Fig. 4.

Variety in the style of minor folding seen in the Basement System rocks, ranging from simple open folds to complex recumbent structures, is illustrated by the examples shown in Plate VI and VII (*a*). The major folds in the area display a corresponding range in style, the main structures being described below.

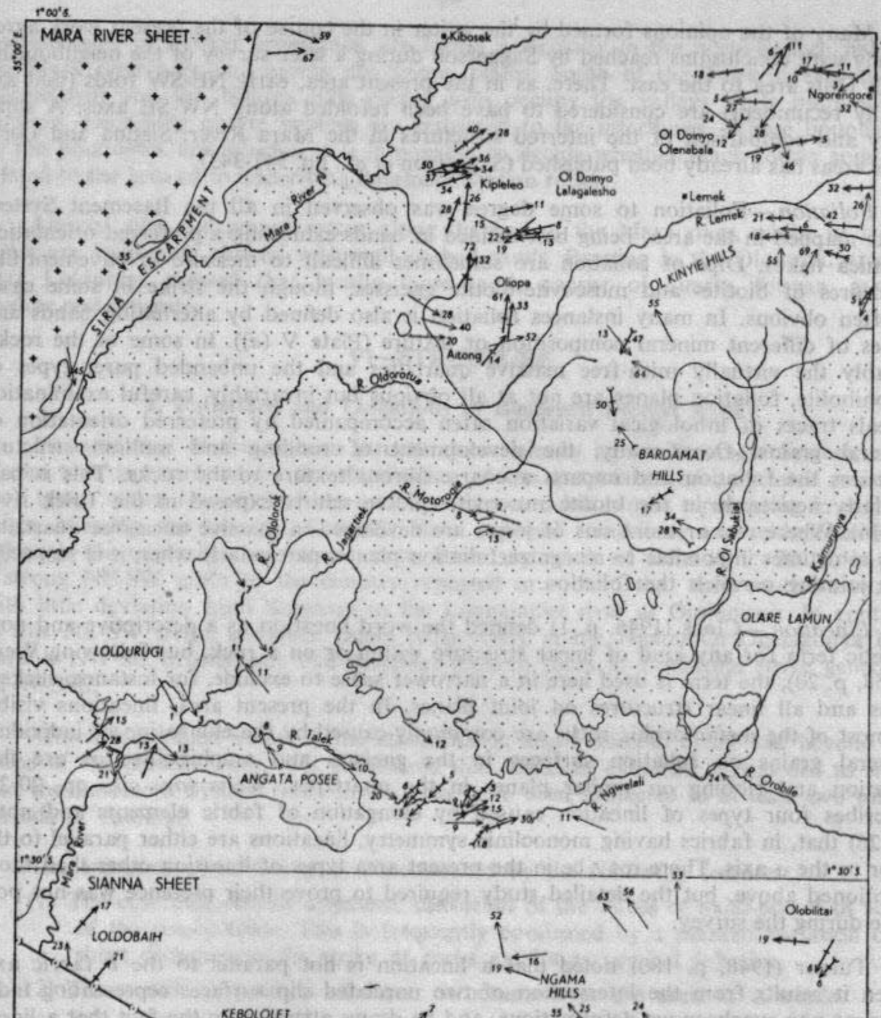


Fig. 4—Lineations and minor fold structures in the Mara River-Sianna area.

Loldurugi-Loldobaih-Kebololet.—Critical structural evidence was obtained from the Loldurugi area near the confluence of the Mara and Talek rivers, where the Basement System rocks display a general NNW-SSE strike and where opposing dips suggest, at first sight, the existence merely of a simple open syncline (the Loldurugi syncline) with lineations indicating a near-horizontal axis trending NNW-SSE. Indications of closures of bands, however, together with an approximate stratigraphical repetition within each of the two limbs of the syncline, reveal the complexity of the structure. Closure of individual bands within the eastern limb of the Loldurugi syncline is best displayed north of the Ololorok-Jagartiek confluence; a marked convergence of bands in the western limb is seen south of Loldurugi, though the actual closures are concealed by the phonolite. The correct interpretation of the M-shaped outcrop, having axial planes of the flanking folds inclined towards a central syncline, involves first a study of the local lineation pattern. Though most of the lineations in the Loldurugi-Ololorok-Jagartiek area trend NNW-SSE, those recorded near the Mara river and towards Loldobaih and Kebololet display a NE-SW orientation (Fig. 4) with plunges to the north-east; on the other hand, similarly orientated lineations and minor fold-axes, measured in the mid-Talek section, plunge generally south-westwards. This plunge depression between the Talek and Kebololet coincides with a continuation of the Loldurugi syncline, clearly indicating refolding of early NE-SW structures by a later NNW-SSE fold. Having established the existence of refolding, the structure at Loldurugi is now convincingly explained as a recumbent fold (having a near-horizontal axial plane which originally trended NE-SW) that was later refolded synclinally (*see* Fig. 5 (*a*)) and the geological sections published with the Mara River and Sianna sheets).

Between Loldobaih and Gegerok both limbs of the Loldurugi recumbent structure were thrown into a series of minor folds, the outcrops and lineation pattern indicates that these folds are locally overturned with axes trending generally NE-SW. These are illustrated by the section on the Sianna sheet and, in view of their orientation, it is believed that these folds were produced during the first period of deformation.

Kipleleo-Oliopa-Aitong.—Further evidence of superimposed folding is presented by the outcrops of quartzite south of Kipleleo where the hills of Oliopa, Ol Doinyo Aitong and Ol Doinyo Mesereji form a striking unbroken semicircular arena, open to the north-west; the shape of this arena can be clearly appreciated when viewed from the Narok-Lolgorien road. The semicircle is composed of two main bands of quartzite representing the steeply dipping limbs of an anticline (the Aitong anticline in Fig. 9) the axial trace of which swings from east-west through NE-SW to NE-SE. This swinging of the axial trace is clearly demonstrated by the marked variation in strike of rocks having vertical foliation. The closure of the quartzite bands is found in the southern part of Kipleleo hill, with the drawn-out compressed hinge of the fold forming the prominent NE-SW trending ridge near Olchorro Lasoit. The northern quartzite band at Aitong is interpreted as containing the axial trace of the Kipleleo syncline with a thickened closure at Ol Doinyo Mesereji. It is suggested that the third or most easterly quartzite band seen at Oliopa (which is related to the quartzite mapped at the foot of the southern slope of Ol Doinyo Aitong and again at Dagurugurueti) swings north-eastwards to reappear at Ol Balagai. The Aitong, Kipleleo and Ol Balagai folds were originally orientated NE-SW and the structure was subsequently modified by refolding along axes trending locally WNE-ESE (the Ol Kimatare anticline and the Musweni syncline in Fig. 9; see also Fig. 5 (*b*)). Evidence of the later folding is seen at Ol Doinyo Mesereji where lineations plunge to the ESE in contrast to the more northerly ones recorded at Oliopa and Kipleleo. The plunge depression along the axis of the Ol Kimatare anticline is not indicative of refolding, the opposing plunge directions in the second fold merely being due to the influence of the pre-existing Lemek syncline. Ramsay (1960, p. 75) notes that in areas of repeated folding "the plunge of the new fold axes varies according to the dip of the surfaces which underwent refolding".

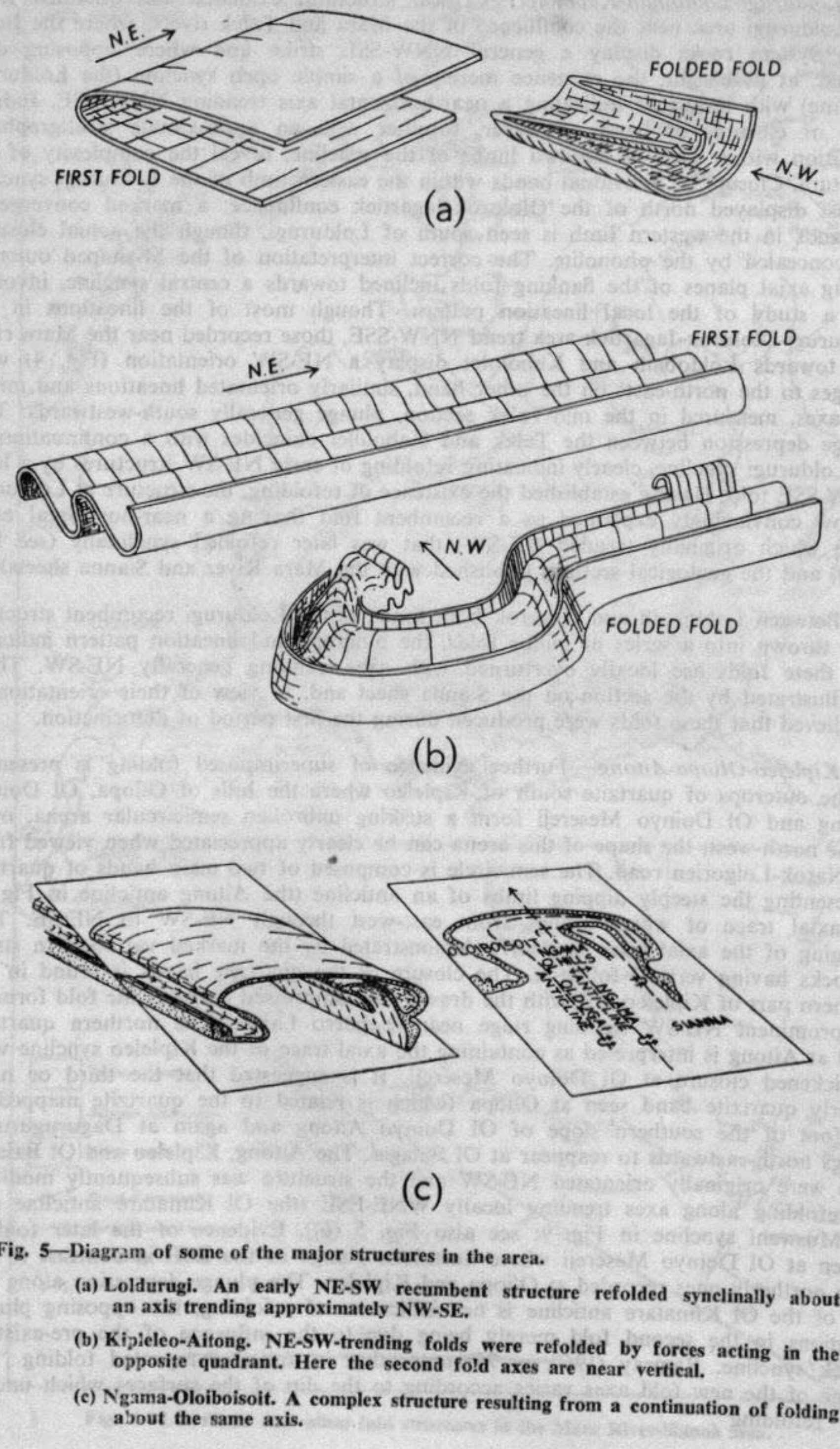


Fig. 5—Diagram of some of the major structures in the area.

(a) Loldurugi. An early NE-SW recumbent structure refolded synclinally about an axis trending approximately NW-SE.

(b) Kipleleo-Aitong. NE-SW-trending folds were refolded by forces acting in the opposite quadrant. Here the second fold axes are near vertical.

(c) Ngama-Oloiboisoit. A complex structure resulting from a continuation of folding about the same axis.

It will be appreciated that the axes of folds produced by the second period of deformation will in many instances be nearly vertical since the compressional forces acted on structures with steeply dipping limbs. Ramsay (1957, p. 287), in a discussion of superimposed folding at Loch Monar, stated: "The geometry of second folds is dependent upon the attitude of the limb of the first fold upon which they have been superimposed. Individual second folds can be traced across the Loch Monar synform: they plunge at low angles to the south-west where they have folded the gently dipping northern limb of the synform, but where they fold the steeply dipping southern limb their axes plunge steeply or even vertically. The plunges of the second folds thus change along the strike traces." In the present area, major structures having very different ultimate shapes have been produced merely by a difference in the inclinations of the axial planes of the earlier folds. At Loldurugi (Fig. 5 (*a*)) the earlier fold was recumbent, whereas at Kipleleo (Fig. 5 (*b*)) the first folds, although having the same NE-SW axial trend as the recumbent structure at Loldurugi, were isoclinal with steeply dipping limbs.

Ol Kinyie-Bardamat.—The Ol Kinyie and Bardamat hills together form an S-shaped feature that is strongly reminiscent of the Kipleleo-Oliopa-Aitong structure. In detail, the pattern is complex with numerous closures of quartzite bands indicating tight folding, though the structure is essentially anticlinal.

In the Ol Kinyie hills the foliation planes dip generally to the NNW indicating isoclinal folding with fold-traces orientated ENE-WSW between Olentutu and the Oladangari watercourse. The broad quartzite band forming the main ridge embraces the trace of the Ol Kinyie anticline, a fold that continues south of the Regero stream as the Bardamat anticline. Complementary fold-traces display a corresponding swing through 90° between the Ol Kinyie and Bardamat hills, a distortion that is related to refolding along roughly NW-SE axes (the Ol Kimatare anticline). Similarly a reverse swing of the trace of the Bardamat anticline occurs at the southern end of the hills. The opposing swing of the Bardamat-Ol Kinyie and Aitong-Oliopa structures is explained by a plunge depression in the second fold axes between the two ranges of hills. At Ol Kinyie and Bardamat lineations indicate a plunge of second folds to the north-west; at Aitong-Oliopa minor structures demonstrate a plunge to the south-east. It is suggested that this plunge depression on the second fold axes is a reflection of an early syncline (the Lemek syncline).

Folds too small to be shown on Fig. 9 provide further evidence of the structural complexity at Bardamat. Near the trigonometrical beacon high foliation dips to the south-west and north-west were recorded. Minor recumbent folds seen at this locality, though having an axial trend varying from north-south to NE-SW, plunge generally to the south-west at 17°, the axial planes of the folds being inclined to the north-west at 25°. A mile and half south-east of the trigonometrical beacon, further minor recumbent folding was observed in muscovite quartzites. There, however, the average axial plunge is 30° to the north-west with the axial planes of the folds inclined at about 15° to the south-west. Thus minor fold structures indicate the local development of recumbent folding along both NE-SW and NW-SE axes.

Lalagalesho-Lolialaram-Olenabala-Dumaroi.—In the range of hills north of the Lemek road, more detailed investigation is required before a full explanation of the structure can be provided. The major folds undoubtedly trend ENE-WSW, as indicated by quartzite outcrops, the majority of the foliation dips and a somewhat diffuse lineation pattern. Local marked swinging of the strike of foliation to a NW-SE direction, together with the existence of occasional lineations having a similar trend, demonstrates the effect of refolding.

Over the greater part of the range, there is no evidence to suggest that more than a single thick band of quartzite is involved, repetition being effected by both folding and faulting. The major structural feature is evidently an anticline, with complication due to doming at Ol Doinyo Lalagalesho. The flanking major synclines (the Kiplelat and Lemek synclines in Fig. 9) cause repetition of the quartzite at Ungulot-Kiplelat, to the north, and in the Ol Kinyie hills to the south.

Oloiboisoit-Ngama-Seganani.—A diagram of the inferred essential structure in a single quartzite band between Oloiboisoit and Ngama is shown in Fig. 5 (*c*). Such a structure might have been produced by the effect of continued folding on a simple fold system leading to involution. It will be appreciated that the process involves marked bending of the axial traces of the original structures though no refolding along new axes has taken place. Since the structure between Oloiboisoit and Ngama remains essentially anticlinal in spite of the complications, the simplified axial trace of this fold (the Ngama anticline) has been inserted in Fig. 9. The associated lineations show that the structures can all be related to the NW-SE phase of folding, with the plunge consistently to the north-west. That the NW-SE folding was preceded by an earlier deformation is indicated by the north and north-easterly plunging lineations at Olchorro Loromon. Presumably elsewhere the first fold lineations have been obliterated.

Other quartzites outcropping at Ol Opelagonya and Ol Olojigoshi are believed to represent complex infolding of the same band as that seen at Oloiboisoit and Ngama, here accompanied by widespread faulting. Fig. 6 is a tectonic profile showing the structure in and around the Ngama hills where the lineation pattern indicates that folds plunge consistently to the north-west. It is believed that the folds shown in the illustration have deformed bands in the upper originally horizontal limb of an earlier recumbent structure, so for the purpose of the profile the effect of first folding can be neglected.

The exact relationship between the Oloiboisoit-Ngama structures and the recumbent fold at Loldurugi will only be established when mapping of the continuations of the bands has been carried out in Tanganyika. The upper quartzite limb of the recumbent fold can be traced to Olchorro Loromon where it overlies the Oloiboisoit band. The latter is unlikely to be the equivalent of the lower quartzite limb of the recumbent structure in view of the absence of amphibolitic rocks immediately underlying the quartzite at Eserusopia. It is considered more likely, therefore, that the Oloiboisoit-Ngama quartzite lies stratigraphically lower in the succession than the quartizite exposed at Loldurugi.

Ol Koroi-Losemodu-Olentoroto-Ol Doinyo Geri.—In the south-eastern corner of the area relics of the first period of folding are preserved between Ol Koroi and the Tanganyika border. Lineations at Ol Koroi show a considerable scatter that could be expected if a series of NE-SW structures were later refolded. Occasional exposures reveal evidence of distorted lineation (*see* Plate VII (*b*)). Although complexly folded in detail, the structure at Ol Koroi is essentially synclinal with the axial trace of the fold trending NE-SW. The continuation of the axis beyond the Longaianiet is not clearly defined but, to the north-east, the trace was subsequently mapped in the neighbouring Loita hills area (*see* Saggerson *et. al.*, 1960, pp. 343-344). The trace of the Losemodu syncline is more easily followed and swings southwards to become overturned at Lenyaguni near the Tanganyika border. The intervening Ol Doinyo Geri anticline which closely follows the Ngorika fault, has also been detected in the area to the east.

The Olentoroto-Ol Lalata hills (Plate II (*b*)) are composed of a double band of quartzite representing the limbs of the fold described below, with a closure towards the east near the Longaianiet river. The quartzite was not found outcropping in the river and is unlikely to be a continuation of the band exposed to the south-east at Ol Melile. A study of air photographs shows that a southwards continuation of the Olentoroto quartzite swings eastwards in Tanganyika to re-enter the present area at Ol Doinyo Geri where both limbs of the recumbent fold become separated. The lower limb was traced from Ol Doinyo Geri by way of Lenyaguni to Ol Pusi Moru

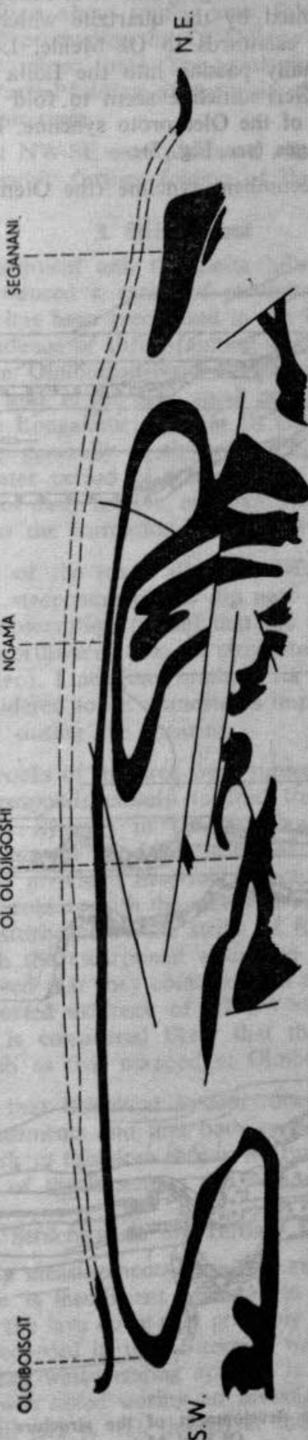


Fig. 6—Tectonic profile showing the structure between Oloiboisoit, the Ngama hills and Ol Olojigoshi. Only the quartzites are shown to illustrate the folding.

where the band again crosses into Tanganyika. It is thought that the upper limb of the recumbent fold is represented by the quartzite which can be traced westwards from Ol Doinyo Geri thence eastwards to Ol Melile, Losemodu and the Anailwa stream (south of Ngorika), finally passing into the Loita hills area. The Losemodu syncline and the Ol Doinyo Geri anticline seem to fold an east-west-trending axial trace, no doubt a continuation of the Olentoroto syncline. It is believed that this complex pattern arose in three stages (*see* Fig. 7): —

(i) The formation of a recumbent syncline (the Olentoroto syncline) by folding about a NE-SW axis.

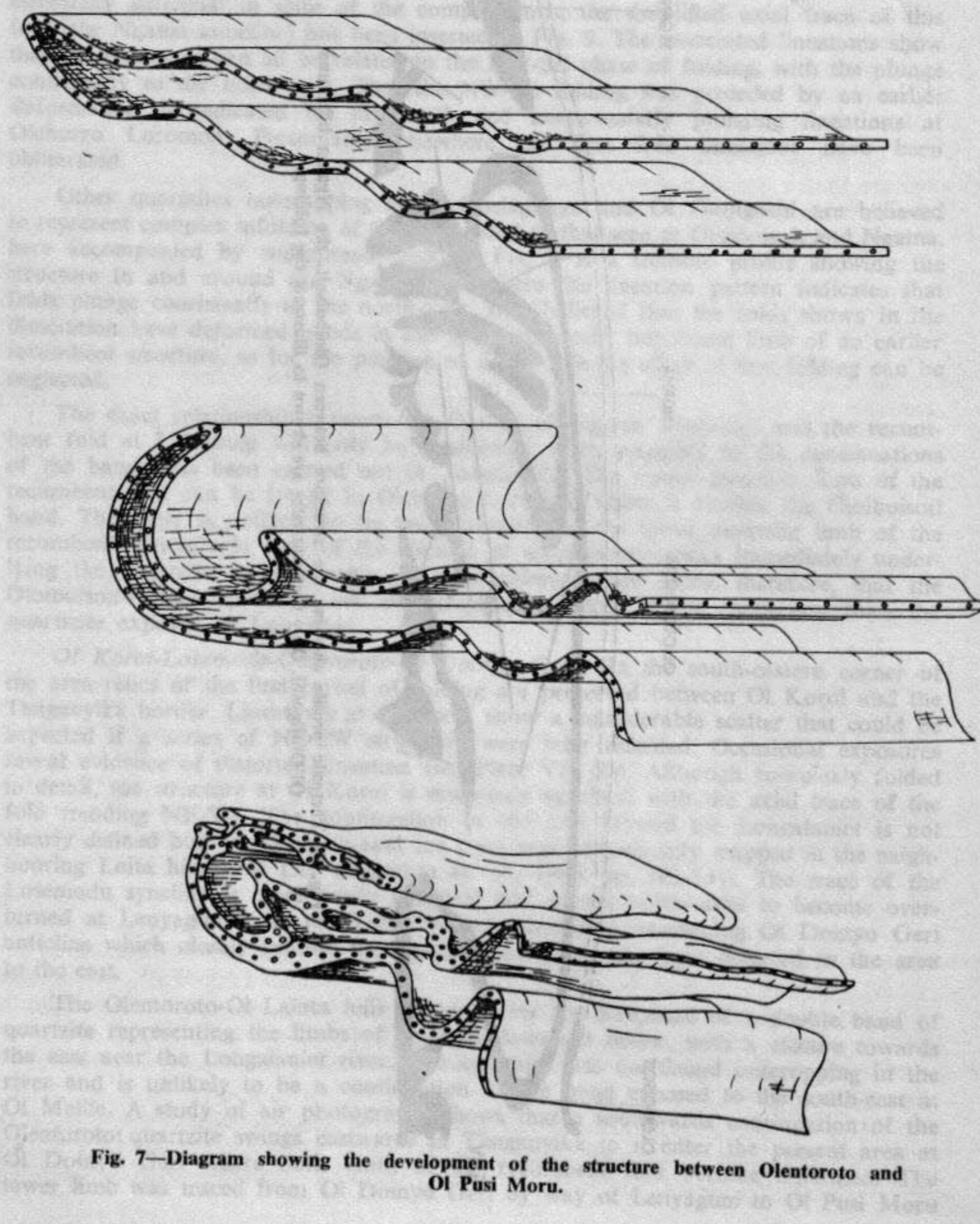


Fig. 7—Diagram showing the development of the structure between Olentoroto and Ol Pusi Moru.

(ii) Continued deformation about similar axes, folding both limbs of the recumbent structure and producing the Ol Doinyo Geri anticline, the Losemodu syncline and other minor folds. The axial plane of the Olentoroto syncline was thus folded. Partial folding of the nose of the Olentoroto syncline could have occurred at this stage.

(iii) Later folding about NW-SE axes produced minor complications on the major structure, with possibly further folding of the nose of the Olentoroto syncline.

3. Siria Thrust

Between the Siria escarpment and the Loita hills early NE-SW folding of the Basement System rocks produced a series of recumbent folds. Thrusting associated with this period of folding has been recognized in the Loita Hills area (*see* Saggerson *et al.*, 1960, p. 343) and evidence of thrust-faulting was also found in the Sianna area. The tectonic profile of the Oloiboisoit-Ngama-Seganani structure (Fig. 6) shows a number of low-angle faults and, in the field, small pegmatite injected thrusts were seen in quartzites exposed in the Longaianiet river at Ol Olojigoshi (Plate VII (*d*)). At this locality, the fault planes dip generally northwards though it is possible that they have been deformed during a later period of folding. It is believed that major thrusting occurred during the period of early folding, approximately along the line of the present Siria escarpment, leading to the formation of a broad mylonitized zone.

The mylonitic gneisses of the scarp all strike NE-SW and dip generally to the south-east at about 60°. A steepening of the dip near the northern boundary of the present area supports the observation (p. 35) that the inclination of the axial planes of the first folds increased northwards (viz. the structures were recumbent at Loldurugi and near vertical at Kipleleo). Lineations in the Siria mylonites plunge generally to the south-east and are considered to be *a* lineations impressed on the rocks parallel to the direction of movement during the shearing.

The Basement System rocks of the area were subsequently refolded about NW-SE axes, a direction that corresponds closely to fold trends mapped in rocks of the Nyanzian and Kavirondian Systems in the neighbouring area to the north-west (Shackleton, 1946, p. 42). Between the Loita hills and the Mara river, evenly spaced zones have been recognized in which first fold structures are dominant; intervening areas display strong NW-SE folding with the earlier structures largely obliterated. There is no indication of any disturbance in the strike of foliation of the Siria mylonites in the present area (though the escarpment swings to a more east-west direction in Tanganyika) and it is believed that they coincide with a zone in which first folds are dominant. There is no reported evidence of NE-SW structures in the Nyanzian and Kavirondian rocks and it is considered likely that they are exposed in a zone of dominant second folds, such as that mapped at Oloiboisoit-Ngama-Seganani.

The evidence suggests that Basement System rocks were thrust north-westwards over Nyanzian lavas and sediments and that both systems were subsequently refolded along NW-SE axes, but work in this area throws no further light on the controversial subject of the relative ages of the Basement and Nyanzian Systems.

4. Structures in the Tertiary Lavas

Reliable surfaces for dip measurements were only rarely found across the outcrops of the phonolite, and there is insufficient evidence to demonstrate convincingly the suspected gentle warping of the lava cover that probably accompanied the post-Miocene faulting in the area. Dips recorded in the Motorogie watercourse, in the centre of the Mara river area, show an east-west-trending syncline in the phonolite. East-west anticlinal arching of the lava was noted during an investigation of alleged underground workings near Loldurugi hill (*see* p. 45), though at this locality the structure seen in the phonolite might have been caused by slumping.

5. Faults

The major faults in the Mara River-Sianna area trend NE-SW and thus parallel the Siria escarpment. A less impressive set of faults striking NW-SE has also been detected, largely by reference to air-photographs, and similarly a set of north-south fractures has been inferred. Only two faults have throws of sufficient magnitude to warrant individual description.

Siria Fault.—The Siria escarpment (Plate II, (a)) is a spectacular fault feature extending some forty miles from near the northern boundary of the present area to beyond the Tanganyika border. A discontinuous cap of Miocene phonolite at the top of the scarp, identical to the lava outcropping at the base, demonstrates the most recent movement of the fault—a downthrow to the east of about 800 or 900 ft. A study of the mylonitized gneisses exposed along the escarpment, and for some distance above and below, tends to confirm an earlier suggestion (Shackleton, 1946, p. 41), that the post-Miocene fault was merely situated in a zone of much older, intense, large-scale thrusting. The presence of a major thrust (the Siria thrust *see* p. 41) in this region would readily explain the non-appearance east of the scarp of Nyanzian rocks comparable with those of the Lolgorien area, which are last seen underlying the lava ten miles west of the Siria escarpment.

Ngorika Fault.—In the south-east corner of the Sianna area a major fault separates the rocks at Ol Koroi from the massive quartzites at Ngorika, following closely the trace of the Ol Doinyo Geri anticline. The fault strikes NE-SW and has a downthrow to the east of about 700 feet; its continuation to the north-east was later mapped during a survey of the Loita hills, where Saggerson (report in preparation) found occurrences of massive pegmatites along the fault-zone. In the present area massive pegmatites were seen in the Longaianiet river south-west of Ol Koroi, striking parallel to the Ngorika fault. The presence of pegmatites injected along the fault-planes is an indication of the early age of the faulting in the Ol Koroi area and shows that, like the Siria fault, the Ngorika fault and its associates were at least initiated in pre-Tertiary times.

6. Joints

Joints, best developed in the quartzites (Plate VII, (*c*)), display a random orientation in the Basement System rocks of the area though a slight concentration occurs in a NE-SW direction.

VII—MINERAL DEPOSITS

No mineral deposits of economic importance were discovered during the present survey and little encouragement or guide can be offered for further prospecting.

Lit-par-lit injection and cross-cutting pegmatite veins were encountered principally in the south-eastern quarter of the area but nowhere are they associated with any significant mineral development. Similarly, no mineralization was noted around the Siria granite (Shackleton, 1946, p. 38).

1. Copper

Green malachite-staining was observed near a thin quartz vein cutting biotite-epidote schists at Angata Oldurorok, near the Ololorok stream south-east of Loldurugi. Exposures in the vicinity are poor, but the occurrence probably has no economic significance.

2. Garnet

Garnets were found both in Basement System schists and gneisses and also locally in pegmatitic veins, but their distribution is erratic and the garnets themselves are invariably of small size so that the occurrences do not warrant further investigation. The garnets are typically reddish brown and translucent to opaque; no gem-quality stones were seen.

3. Graphite

A float specimen collected by a prospector from the Lemek stream at Musweni was found to contain finely disseminated graphite, but no graphite-bearing bands were seen during the survey.

4. Mica

Although muscovite is a common constituent of the pegmatites in the area, distribution is erratic and individual books rarely contain flakes larger than one square inch. None of the occurrences can be considered to be of economic value.

5. Carbon Dioxide

Bubbles of nearly pure carbon dioxide rise steadily from a small permanent spring situated between the Amala river and Olchorro Lelela. The total gas flow is small and the occurrence is unlikely to indicate a deposit of economic importance. The analysis of a gas sample gave the following results:—

	%
Carbon dioxide	99·25
Methane	0·18
Oxygen	0·15
Residual inert gas	0·42

Anal: E.A. Industrial Research Organization, Nairobi.

The oxygen and inert gas (? nitrogen) probably represent air contamination during sampling.

The analysis of a water sample from this locality is given on p. 46.

6. Diamonds

Rumours have arisen from time to time regarding the existence of diamonds in the Mara River area and Exclusive Prospecting Licence No. 124 was granted to the Ansurfox Mining Company Limited for one year from February, 1957 (Notice No. 1640 of 7th May, 1957), to prospect precious metals, non-precious metals, radio-active minerals and diamonds. The E.P.L. covered some 880 square miles of the Narok District including, generally speaking, the south-eastern half of the Mara River area. New Consolidated Gold Fields Limited accepted an option over the E.P.L. and a prospecting team carried out shallow pitting and trenching on the plains south and south-east of the Bardamat hills where diamonds were said to have been found some thirty years ago. The gravels of the Talek and Mara river were also examined. Mineral assemblages regarded as being associated with diamonds were not found, and New Consolidated Gold Fields relinquished their option over the E.P.L. in mid-August, 1957.

The E.P.L. area was reduced to some 123 square miles on renewal in February, 1958 (Government Notice No. 2242 of 24th June, 1958) and covered the Mara, Talek, Ololorok and Jagartiek confluences together with the south-eastern part of Loldurugi (Omarti) hill and eastwards to Ol Doinyo Jegonobirr and the plains south-west of the Bardamat hills. The licence expired in February, 1959 (Gazette Notice No. 867 of 3rd March, 1959).

The reduced area included what were thought to be underground workings near Loldurugi hill. Two shaft-like openings in the ground were shown to E.G. Surridge (of Ansurfox) and the writer during an investigation of excavations reported to have been made by German prospectors before the 1914-18 war.

The western shaft (approx. 20 ft. deep through phonolite) had an obvious "drive" at the foot but was not entered during this visit. The eastern shaft (some 8 ft. deep and also through phonolite) was examined briefly and was found to have two tunnels, one sloping gently eastwards beneath the lava cap and a second small tunnel on the opposite side of the shaft almost entirely blocked by fallen rock. Surprisingly little spoil was found in the vicinity of the shafts.

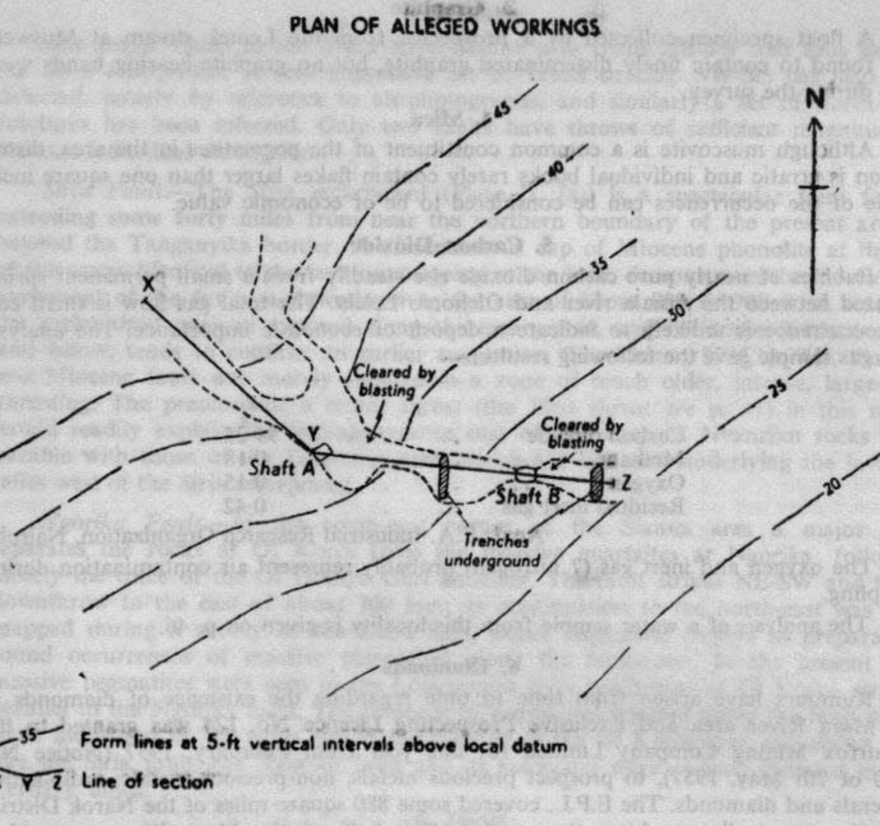


Fig. 8—Plan and section of the alleged workings at Loldurugi.

Since only a cursory examination was possible during this visit to Loldurugi, New Consolidated Gold Fields Limited undertook clearing of the tunnels Samples sent to the writer during the initial stages of the clearing were identified as weathered phonolite with possibly some tuff, while gravels washed from the surrounding streams were found to contain no concentration of any mineral of economic importance, the commonest grains being quartz, garnet, ilmenite and epidote.

The following conclusions were reached after further examination of the "workings":—

(1) It is believed that the shafts and tunnels at Loldurugi were formed by natural processes and do not, in fact represent mine workings.

(2) The small accumulation of lava boulders around shaft B and the discovery of a section of an old ladder indicate past exploration of the holes, but there is no evidence to suggest that any appreciable enlargement of the natural features was carried out.

(3) The tunnels show strong structural control east of shaft A and apparently developed as a result of an intersecting joint pattern in the lava. Folding or slumping produced an east-west anticline that locally controlled the orientation of the tunnel joining shafts A and B.

(4) Both shafts coincide with a marked zone of lateritization at joint intersections or between joint planes.

(5) The caverns beneath the lava cap are thought to have formed by a combination of two processes:—

(*a*) Mechanical removal of weathered material by percolating water; percolation along joint-planes has been observed in the "workings" and small temporary springs exist on the surface in the shallow valley east of the holes, near the inferred edge of the lava sheet.

(*b*) Removal in solution of a small quantity of calcareous material from the underlying Basement System rocks with subsequent slight subsidence beneath the lava. The Basement System rocks mapped in the Ololorok stream are dominantly biotite-epidote schists, underlain by hornblende schists, and are believed to be metamorphosed semi-calcareous sediments. They invariably contain a little free calcite (pp. 15 and 16) and it is of interest to note that calcite veining was seen in an exposure south-east of the Loldurugi shafts, near the Ololorok stream.

(6) There is no evidence to suggest that any mineral deposits of economic importance occur in the Loldurugi district. It should be emphasized, however, that if diamonds do in fact exist in the area they are only likely to be located by the systematic treatment of appreciable quantities of gravel, after the necessary guide minerals have been located.

7. Water

The Mara river and both its head-streams (the Nyangoris and the Amala) are perennial, and although the Talek and Longaianiet only flow during the wet months of the year, water can be readily obtained from their courses by shallow pitting in the sand. Numerous small springs are to be found around the quartzite hills, but only the more important permanent supplies are shown on the maps, e.g. at Kipleleo, where a small dam has been constructed below the Tsetse Survey and Control house; at Aitong, Koyage and Olduroto Labardamat, all relied upon by the Masai as watering places for stock during the drier parts of the year; and at Sianna, where two permanent fresh springs exist on opposite sides of the hill.

At a spring situated on the southern flank of a small quartzite ridge near the Amala river, about half a mile from the northern boundary of the area, a steady flow of carbon dioxide can be seen escaping through several marshy pools. A sample of the spring water was analysed, giving the following results:—

Turbidity	None
Colour	None
Odour	None
Suspended Matter	Slight
pH	6·3
	Parts per million
Alkalinity (as $CaCO_3$)	
Carbonate	Nil
Bi-carbonate	878·0
Ammonia	
Saline	Trace
Albuminoid	0·06
Chlorides (as Cl)	67·0
Sulphates (as SO_4)	48·0
Nitrites (as NO_2)	Nil
Nitrates (as NO_3)	Nil
Calcium (as Ca)	107·0
Magnesium (as Mg)	63·0
Iron (as Fe)	0·4
Silica (as SiO_2)	8·0
Total Hardness	52·6
Permanent Hardness	Nil
Temporary Hardness	52·6
Total Solids	1,330·0
Fluorides (as F)	2·5

Anal: Government Chemist, Kenya, 8th April, 1958.

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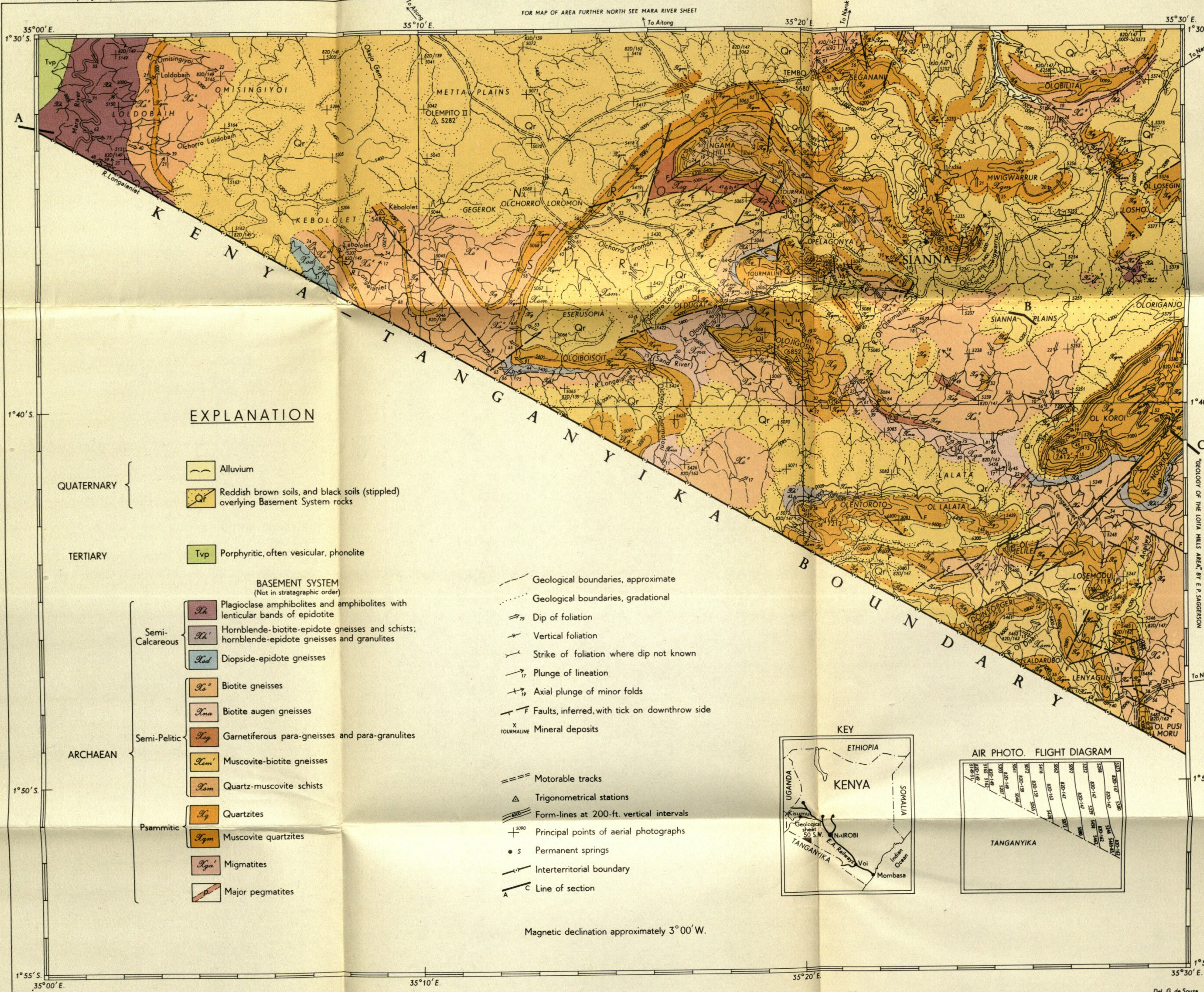
G.P.K. 3298—1m—11/61

GEOLOGICAL MAP OF THE SIANNA AREA

To accompany Report No. 66

DEGREE SHEET No. 50, SOUTH-WEST QUARTER (Directorate of Overseas Surveys Sheet No. 158)



GEOLOGICALLY SURVEYED BY L. A. J. WILLIAMS, GEOLOGIST
Between March 1957 and March 1958

MINES & GEOLOGICAL DEPARTMENT, KENYA

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SECTION FROM A to C
Scale equal to that of map
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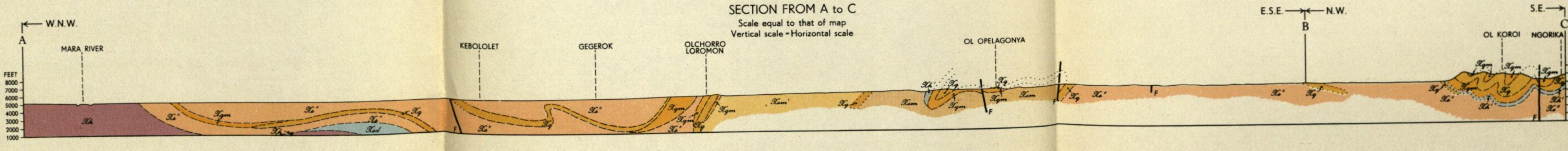
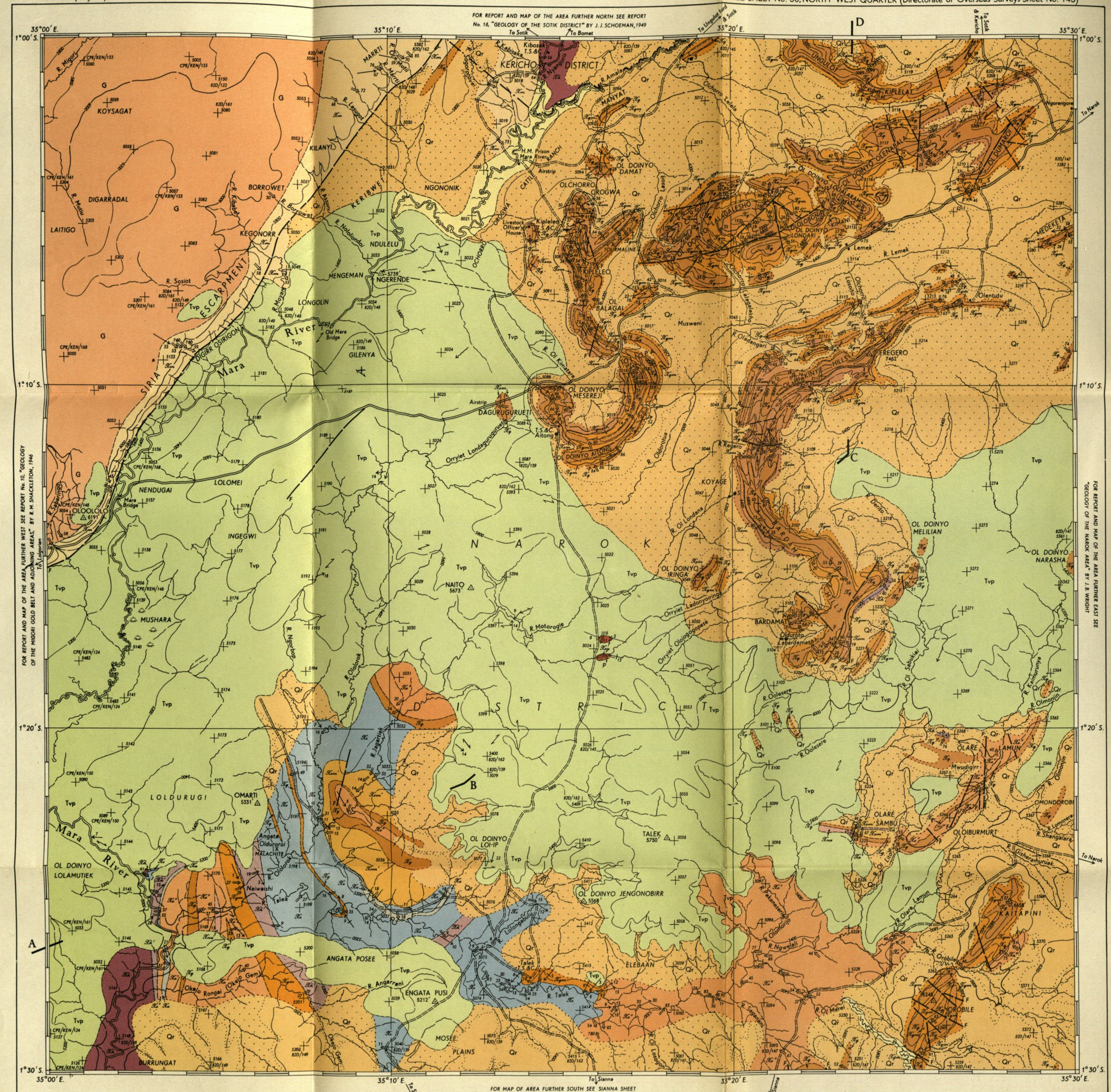


GEOLOGICAL MAP OF THE MARA RIVER AREA

To accompany Report No. 66

DEGREE SHEET No. 50, NORTH-WEST QUARTER (Directorate of Overseas Surveys Sheet No. 145)



EXPLANATION

QUATERNARY
- Alluvium
- Qr — Reddish brown soils and black soils (stippled) overlying Basement System rocks

TERTIARY
- Tvp — Porphyritic, often vesicular, phonolite with rare tuff. Largely covered by black soils and perhaps overlain by thin ash beds at the eastern boundary of the area

BASEMENT SYSTEM
(Not in stratigraphic order)

ARCHAEAN

Semi-Calcareous
- Plagioclase amphibolites and amphibolites with lenticular bands of epidotite
- Hornblende-biotite-epidote gneisses and schists; hornblende-epidote gneisses and granulites
- Biotite-muscovite-epidote schists

Pelitic
- Garnetiferous mica schists

Semi-Pelitic
- Biotite gneisses
- Biotite augen gneisses
- Garnetiferous para-gneisses and para-granulites
- Muscovite-biotite gneisses
- Quartz-muscovite schists

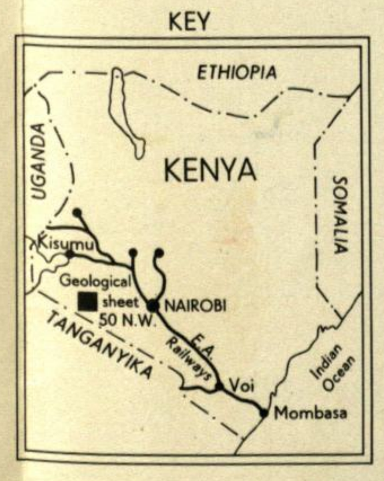
Psammitic
- Quartzites
- Muscovite quartzites
- Mylonitic gneisses of the Siria Escarpment (biotite-muscovite gneisses with subordinate sheared amphibolites, quartzites and epidotites)
- Major pegmatites

INTRUSIVES
- G — Biotite-hornblende granite

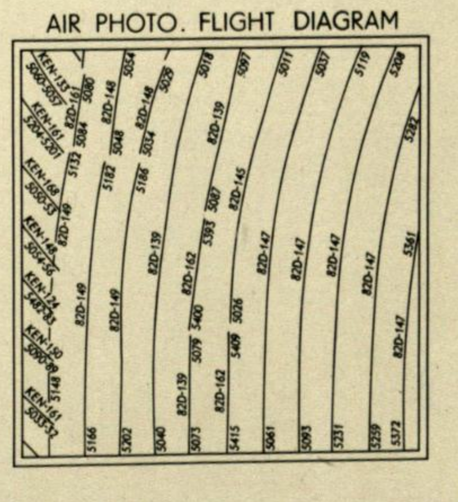
- Geological boundaries, approximate
- Geological boundaries, gradational
- Dip of lava
- Lava horizontal
- Dip of foliation
- Vertical foliation
- Strike of foliation where dip not known
- Direction of flow in lava
- Plunge of lineation
- Preferred orientation of phenocrysts in lava
- Axial plunge of minor folds
- Faults, inferred, with tick on downthrow side
- TOURMALINE Mineral deposits
- Roads
- Motorable tracks
- Trigonometrical stations
- Form-lines at 200-ft. vertical intervals
- Principal points of aerial photographs
- Springs, permanent and seasonal
- Dams
- Houses and stores
- T.S.&C. Tsetse Survey & Control stations
- Boundary of Olchorro Orogwa Cattle Ranch
- Provincial boundary
- Line of section

Magnetic declination approximately 3°00' W.

KEY



AIR PHOTO. FLIGHT DIAGRAM



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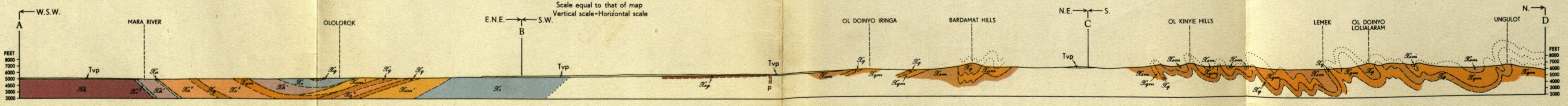
SECTION FROM A to D
Scale equal to that of map
Vertical scale = Horizontal scale



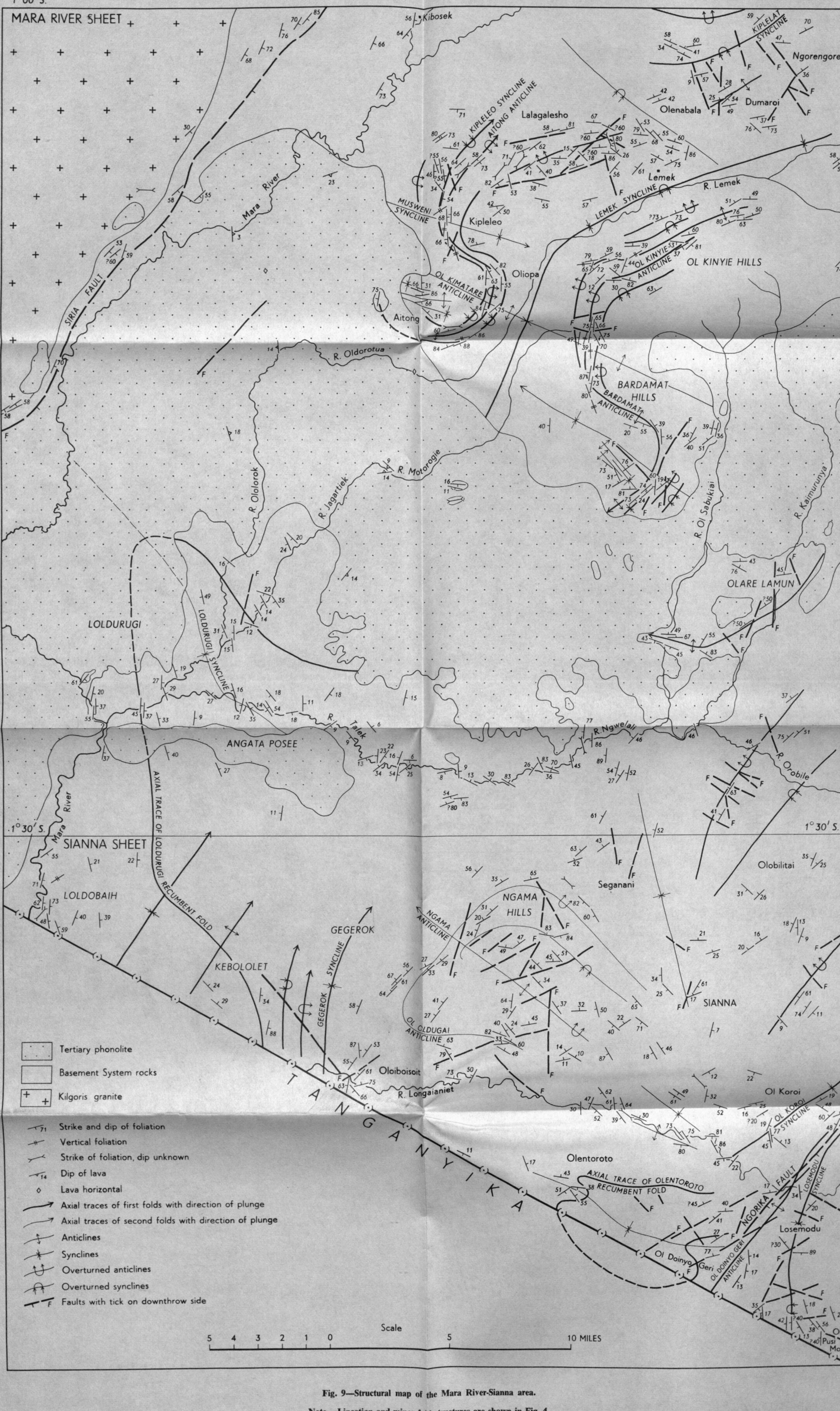


Fig. 9—Structural map of the Mara River-Sianna area.

Note.—Lineation and minor fold structures are shown in Fig. 4.