Report No. 60

GOVERNMENT OF KENYA

MINISTRY OF NATURAL RESOURCES
GEOLOGICAL SURVEY OF KENYA

GEOLOGY OF THE SOUTH HORR AREA

DEGREE SHEET 19, SOUTH-EAST QUARTER
(With two coloured geological maps)

by

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Twenty Shillings - 1963

FOREWORD

The report on the South Horr area provides a map and description of the northernmost part of the Great Rift Valley of Kenya before it loses its clear identity in the Lake Rudolf basin. The area includes a small portion of Lake Rudolf and the small volcanic area at its southern tip, where volcanicity has occurred within the memory of living man, and where the dying or quiescent phases of volcanicity can still be seen. The author considers that slight movements in the floor of the Rift Valley might well produce another episode of volcanicity.

The area is one of great diversity, ranging from high hills in the east, composed of ancient rocks and clothed in parts in forest and favoured by a temperate climate, to the sandy low-lying plains with a salt lake that deposits crusts of soda in the Suguta valley. In the north-east there is the edge of the great plain that covers much of northern Kenya, and around the hills stretches of lava country on which there is little soil or vegetation. The area is remote and parts of it difficult of access and most trying to work in. It is greatly to Mr. Dodson's credit that he was able, with the assistance only of a small force of Africans, to map the area under such inhospitable conditions.

The area is so remote that the few mineral deposits found in it have no economic value, and unless extensive deposits or deposits of high-value minerals are found there is no prospect of mineral development. The author also concludes that there is little value in developing sources of water in the waterless parts of the area owing to the prevalent lack of grazing.

Nairobi,
February 26th, 1960.

WILLIAM PULFREY,
Commissioner (Mines and Geology).

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(at centre)

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ABSTRACT

The report describes an area in northern Kenya of 1,187 square miles extent, bounded by the meridians 36° 30′ E. and 37° 00′ E. and by latitudes 2° 00′ N. and 2° 30′ N. The area includes the eastern wall of the Great Rift Valley and the southern shores of Lake Rudolf. The main physiographic units are (*a*) the Nyiru and Mara mountain ranges, (*b*) the South Horr valley, (*c*) the lowland area north and south-east of the mountain ranges, (*d*) the lava fields west and north-east of Nyiru and (*e*) the Suguta valley. An account is given of their physical features, items of geographical interest and the accessibility of the area.

The rocks exposed in the area include (1) Precambrian schists, gneisses and granulites of the Basement System, meta-intrusives, and anatectic rocks derived from siliceous gneisses, (2) Tertiary sediments, (3) Tertiary volcanic rocks, (4) Pleistocene volcanic rocks and sediments, and (5) the most recent lava flows in Kenya Colony. Descriptions of the various rock types are given and the structures of the various beds are discussed.

There is record of at least two other visits by explorers to the southern shores of Lake Rudolf within a few years of Count Teleki's expedition. Major-General Sir Percy Cox, President of the Royal Geographical Society, introducing A. M. Champion's (1935) paper, described a visit to that area by Dr. Donaldson Smith who reported having seen Teleki's volcano in eruption. Later, in 1899, it was visited by Captain Welby who found the volcano in a quiescent state (Welby, 1900).

A. M. Champion explored the southern shores of Lake Rudolf in 1932 and was able to record (Champion, 1935) that contrary to Cavendish's statement, Teleki's volcano had not been destroyed by an explosion. Champion made several interesting observations. He described former beach-levels on Naboiyoton ash-cone, and fossiliferous deposits on shelves at various nearby localities, all of which lay between 250 ft. and 300 ft. above lake-level. He later concluded (Champion, 1937, p. 172) that the volcanic rocks of the Barrier had separated the Suguta valley from Lake Rudolf and suggested that the Suguta river may have been one of the headwaters of the Nile.

Rock specimens collected by Champion were later described by W. Campbell Smith (1938).

V. E. Fuchs took part in two expeditions to Lake Rudolf, giving accounts of his work in 1934, 1935 and 1939. In 1930/1931 he studied Pleistocene lake deposits at Lakes Baringo, Rudolf, Edward and George. Concerning his investigations at Lake Rudolf, the only record relevant to the present area consists of descriptions of fossil beds on the western shores of the lake, and his recognition of lake-level fluctuations. In 1934 work was concentrated on Lake Rudolf alone. In reporting the work Fuchs (1939) briefly described the Basement System rocks, younger volcanics, and fossiliferous lacustrine sediments of the Lake Rudolf basin. He described the fluctuations of the lake, specifying a total advance and retreat range of over 500 ft. as compared with the 1934 level. He estimated that the highest level reached by the lake since early Pleistocene times was about 330 ft. above the 1934 level. He drew up a tabulated correlation of the geological sequence of the Rudolf basin with successions of similar time range in Uganda and Kenya as visualized by Wayland, Gregory and Leakey.

In 1932/1933 C. Arambourg led a part-geological, part-anthropological expedition over a wide area through the Turkana District west of Lake Rudolf, and to the Omo delta at the northern end of the lake. He gave an outline of the rock types encountered in Turkana and described the fossiliferous beds of the Omo and other localities (Arambourg, 1943, 1947). He concluded that the structures of Turkana and the Lake Rudolf basin follow a general north-south trend which has been superimposed on earlier fold structures of the same trend in the Basement System. He deduced the following tectonic history for the area he investigated:—

1. An early phase of post-Archaean faulting.
2. A second tectonic phase, which was accompanied by lava outpourings, believed to be of Miocene age.
3. A third tectonic phase which was responsible for the main rift faulting.
4. Final faulting, after the early Quaternary deposition of the Omo beds. It was confined to the Lake Rudolf trough, and resulted in the tilting of small fault-blocks, mostly to the west. These movements were considered to be contemporaneous with those that affected Kamasian lacustrine sediments elsewhere in Kenya.

B. H. Baker carried out a geological survey of the Baragoi area, due south of the present area, in 1955 (Baker, 1963). He described the Basement System rocks of the Baragoi area as a succession of metamorphosed and igneous rocks with migmatites and granitic intrusives derived from the metamorphic rocks by granitization. He concluded that the Basement System structures are dominated by a complex syncline with a closure in the south-eastern corner of the area, but passing into a series of folds at the common boundary with the present area. Baker described the volcanic rocks of Baragoi as ranging from Miocene basalts to Recent lava, believed to be basalt and possibly contemporaneous with the lava outpourings from Teleki's volcano. He identified two post-Archaean tectonic phases: tilting in a westerly direction at the close of the Pliocene, and Pleistocene rift-faulting. Differences that will be apparent between the adjacent parts of the map of the Baragoi area and the map of the present area arise mainly from the fact that in the South Horr area there are excellent hill-slope exposures on the Nyiru and Mara ranges that allow more detailed subdivision of the Basement System rocks than in the neighbouring area. In addition the Tirr-Tirr Series, described by Baker as predominantly trachytic, includes considerably more basalt in the present area and the writer was able to subdivide the series into trachyte and basalt formations.

III—PHYSIOGRAPHY

The area can be divided into several physiographic regions, which result largely from the rock types and structures in them.

The mountain ranges, Nyiru and Mara, rise between 3,000 and 5,000 ft. above the surrounding countryside. Nyiru, in particular, forms a highly prominent physiographic feature, which can be seen from many miles away. Following the regional strike, these two mountain ranges are elongated in a roughly north-south direction and both taper off fairly gently northwards and more steeply to the south, while their east and west faces are often precipitous. As is so often the case in the Basement System areas of East Africa, the most prominent features, such as rocky crags and high points, are composed of homogeneous granitoid gneisses or at least of compact, rather massive biotite gneisses. Nyiru is nearly flat-topped, its summit plateau lying at more than 8,000 ft. Two small pointed hills, Mowongosowan and Kosikos, form peaks which viewed from a distance are insignificant features on the mountain range. One of the most impressive physical features on the Nyiru range is the large semi-conical rock Ben, almost directly overlooking South Horr on the eastern slopes of the mountain. The Mara range consists of tapering razor-backed ridges, trident-shaped in plan, with the prongs pointing north. Three pointed peaks, Sufuku, Mumsu and Borali, form distinctive high points. Mumsu is the most impressive as it consists of seven rounded peaks reminiscent of the crown of a molar tooth. On the north-western ridge of the Mara range, a lower-lying hill, Koros, forms a highly distinctive feature. Koros is composed of massive north-south-striking granitoid gneiss, which has exfoliated around a system of east-west joints to form five large, equal-sized, rounded peaks. A few small isolated hills, which may be regarded as outliers of the two mountain ranges, are dotted on the plains to the south and north-east of Nyiru and Mara.

Geological structures influence the physiography of Nyiru and Mara. The best example of relationship between topography and structure is the steep-limbed anticline at Leyosi, the south-eastern tip of Nyiru. The anticline is composed of a massive granitoid gneiss core, encased by less resistant layers, most of which have been stripped by erosion. The grantoid gneiss forms a round-shouldered ridge following the trend of the fold, while the adjacent valley to the west is cut through steeply-dipping synclinally folded rocks.

The open plains to the north, east and south-east of Nyiru and Mara are part of an extensive plain which stretches eastward as far as the eye can see. The plain represents the most typical feature of the eastern and central portion of the Northern Province of Kenya. In the present area the plain consists of waterless sandy flats supporting sparse, stunted vegetation. The monotony of the plain is broken by small hills, dotted about, and to a lesser extent by sand-choked river-courses. Being flat, sandy, and possessing little vegetation cover, this region is being increasingly subjected to wind action. Immediately before the seasonal rains, when vegetation has been intensively cropped by herds of goats and camels, sand-storms are frequent and sometimes of great intensity. Numerous minor sand-dunes can be seen and a large sand-pile is banked against the western, or leeward, side of the narrow ridge next to the South Horr-Marsabit road intersection in the north-eastern part of the area (*see* Plate VII, Fig. 1). It is probable that over-grazing by stock has notably increased the part played by wind-blown sand over the plains as a whole. The dangers of large-scale sand movement are well known, the remedies difficult to put into operation in an area occupied by nomadic tribes.

West and north of Nyiru, numerous lava flows of various ages form a series of *treppen*. The *treppen* are cut by north-south fault-scarps and deeply incised by river-courses. The valleys are usually steep-sided and frequently attain a depth of 500 ft. The Iyuk plateau forms the most prominent feature in the lava-fields as it rises over 1,000 ft. above the surrounding country, the upper layers of volcanic rocks in it having been notably eroded. Erosion of the lava-fields west and north of Nyiru has produced only a thin mantle of soil, the lava flows remaining as rough, bouldery sheets, in places devoid of vegetation.

The most interesting physiographic feature in the area is the large volcanic mound known as the Barrier. It was so named by Champion as it constitutes a barrier between Lake Rudolf and what was formerly a southern extension of the lake, the Suguta valley. Emplacement of the earliest Barier volcanic rocks probably took place in middle Pleistocene times and there has been almost continuous volcanic activity up to now, so that the Barrier is not perceptibly affected by erosion. The mass is roughly dome-shaped, sloping from the shores of Lake Rudolf in the north and from Lake Suguta in the south, both at about 1,200 ft. above sea-level, to a maximum height of just over 3,300 ft. The Barrier has several interesting features.

Viewed from a distance the Barrier resembles a massive volcano as its flanks slope gently up to a large crater-like depression, nearly 4,000 yards in diameter and about 500 ft. deep. This structure was described by Champion (1937, p. 169) as a crater but there is clear evidence of caldera collapse. It is probable that the caldera occupies the site of the original volcano responsible for the outpourings of intermediate lavas that built up the Barrier. There is evidence of two and perhaps three collapse sinkings, the earliest movement being indicated by an arc-shaped, steep-faced wall to the west of the caldera. The second collapse produced the roughly circular caldera. The floor of this depression is covered by a series of lava flows believed to have been extruded during the subsidence. At two points along the northern rim of the caldera, recent outpourings of viscous lavas piled up until they finally overflowed the rim to form prominent plateau-like hills overlooking the depression. Champion quoted the name *Kakorinya* for the caldera but, although several different names were obtained from local Turkana tribesmen, the most persistently offered name during the present survey was *Nagaramasainia*. Several small steam-jets are situated on the south-western edge of the caldera rim.

A visit to Teleki's volcano proved that it has changed little since its discovery, and the writer could not find any evidence to support Cavendish's statement (1898, p. 390) that the volcano had disappeared through volcanic action. As Cavendish made his statement purely on the strength of information obtained from local tribesmen, it is fair to state that it is the writer's experience that little reliable information can be obtained from the inhabitants of the area. Before accepting either a place-name or an account of the past history, it is necessary to check and re-check the information. Few Turkana tribesmen visit the southern shores of Lake Rudolf and many hold the region in awe. In earlier writings Teleki's volcano has been referred to as *Nagira Mwaiten* and *Luburrua*, the latter name being quoted in the *Encyclopaedia Britannica*. No Turkana questioned by the writer had heard these two names. Apparently there is no specific African name for Teleki's volcano, but *Lugugugut*, meaning "the place that is burnt", is a term used to describe both Teleki's and a similar volcano, named Andrew's volcano by Cavendish, on the southern slopes of the Barrier. Champion's description and sketch-map present a good picture of Teleki's volcano. The volcano consists of two elongated irregular mounds, the larger mound being studded with numerous minor craters, several of which form a compound crater at the crest of the volcano. The westerly mound includes a line of three explosion-type craters with a larger off-set crater, which erupted southwards. Both mounds are covered by a carpet of dull bluish black, highly scoriaceous ash which, owing to its high porosity, is totally non-reflective. The sombreness of this dull material is difficult to imagine, especially when pictured in its setting of a stark landscape of vegetation-free lava-flows to the north with only scanty vegetation on the older volcanics to the south. In patches a yellowish discolouration can be seen in the black scoriaceous ash, and if the upper few inches of ash are scraped aside, abundant sulphur is exposed. As the sulphur is fine-grained and thus easily removed by wind action, little remains exposed on the surface. A pungent smell of sulphur gases can be detected on the crest and in the composite crater, but the discharge of gases has obviously decreased since von Höhnel's visit when he reported (1894, p. 223): "An overwhelming smell of sulphur and chlorine . . ." and ". . . black clouds of smoke were driven away from us by the prevailing winds. . . ."

Andrew's volcano on the southern slopes of the Barrier is similar to Teleki's volcano in many ways. Like Teleki's volcano it is known by Turkana as Lugugugut. Cavendish named the cone Andrew's volcano in honour of his companion during his expedition to that area. The volcano has erupted within the last few hundred years, the most recent lava-flow forming a highly conspicuous black, rocky tongue which extends from the cone down to Lake Suguta (*see* Plate IV, Fig. 1). A feature common to both Andrew's and Teleki's volcano is the presence of a blanketing layer of dull black scoriaceous ash which covers the cones and the countryside immediately around.

Several large volcanic ash cones form prominent features on the Barrier. The three most important cones are Naboiyoton, Wargess (referred to as Abili Agituk by earlier writers), on the shores of Lake Rudolf, and Murniau east of Lake Suguta. A few smaller less significant ash-cones are dotted about the Barrier, mostly projecting through younger lava-flows. The three large ash-cones are pale yellowish to buff-coloured, contrasting with the blackness of surrounding lava-flows. Being soft and friable, all show a greater or lesser degree of weathering, Murniau in particular being deeply fluted.

The remaining item of physiographic interest on the Barrier is the intensely faulted lava-field known as Latarr. The fault-scarps, completely unaffected by erosion, form a series of steep-sided steps extending to the southern shores of Lake Rudolf, where they form a series of narrow finger-like peninsulas and correspondingly narrow bays.

The southern tip of Lake Rudolf lies within the limits of the present area. Lake Rudolf is one of the larger lakes of Africa, the second largest lake in East Africa, and is over 150 miles long, only seven miles of its length being included in the area mapped. South Island, also known as El Molo Island and von Höhnel Island, occurs a few miles to the north of the northern limits of the area. Being an area of internal drainage, Lake Rudolf is strongly saline, containing a high percentage of sodium salts.* As a result the water has an unpleasant odour and a soapy unpalatable taste, although it can be consumed without immediately obvious ill-effects. Daily winds around Lake Rudolf are violent. No accurate measurements have been taken but it is safe to say that the more violent winds exceed a speed of 60 miles per hour. During the peak of wind activity waves on the lake are whipped up to 6 ft. high. Most of the lake shore-line included in the area is rocky, consisting of layers of lava boulders or minor cliff faces where recent lava-flows have extended to the water line. In the south-western corner of the lack, however, the shore-line opens out to form a gently curving arc with

* For analyses of water samples from Lake Rudolf, *see* p. 50.

sandy and shingle beaches. An interesting aspect of that region is the presence of 12 sand dunes which are all parallel to the shore-line. In appearance they are like successions of fore-dunes found in areas of marine retreat. The dunes are compacted and are composed of a considerable amount of shingle or coarser material, and since this bay is reasonably well protected from wind action by the surrounding higher ground, the dunes have been fairly well preserved. The dunes are about 12 to 15 ft. high with a wave-length between crests of about 50 ft. Further inland finer wind-blown sands are heaped up against obstacles to form dunes aligned to face the prevailing winds, thus being almost parallel to the dune alignment in the centre of the coastal area.

The Suguta valley represents a former extension of Lake Rudolf south of the Barrier, sealed off from the lake by the emplacement of the Barrier volcanic rocks. The valley is more than six miles wide at its northern extremity but widens to the south. Suguta is unique in that for most of the year it is a desert affected by aeolian action only, while for short periods during rainy seasons it becomes flooded to form an extensive shallow lake. Within the limits of the present area the valley is bounded by the Barrier to the north and by fairly low-lying but steep-faced fault-scarp walls of lava to the east. The valley floor is remarkably flat and is composed of fine sands, grits and gravels. A few volcanoes such as Emuru Gumol rise above the sediment-covered floor. Most of the valley is free from any form of vegetation but a few isolated bushes such as *Salvadora persica*, the toothbrush tree, and doum palms (*Hyphaene coriacea*) can be seen at the mouth of the Losergoi river-course. During severe wind-storms the amount of sediment lifted from the valley floor becomes sufficiently great to reduce visibility to about 50 yards. Locally, features associated with wind erosion, such as sand dunes, are developed but occasional flooding of the valley prevents the extensive formation of characteristic desert topography. The valley does not, therefore, have a landscape typical of either deserts or river valleys, although in general the influence of the flooding is predominant.

A highly saline lake occupies the northern end of Suguta. Champion (1935, p. 327) described a locality where the water of this lake ". . . disappeared into the ground and may or may not pursue an underground course to the lake. . . ." Despite careful examination of the lake during the driest period of the year, when the level was below average, the writer did not find any spot into which lake water disappeared. The possibility of an underground connexion between Lake Suguta and Lake Rudolf must be considered highly unlikely. The lake is typical of soda-rich lakes found in East African rift valleys. A strong odour reveals the presence of excess soda, which forms a whitish crust around the shore-line during the dry season. The water is undrinkable but local tribesmen state that immediately after heavy rains a layer of drinkable water forms over the saline water, the two remaining more or less separate for several days. The lake floor is composed of foul-smelling black mud. Large numbers of flamingo are attracted to the lake.

East of Suguta there is an open desert plain with a wild desolate appearance. Unlike Suguta it is never flooded. In part it has an *erg* topography with moving sands in dune form, while at its northern end it is more rocky and is partly covered by ill-sorted pebble-sheets. Though the effects of abrasion caused by wind-borne particles are apparent on most of the boulders strewn about the sand, no well-formed ventifacts were observed.

Drainage.—The area includes two distinct drainage systems (*see* Fig. 1). Lake Rudolf and the Suguta valley are the recipients of internal drainage, receiving the greater share of the rainfall run-off west of Nyiru mountain and around the lake shore, while the second system drains the eastern slopes of Nyiru, the entire Mara range and the more easterly lava-flows. Most of the rivers flowing into Suguta and Lake Rudolf have been forced to cut courses through a series of lava-flows or pyroclastic accumulations. It is interesting to note that at least some of the major rivers in this region are superimposed on their original courses. Evidence of this superimposition is apparent in gorges exposing the junction between the lavas and underlying Basement System rocks or Miocene sediments resting on them. In each case the existence of a previous gorge is shown by the shallow V profile of the junction, the floor of which is sometimes as much as 400 ft. below the shoulders of the original valley. Typically, the rivers flowing through the lava-fields are immature, their gorges being deeply incised to as much as 1,000 ft. and contrasting with the relative flatness of the lava terrain. Water can be obtained in most of the river-courses, in some cases by digging in shallow sand, but often it is available at springs emerging from cracks or joints in the lava floor or walls of the river-courses. The solid lava is impervious, preventing general dispersion of the water, so that surface run-off passes into joints or fault-line cracks. The water, thus channelled, moves downwards until it can escape in a river-bed or valley side in the form of springs.

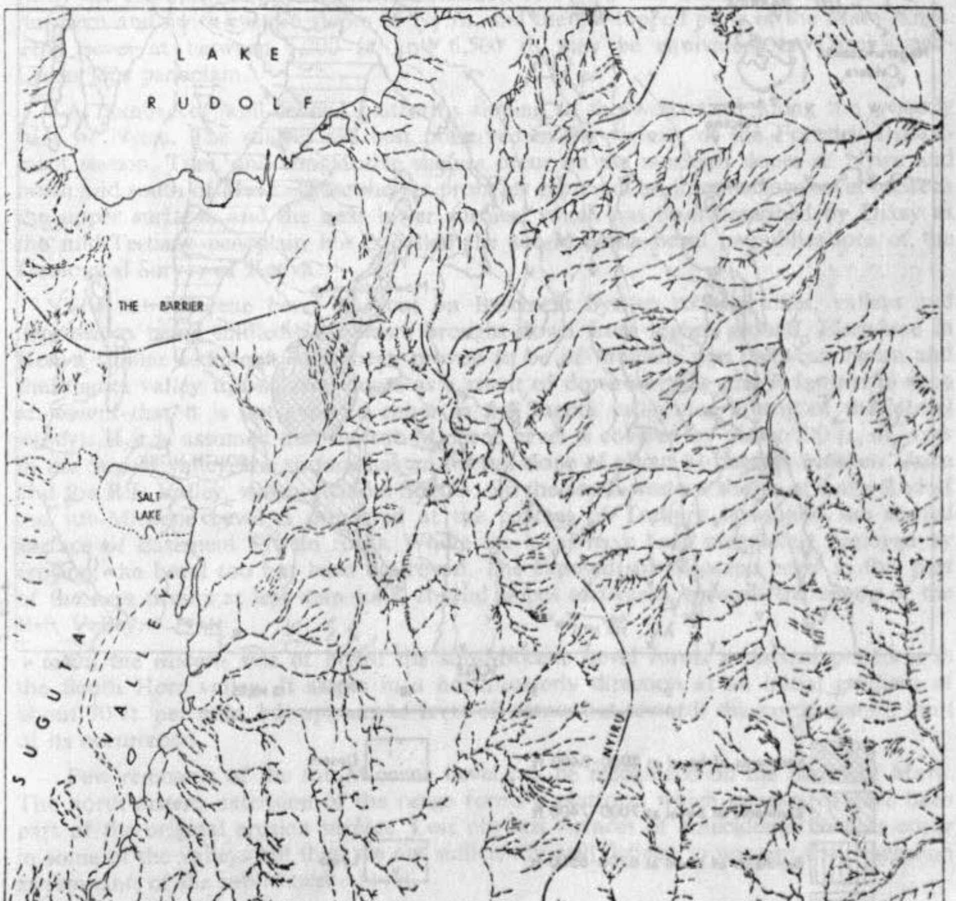

Fig. 1—Drainage of the South Horr area

The easterly-flowing river-courses present a complete contrast to those of the Rudolf-Suguta basin. Since end-Tertiary times at least, they have not been disturbed either by tectonic movement or by the outpouring of volcanic rocks. As is typical of the greater part of the arid northern regions of Kenya, these river-courses are broad, sand-choked, and show mature development.

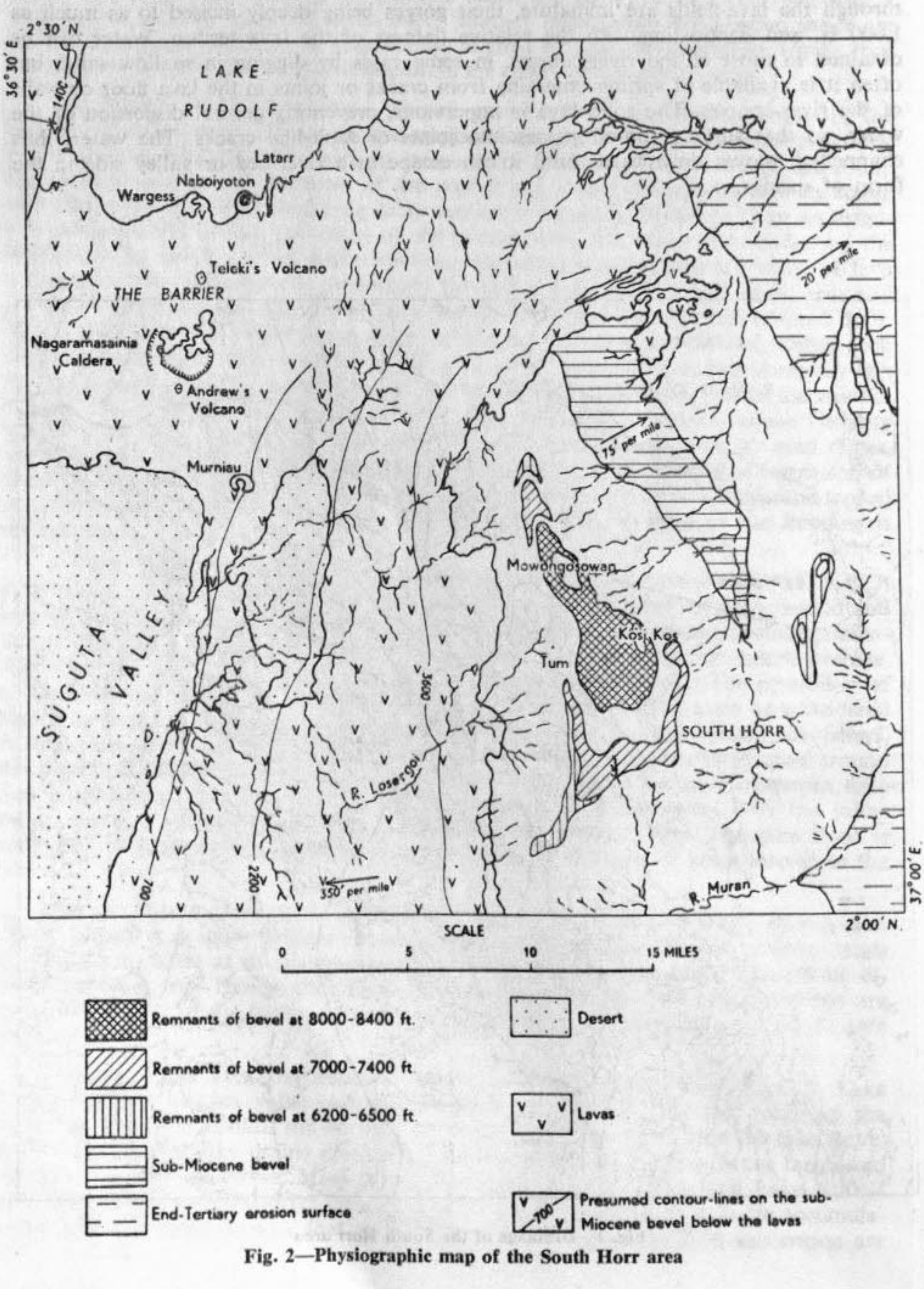

Fig. 2—Physiographic map of the South Horr area

Erosion Surfaces.—Two well-defined erosion surfaces are apparent in the area, and in addition, bevels occur at various levels above them. The bevels may be equivalent to older peneplains described by Dixey (1948) and Shackleton (1946), but the writer does not consider their appearance or situation sufficiently diagnostic of peneplains of wide extent to describe them as erosion surfaces or to assign an age to their development.

The oldest erosion bevel is represented by a plateau, only slightly dissected, capping Nyiru mountain (*see* Fig. 2). The two highest peaks of Nyiru, Mowongosowan and Kosikos, project a few hundred feet above the upper plateau. This plateau is possibly equivalent to the undated surface described by Dixey as the "8,300-ft. peneplain".

Nearly 1,000 ft. below the upper plateau on Nyiru, a series of smaller plateaux or shelves can be recognized. They are best seen towards the southern end of the range. The northern end of Nyiru forms a gentle slope but the southern end of the mountain terminates in a series of widely separated platforms, the uppermost being at about 7,400 ft. Shackleton (1946, p. 2) described a bevel at about the same altitude in the Maralal area as a remnant of a Cretaceous peneplain. Remnants of a subsequent surface form the crestlines of the southerly extension of Nyiru and Lossom, platforms on the northern and north-eastern slopes of Nyiru, and the flat-topped parts of the Mara range. This bevel at between 6,200 ft. and 6,500 ft. may be equivalent to Dixey's end-Cretaceous peneplain.

A number of well-defined platforms sloping to the west occur along the westerly base of Nyiru. The shelves are best preserved in the vicinity of the Forestry Department station, Tum, and comparable shelves occur on the northern slopes of Nyiru and north and south of Mara. These shelves probably represent an intermediate bevel between the upper surfaces and the next lower surface, which has been described by Dixey as the mid-Tertiary peneplain but is called the sub-Miocene bevel in publications of the Geological Survey of Kenya.

The sub-Miocene bevel was cut on Basement System rocks, gullies, valleys and depressions being infilled with waste brought down from higher ground. Elsewhere in Kenya similar sediments have been proved to be of Miocene age. Between Nyiru and the Suguta valley this surface slopes as a result of down-warping and is faulted to such an extent that it is not exposed either in the Suguta valley nor in any of the lateral valleys. If it is assumed that the sub-Miocene bevel is covered by about 500 ft. of lavas in the Suguta valley, the surface has an overall slope of about $3\frac{1}{2}$ degrees between Nyiru and the Rift Valley, which includes Suguta. On the south-western shores of Lake Rudolf the sub-Miocene bevel is preserved at the contact of Tertiary lavas and the eroded surface of Basement System rocks. Where the lavas have been completely removed by erosion, the bevel too has been destroyed. The exposed sub-Miocene bevel in this part of the area occurs at less than 1,400 ft. and slopes eastwards, towards the centre of the Rift Valley.

On the eastern side of Nyiru the sub-Miocene bevel forms a distinct platform in the South Horr valley. It slopes in a north-easterly direction at an initial gradient of about 70 ft. per mile, but appears to level off somewhat towards the north-eastern limit of its occurrence.

Few remnants of the sub-Miocene bevel can be recognized on the flanks of Mara. The north-eastern extension of the range forms a platform which appears to have been part of the original erosion surface. Less obvious terraces of coincidental heights occur in some of the valleys but they are not sufficiently well defined to warrant their inclusion as remnants of the sub-Miocene bevel.

By far the most obvious of all the erosion surfaces in the area is the low-lying plain in the north-east corner. Described by Dixey as the end-Tertiary peneplain, this vast sandy plain stretches eastward for as far as the eye can see, forming the most characteristic physiographic feature of northern and eastern Kenya.

IV—SUMMARY OF GEOLOGY

The oldest rocks in the area belong to the Basement System of Kenya, which consists of a considerable thickness of marbles, quartzites, granulites, gneisses and schists. The system represents an original sedimentary sequence of calcareous, psammitic, semi-pelitic and pelitic rocks of geosynclinal dimensions, the rocks being converted to their present conditions during orogenesis. The writer believes that some of the psammitic rocks in the present area, which have been converted to coarse-grained granitoid gneisses, achieved a state of mobility approaching that of intrusive granite. The original sediments were invaded by molten basic material, now represented by numerous amphibolite and plagioclase-amphibolite bodies, and less abundantly by ultra-basic material, now converted to anthophyllite, talc and other alteration products. Towards the close of the orogenesis that caused the metamorphism of the Basement System rocks they were extensively invaded by pegmatites and aplites.

The next oldest rocks in the area are patchily distributed sediments which appear to be similar to those Shackleton (1946, p. 27) recognized as of Miocene age. The Tertiary sediments in the area appear to be infillings of localized hollows rather than remnants of large-scale sedimentation.

Overlying the Basement System floor and the patchy Miocene sediments are volcanic rocks ranging from Tertiary to Recent age. The oldest volcanic rocks are fine-grained basalts associated with pyroclastics. Later flows consisting of trachytes and basalts were unconformably laid on the older westerly-tilted lavas. The Barrier separating Lake Rudolf and the Suguta valley is a volcanic mound consisting of agglomerates and trachytes, together with younger olivine and augite basalts and basanites. The most recent lavas in the area include those extruded from Teleki's volcano on the north slopes of the Barrier.

During the Pleistocene, lake-beds were formed on the shores of Lake Rudolf, on the Barrier and on the flanks of the Suguta valley. The beds include fine silts, gravels, diatomaceous bands and a few shelly horizons. With the drying up of the Suguta valley, evaporites were deposited locally around the shrinking lake.

The geological history of the area can be summarized as follows:—

Recent	Recent outpourings of lava	Basalts from Teleki's and Andrew's Volcanoes.
		Trachyte flows in Nagaramasainia caldera.

Slight Faulting

Upper Pleistocene	Onset of desert conditions in Suguta valley.
	Drying up of Suguta Lake, saline deposits.
	Naboiyoton ash-cone.
	Sedimentary deposits around Lake Rudolf, on the Barrier and in the Suguta valley.

Trough Faulting

Middle to Upper Pleistocene	Lacustrine sedimentation at 220 ft. above present Lake Rudolf.
	Volcanic rocks of the Barrier—Olivine basalts and basanite.
	Intermediate volcanic rocks.
	Ash-cones.
	Agglomerates.
	Younger lavas of Mt. Kulal.
Lower to Middle Pleistocene	Lavas of the Serima valley and intercalated sediments.
	Sedimentation at 330 ft. above present Lake Rudolf.

	Tilting. Slight Faulting
Pliocene?	Tirr Tirr Series—Olivine basalt. Fine-grained trachytes. Rhyolites, agglomerates at Iyuk.
	Tilting
Miocene	Porphyritic basalts. Fine-grained basalts and pyroclastic rocks. Erosion. Deposition of Miocene sediments. Maturation of Sub-Miocene peneplain.
Miocene to Paleozoic	Successive periods of erosion and peneplanation.
Precambrian	Silica-rich intrusions. Folding, regional metamorphism, granitization. Fracturing, basic and ultra-basic intrusions. Geosynclinal sedimentation.

V—DETAILS OF GEOLOGY

1. The Basement System

The oldest rocks in the area are metamorphic rocks of the Kenya Basement System, which is Precambrian. They occupy about one-third of the area and except for three outcrops are confined to the south-eastern portion of the area. The outcrops separated from the main exposures are on the hill of Radj, south-east of the debouchure of the Losergoi river with the Suguta valley, at the southern margin of the area south of Radj, and on the western shores of Lake Rudolf. In the south-eastern part of the area, the Precambrian rocks are partly covered by residual and transported soils, but they also form the two high, impressive mountain ranges of Nyiru and Mara.

The following is considered to be the most satisfactory classification of the rocks of the Basement System in the area:—

Meta-sedimentary Rocks	(*a*) Crystalline limestones (*b*) Calc-silicate rocks (*c*) Pyroxene garnet gneisses (*d*) Hypersthene biotite gneisses (*e*) Epidote gneisses (*f*) Diopside gneisses	Calcareous.
	(*a*) Pelitic biotite gneisses (*b*) Sillimanite gneisses (*c*) Graphitic schists and gneisses	Pelitic.
	(*a*) Biotite gneisses (*b*) Hornblende-biotite gneisses (*c*) Hornblende gneisses	Semi-pelitic.
	(*a*) Quartzo-felspathic granulites (*b*) Granitoid gneisses (*c*) Augen gneisses	Psammitic.
Migmatites	(*a*) Biotite migmatites. (*b*) Hornblende migmatites.	

For convenience other rocks closely associated with the Basement System, and which are considered in later sections of the report, are listed here:—

Pre-metamorphic Intrusives (*a*) Amphibolites and plagioclase amphibolites.
(*b*) Ultra-basic intrusives.
(*c*) Meta-gabbro.
(*d*) Garnetiferous felspathic ortho-granulites.

Anatectic rocks (*a*) Granites.
(*b*) Aplites.
(*c*) Pegmatites.

Quartz veins.

Though the part of the area occupied by outcropping Basement System rocks is not extensive compared with many other areas in Kenya Colony, the local succession is particularly well exposed on the eroded rocky slopes of the Nyiru and Mara ranges. Consequently the writer was able to measure the succession tabulated below. The sequence in the Baragoi area to the south of the present area, described by B. H. Baker (1963, p. 7), is included for comparison. The apparent differences in the two successions stem from the more detailed subdivision adopted by the writer, in view of the excellence of the mountain slope exposures in the South Horr area.

South Horr Area	Thickness	Baragoi Area
	Feet	
TOP		
Biotite gneisses, in parts mobilized, with ultra-basic intrusives, amphibolites, graphitic schist.	2,000	Gneissose granite. Plagioclase amphibolites
Biotite migmatites	±0– 600	
Granitoid gneisses	±600–1,400	Granitoid gneisses.
Biotite gneisses with amphibolite	±600–1,600	Plagioclase amphibolites with amphibolites and muscovite-biotite gneisses.
Augen gneisses	±600	Biotite gneisses.
Pelitic biotite gneisses	±600	
Granitoid gneisses	±1,200–2,000	
Banded biotite gneisses	±1,600	
Biotite gneisses	±1,600	
Granitoid gneisses	±1,200–2,000	
Banded biotite gneiss	±1,600	
Biotite gneisses	±1,600	
Granitoid gneisses	±1,200	
Banded biotite gneisses	±1,100	
Biotite gneisses	±3,000	
Hornblende-biotite gneisses	±2,500	Hornblende migmatites.
Diopside gneisses	±400	
Biotite gneisses	±1,200	
Banded biotite gneisses	±600	
Biotite gneisses	±1,000	
Hornblende migmatites	±900	
Biotite gneisses	±1,100	
Amphibolites	±1,000	
Biotite gneisses	±900	
Hornblende-biotite gneisses	±900	
Granitoid gneisses	±1,400	Biotite migmatites.
Amphibolites	±1,400	
Biotite migmatites	±1,000	
BOTTOM		

(1) Calcareous Rocks

(a) *Crystalline Limestones*

Limestones form an insignificant part of the geological sequence in the area mapped. They occur as narrow lenses and as discontinuous bands usually less than 10 ft. wide. The mapped limestones occur in the Muran valley, south of South Horr, on the western slopes of Mara, on the north-eastern slopes of Nyiru and in the core of the Tum syncline. Shackleton (1946, p. 7) and Saggerson (1957, p. 9) have noted the frequent association of limestones and graphitic rocks in the Basement System. In the present area, at Tum, marble lies adjacent to a band of graphitic gneiss, while on Mara narrow bands of limestone are enclosed in graphitic schists.

Most of the limestones are white or pale blue and they are usually coarse-textured. Banding or mottling is not common. Specimen 19/2*, a compact, mottled grey and white limestone, consists of medium-grained calcite, abundant muscovite flakes which are concentrated along seams, and small grains of magnetite. The magnetite is responsible for the grey colouring of the mottles. Both at Tum and on Mara the limestone near the graphitic rocks contains graphite flakes. None of the marbles contains calc-silicate minerals.

(b) *Calc-silicate Granulites*

The calc-silicate rocks occur as variable-sized lenses intercalated among the finely banded layers of migmatites and other banded rocks. They often form rough boudinage structures around which the less competent surrounding layers have been folded. The lenses vary in size from a few inches to 10 ft. in length.

In the hand-specimen the calc-silicate granulites are mottled or patchy, greenish, greyish or, when rich in garnets, reddish rocks. They are invariably tough and are highly resistant to weathering. Consequently, they stand out from weathered surfaces as small ridges or as rounded knots. Specimen 19/175, from a minor lens included in a banded gneiss exposed in the Muran valley, is far more calcic than most of the calc-silicates examined and resembles those described by Dodson (1955, p. 9) and Bear (1952, p. 9) from central Kenya. It is composed of hornblende, epidote, calcite, calcic garnet, quartz and felspar. A crushed sample of calcareous granulite from near Borali was examined, as small grains of a sparsely distributed metal sulphide could be observed in a hand-specimen. The following minerals were recognized: diopside, epidote, garnet, plagioclase ($An_{50\text{-}60}$), with apatite as an abundant accessory mineral and a few minute grains of pyrite.

Shackleton (1946, p. 8) attributed the composition of calc-silicate granulites to reaction between limestone and granitizing fluids. The writer considers that the materials introduced during granitization are mainly potassium and sodium. It seems more likely, therefore, that the granulites, if formed by granitization, would be the result of granitization of a calcareous pelite. The writer believes, however, that they represent almost closed metamorphic systems, little affected by granitization.

(c) *Pyroxene-garnet Gneisses*

West of Nyiru, pyroxene-garnet-rich rocks form a series of low ridges and rocky exposures, which protrude from the sandy soils covering most of that region. The resistance to weathering of these outcrops as compared with the surrounding material suggests that they represent lenses enclosed in a thick band of garnet-free hornblendic rocks—it is known that when free of garnet the hornblendic rocks are particularly prone

* Numbers 19/2, etc., refer to specimens in the regional collections of the Mines and Geological Department, Nairobi.

to erosion. The exposures of the garnet-rich rocks are distinctive, as weathering leaves a dark maroon-coloured gravel composed almost entirely of garnets, ranging in size from less than a tenth of an inch to several inches across. Garnet-rich gravels surround most of the outcrops.

Specimens 19/129, 19/130 and 19/138 are typical of those rocks. They vary in the hand-specimen from lumpy, coarse-grained reddish to greenish blotchily-coloured rocks to more homogeneous pale brownish or greyish fine-grained granulitic rocks. In thin section they are seen to be variously composed of plagioclase, ranging in composition from about An_{30} to An_{50}, quartz, pyroxene, garnet, sphene, epidote, ilmenite, scapolite and rare zircon. The pyroxene is a dark green hedenbergitic variety with a slight bluish tinge and occurs both as subhedral to anhedral grains and in complex graphic intergrowths with plagioclase. These intergrowths usually, but not always, surround crystalloblastic garnets, when the pyroxene vermicules exhibit radial or tangential arrangement with respect to the margins of the garnets. The garnet, presumably of calcic almandine composition, varies from pale pinkish to a bright salmon colour in different rocks and sometimes in the same rock. It occurs as medium-sized irregular or subhedral to euhedral grains, in coarse graphic intergrowth with plagioclase. Larger crystals have the "coronas" of symplektitic pyroxene.

Most of the medium-sized garnets contain numerous inclusions, larger grains being almost free of them. The chadacrysts are plagioclase, quartz, pyroxene, epidote, sphene and magnetite. The scapolite occurs as roughly equant anhedral grains of moderate birefringence, indicating predominance of the calcium-rich meionite molecule.

Baker (1963, p. 12) considered similar, but hornblendic, rocks in the Baragoi area as the product of granitization of amphibolites. The writer agrees with this explanation in general but, in view of the presence here of nearby amphibolites, considers it likely that the original composition of the pyroxene-garnet gneisses was more calcic than typical amphibolites.

(d) *Hypersthene Gneisses*

On the extreme eastern slopes of Mara, hypersthene-bearing gneisses are exposed as linear dark bouldery heaps. Owing to intensive shearing, which tends to make all the rocks in the region look alike, their relationships with nearby rocks are difficult to assess, but their contacts where exposed are sharply defined.

The hypersthene gneisses are blotchy greyish to brownish, with apparently medium-grained textures. Specimens 19/58, 19/80 and 19/81 are examples. In thin section it is seen that they are medium- to coarse-grained, the crystals showing pronounced strain effects, and the quartz and felspar grains being elongated. Thin crush-zones occur between the elongated grains and parallel to their long axes. The gneisses are composed of quartz, orthoclase, microcline, microcline-perthite, oligoclase, hypersthene, clinopyroxene, biotite, hornblende, magnetite and the accessory minerals apatite and rare zircon. The hypersthene is pleochroic from pinkish to bluish green, and occurs as irregular grains with minute schiller inclusions or larger coalesced irregular iron-ore grains. The pale green clinopyroxene, probably diopside, occurs both as irregular grains and as elongated shreds with abundant inclusions of iron ore. Some of the hypersthene is partly replaced by hornblende.

(e) *Epidote Granulite*

A number of the slightly calcic and calc-silicate rocks found in the area contain epidote as an essential constituent. A single lens on the eastern slopes of Nyiru, about one mile to the south-west of South Horr, is, however, composed of epidote and felsic minerals, to the exclusion of other ferromagnesian minerals.

In the hand-specimen this rock bears a resemblance to quartzo-felspathic granulites found in the area. It is a whitish to pale greyish green granular rock and forms a series of prominent rocky outcrops along the strike. The band is less than 8 ft. thick. Specimen 19/21 from this band is a granular medium-textured rock composed of epidote, plagioclase and quartz. The epidote, a faintly pleochroic pale yellow to colourless variety, is present as variable-sized grains, with a tendency to form granular aggregates.

In view of the compactness of this lens, which is enclosed in a semi-pelitic band, the writer believes that the rock originated as a magnesium-deficient lens of semi-pelitic composition which, by virtue of its compactness and situation, was not affected by metasomatism.

(f) *Diopside Gneiss*

A single lens of this rock type outcrops discontinuously about 2½ miles west-north-west of Tum. It occurs as a narrow lens along the margin of a broad horizon of granulitic pyroxene-garnet-rich rocks previously described. In the hand-specimen (19/136) it is a mesotype pale greyish to greenish even-grained rock.

In thin section the rock is seen to be allotriomorphic and composed of pale green diopside, hornblende, quartz, orthoclase, oligoclase, and a small amount of replacive microcline, ilmenite and abundant apatite, present as large and small rounded crystals and grains. A few small grains of sphene and less common idiomorphic crystals of zircon are the other accessory minerals present. The diopside is mainly developed at the junctions of quartz and felspar grains, patchily forming an irregular network in the rock.

(2) Pelitic Rocks

(a) *Pelitic Biotite Gneisses*

As these rocks are particularly susceptible to weathering, they are poorly exposed in the lower-lying areas. The depth of erosive incutting on the two mountain ranges has, however, exposed the softest rocks in most valleys, gorges and gullies. The pelitic biotite gneisses form persistent bands in the area, but are perhaps best exposed in the south-eastern part of Nyiru (Leyosi peak), where they are anticlinally folded around a tough core of massive granitoid gneiss and where over a small area a thin remnant forms a saddle covering the granitoid gneiss. Junctions between the biotite gneisses and adjacent psammitic or semi-pelitic rocks are invariably sharp.

In the hand-specimen the pelitic biotite gneisses bear a superficial resemblance to some fine-grained plagioclase amphibolites. They are typically dark, often fine-grained, well-foliated rocks composed of biotite and felsic minerals. As previously mentioned, they sometimes include lenses of calc-silicate granulites. Lenses of hornblende enrichment, grading into the surrounding biotite-rich layers, are a fairly common feature. The biotite in these rocks is usually a green variety and accounts for up to 40 per cent of the total rock composition. The felsic minerals are quartz, plagioclase (usually An_{20-30}), orthoclase and less commonly microcline, which is both replacive and forms intergrowth textures with quartz. Diopside and epidote are rare constituents. The most common accessory minerals are zircon, which is frequently present as inclusions with pleochoic haloes in the biotite flakes, and apatite. Specimen 19/3 from the Muran valley is typical of the pelitic biotite gneisses. It is composed of reddish brown to olive-green biotite, plagioclase (An_{25}), orthoclase and quartz. Accessory minerals are colourless garnet, apatite, magnetite and zircon.

(b) *Sillimanite Gneisses*

Two outcrops of sillimanite-bearing gneisses were recorded in the area. The more easterly of the two occurrences forms a conspicuous line of rounded whitish boulders, similar in general aspect to the numerous pegmatite vein outcrops in the area. It lies adjacent to a folded graphite schist bed on the western slopes of Mara, two miles north-east of South Horr. The outcrop of sillimanite gneiss is narrow and is visibly persistent for less than half a mile. It appears to be a lens. In general appearance the rock is unusual, the best comparison perhaps being with a ripe maize cob. It consists of porcellaneous white, rounded, lumpy *faserkiesel* projecting from a fine-grained white micaceous ground-mass. This texture is frequently emphasized by a dark surface staining by iron oxide of the porous ground-mass, the seed-like *faserkiesel* being unaffected. The *faserkiesel* are between a quarter and a half an inch long, their axes orientated parallel to the local lineation which plunges at 15° to 8° east of north. Specimen 19/160 from this locality was found in thin section to consist of a fine-grained equigranular mosaic of quartz, oligoclase and less abundant muscovite, scattered with medium-sized aggregates of sillimanite. Individual fibres, slender prisms and groups of fibres of sillimanite orientated along the foliation planes, are also scattered through the ground-mass, but nearer the *faserkiesel* are progressively concentrated. The accessory minerals present are scanty magnetite and graphite. The adjacent graphitic schist contains abundant sillimanite; specimen 19/175 includes sillimanite aggregates up to a quarter of an inch long. The aggregates, though similar in thin section to those of specimen 19/160, do not form the distinctive lumps on the weathered surfaces.

The other exposure of sillimanite-bearing gneiss outcrops on the eastern slopes of Mara, in the Arrage valley, just on two miles east-south-east of Borali peak. This outcrop is too narrow to be shown as a separate band but is recorded on the geological map in words. It is a dark greyish micaceous gneiss scattered with small euhedral garnets and numerous white silky tufts of sillimanite. Specimen 19/52 is composed of quartz, felspar, biotite, sillimanite, garnet and accessory minerals. The quartz, which was originally present as large crystals, has been shattered and now consists of smaller grains, the larger of them showing strain polarization. The proximity of the horizon to strong shear-zones in the north-eastern part of Mara may account for the crushing. The felspar present is mainly untwinned plagioclase (An_{25-30}) with a small amount of orthoclase. Brown biotite accounts for about 15 per cent of the total rock composition and occurs among sillimanite needles and intergrown with the larger garnet crystals. The garnets are pale pinkish, and presumably of almandine composition, the larger crystals including or being intergrown with quartz, felspar and biotite. The accessory minerals are rare zircons and apatite.

(c) *Graphitic Schists and Gneisses*

Several graphitic beds are exposed in the area. Their outcrops vary greatly according to their composition. On the western slopes of Mara, a fine-grained graphitic schist in an anticline outcrops in a broad shallow V. It is noticeably more resistant than the surrounding gneisses, and heaps of slabby schist form low mounds along the strike. The other graphitic rocks in the area are gneissic and as a rule are less resistant than surrounding rock layers, with the result that they outcrop only sporadically in the Andere valley, north-eastern Nyiru, on the small hill immediately west of the South Horr-Marsabit road intersection, and against the granitoid gneiss core of the Tum syncline on the western slopes of Nyiru.

The Mara graphite schist is a fine-grained grey to silvery micaceous, schistose rock, almost free of other visible minerals. It consists of highly irregular graphite flakes, radiating tufts of sillimanite, abundant quartz, less common orthoclase, and a few flakes of muscovite. Tests carried out in the Mines and Geological Department proved the carbon content of samples of this schist to be approximately 15 to 16 per cent, sillimanite accounting for about 3 per cent of the total rock composition. The other graphitic rocks are gneissose and similar to each other in general characteristics. They are silvery-greyish soft, often crumbly, gneissose rocks composed essentially of kaolinized felspar, soft friable altered biotite and medium-sized graphite flakes up to a maximum length of a quarter of an inch. Heavy mineral concentrates extracted from these rocks show that small quantities of accessory apatite and zircon are present.

The common relationship between crystalline limestones and graphitic rocks in the Basement System has already been mentioned (p. 15). It might be supposed from this relationship that the graphite had been derived from carbon released from the limestones. If, however, carbon had been lost from the limestone in the form of either of the carbon oxides, the remaining calcium oxide would have reacted with silica or silicates to form calc-silicate minerals. There are only a few calc-silicate rocks of minor significance in the area and, since the limestones are free of calc-silicate impurities, it must be concluded that the source of carbon was not the limestones.

(3) Semi-pelitic Rocks

(a) *Biotite Gneisses*

In most parts of Kenya Colony occupied by the Basement System, the most common rock type is a homogeneous biotite gneiss derived from semi-pelitic rocks, and in the South Horr area such biotite gneisses constitute an important part of the succession. Normally the semi-pelitic biotite gneisses contain less biotite than the pelitic types. Although localized gradations between the two types occur, there is little danger of confusion between them in the field.

The biotite gneisses form conspicuous outcrops, often of well-foliated slabby layers, but less commonly as massive cliff faces or ridges. Some of the more impressive physiographic features in the area are composed of such gneisses.

The semi-pelitic biotite gneisses are usually mesotype grey, pinkish or cream-coloured rocks, or when iron-stained reddish, characterized by abundant and evenly distributed small to medium-sized flakes of biotite. They are strongly gneissic, the preferred orientation of the biotite crystals emphasizing that feature. Specimen 19/29 from the eastern slopes of Mara is typical of a slightly calcic type of biotite gneiss. It has a granoblastic texture and is composed of biotite, quartz, orthoclase, plagioclase (An_{25}), epidote, sphene and other accessory minerals. The biotite is a dark greenish brown variety occurring both as individual crystals with preferred orientation and intergrown with epidote and sphene to form glomerate aggregates. Epidote and sphene occur in the same manner. The other accessory minerals are medim-sized rounded apatite grains and small rare zircon prisms.

Specimen 19/97 from the Tum area is a coarse-grained biotite gneiss distinguished from specimen 19/29 by the presence of less biotite and plagioclase, the absence of sphene and epidote as primary minerals and the appearance of microcline. Texturally, specimen 19/97 exhibits slight stress, manifested chiefly by strain polarization of quartz grains. Microcline extensively replaces orthoclase and plagioclase. Accessory minerals are magnetite, apatite, sphene and zircon.

(b) *Hornblende-biotite Gneisses*

In semi-pelitic meta-sediments containing more lime than the biotite gneisses, hornblende supplements biotite as the ferromagnesian constituent. Hornblende is, however, seldom present in highly metasomatized rocks, as the introduction of potash invariably causes the conversion of the hornblende to biotite. Transitional stages of the conversion of biotite to hornblende, of course, allow co-existence of the two minerals.

Hornblende-biotite gneisses form an important band in the slightly calcic succession of rocks to the west of Tum. It extends from west of Tum, where it emerges from beneath a covering of lava, in a north-north-easterly direction to the northern slopes of Nyiru where it is once again overlain by lava-flows.

In the hand-specimen hornblende-biotite gneisses are often subject to wide variations of colour, composition and texture, but in the present area they are consistently mottled, pale greyish, fine- to medium-grained rocks. In specimen 19/73 from the northern slopes of Nyiru, the hornblende crystals are larger but subordinate to the biotite. The hornblende is a bluish green variety and some grains are intergrown with biotite. The biotite is a highly pleochroic brown variety. Garnet is an essential constituent in this specimen, occurring as medium-sized, pale pinkish, subhedral crystals, with inclusions of quartz, felspar, apatite, iron ore and rutile. Chemical tests proved that calcium is an important ingredient in its composition. Secondary calcite is an alteration product associated with one of the garnets. Muscovite is a rare constituent, intergrown with biotite. The accessory minerals are abundant apatite, occurring both as rounded grains and as prismatic crystals, titaniferous magnetite, zircon and rutile. Specimen 19/99 from west of Tum was collected from the same band as specimen 19/73. It is generally similar to it but does not contain garnet.

(c) *Hornblende Gneisses*

Hornblende-bearing meta-sedimentary rocks without biotite are rare in the present area. A narrow exposure outcropping in the South Horr valley, near the Muran river, is the only example mapped in the area. In general appearance the rock is similar to the biotite gneisses. It is a medium- to fine-grained rock, flecked with small hornblende crystals concentrated in thin bands about a tenth of an inch across, the bands being spaced about a quarter of an inch apart. Specimen 19/18 from this exposure is seen in thin section to be an inequigranular rock composed of quartz, orthoclase, plagioclase (An_{20-30}) bluish green hornblende, magnetite, and the accessory minerals garnet, apatite and rare zircon. The presence of hornblende in place of biotite in this rock may be due to a slight calcic enrichment in the original sediment.

(4) Psammitic Rocks

(a) *Quartzo-felspathic Granulites*

No true quartzites were found in the area, and several rocks, thought in the field to be quartzites, proved on microscope examination to contain an appreciable amount of felspar. Texturally, too, these rocks are unlike the typical equigranular Basement System quartzites. They are more resistant than most of the associated rocks and are exposed as lines of prominent whitish boulders even in areas where adjacent rocks have been eroded to sand.

In the hand-specimen the granulites are whitish, reddish or pale bluish, fine- to medium-grained rocks, nearly devoid of dark minerals. Their felspars are invariably whitish to pale grey and as in all exposures examined they are unaltered, they are clear and not unlike quartz on cursory examination. As do the Basement System quartzites, these granulites often contain magnetite and pyrite. Specimen 19/16 from the South Horr valley consists of an intricate mosaic of interlocking quartz and felspar grains, with pyritohedra and irregular grains of pyrite, granular to subhedral sphene, and a few small zircon and apatite prisms. Muscovite was recognized in the hand-specimen only. The felspars are orthoclase and a small amount of faintly twinned or untwinned oligoclase (An_{10-15}). Specimen 19/23, also from the South Horr valley, is similar in appearance and general composition but is more granular textured. Specimen 19/60 from the Tum syncline is a fine-grained almost translucent pale greyish rock composed of felspar, quartz, pyrite, biotite and the accessory minerals sphene and zircon. The felspars are microcline, orthoclase and oligoclase. Microcline replaces orthoclase, plagioclase and quartz, sometimes with the formation of marginal intergrowths. The quartz grains are often elongated along the lineation direction and are characterized by irregular margins. They invariably exhibit strain polarization. The biotite occurs as thin plates and is pleochroic from almost colourless to brownish. Specimen 19/71 from the north-eastern slopes of Nyiru is exceptional in that it includes abundant pale maroon crystallo-blastic garnets between one-eighth and one-quarter of an inch in size. Graphite, too, is present as medium-sized flakes crowded in narrow discontinuous seams. In thin section the rock is allotriomorphic textured and composed of quartz, perthite, plagioclase (An_{15}), garnet, epidote, and the accessory minerals graphite, titaniferous iron ore and rutile.

The most likely explanation of the origin of these rocks is granitization of either quartzites or, more probably, semi-pelitic sediments deficient in ferromagnesian minerals. The influence of granitization on some of these granulites is indicated by the growth of microcline, frequently at the expense of pre-existing minerals. Megascopically, specimen 19/22 from the South Horr valley is similar to the other granulites which contain variable amounts of microcline, but examination of a thin section proves that microcline in it accounts for over 60 per cent of the total composition.

(b) *Granitoid Gneisses*

Granitoid gneisses form the most striking physiographic features in the area. They are tougher and more resistant to erosion than the other gneisses and a number of cliff faces, exfoliation rock slabs and massive rounded boulders owe their existence to being composed of such rock. Borali, Mumsu, Leyosi, Ben and Koros are examples of the more impressive physiographic features composed of granitoid gneiss. Bands of granitoid gneiss are repeatedly exposed by the extensive folding in the area, and sometimes act as cores around which less resistant rock layers are folded. Examples of granitoid cores are to be seen in the Tum syncline and the Leyosi anticline.

Typically the granitoid gneisses are pale yellowish, or buff to pinkish in colour, medium- to coarse-grained in texture and composed essentially of quartz, potash felspar, rare plagioclase, biotite and iron ore. They are massive or faintly foliated rocks. The pegmatites usually have diffuse marginal contacts and in composition and mineralization bear strong relationship with the granitoid host-rocks. The quartz lenticles are often surrounded by a margin of reddish iron oxide staining.

Specimens 19/10, 19/43, 19/53, collected from various localities in the South Horr valley, are representative of the granitoid gneisses. They are medium- to coarse-grained rocks with allotriomorphic textures showing little or no preferred orientation. Microcline is the most abundant felspar, and frequently replaces orthoclase, plagioclase and quartz. The potash felspars in these rocks are prone to sericitization. Biotite present is usually a green variety sometimes intergrown with muscovite; in specimen 19/10 it has altered to chlorite. The plagioclase is a medium oligoclase (approximately An_{20}). Quartz occurs both as large recrystallized anhedral grains and as smaller rounded grains reminiscent of sedimentary particles. Magnetite is usually present in euhedral to subhedral crystals, sometimes altered to martite or hematite. Accessory minerals are rare, the most constant being zircon and apatite. Sphene is sparsely represented in heavy mineral residues extracted from hand-specimens. Despite the fact that pyrite occurs in the quartz lenticles previously mentioned, it is rare in the granitoid gneisses.

The granitoid gneisses in the present area are undoubtedly the product of granitization and accompanying partial recrystallization of coarse-grained psammitic sediments. Owing to the permeability the parent rock underwent a greater degree of granitization than any other rock types in the area. Granites in the area show strong textural and mineralogical affinity to the granitoid gneisses, and it is the writer's opinion that the two types are gradational, the granites being localized portions of the gneisses which achieved mobility.

(c) *Augen Gneisses*

An augen gneiss forms a prominent, consistent marker horizon throughout the folded succession on the Nyiru and Mara ranges. It is separated from one of the granitoid gneiss bands by a narrow bed of pelitic gneiss. As it is less readily weathered than the pelitic or nearly semi-pelitic gneisses, the augen gneiss frequently crops out as low rocky ridges. North of Nyiru augen gneiss is exposed in the sandy plains as a series of steeply-inclined slabby hills. Unlike the granitoid gneisses the augen gneisses do not form cliff faces of massive boulders, as they retain a flaggy foliated structure.

The augen gneisses are medium- to coarse-grained porphyroblastic rocks consisting of a mesotype pale greyish to pinkish foliated ground-mass with included dull whitish to pink felspar porphyroblasts between ¼ in. and about 3 in. in length. Specimens 19/1, 19/48 and 19/63 from the augen gneiss band exposed along the eastern slopes of Nyiru are typical of the local variations found in this horizon. The ground-mass in thin section is seen to have allotriomorphic texture, and to be composed of quartz, orthoclase, microcline, perthitic intergrowths, biotite, hornblende, garnet in 19/48 and accessory apatite. The porphyroblasts are always microcline.

Harpum (1954, p. 183) and Baker (1963, p. 11) have noted a close relationship between augen gneisses and pegmatites. They both state that *permeated* augen gneisses sometimes merge gradationally into pegmatites. In the present area there is also evidence of a connexion between pegmatites and the augen gneisses, best illustrated in the Muran river-bed on the south-eastern slopes of Nyiru, where a large river-cut section of the gneiss is well exposed. In this rock wall, numerous pegmatites, mostly orientated along the foliation and scattered through the gneiss, consist chiefly of aggregates of felspar porphyroblasts, similar in composition but usually much larger than the augen of the host-rock. Harpum (*op. cit.*) pointed out that in many parts of Tanganyika, augen gneisses are frequently developed under conditions of shearing stress. Evidence in the present area suggests that there has been a certain amount of stress associated with the development of the augen gneisses, though there is little doubt that they are products of metasomatism resulting from permeation. The reason for selective porphyroblastesis and localized stress must be sought in the original rock composition. The writer believes that the two factors responsible for the growth of the augen were the permeability of the original sediment, increasing its absorptiveness to introduced potash-rich solutions, and a sufficiently high mica content to allow movements in it under stress preferentially to movements in adjacent layers.

(5) MIGMATITES

(a) *Biotite Migmatites*

Most of the Precambrian rocks in the present area have undergone a greater or lesser degree of granitization, the process during which rocks are converted to a more granitic form (*see* p. 44). The migmatites represent a stage in granitization, and are characterized by the presence of clearly recognizable introduced material in the form of pegmatitic stringers, veinlets or lenses.

Migmatites occur in most parts of the area occupied by Basement System rocks. They vary greatly in texture and to a lesser extent in mineral composition, and usually grade into neighbouring non-migmatized gneisses. In the field they are recognized by their heterogeneous banded or mottled nature (*see* Plate 1). The host-rock is usually a dark, pelitic, biotite-rich schistose type, as on the northern slopes of Nyiru. This type strongly resembles the pelitic biotite gneisses in the area and there are gradations and intermediate stages between the two rock types, which as a result are difficult to define. The reason for the greater prevalence of pelitic host-rocks is that such rocks are more schistose and more complexly jointed than the more massive psammitic rock layers.

The introduced material is present in a variety of forms which the writer found possible to classify into three main types. It must be admitted, however, that the classification is at times indefinite and gradational forms occasionally found. The most commonly occurring form is a concordant band, parallel with the foliation. These bands are often parallel-sided, varying from less than 1 in. to about 2 ft. in width, and characteristically have sharp contacts which suggest intrusive emplacement. An almost equally common form is normally lensoid, impersistent and often curving or cuneiform. Contacts between this type and the country rock are invariably diffuse. The remaining type is usually irregular with uneven, gradational contacts, and frequently with inclusions of unaltered country rock along their margins, so that they resemble pseudo-breccias. The introduced material is composed largely of quartz, microcline, orthoclase, plagioclase (oligoclase or less commonly albite), with a small amount of mica, usually biotite but occasionally muscovite, epidote and, rarely, hornblende. Where the felsic veinlets or lenses cut across hornblende enriched streaks in the host-rock, the hornblende immediately adjacent to the felsic vein is converted to biotite. Specimen 19/34 from the eastern slopes of Nyiru was cut from near the contact between a felsic vein and a pelitic host-rock. As is typical of the migmatites, the specimen exhibits intense microcline replacement of orthoclase, quartz and plagioclase.

Mesotype migmatites are found on Mara and are similar in most respects to the migmatites already described except that the host-rock is of semi-pelitic composition, with the result that the contrast between the two components is less obvious. In extreme cases of localized felsic enrichment, the migmatitic veins or lenses remain as "ghost" relics. In mineral composition, these migmatites differ from those described above mainly in that there is a higher microcline content with proportionately less plagioclase in the host-rock. Specimen 19/51 from the western slopes of the Arrage valley about 4½ miles north-east of South Horr is typical of the mesotype migmatites.

(b) *Hornblende migmatites*

Unlike the Baragoi area to the south, where Baker (1963, pp. 13-17) recorded a variety of hornblende migmatites, the present area has few hornblendic rocks that have been migmatized. These consist exclusively of amphibolites that have been cut by pegmatite-like stringers, veins and lenses. The felsic veining is rarely parallel, the most common forms being crescentic or folded lenses and fine ptygmatic veins.

The most obvious effect of migmatitization of the amphibolites is the metasomatic effect of potash solutions along a narrow margin around each of the felsic lenses. As a result biotite appears with the hornblende and potash felspar replaces plagioclase in this narrow zone. Specimen 19/140 from about five miles north-west of Tum illustrates the effects along the outer edge of a potash-enriched zone surrounding a felsic lens about 7 ft. long and just less than 2 ft. wide. The rock is allotriomorphic and composed of orthoclase, microcline, plagioclase (An_{30}), biotite, hornblende and quartz with accessory apatite and magnetite. Microcline occurs as sparsely distributed small grains, replacing the plagioclase and orthoclase felspar. Biotite intergrowth with hornblende has taken place on a limited scale only.

Migmatitization of amphibolites in the present area has taken place on the smallest scale only, but Baker, in the Baragoi area, observed migmatitization of amphibolites on a sufficiently extensive scale to form hornblende granitoid gneisses.

2. Pre-metamorphism Intrusive Rocks

(1) AMPHIBOLITES

Though present in most parts of the area in which Basement System rocks are exposed, amphibolites are most abundant in the South Horr valley, where they occur as prominent linear outcrops of dark slabby rock, frequently forming narrow ridges.

The most prominent ridge extends from just north of the Muran river road-crossing, where the rock emerges from a small alluvial plain, to just east of South Horr. As that region is only patchily covered by grass the dark rocks stand out in bold relief against the lighter-coloured gneisses and sandy soils. Contacts between the amphibolites and gneisses are invariably sharp. The bodies vary in size from small lenses to bands several hundred yards wide and extending for over five miles.

The amphibolites vary from an extreme dark greenish fine-grained slabby type, seemingly devoid of felsic material, to mesotype, coarse-grained greenish grey mottled rocks, but examination of thin sections proved that some of the amphibolites recorded in the present area fall into the plagioclase amphibolite class. These rocks are seldom much affected by granitization although they are frequently cut by pegmatite and quartz veins. Along the margins of the pegmatites there is a slight enrichment of potash resulting in biotite replacement of hornblende and the growth of potash felspar. Specimen 19/92 from the Tum syncline is a coarse-grained epidioritic amphibolite. It is allotriomorphic, showing preferred orientation of hornblende grains, best observed in the hand-specimen. It is composed of green hornblende, plagioclase (sodic andesine) biotite and accessory apatite. Diopside and epidote are commonly found in the amphibolites, often being concentrated in narrow lenses or ill-defined bands. Quartz and the potash felspars are uncommon in the amphibolites, but found sometimes in the mesotype examples. Sphene and ilmenite are usually present as accessory minerals.

The amphibolites appear to be derived from basic intrusives, their mode of occurrence and occasional relic igneous textures, not observed in the present area, providing evidence of their nature. They appear to represent an extensive intrusive phase. As in their present condition the amphibolites are obviously the result of intense metamorphism it is concluded that they were emplaced prior to the regional metamorphism of the Basement System and, therefore, that they may represent the basic intrusive phase of the orogenic cycle. Amphibolitization of the basic rocks probably took place in two phases, the earlier consisting of conversion of pyroxenes to hornblende, and the growth of sodic plagioclase at the expense of plagioclase of more basic composition, the later phase being one of recrystallization with the schistose or fissile structures typical of most amphibolites.

(2) Ultra-basic Rocks

Numerous intrusive bodies of ultra-basic rocks are scattered about the areas of exposed Basement System rocks, but they tend to be concentrated in the floor of the South Horr valley. They vary from small narrow bodies to more extensive sheets, all being concordant with the country rock.

In hand-specimens these rocks vary from pale greenish or whitish talcose types to compact green, buff or dark grey rocks forming bouldery exposures. Typically they are of pyroxenitic composition with a variable degree of alteration of the pyroxene. About two miles south of the Muran river, alongside the Baragoi-South Horr road, a narrow lens of greenish ultra-basic rock includes segregations of somewhat friable buff-coloured anthophyllite. The anthophyllite fibres attain a maximum length of about 3 in. but the mineral is present in limited quantity only and is of obviously poor quality. Several exposures of the ultra-basic rocks are cut by reticulated veins of magnesite, the largest veins observed being less than ½ in. wide, with the average width about ⅛ in. Aggregates of small phlogopite flakes that occur in a discontinuous seam along the margins of one of the ultra-basic intrusives occurring about halfway between the Muran river and South Horr are exposed in a few shallow pits excavated by a prospector. The largest of the aggregates is about 6 in. long and includes phlogopite flakes up to 1 in. in length, haphazardly clustered into separate lumps.

Plate I—Typical migmatite textures in rocks of the Basement System in the South Horr Valley.

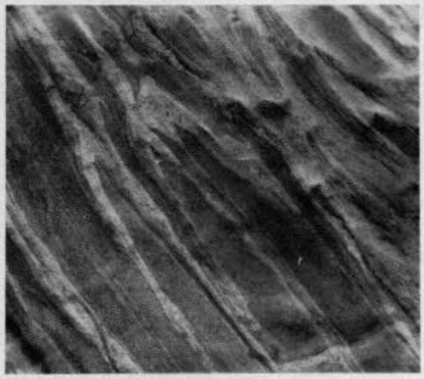

Fig. 1—The exposure is approximately two feet across.

Fig. 2—The exposure is approximately two feet across.

Fig. 3—The exposure is approximately two feet six inches across.

Plate II

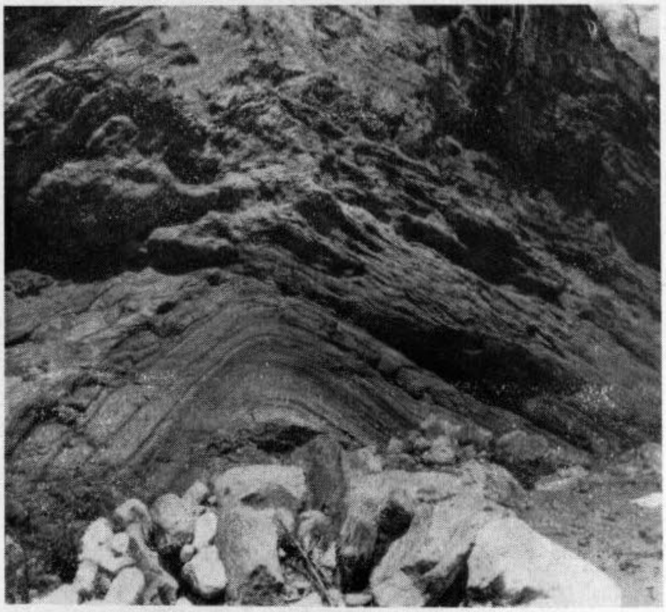

Fig. 1—Minor fold with crenulated limbs in the South Horr valley syncline.

Fig. 2—Black scoriaceous ash on the slopes of Teleki's Volcano. The dead trees scattered about are believed to have died during the most recent eruption.

Fig. 1—The most recent lava flow from Teleki's Volcano.

Fig. 2—The slaggy, wrinkled surface of the most recent lava at Teleki's Volcano.

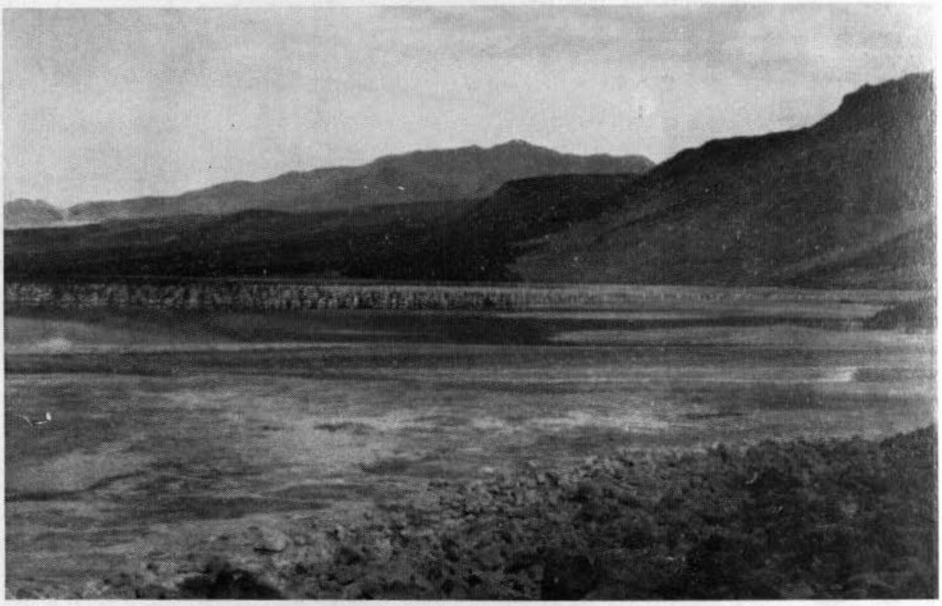

Fig. 1—The salt lake at the northern end of the Suguta valley. The recent lava flow from Andrew's volcano can be seen as a dark tongue at the far end of the lake.

Fig. 2—View of the salt lake and the volcano Lengurungi from the Andrew's volcano lava flow.

Plate V

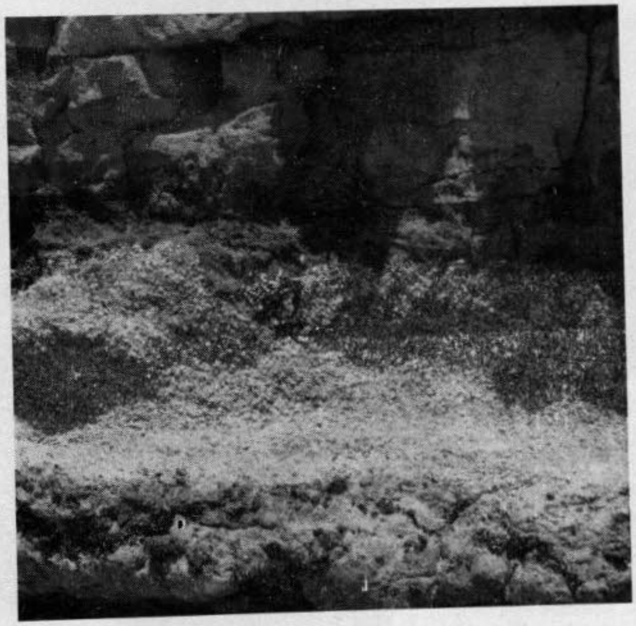

Fig. 1—Lake sediments at Nakwamosin, at a level of 200 feet above Lake Rudolf.

Fig. 2—Shelly limestone bed in the sediments at Nakwamosin.

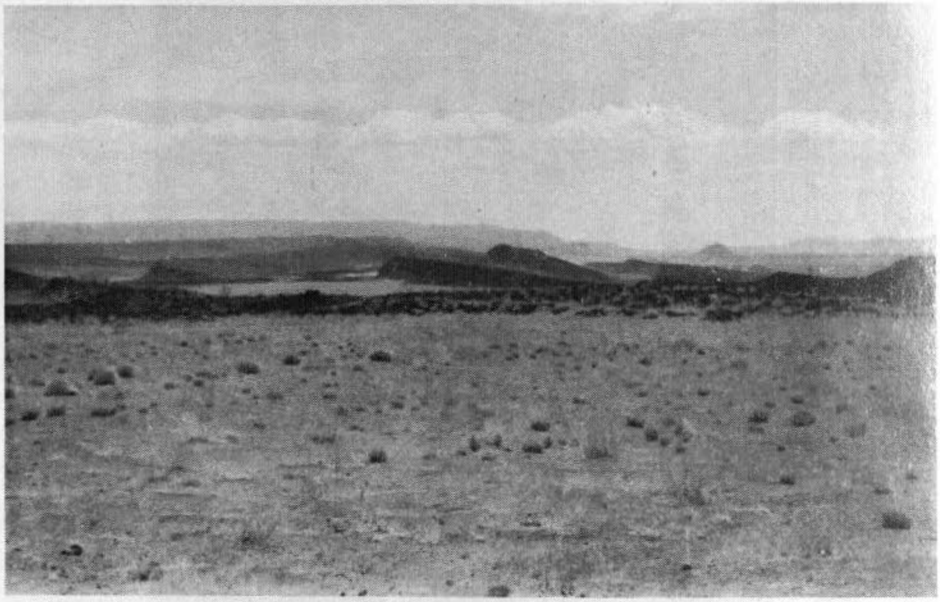

Fig. 1—View from Murniau volcano showing tilted olivine basalts in the background with soft agglomeratic ashes in the foreground.

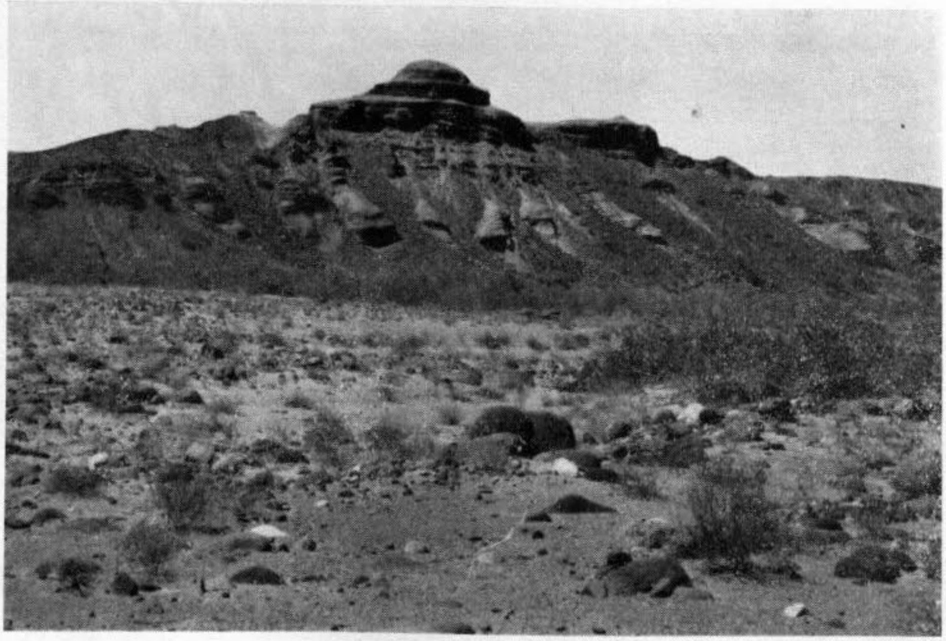

Fig. 2—Lacustrine sediments in the Losergoi river-course, near the Suguta valley.

Plate VII

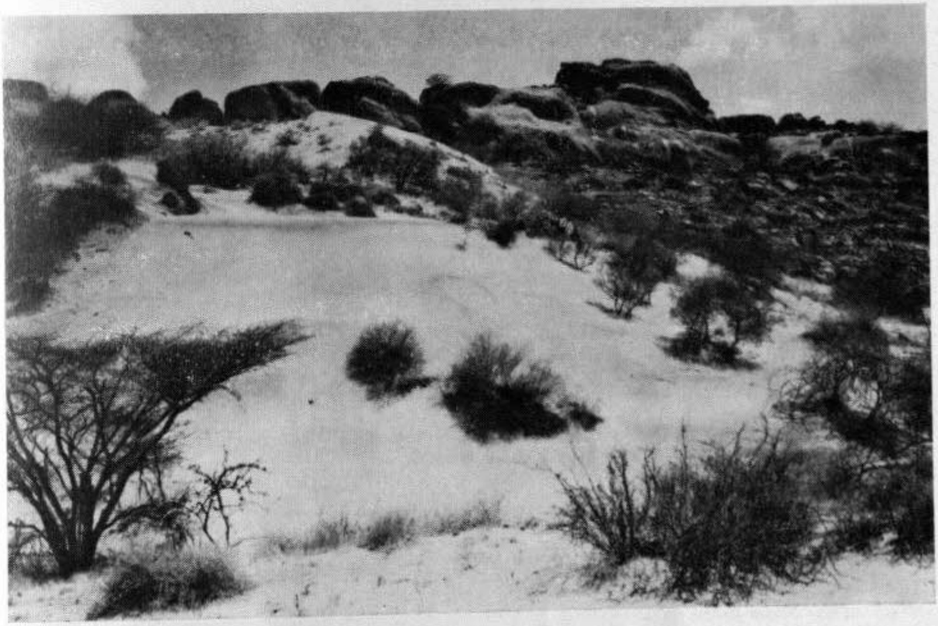

Fig. 1—Windblown sand heaped up behind a rocky ridge in the plains to the north-east of Nyiru.

Fig. 2—Sand dunes north of the Losergoi river-course near the Suguta valley.

Plate VIII—Fossils from the South Horr area.

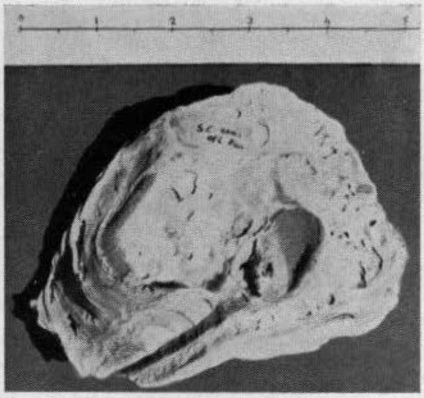

Fig. 1—*Aetheria elliptica*, from middle Pleistocene lake-beds near the south-east shores of Lake Rudolf

Fig. 2—*Mutela nilotica*.

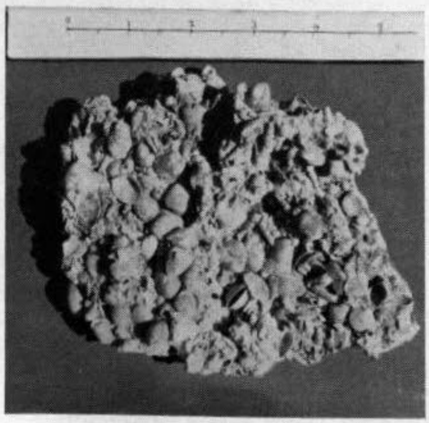

Fig. 3—Shelly limestone composed mainly of *Melanoides tuberculata* and *Corbicula africana*. The scales are in inches.

Examples of the ultra-basic intrusive rocks are provided by specimens 19/76, 19/31 and 19/35. Specimen 19/76, a greenish grey coarsely crystalline rock from Lol Marlu in the south-eastern corner of the area, is a peridotite, consisting of partly serpentinized olivine, enstatite, iron ore, and secondary tremolite, serpentine and talc. Specimens 19/31 and 19/35 from the western slopes of Mara, near South Horr, exhibit the extremes of development of tremolite-actinolite, anthophyllite and talc respectively. Greenish staining, characteristic of many of the altered ultra-basic rocks, is probably due to the presence of nickel. Chemical tests proved the existence of strong traces of nickel in every specimen collected in the area.

(3) Meta-gabbro

A single lens of an intrusion of gabbroic composition occurs adjacent to an ultra-basic body alongside the Baragoi-South Horr road. It is a mottled greyish medium- to coarse-grained rock and forms a prominent rocky ridge. Specimen 19/19 from this occurrence is a medium-grained allotriomorphic-textured rock composed of hornblende, labradorite felspar, diopside, epidote, and a little accessory apatite.

Baker (1963, p. 25) has described other gabbroidal rocks from the Baragoi area further south.

(4) Garnetiferous Felspathic Ortho-granulites

The north-eastern extension of Mara range is partly composed of an interesting garnetiferous felspathic granulite. The adjacent beds are hornblende-hypersthene-bearing gneisses. As that area has been intensely sheared, most of the rocks forming the ridge show signs of stress while some, such as specimen 19/78 from the main shear-zone, have been severely crushed.

Specimen 19/77 from the peak of this range is a brownish to reddish-stained medium-grained rock studded with abundant maroon-coloured garnets. Shearing has allowed the formation of small quartz lenses in the rock. A slightly banded effect is produced in exposures by a succession of narrow shear-planes. In thin section the rock was found to be granular and composed of orthoclase, perthite, occasional plagioclase (oligoclase), garnet, biotite and iron ore. The felspars are irregular and fractured, the albite twinning of the plagioclase being only just visible. The garnets, a pink variety of almandine composition, are fractured but not disintegrated. The biotite is unusually pleochroic from pale yellowish green to reddish brown. Iron ore is present both as magnetite and as the hydroxide limonite.

3. Anatectic Rocks

(1) Granites

The granites in the area are rocks with variable but homogeneous textures, which attained a state of mobility, however localized, in relation to the rocks of the Basement System. They are of minor importance in the succession, occurring in the south-eastern corner where coarse-grained granite forms a small tor and at several localities in the psammitic gneiss bands.

The granite tor is slightly elongated but well rounded and is characterized by large convex exfoliation surfaces. In the hand-specimen the rock that composes it is pale buff to pinkish, coarse textured and homogeneous, with microcline forming pinkish to dull grey porphyroblasts up to ¼ in. across. In thin section (specimen 19/62) it is seen to be coarsely granitic and composed of microcline, orthoclase, sodic plagioclase, quartz, biotite, muscovite and the accessory minerals sphene, apatite and zircon. The microcline replaces orthoclase and quartz, and forms graphic intergrowths with quartz. A few crystals of the biotite have been replaced by chlorite. Zircons enclosed in the biotite flakes are surrounded by pleochroic haloes.

The other granites are far more limited in extent, the only notable occurrence being in the most northerly exposed section of a band of anticlinally folded granitoid gneiss about two miles east of South Horr on the western slopes of Mara. Gradations of these granites can sometimes be traced from heterogeneous, foliated grantoid and biotite gneisses, through an augen zone which appears to be an intermediate stage, to a granitic-textured rock. The augen stage has no connexion with the augen gneiss which forms a definite horizon in the metamorphic succession. The zone of granite mobilization sometimes cuts across the local strike. It was found that the granites vary little in composition from the rocks from which they were derived, the only changes being that microcline is more abundant and the texture both more coarse grained and of a more homogeneous nature, free of preferred orientation. Features indicating mobilization are marginal intrusion and, in some cases, complete or partial digestion of adjacent rocks along marginal contacts, resulting in local enrichment or the presence of small xenoliths along the margins. Contacts are always diffuse.

The granites in the area are products of granitization processes sufficiently advanced to induce localized mobility. There appears to be a connexion between deformation and mobilization, the areas of greatest stress such as the axes of folds being more liable to have granites formed in them than other parts of rock bands. Baker (1963, p. 31) noted a connexion between such granites and pegmatites. In the present area no such relationship was observed, but the writer considers it likely that the intrusion of pegmatitic material would influence any tendency there was for their host to attain mobility.

(2) Aplites

Aplites are uncommon in the area and where present occur as insignificant veins and stringers, seldom more than a few inches wide. They either form cross-cutting anastomosing vein networks in various gneisses, showing a preference for those with best-developed jointing systems, or they occur as minor concordant sill-like intrusions. Contacts with the country rocks are sharp but there is little textural variation in the aplites between the contact and their centres.

The aplites are pale pinkish to buff leucocratic rocks sprinkled with small flakes of biotite, muscovite and magnetite. They are usually homogeneous and roughly equigranular, although specimen 19/11 from the Muran river gorge, south of Nyiru, is strongly gneissic and inequigranular textured. In thin section, however, the composition is seen to be typically aplitic with microcline, orthoclase, oligoclase, quartz, green biotite partly replaced by chlorite, and the accessory minerals magnetite, pyrite and zircon. The aplites are characteristically rich in potash.

(3) Pegmatites

The area is particularly rich in pegmatites. They tend to be concentrated in certain zones, most of which are areas in which mobilized granite occurs, such as the western ridge of the Mara range, the southern part of the South Horr valley and the Lol Marlu ridge in the south-eastern part of the Mara range. So numerous are pegmatites in some parts of these regions that it would be difficult to demarcate an area of 50 square yards not cut by them.

Three types of pegmatite are found among the Basement System rocks:—

Segregation pegmatites.
Permeation pegmatites.
Intrusive pegmatites.

The *segregation* pegmatites mostly occur in migmatites or other receptive host-rocks that have undergone deformation. They occur as lenses, patches and stringers and are characterized by gradational contacts. In the more pelitic host-rocks, dark margins deficient in felsic minerals often surround these pegmatites. They are usually composed of sodic plagioclase felspar, with lesser amounts of potash felspar, quartz and the ferro-magnesian minerals biotite or hornblende. The *permeation* pegmatites are limited in size and distribution and are usually found in coarse-grained psammitic rocks only. Their grain varies from medium to coarse, they often have porphyritic texture and occur in lenses up to about 20 ft. long. These pegmatites are composed mainly of potash felspar, a little quartz and only rarely dark minerals. When mica is present it usually occurs as haphazardly-arranged flakes concentrated along the margins. The *intrusive* pegmatites are characterized by sharp contacts and roughly parallel-sided sheet-like form. They are both concordant and cross-cutting. In the area mapped they vary from small bodies less than 10 ft. long to larger veins up to 20 ft. wide. The intrusive pegmatites are usually composed of potash felspar, myrmekite and quartz; where mineralized they contain muscovite, biotite, magnetite and rarely garnet. Complex pegmatites, like those recorded by Baker (1963, p. 35) in the Baragoi area, also occur in the South Horr valley. Typically, they consist of a core of white milky quartz enclosed by coarse-grained microcline or, less commonly, sodic plagioclase, followed by fine-grained felspar and quartz with an outer aplitic banded zone. While none of the exposed zoned pegmatites in the area is well mineralized, it was noted that the more important concentrations of valuable minerals are found in the coarse-grained zones immediately surrounding the quartz cores. The mineralization consists mainly of muscovite, the iron ores magnetite and specularite, garnet and localized occurrences of biotite, hornblende and graphite. The largest books of muscovite found were less than 10 in. across and the mica is striated, spotted and of generally poor quality. In the north-eastern part of the Mara range, yellow staining in a pegmatite which resembled the yellow uranium oxides proved to be iron hydroxide. Two small crystals of the radio-active mineral samarskite were found about three miles north-east of South Horr and it is presumed that they were originally contained in a pegmatite.

There is a close relationship between the mineralizations of pegmatites and characteristic minerals of their country rocks, indicating that the pegmatites are derived, in part at least, from the metamorphic succession. As previously stated, in localized areas metamorphism and allied processes have caused the formation of mobile bodies. The writer considers the pegmatites to be felsic fractions of completely mobilized rocks and introduced into the upper, less affected country rock as the veins, stringers or other bodies that are now seen.

4. Quartz Veins

Quartz veins occur in most parts of the area occupied by Basement System rocks. They vary from narrow veins less than 1 in. thick to large lenses up to 20 ft. across. Some of the quartz cores of zoned pegmatites, being more resistant to erosion than the surrounding layers, project from the soil overburden, giving the erroneous impression that they are simple quartz veins. While by no means a fixed rule, the pegmatite cores are generally milky white, the quartz of veins tending to be more transparent.

None of the quartz veins examined contained mineralization of note—magnetite, specularite and ilmenite occur in some. In one of the veins small cavities, possibly originally occupied by mica or iron ore, have been infilled with chalcedony.

5. Tertiary Sediments

Coarse gritty sediments, overlying the Basement System rocks, are patchily exposed underlying some of the oldest lavas in the area. At a number of localities there are no sediments, the lavas directly overlying the older crystalline rocks. Judging from the irregularity of their distribution and their variability of thickness, it seems likely that the sediments are valley infillings. No accurate measurements of the exposed sediments were possible but it is unlikely that they exceed a thickness of 100 ft.

The sediments vary from medium- to fine-grained reddish sandy beds, alternating with well consolidated coarse, gritty conglomeratic buff to pale grey beds containing angular to rounded quartz and felspar pebbles or, less commonly, gneiss pebbles. The more coarsely conglomeratic horizons are usually found at the base, but the upper layers do sometimes contain ill-sorted conglomerates. In the Maralal area, Shackleton (1946, p. 27) mapped sediments in similar situations. He described the most characteristic type as coarse light-coloured grit with well-rounded pebbles of quartz, a description which suits the sediments of the present area. From the contained fossils *Deinotherium hobleyi* and *Mastodon* spp., Shackleton was able to date his sediments as Miocene. No fossils were discovered in the sediments exposed in the present area, but there can be no doubt that they are the equivalents of the Miocene sediments of the Baragoi and Maralal areas. Their age and their mode of occurrence suggests correlation with the Turkana Grits (Dixey, 1948, p. 20) of north-western Kenya.

6. Tertiary Volcanic Rocks

(1) Fine-grained Basalts and Pyroclastic Rocks

The oldest exposed lavas in the area outcrop in the deep gorge cut by the Losergoi river, which flows from the Tum area on the western slopes of Nyiru in a general westerly direction to the Suguta valley. These lavas were deposited on a valley floor which subsided from time to time so that the oldest volcanic rocks, covered by later lavas, probably occur closer to the centre of the Suguta valley. The gorge is not sufficiently deep to expose the junction of the lowest lavas and the underlying Precambrian rocks. Owing to successive subsidences and rift faulting, the early volcanics are tilted at anything up to 20 degrees in a westerly direction, or rarely in an easterly direction. The fault-blocks, however, are normally tilted a few degrees only.

The oldest lavas exposed are fine-grained basalts intercalated with ashes, tuffs and agglomerates. The individual lava-flows are rarely thicker than 200 ft. and tend to thin out, wedge-fashion, to the east and north. The early lava extrusions formed a series of wedge-shaped lavas and pyroclastic rocks successively overlapping, to the extent that some of the youngest lavas of this series directly overlie the Precambrian gneisses higher up the valley. The oldest lavas vary from pale grey slate-like, highly fissile types to darker greenish grey, slightly coarser, porphyritic types. Amygdaloidal and coarsely porphyritic types are absent. Specimen 19/105 from the lower reaches of the Losergoi valley is a particularly fissile example. It has microgranular texture with sparse phenocrysts of felspar and is composed of plagioclase, augite, somewhat altered olivine and iron ore. A darker, more porphyritic lava, specimen 19/107, from the same locality, consists of a finer-grained ground-mass with small phenocrysts of augite, iron ore and plagioclase. The intercalated pyroclastic rocks are fine-grained brick-red to pale buff ashes, greyish ashes and brownish to grey agglomerate. The agglomerate includes fragments of fine-grained lava and tuff. The pyroclastic rocks, like the lavas, are generally wedge-shaped, few layers being traceable from one valley to the next. The thickest layer of red ash was found to be over 50 ft. thick.

The upper part of this group of volcanic rocks includes flows of slightly more porphyritic lavas, the most characteristic being a porphyritic augite basalt that directly overlies Basement System gneisses in the Radj valley, towards the southern boundary of the area. The augite basalt is in turn unconformably overlain by coarse-textured basalts of a different group. The augite basalt is a medium-grained bluish grey lava with conspicuous dark phenocrysts of augite scattered through it. Amygdales are rare but, when present, are invariably infilled with zeolites and calcite. A thin section of specimen 19/169 from the Radj valley shows that the rock consists of a medium- to fine-grained ground-mass of iron ore, pyroxene and plagioclase, with medium-sized phenocrysts of titanaugite and iron ore. The augite occurs as euhedral to subhedral pale mauve prisms, some of which exhibit faint zoning. Iron ore is present as subhedral octahedra or in complex skeletal structures.

The abundance of intercalated tuffs and ashes, particularly the brick-coloured types, the fact that augite is the main ferromagnesian constituent, and the stratigraphic position of these volcanic rocks, indicates a relationship with Shackleton's Samburu Series (1946, p. 29) and Baker's equivalent porphyritic basalts and tuffs (1963, p. 41). Owing to the variability of the Samburu Series, detailed correlation with the lowest group of Tertiary volcanic rocks in the present area is not possible.

The Rumuruti Phonolites described by Shackleton (1946, p. 31) as overlying the Samburu Series were not recognized in the present area. Baker states that they thin to the north and it must be considered highly unlikely that they persist as far as the limits of the present area.

(2) Porphyritic Basalts

The oldest lavas are unconformably overlain by another series of basalts characterized by the presence of highly porphyritic flows. They form a considerable thickness in the total volcanic succession and occupy an extensive area. The best localities for seeing members of this group are in the upper valleys of the east-west flowing rivers that discharge into the Suguta valley. In some valleys these basalts approach 1,000 ft. in thickness and it is safe to assume that their maximum thickness is in excess of this figure. The lavas thin out in a north-easterly direction and at the Iyuk plateau they are less than 500 ft. thick.

The succession is almost devoid of pyroclastic rocks. The few narrow layers of tuffs and ashes which do occur are slightly more abundant towards the north-eastern part of the area occupied by the lavas. The ashes and tuffs are pale grey to whitish or pale brown, and usually show crude bedding. One of the ash layers contains a considerable amount of pumice fragments and lapilli. The lavas are coarsely porphyritic brownish to grey basalts, medium-grained greyish to purple amygdaloidal basalts, and fine-grained bluish grey basalts. The porphyritic basalts are highly distinctive. They occur both as vesicular, almost scoriaceous lavas with abundant slender prisms of labradorite, and smaller greenish olivine phenocrysts, and as coarser-grained compact lavas with stout prisms of calcic labradorite, accounting for up to 20 per cent of the total rock composition. Specimen 19/116 from the Losergoi valley, about five miles south-west of Tum, an example of the second kind of porphyritic lava, has a fine-grained ground-mass of granular specks of iron ore, small prisms of plagioclase, pale greenish augite and olivine, supporting large prisms of labradorite up to ½ in. long and smaller phenocrysts of olivine, partly or wholly replaced by iddingsite. Specimen 19/112 from the same locality is an example of the non-porphyritic basalts. It occurs as a fissile layer with well-defined partings. In the hand-specimen it is a dull bluish black rock with an even-grained texture and with a few small felspar and iddingsite phenocrysts. In thin section it is seen to have a ground-mass with basaltic texture of medium-grain size, and to be composed of labradorite, titanaugite, some of which has been replaced by chlorite, and iron ore. The labradorite and pyroxene also form microphenocrysts, but the most prominent microphenocrysts are olivine patchily replaced by iddingsite. Specimen 19/142 from about three miles north-west of Tum is a coarse-grained mauve-coloured amygdaloidal basalt. The vesicles are seldom completely infilled, but are usually lined with calcite and zeolites. Texturally this lava is approximately intermediate to the other basalts of this group, being medium-grained and including a moderate amount of phenocrysts. It is distinguished from them by more abundant augite and altered olivine, particularly in phenocryst form.

The lavas forming the Loriyu plateau on the western side of Lake Rudolf are probably contemporaneous with the porphyritic basalts on the eastern side of the Suguta valley. They directly overlie the Basement System rocks in that part of the area, forming a lava cap several hundred feet thick. Specimen 19/157, a porphyritic basalt which forms a prominent flow in the succession on the plateau, is intercalated with finer-grained less porphyritic basalts. In thin section it is seen to be composed of a fine granular ground-mass with olivine, augite and labradorite phenocrysts. The augite phenocrysts are somewhat rounded, probably as a result of late resorption. The upper lavas of the plateau are similar to the non-porphyritic basalts of other parts of the area.

(3) Acid Volcanic Rocks of Iyuk

The Iyuk plateau consists of a thickness of about 600 ft. of volcanic rocks of acid composition, capping about 400 ft. of the porphyritic basalts, which overlie a foundation of Basement System gneisses. The plateau block shows evidence of two phases of tilting. The early movement tilted the Basement System rocks and basalts before extrusion of the acid volcanic rocks. As far as can be estimated this tilt was about 8 degrees to the west. Later movement affected the entire Iyuk volcanic succession, tilting the acid lavas to west-south-west at about 10 degrees, the total tilt of the underlying lavas being nearly 18 degrees in an approximately westerly direction. The volcanic rocks heaped up to form the higher part of the Iyuk plateau probably originated from a nearby source, as the layers did not spread out like the basalts.

The acid volcanic rocks are easily distinguished from the basalts as they are lighter coloured and obviously free of olivine or replacive iddingsite, which characterizes most of the basic lavas in the area. The lowermost flows consist of buff to greyish fine-grained porphyritic rhyolite. Specimen 19/133 from the south-eastern part of Iyuk is an almost felsic-textured rock, which is in part spherulitic. In thin section it is seen to be composed of a fine-grained ground-mass of felspar, quartz, iron ore and altered ferromagnesian minerals with potash felspar phenocrysts. Overlying this lava is a layer of coarse greenish grey agglomerate, of which the matrix is represented by specimen 19/134, in which angular fragments and idiomorphic prisms of potash felspar, some quartz grains and rare grains of ferromagnesian minerals are contained in a fine-grained matrix of felspar, quartz, ferromagnesian minerals and oxidized iron ore. The uppermost lava is pale buff to pale greyish, fine-grained and somewhat fissile. Specimen 19/135 is a lava composed of a fine-grained ground-mass of felspar, quartz and altered amphibole, with phenocrysts of orthoclase. It exhibits a fluidal texture in the hand specimen.

(4) Tirr Tirr Series

Lavas of the Tirr Tirr Series (*see* Baker, 1963 p. 45) directly overlie the older basalts in the western part of the Emuru Akirim plateau. Baker considered these rocks to be of Pleistocene age, but the writer believes that the series was affected by late Pliocene tilting. The tectonic movements responsible for the tilting, which was also recognized by Baker in the Baragoi area to the south, affected the older fine-grained and porphyritic basalts, the Iyuk volcanic rocks and the Tirr Tirr Series, but did not affect the Lower Pleistocene sediments exposed near Murniau cone. Between Radj and the Suguta valley the series is tilted at between 5 and 7 degrees to the west. On the Emuru Akirim plateau, however, it is not noticeably tilted, but the underlying fine-grained and porphyritic basalts, which are steeply tilted in the Radj valley, show progressively less tilt, while in the Losergoi valley near Tum the porphyritic basalt flows are horizontal. It must be concluded, therefore, that most of the tectonic activity was centred near the Suguta valley trough, the outer margins of the lava-fields remaining fairly stable.

The uppermost lavas of the Tirr Tirr Series overlap the wedge-shaped older lava-flows, to directly overlie the Basement System gneisses west of Losom. The series, like the underlying basalts, consists of a succession of wedge-shaped lava-flows that thin out rapidly to the north and east. The lavas appear to have issued from fractures in the region of the Suguta valley, flowing out on a faulted, tilted surface composed of the older basalts. The lowest member of the Tirr Tirr Series in the present area is a fine-grained bluish grey trachyte that is exposed along the eastern shoulders of the Suguta valley and in some of the nearby deeply cut valleys. It also forms Emuru Gumol, the isolated volcanic plug in the Suguta valley. Specimen 19/108 from Emuru Gumol is a fine-grained, porphyritic, trachytic-textured lava composed of a ground-mass of orthoclase felspar, biotite, iron ore both as octahedra and as irregular granules, augite and calcite with phenocrysts of felspar, augite and magnetite. The biotite occurs as flakes up to 1 mm. in size, the biggest felspar laths attaining a length of slightly less than 1 mm. The biotite is characterized by pleochroism from pale greenish yellow to chestnut. The calcite appears to be a late infilling and frequently occurs in association with biotite. The rock includes abundant reddish brown prism-like grains which appear to be the alteration products of a ferromagnesian mineral.

The upper lavas are remarkably constant throughout their extent. They vary from medium-grained to coarse-grained bluish to greyish olivine basalts, in which the olivine is more or less replaced by iddingsite or by iddingsite and bowlingite. Specimen 19/170 from the south-eastern margin of the Emuru Akirim plateau is a coarse-grained basaltic textured lava consisting of a ground-mass of augite, labradorite, olivine, iron ore and calcite, with phenocrysts of labradorite and olivine. Specimen 19/100 from the Radj hill area is generally similar in texture and composition but is finer-grained and the olivine much less altered.

7. Pleistocene Volcanic Rocks and Sediments

The sequence of events in Pleistocene times is not absolutely clear—there is every likelihood that some of the events took place simultaneously, and others, notably the deposition of sediments, continued over relatively long periods during which phases of volcanism commenced and ended. The writer concludes that the history of the area during the Pleistocene is characterized by almost continuous slight tectonic movement, volcanism and sedimentation, with peak phases of fracturing and lava outpourings, not necessarily coincidental with sedimentary beach-level deposition. The following is considered to be the sequence during the Pleistocene period:—

5. Upper Pleistocene Lacustrine sediments:
    - (*c*) Saline deposits in the Suguta valley.
    - (*b*) Suguta valley deposits.
    - (*a*) Lake Rudolf sediments at 220-ft. beach level.
4. Volcanic rocks of the Barrier:
    - (*d*) Olivine basalts.
    - (*c*) Intermediate volcanic rocks.
    - (*b*) Ash cones.
    - (*a*) Agglomerates.
3. Younger lavas of Mount Kulal.
2. Lavas and sediments of the Serima valley.
1. Lacustrine sediments near Murniau.

(1) Lacustrine Sediments near Murniau

Immediately east of the ash cone Murniau, to the east of the Suguta salt lake, fossiliferous sediments are exposed in a fault-scarp caused by a fault with westerly downthrow of about 160 ft. That part of the area is intensely faulted, but few of the fault-scarps exceed a height of more than 30 ft., so that similar sediments are not exposed in any other scarp. The sediments are slightly coarser-grained at the top, fine-grained at the bottom and are yellowish buff or greyish. They are tilted in a south-westerly direction at about 2 degrees. The exposed section is as follows:—

		Feet
Upper Pleistocene to Recent	White diatomaceous clays with abundant *Melanoides tuberculata.*	3
Middle (?) Pleistocene	Brownish grey massive agglomerate	68
Lower to Middle Pleistocene	Pale yellowish to light grey, medium to coarse-grained gravels with abundant fragments of *Melanoides tuberculata* and *Corbiculina* ..	7
	Buff to greyish fine-grained calcareous silts and clays with abundant mollusc fragments (*Iridina* (?) and rare *Melanoides tuberculata*)	80

The fossils found in the lower beds are recrystallized and appear to be older than any other fossils collected by the writer. The fact that the sediments are overlain by the oldest volcanic material of the Barrier, and cut by faulting which is believed to have occurred at the end of the Middle Pleistocene, indicates that they are at least of Middle Pleistocene age. At present the sediments lie nearly 500 ft. above Lake Rudolf, but owing to the intensely faulted nature of the area in which they occur, comparison of their altitude and the present Lake Rudolf level is of little value.

It would seem likely that since the beds bear little resemblance to the sediments at the "300-ft. level" at Serima they belong to the "330-ft. level" described by Fuchs (1939, p. 251) or, less probably, to an older Lower Pleistocene sedimentary phase like that described by Fuchs as occurring at Gaza on the central eastern shores of Lake Rudolf, or like that in the Omo delta area at the northern end of the lake (Arambourg, 1943, p. 186).

(2) Lavas and Sediments of the Serima Valley

The Serima river-course debouches on the eastern shores of Lake Rudolf just south of the northern limit of the present area. The deep gorge cut by the river affords a good exposure of the local volcanic rocks and in the lower reaches includes a thin sedimentary band. Owing to adverse weather conditions during the writer's visit to that region, the gorge received cursory attention only. V. E. Fuchs examined the gorge and immediate surroundings in greater detail and his observations are incorporated in the description that follows.

The oldest exposed Pleistocene lavas are medium-grained greyish olivine basalts in which iddingsite has partly replaced the olivine. Judging from the age of the sediments included in the sequence the lowermost lavas are probably of lower Pleistocene age. The sediments near the mouth of the gorge described by Fuchs (1939, p. 256) outcrop at several localities to the north and south of Serima but are mostly obscured by later volcanic rocks and hill-wash. The bed varies in thickness from about 8 ft. to about 3 ft.

and consists of a rock with a calcareous, pale buff to greyish matrix containing ash and lava fragments. Fossils are sparse, but where present are concentrated in the upper and lower parts of the bed and in slightly fossiliferous lenses scattered about the horizon. Identifications quoted by Fuchs were as follows:—

Remains of fish skeletons	*Lates* sp.
	Clarias sp.
Mollusca	*Melania tuberculata.*
	Viviparus sp.
	Unio sp.
	Aetheria elliptica.

Fuchs considered the bed to be Middle Pleistocene, and equivalent to the deposits of the 300-ft. beach at the type locality on the east side of the Losidok range on the western side of Lake Rudolf.

Preceding the final phase of volcanic activity in the vicinity of the Serima valley, a number of scoriaceous cones were built up, most of them aligned along a roughly north-south line that probably indicates a fracture now covered by the youngest lavas.

The youngest lavas in that part of the area are olivine basalts, which flowed over a slightly tilted surface of the earlier Pleistocene basalts to form extensive bare lava-fields, through which the scoriaceous cones project. Specimen 19/87 from the upper lavas is representative of all the Serima olivine basalts. It is a dark grey medium-grained porphyritic basalt with a coarse-grained ground-mass of plagioclase (labradorite), augite, olivine pseudomorphs, iron ore and secondary calcite, containing phenocrysts of labradorite, olivine largely replaced by iddingsite, and augite.

(3) Younger Lavas of Mount Kulal

In the north-eastern corner of the area, a low plateau is formed by lavas which flowed from volcanoes on the southern slopes of Kulal, a volcanic pile a few miles north of the present area. Fuchs (1939, p. 246) considered that the oldest lavas of Kulal date back to Miocene times. The oldest lava-flows do not enter the area mapped, the lavas present being perhaps the result of the more recent phases of Kulal volcanism, during the Middle or Upper Pleistocene. The most recent flows were extruded from scoriaceous cones, which built up on the main lava-flows.

Specimen 19/162 from the main lavas in the north-eastern corner of the area is a medium- to coarse-grained amygdaloidal basalt. The amygdales are seldom more than ¼ in. in diameter and are usually infilled with calcite. In thin section the lava is seen to have an ophitic texture and to be composed of mauve to neutral-coloured titaniferous augite, labradorite, abundant olivine mostly rimmed with replacive iddingsite, iron ore and secondary calcite. The youngest flows are invariably composed of coarsely porphyritic basalt such as specimen 19/163, from the westerly of two younger flows, which consists of a fine ground-mass of plagioclase, pyroxene, iron ore and only rare olivine, with abundant stout idiomorphic phenocrysts of labradorite.

(4) Volcanic Rocks of the Barrier

The Barrier is a composite volcanic ridge that cuts off the Suguta valley from Lake Rudolf. The emplacement of the volcanic rocks took place in at least four phases including a recent rejuvenation, which resulted in a number of lava outpourings, the youngest being extruded at the close of the last century. The volcanoes responsible for the recent activity still show signs of life in the form of gaseous fumaroles and solfatara, and it is possible that with further fracturing or crustal movements of sufficient displacement there will be a renewal of volcanic activity.

The formation of the Barrier is believed to have begun during the upper Middle Pleistocene period. Evidence for the dating is provided by the presence of beach deposits 220 ft. above the level of Lake Rudolf on the northern slopes of the Barrier, and by a well-defined beach platform on the slopes of the ash cone Wargess (Abili Agituk). The absence of older sediments or beach platforms at the 300-ft. or 330-ft. levels, such as are described by Fuchs (1939, p. 251) in other localities of the Lake Rudolf basin, indicates that the Barrier was emplaced between the Middle Pleistocene 300-ft. and 330-ft. depositions and the Upper Pleistocene 220-ft. sedimentation.

(*a*) *Agglomerates*

The earliest apparent volcanic phase at the Barrier was the extrusion of a thick layer of agglomerates which built up a ridge that sealed off the Suguta valley from the Lake Rudolf, as is indicated by the fact that none of the Barrier lavas examined show evidence of having flowed into water or over a moist surface. The presence of abundant fragments of lava in the agglomerate suggests, however, that it followed the pouring out of lavas at that locality.

The agglomerates are brownish to grey, usually compact and coarse-grained, but on the eastern slopes of the Barrier they tend to be more ashy and finer-grained. In the vicinity of the ash cone Murniau the agglomerate forms bare rock surfaces often devoid of vegetation. Specimen 19/123 from near Murniau has a fine dark brown ground-mass with inclusions of fine-grained lava and idiomorphic crystals of orthoclase. Fragments of volcanic glass and obsidian are found in most exposures but are rare in the agglomerates on the eastern slopes of the Barrier. Specimen 19/173 from the eastern slopes of the Barrier consists of orthoclase crystals and spherulitic zeolitic material.

(*b*) *Ash Cones*

Several ash cones protrude through younger lavas to form prominent physical features on the Barrier. They are yellow to buff-coloured, contrasting strongly with the chocolate brown, grey or black lavas.

The two most important cones of this phase are Murniau on the southern slopes of the Barrier, and Wargess, which overlooks the southern shores of Lake Rudolf. Other, less important cones of this phase are scattered about the north-west, southern and south-western slopes of the Barrier. The largest and best preserved ash cone, Naboiyoton, despite its similarity of appearance and composition, is, however, obviously younger than the other cones. The early ash cones are extensively faulted, Murniau and Wargess being cut by at least four and six faults respectively. Owing to their incoherence the cones are much eroded and have prominent gullies down their sides, and alluvial fans around their bases. The ashes that form the cones are usually fine-grained but sometimes contain scoriaceous material, pumice and rarely fragments of lava. Naboiyoton is unfaulted and well preserved, the ash walls being only slightly corrugated by erosion. It is an almost perfectly symmetrical cone rising over 600 ft. above lake-level, and topped by a large shallow crater. Wargess has a well-defined beach platform at about 220 ft. above Lake Rudolf. The absence of an equivalent bevel on Naboiyoton suggests that it was built up during the Upper Pleistocene.

(*c*) *Intermediate Volcanic Rocks of the Barrier*

The central part of the Barrier was built up by a series of outpourings that commenced with the extrusion of phonolites and accompanying pyroclastics. The closing stages of this phase are characterized by more porphyritic flows of soda trachytes, and the extrusion of extensive beds of pumice. During Recent times, renewal of volcanic activity at this locality caused the outpouring of two trachytic-textured lava-flows from the northern rim of Nagaramasainia caldera, but as these flows are so obviously younger than the other intermediate volcanics they are described under the heading of Recent volcanics.

Nagaramasainia caldera is a collapse structure and is believed to have formed during the Middle Pleistocene near the close of the outpourings of trachyte and pumice, when the more viscous and more porphyritic lavas were extruded. A commonly accepted theory of caldera formation is that, with continued volcanism from a centre and the building up of parasitic cones on the slopes of the main crater, the central part of the cone becomes inadequately supported and finally collapses into the volcano.

Campbell Smith (in Champion, 1937, p. 170) described the intermediate lavas of the Barrier as phonolitic trachytes. The writer has previously expressed the opinion (Thompson and Dodson, 1963, p. 26) that the term "phonolitic trachyte" is misleading, preferring "soda trachyte" when a trachyte contains soda-rich minerals, but no recognizable felspathoid mineral or felspathoidal mineral that can be deduced by chemical analysis.

The *phonolite* forms a fan-shaped lava-flow extruded southwards from the caldera. Specimen 19/154 from the south-western caldera rim is a fine-grained compact dark grey porphyritic rock. The phenocrysts consist of dirty white porcellaneous prisms of anorthoclase up to ¼ in. long, and small greenish waxy looking analcite grains about 1/10 in. across. The rock is not vesicular but irregular cavities are partly infilled with zeolites or calcite. In thin section the rock is seen to consist of a fine-grained yellowish hemi-crystalline ground-mass with small crystals of anorthoclase, orthoclase, iron-ore and aeginine-augite. Some of the larger anorthoclase crystals show marginal resorption. The analcite occurs in patches, usually with turbid centres. The presence of analcite as an essential constituent in this rock qualifies it as an analcite phonolite.

The *soda-trachytes* were extruded in two phases. The older trachytes are fine-grained grey rocks with rare phenocrysts of sodic orthoclase or anorthoclase. Specimen 19/152 from the north-western slopes of the Barrier is a fine-grained porous trachytic-textured rock composed of anorthoclase, aegirine-augite, the sodic amphibole kataphorite, iron-ore and secondary calcite. The aegirine-augite occurs in skeletal crystals up to 2 mm. in length, and the kataphorite is pleochroic X = mauve to brownish, Y = dull green, Z = greenish blue. The younger of the trachytes forms a prominent flow on the south-eastern slopes of the caldera, overlying the analcite phonolite. Specimen 19/155, an example of this trachyte, is a grey, coarse-grained porphyritic rock. In thin section it is seen to have ophitic texture and to be composed of green aegirine-augite, aegirine and cossyrite in ophitic patches, sodic orthoclase and analcite. The pyroxenes sometimes occur as marginal concentrations around patches of the analcite. The cossyrite is pleochroic as follows: X = clear mauve-brown, Y = dark mauve-brown, Z = very dark brown. Towards the close of this phase pumiceous ash was ejected, covering areas on the north and north-western sides of the caldera. The ash is pale greyish to buff and consists of pumiceous fragments not larger than 1 in. across. The porphyritic trachytes may be younger than the pumice.

(*d*) *Olivine Basalts and Basanites*

Following the phonolite and trachyte outpourings, which were confined to the upper part of the Barrier, numerous olivine-bearing basaltic lavas flowed out along the north-western and eastern slopes of the Barrier. The north-eastern shoulders of the Suguta valley are composed of similar lavas. Some of the lavas are classified as basanites as they contain small quantities of felspathoid mineral, believed to be nepheline. The majority of the lava-flows, however, are basalts in which no felspathoid mineral is recognizable either by direct observation or following staining. Champion (1937, p. 171) described a sample of nepheline basanite from the Neangoil river-course on the south-western shores of Lake Rudolf. Campbell Smith, who described Champion's rock specimens in the light of chemical analysis, later reclassified this rock as an olivine basalt with a small amount of interstitial nepheline (Campbell Smith, 1938, p. 528). The following is the chemical analysis and norm quoted by Campbell Smith:—

	%		%
SiO_2	45·27		
TiO_2	2·40		
Al_2O_3	13·91	or	5·72
Fe_2O_3	3·41	ab	11·84
FeO	7·13	an	25·47
MnO	0·15	ne	3·29
MgO	10·76	hl	0·03
CaO	12·68	z	0·05
NaO	2·14	di	28·42
K_2O	0·97	ol	13·92
H_2O+	1·30	mt	4·95
H_2O-	0·13	il	4·6
ZrO_2	0·03	ap	0·6
$P_2'O_5$	0·26	pr	0·35
Cl′	0·02		
S″	0·16		
BaO	0·03		
SrO	0·02		
	100·77		
Deduct for S″, Cl′	0·09		
	100·68		

Anal: M. H. Hey.

No specimens were collected during the present survey from the lava in the river-course, but specimen 19/156 from the eastern extension of the same lava-flow west of Wargess agrees closely with Champion's description. It is a porphyritic rock with a fine-grained gound-mass of augite, idiomorphic magnetite, olivine and laths of labradorite. Champion stated that small quantities of interstitial material, unrecognizable under the microscope, were proved in his specimen to be nepheline by microchemical tests. The writer attempted to detect felspathoid minerals by staining with methylene blue, following treatment with phosphoric acid, and though the results were not entirely conclusive they suggested the presence of felspathoid minerals. The rare phenocrysts of specimen 19/156 are olivine, labradorite and dull green augite. Specimens 19/121 from the south-eastern slopes of the Barrier and 19/147 from the highly faulted Latarr area and a number of other samples from the olivine-bearing lavas are generally similar but are usually more porphyritic and finer-grained. The phenocrysts are labradorite, olivine and neutral-coloured augite, the last being up to ½ in. long. Staining tests carried out on the two samples mentioned showed fine aggregates of felspathoid mineral in the ground-mass of specimen 19/147 only.

These olivine basalts were the last lavas extruded during the Pleistocene period. At the close of the Middle Pleistocene, complex faulting cut the basalts at Latarr, at the north-eastern shoulders of Suguta, and in the Neangoil valley. During the Upper Pleistocene the area was relatively stable, when it was characterized by lacustrine sedimentation. The final phase of volcanism on the Barrier took place in recent times.

(5) Upper Pleistocene Lacustrine Sediments

Following the volcanic phase that led to the building of the Barrier there was a period of quiescence, during which the lake-level rose to a maximum height of just over 220 ft. above the present level. It seems likely that the emplacement of the Barrier contributed to the rise of lake-level that led to deposition of the "220-ft." sediments.

Following the separation from Suguta, the reduced lake continued to receive water from the Omo river at the northern end and the Turkwell river in the west. It is unlikely that the rivers discharging into Suguta contributed much to the original greater Lake Rudolf and it is likely that the Suguta valley extension was shallow, offering a greater surface area for evaporation and offsetting the amount of inflowing water in other parts of the lake. With minor fluctuations the lake-level has steadily dropped since the Upper Pleistocene to the present. The Suguta valley is today a trough-shaped desert, with a small salt lake at is northern end. During rainy seasons the valley is sometimes flooded for a week or two, so it is likely that during the Gamblian pluvial period it was filled with water, although probably not so high as the Lake Rudolf level. As previously stated (p. 8), the writer found no evidence in support of Champion's suggestion (1935, p. 327) that the lake water might flow underground into Lake Rudolf. Since the Upper Pleistocene the Suguta lake has progressively retreated to its present position. As a result of the evaporation, a small quantity of salt has been deposited.

(a) *Lake Rudolf Sediments at the* 220-*ft. Level*

The severity of local winds and the recent volcanism have destroyed most of the original lacustrine deposits around the southern shores of Lake Rudolf. At only two localities were deposits discovered at the 220-ft. level in which the original bedding remains intact. Several other patches of fossiliferous sedimentary material, such as in the Neangoil valley, have suffered erosion and are largely reconstituted.

The best locality for the 220-ft. level sediments is at Nakwamosin, on the south-eastern shores of Lake Rudolf (*see* Plates V and VIII). About 20 ft. of sediments are exposed in a small depression where they have been protected from the prevailing winds. The exposed section is as follows: —

	Thickness	
	Feet	*Inches*
Patchy overburden of ashy soil		
5. White diatomite	5–11	
4. Grey diatomaceous layer with dark coarser-grained sandy lenses along the upper and lower edges. Fossil fish vertebra and dorsal spines: *Lates niloticus* (Nile perch). *Clarious* sp. (cat-fish).	1½–2½	
3. Shelly limestone, composed of shells cemented in a greyish calcareous matrix. .. .. Fossils:— common: *Melanoides tuberculata.* *Corbicula africana.* rare: *Corbicula consobrina* (?) *Aetheria elliptica.* *Mutela nilotica.* *Mutela iridina* (?) *Mutela truncata* (*sensu* Arambourg, probably not of Von Martens and possibly new).	1½–2½	
2. Whitish conglomeratic bed composed of lava pebbles cemented in a calcareous matrix. Fossils:— *Melanoides tuberculata.* *Corbicula africana.*		0–10
1. Pale grey ashy sediment. Fossils:— *Melanoides tuberculata.* *Corbicula africana.* *Aetheria elliptica.*	>4	

No sediments deposited after the 220-ft. level deposits are preserved in the present area. They have been eroded and either reconstituted or removed by wind-action. The youngest deposits around the lake shore are shingle and sandy beaches and pale yellow to buff-coloured clay deposits. The latter contain sparsely distributed present-day shell, fish and reptile remains.

(b) Suguta Valley Deposits

The best exposures of lacustrine sediments in the Suguta valley region occur in the lower reaches of the Losergoi valley (*see* Plate VI, Fig. 2). The upper beds of these sediments are generally missing or have been reworked by wind-action. Much of the dune material in that area is derived from them. The most easterly of the Losergoi valley sediments are mainly of deltaic origin, consisting of ill-sorted conglomeratic washes. The sediments at the mouth of this valley, however, include diatomaceous clays with very sparse megascopic fossils. Although some of these sediments occur at nearly 300 ft. above the present floor of the Suguta valley, there is little doubt that they were deposited after the emplacement of the Barrier as there are slight recognizable traces of equivalent shelves on the south-western slopes of the Barrier, where the older volcanics are not covered by recent lava-flows. The present floor of the Suguta valley cannot be accepted as a base from which to compare the levels of sediments flanking the valley with those of Lake Rudolf. The valley represents the original greater Lake Rudolf floor, and is therefore not related to the 1934 lake-level accepted by Fuchs and on which the levels of earlier lake sediments were based.

The exposed section of the most easterly sediments in the Losergoi valley is as follows: —

	Approximate Thickness
	feet
9. Recent aeolian sands	19
8. Pale grey conglomerates containing lava boulders and with calcareous matrix	10
7. Dirty-white diatomaceous band with conglomeratic partings	6
6. Reddish brown conglomerate with coarse, sandy matrix and fairly small pebbles	9
5. Finely bedded reddish to buff slightly diatomaceous band	7
4. Reddish conglomerate with coarse matrix	4
3. Diatomaceous bands alternating with fine-grained sandy partings ..	6
2. Dark-grey fine-grained sandy bed	8
1. Well consolidated compact conglomerate	11

Near the mouth of the Losergoi the exposed section is as follows: —

	Thickness
	feet
3. Pale grey to whitish powdery diatomaceous sediments with very rare fossils:— *Melanoides tuberculata.* *Lates niloticus* (vertebrae). Mammal bones	>24
2. Well compacted conglomerate composed of rounded lava boulders in a silt matrix	8
1. Pale buff to grey sandy bed with conglomeratic and silty partings ..	>12

From the composition of these sediments it is apparent that an appreciable proportion of them was laid as deltaic flood depositions, the finer-grained diatomaceous layers representing more stable lacustrine sedimentation.

At several localities, small diatomaceous fossiliferous deposits, believed to be of late Upper Pleistocene to Recent age, have been preserved in shallow depressions or hollows. The largest of these occur in the vicinity of the ash cone Murniau, due east of Suguta lake. Typically, the deposits consist of up to 5 ft. of white chalky diatomaceous clay, crowded with perfectly preserved shells of *Melanoides tuberculata*. They are probably the result of deposition in small lakes that occupied localized depressions during a Recent wet period.

(c) *Evaporite Deposits in the Suguta Valley*

Following the Upper Peistocene pluvial period, which probably corresponded with the Gamblian pluvial period of the Lake Naivasha area (Thompson and Dodson, 1963, p. 43), Suguta lake steadily retreated to its present position at the northern end of the valley (*see* Plate IV, Fig. 2). With increased salinity of the lake-water, evaporites were deposited along the retreating shoreline. The best preserved deposits have been protected by the recent lava which flowed down the southern slopes of the Barrier to the Suguta lake from Lugugugut or Andrew's volcano, covering the lake deposits. The evaporite consists of variable-sized layers of matted fine acicular crystals, contained in a clay about 5 ft. thick.

Analysis of a typical sample of the crystals gave the following results:—

	1.	1a.
	%	%
Na_2CO_3	24·92	24·92
$NaHCO_3$	20·14	20·14
Cl	20	32·95 (NaCl)
SO_3	4·25	7·54 (Na_2SO_4)
Insoluble..	14·64	14·64
		100·19

Analyst: Mrs. R. Inamdar.

1. Analytical results.
1a. Recalculation of the analytical results: Cl calculated to NaCl, and SO_3 to Na_2SO_4.

Microscope examination confirmed the presence of trona. The writer believes that the high percentage of chloride, carbonate and sulphate in the evaporite are a result of the action of chlorine, carbon dioxide and the oxides of sulphur, all of which are gases released during lava extrusions. The gases, combining with water, form hydrochloric, carbonic, sulphurous and sulphuric acids, capable of attacking felspars and felspathoids, particularly the sodic varieties, leading to the formation of soluble soda salts like those deposited in Suguta.

8. Quaternary Deposits

The youngest deposits in the area consist of soils derived from Basement System rocks in the eastern portion of the area, aeolian deposits in the Suguta valley and in a desert a few miles east of the northern end of Suguta, and rare secondary limestone precipitates.

A thick mantle of soil covers an appreciable portion of the area not overlain by lava. The open plains north, east and south of the Nyiru and Mara ranges are covered by buff sandy quartzose soils, almost devoid of humus and leached of most of their original argillaceous material. These soils support a scanty cover of vegetation and are being progressively eroded by winds. In the South Horr valley, permanent water in some of the streams draining Nyiru, and adequate protection from the effects of the east-west prevailing winds, has promoted a much denser covering of vegetation. The valley soils vary from fine-grained greyish alluvium to reddish soils rich in iron oxide. *Dongas* cut by the main river-courses indicate that the soil mantle in some places exceeds a thickness of 50 ft. The plains immediately west of Nyiru are covered by soils derived partly from the Basement System rocks and partly from the oldest lavas in the area. They are reddish brown, and support a fairly evenly distributed grass covering which ends at the edge of the younger lava fields further west. The forested plateau capping Nyiru is covered by dark grey and humus-rich thick residual soils, which support either dense forest or luxuriant grass.

The Suguta valley is almost entirely covered by fine-grained buff to pale grey sands, composed mainly of well-rounded quartz, felspar and iron-ore grains. Wind-blown sands are less obvious in the Suguta valley than in the neighbouring desert as the water-table in the valley is probably less than 20 ft. below the surface, and the water, assisted by the presence of soda salts, provides a certain amount of coherence, which prevents excessive sand movement of the lower layers. The adjacent desert has both sandy deposits, often in the form of dunes (*see* Plate VII, Fig. 2) and pebbly or rocky plains. As previously stated, most of the sandy desert soils appear to be derived from former lake sediments. An overall desert varnish is apparent on all the lava boulders and pebbles, but no faceted ventifacts were discovered.

Kunkar or secondary limestone is rather rare, the best exposures being in the river-courses cut through solid lava. In discussing the drainage in the lava areas (*see* page 9), mention was made of the movement of underground water through joint-planes and other crevices in the lava. The waters from the springs discharging into the river-courses are invariably strongly saline and contain an appreciable amount of calcium derived from the lavas by the decay of calcic plagioclase felspar. Towards the southern end of the Suguta valley, siliceous sinter has been deposited around the Logippi steam-vent.

9. Recent Volcanic Rocks

During the past few hundred years there have been eruptions from three localities on the Barrier. The oldest of the three eruptions consisted of lava outpourings from two fissures along the margin of the northern rim of Nagaramasainia caldera. The two more recent volcanoes, Andrew's or Lugugugut, and Teleki's, were described in an earlier chapter in connexion with their physiographic significance (*see* page 7).

(1) Caldera Trachyte

The lava eruptions on the caldera rim were possibly caused by a slight renewal of subsidence along the northern edge of the caldera. At the bottom of the northern wall there appears to be a small step, which may indicate the extent of a later collapse movement. The lava, a fine-grained sodic trachyte, welled out from two fissures, in a series of extrusions, building up against the caldera wall, and finally flowed out over the northern rim. The lava mounds were rapidly built up as the extruded material was of particularly viscous consistency. The lava is a fine-grained, porous, greenish grey trachytic-textured rock. Specimen 19/153 from the more westerly of the two lava-flows is deceptive in appearance. Owing to its lightness of colour and variable porosity it gives an impression of being weathered. The lavas, however, rest directly on recent soils, reworked pyroclastics and the older lavas, and the flows exhibit all the characteristics of recent extrusion, with well-defined flow-wrinkles and a somewhat oxidized skin. In thin section the rock is seen to be highly vesicular and slightly porphyritic, the ground-mass being composed of prisms of anorthoclase (?), irregular specks of cossyrite and small prisms of aegirine in a base of analcite (?). The rare phenocrysts present are anorthoclase.

There are several weak steam-jets around the south-western edge of the caldera.

(2) Teleki's Volcano

Teleki's volcano has erupted on several occasions within recent times. The lava-flows, of which five are recognizable, spread out to form extensive sheets between the volcano and the southern shores of Lake Rudolf (*see* map at end). A thin discontinuous veneer of oxidization covers the lava of the oldest flows, colouring the rock a dark chocolate brown. The more recent flows are dark grey and still retain the thin wrinkled slag-like skin characteristic of very recent lava-flows (*see* Plate III). Between the most recent outpourings and the earlier eruptions, the volcano extruded a carpet of pitch black, dull scoriae. They were thrown as much as a mile from the volcano, covering some of the older lava and building up the present-day cone of Teleki's volcano (*see* Plate II, Fig. 2). The ash scoriae are not more than 1 in. in diameter, and usually less than ½ in.

across. They are made of vitreous material and, as they are highly porous, are only slightly heavier than rhyolitic pumice. The most recent eruption took place in 1895. The lava flowed out from a small vent towards the centre of the cone, curving round from an initial north-westerly to a north-easterly course, to reach a point just south of the ash cone Naboiyoton. The lava has texture varying from vitreous to fine-grained granular aphanitic, and usually contains small phenocrysts of felspar, pyroxene and olivine. The slaggy skin covering the younger flows is nearly always glassy with only rare plagioclase microphenocrysts. A. Rosiwal (1891, p. 509) described a specimen from the Teleki's volcano lava as a vitriophyric basalt. Campbell Smith, in a petrological note in Champion's paper (1937, p. 167) described the lava as a basanitiod, a term used to describe rocks with the composition of basanite but normally with a glassy groundmass and without felspathoids.

Later, on the strength of chemical analysis, Campbell Smith (1938, p. 532) considered "glassy trachybasalt" the most appropriate term for the Teleki's volcano lavas, the holocrystalline equivalent being anorthoclase basalt. His examination of the plagioclase present showed that the felspar microlites varied from labradorite (An_{57}) to bytownite (An_{74}), with an overall tendency towards a composition of about An_{67}. He noted that many of the microphenocrysts have basic cores with round outlines, surrounded by more acid shells. He considered the average composition of the felspar in the lava to be about An_{60} (labradorite).

The following are analyses quoted by Campbell Smith (1938, p. 530) of two samples from flows originating from Teleki's volcano and two from the lava of Andrew's volcano:—

	1	2	3	4
	%	%	%	%
SiO_2	50·58	50·27	46·25	45·41
Al_2O_3	17·20	18·09	13·28	13·06
Fe_2O_3	1·22	1·65	2·55	2·94
FeO	8·49	8·64	7·65	7·64
MgO	4·06	2·18	12·36	12·05
CaO	8·05	8·74	12·62	12·01
Na_2O	4·57	4·32	2·00	2·26
K_2O	1·88	2·04	0·53	0·91
H_2O+	0·00	0·00	0·04	0·74
H_2O-	0·03	0·04	0·02	0·01
TiO_2	2·73	2·88	1·98	2·72
P_2O_5	0·79	0·95	0·14	0·36
SO_3	nil	nil	0·05	—
Cl′	0·08	0·03	0·06	—
S″	0·10	0·11	0·08	0·11
MnO	0·27	0·14	0·12	0·28
BaO	0·10	0·19	0·01	0·11
SrO	0·05	tr	0·04	tr
ZrO_2	0·03	0·02	0·02	0·02
$(CeY)_2O_3$	0·01	tr	0·01	—
	100·24	100·29	99·81	100·63*
Deduct for S″/, Cl′	0·07	0·06	0·05	0·06
	100·17	100·23	99·76	100·57†

Analyst: M. H. Hey.

* 100.72 in original.
† 100.66 in original.

Norms

	1	2	3	4
	%	%	%	%
or	11·1	12·05	3·1	5·55
ab	34·05	34·05	14·15	13·6
an	21·15	23·95	25·85	22·7
ne	2·0	1·2	1·25	3·4
hl	0·12	0·05	0·15	0·0
z	0·05	0·04	0·04	0·04
di	11·5	12·4	28·7	27·6
ol	10·95	7·1	18·4	17·25
mt	1·8	2·4	3·7	4·2
il	5·2	5·5	3·8	5·2
ap	2·0	2·35	0·34	0·9
pr	0·2	0·2	0·16	0·2

1. Basalt (glassy soda trachybasalt) from the most recent flow from Teleki's Volcano. Taken near the northern fissure of the volcano.

2. Basalt (soda trachybasalt) from an earlier flow, taken at a point south-west of the main crater, Teleki's Volcano.

3. Olivine basalt with interstitial nepheline, from the most recent flow of Andrew's Volcano.

4. Lapilli (glassy basalt) from north-west of Andrew's Volcano cone.

Specimen 19/148 is typical of the Teleki's volcano lavas. It is micro-porphyritic, with small phenocrysts of plagioclase set in a matrix of plagioclase and glass with scattered olivine and augite crystals. The glass is crowded with abundant skeletal and dendritic patches of magnetite. The plagioclase is a slightly sodic labradorite (An_{58}). No felspathoid is recognizable but in view of the prevalence of felspathoid minerals in the older olivine basalts of the Barrier and the somewhat sodic nature of the intermediate lavas of the Barrier there is every likelihood that these would have contained small quantities of nepheline if completely crystallized. The writer, therefore, considers the term basanitoid to be appropriate for these rocks.

Early writers described the pungent smell of sulphur gases discharging from vents on Teleki's Volcano. During the writer's visit to the volcano on 17th March, 1957, no escaping gas could be isolated, but the smell of gases, particularly sulphur dioxide, could easily be detected at any point on the cone, especially towards the centre of the crater from which the most recent flow took place. The continuous discharge of sulphurous gases has led to the deposition of sulphur, extending to at least 3 ft. below the surface. The sulphur occurs as fine flour-like yellow powder disseminated through the ash. The intense prevailing winds ensure that the surface is kept free of the fine powdery sulphur. Several vents, scattered about minor craters, discharge a small amount of steam. The steam vents are recognizable by reddish oxidized zones around their openings. A pungent odour of sulphurous gas in the steam indicates admixture of other gases.

As the site of the most recent volcanic activity in Kenya, there has been some speculation as to the probability of a rejuvenation of volcanicism. The writer believes that there are certain factors that might bring about a renewal of activity. The volcano occurs in an intensely faulted zone situated in the Rift Valley, a tectonic trough known to have undergone slight movement within the last 30 years. A slight increase of movement alone might initiate another phase of volcanism.

(3) Andrew's Volcano or Lugugugut

Lugugugut is situated on the southern slopes of the Barrier, nearly opposite Teleki's Volcano on the northern slopes. While the lavas extruded from Teleki's flowed down to the shores of Lake Rudolf, those of Lugugugut flowed down to Suguta lake. The lavas and pyroclastic rocks extruded from the two volcanoes are similar. The Lugugugut eruptions commenced some time after the earliest extrusions from Teleki's, but the volcanism did not continue to the date of the last lava outpouring from Teleki's Volcano in 1895. Lugugugut cone is mainly composed of reddish slaggy scoriaceous material, partly covered by dull black porous scoriae, similar to that found at Teleki's Volcano. The cone includes three medium-sized craters with at least four smaller explosive vents. The area around the cone is strewn with lapilli and volcanic bombs. Champion (1937, p. 168) suggested that they might have been ejected 10 to 15 years before his visit to the volcano. The writer considers that unlikely, as the bombs retain a deceptively unaltered appearance for a number of years and there is no evidence at the volcano to suggest activity within the last 100 years.

In the hand-specimen the lava is a porous dark grey rock, speckled with medium-sized olivine crystals. In thin section (19/124) phenocrysts of augite and olivine are seen to be enclosed in a ground-mass consisting of small felspar laths, augite prisms, magnetite grains and interstitial glass. Unlike the lavas from Teleki's. no plagioclase phenocrysts are present. Campbell Smith, in a petrological note in Champion's paper, referred to this lava as a limburgitic olivine basalt. As an analysis of the rock (*see* p. 41, anal. 3) shows that the basalt is not notably alkaline, the unqualified name olivine basalt is considered more appropriate.

A small amount of steam and sulphurous gases is released from vents scattered about the cone.

VI—METAMORPHISM AND GRANITIZATION

The nature of the Basement System rocks in the area is believed to be the result of intense regional metamorphism accompanied by granitization, a succession of arenaceous, argillaceous and calcareous sediments with intercalated volcanic sheets being converted into psammitic and pelitic gneisses, granites, crystalline limestones, calc-silicate rocks and amphibolites. Metamorphism and granitization in the present area are thought to be processes allied to geosynclinal orogenesis. During the early phases of folding and depression, the raised temperatures and pressures effected recrystallization and the development of mineral assemblages indicative of the metamorphic conditions. It is believed that granitization followed regional metamorphism.

As a whole, the rocks are representative of the amphibolite facies of Eskola, or the almandine amphibolite facies of Fyfe, Turner and Verhoogen (1958, p. 207), indicating high temperatures and pressures. The greater portion of the rocks falls within the sillimanite-almandine subfacies described by Turner and Verhoogen (1951, p. 466). The index mineral sillimanite is present at two horizons and occurs in association with almandine and orthoclase, the typical mineral assemblage of this subfacies. West of Nyiru a succession of hornblende-garnet-rich rocks are probably representative of the hornblende granulite subfacies. The typical mineral assemblages found in these rocks are as follows: —

Hornblende-epidote.

Hornblende-almandine-epidote.

Hornblende-diopside-epidote.

This subfacies represents slightly more deep-seated regional metamorphism, transitional between the almandine, amphibolite and the eclogite facies. The implication of this relationship is that the garnet-hornblendic rocks were of a deeper-seated nature. Their present position, underlying the succession of semi-pelitic and psammitic rocks which form the Nyiru and Mara massifs, is probably the original stratigraphic sequence.

The processes responsible for the conversion of some of the original sediments to the various granitoid rocks in the present area fall into the category of granitization. Granitization requires at least two conditions: a rise of temperature to allow recrystallization, and the introduction of material to promote the growth of certain minerals, i.e. metasomatism. The compressive phase of an orogenic cycle, followed by depression of the roots of the folded sediments into the substratum, ensures sufficiently high temperatures to effect recrystallization. The sequence of metasomatism is believed to be as follows. Initially, acqueous solutions with a high soda content invade the high-grade metamorphosed, folded sediments, inducing the growth of sodic plagioclase. This is followed by the introduction of potash-enriched solutions which induce the growth of potash felspar, and typically the potassic minerals biotite and muscovite, sometimes at the expense of existing ferromagnesian minerals such as hornblende. The limestones undergo metamorphic recrystallization, but remain largely unaffected by metasomatism. Locally, when temperatures are sufficiently high, the metamorphic rocks attain a state of mobility and adopt the characteristics of intrusive granites. These granites often occur in regions of localized strain such as in the axes of folds, where temperatures have been raised by the release of kinetic energy, triggered by strain or direct stress during deformation.

The origin of the granitizing fluids is assumed to result from differentiation of a silica-rich melt produced either by the intrusion at depth of a basic magma into the roots of the folded geosynclinal sediments or by the depression of the sediments into a high-temperature substratum. There is, of course, the likelihood that both processes combined to produce the melt from which the alkali-rich material is derived. In regions occupied by metamorphic rocks, intrusive pegmatites produced by granitization of the former sediments contain mineralization similar to the host rocks. This close relationship is recognizable in most parts of Kenya (Dodson, 1957, p. 90).

VII—STRUCTURAL GEOLOGY

1. Basement System Structures

(1) Major Structures

The Basement System rocks are folded and, along the eastern margin of the area, intensely sheared. Only a few minor faults other than the shearing were recognized. The folds mapped, from west to east, are as follows (*see* Fig. 3):—

(*a*) *Tum Syncline*.—A steep-sided blunt-nosed syncline, whose limbs approach vertical near the granitoid gneiss core south-east of Tum.

(*b*) *The Losom Monocline*.—The gneisses in its eastern flank dip gently away from the Tum syncline in the south; in the north, near Tum, the monocline passes into an anticlinal fold.

(*c*) *The Laldama Syncline*.—This syncline, plunging gently to the south, is hardly recognizable towards the central part of Nyiru.

(*d*) *Leyosi Anticline*.—The anticlinal fold immediately east of the Laldama syncline also plunges to the south. Leyosi hill, on which the Nyiru trigonometrical beacon is erected, consists of a steep-sided anticline with a granitoid gneiss core, surrounded by shells of pelitic gneiss, augen gneiss and biotite gneiss. A saddle of the pelitic gneiss straddles part of the core. The fold rapidly dies out to the north.

(*e*) *South Horr Valley Syncline*.—This is a broad, shallow, trough-like complex syncline, incorporating numerous minor folds.

(*f*) *Mara Anticline*.—In the vicinity of the Muran river, this anticline is a gentle fold, the limbs dipping at about 10 degrees to the east and west respectively. Further north, east of South Horr, it is compressed and forms a steep-sided fold with a sharp crest.

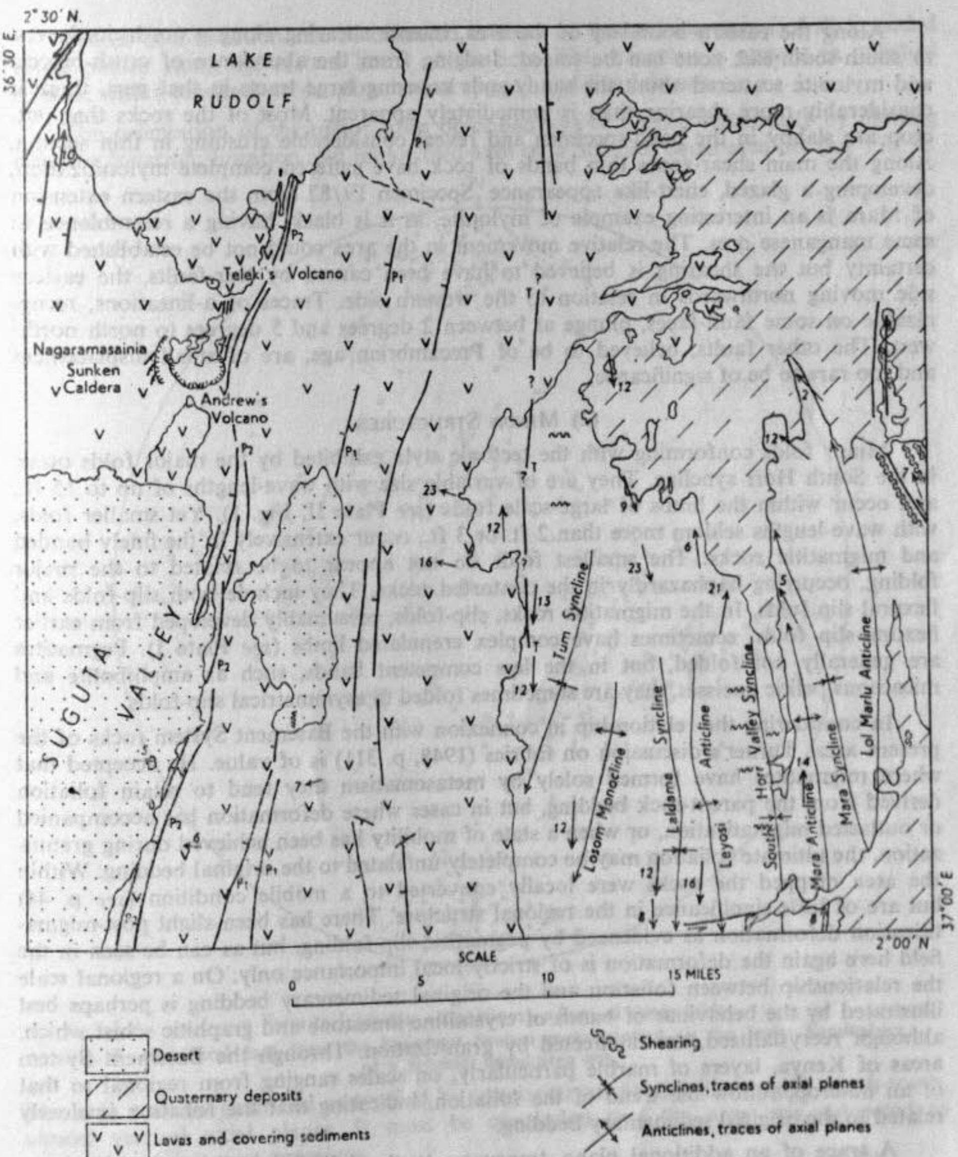

Fig. 3—Structural map of the South Horr area

(g) *Mara Syncline.*

(h) *Lol Marlu Anticline.*—In the central and eastern sectors of the Mara range, a broad anticline, plunging to the north, is locally overfolded.

The folding shows an overall homogeneity with regular nearly north-south striking axes.

Along the eastern boundary of the area, intense shearing along a north-north-west to south-south-east zone can be traced. Judging from the abundance of crush-breccia and mylonite scattered about the sandy soils covering large tracts in that part, there is considerably more shearing than is immediately apparent. Most of the rocks that outcrop are slabby in the hand-specimen and reveal considerable crushing in thin section. Along the main shear-zones thin bands of rock have suffered complete mylonitization, developing a glazed, chert-like appearance. Specimen 19/82 from the eastern extension of Mara is an interesting example of mylonite, as it is black, having a resemblance to some manganese ores. The relative movement in the area could not be established with certainty but the shearing is believed to have been caused by tear-faults, the eastern side moving northwards in relation to the western side. Traces of a-lineations, recognizable on some fault-faces, plunge at between 2 degrees and 5 degrees to north north-west. The other faults, believed to be of Precambrian age, are of small displacement and too rare to be of significance.

(2) Minor Structures

Minor folds conforming with the tectonic style exhibited by the major folds occur in the South Horr syncline. They are of variable size with wave-lengths of up to 15 ft., and occur within the limbs of large-scale folds (*see* Plate II, Fig. 1). Yet smaller folds, with wave-lengths seldom more than 2 ft. or 3 ft., occur extensively in the finely banded and migmatitic rocks. The smallest folds do not appear to be related to the major folding, occurring haphazardly in the contorted rocks. They include both slip-folds and flexural-slip folds. In the migmatitic rocks, slip-folds, presumably developed from earlier flexural-slip folds, sometimes have complex crenulated limbs (*see* Plate I). Pegmatites are generally not folded, but in the less competent bands, such as amphibolite and micaceous pelitic gneisses, they are sometimes folded in asymmetrical slip-folds.

In considering the relationship in connexion with the Basement System rocks of the present area, Turner's discussion on fabrics (1948, p. 311) is of value. He accepted that where migmatites have formed solely by metasomatism they tend to retain foliation derived from the parent-rock bedding, but in cases where deformation has accompanied or outlasted migmatization, or when a state of mobility has been achieved during granitization, the ultimate foliation may be completely unrelated to the original bedding. Within the area mapped the rocks were locally converted to a mobile condition (*see* p. 44) but are of little significance in the regional structure. There has been slight post-migmatitization deformation as evidenced by pegmatitic slip-folding, but as can be seen in the field here again the deformation is of strictly local importance only. On a regional scale the relationship between foliation and the original sedimentary bedding is perhaps best illustrated by the behaviour of bands of crystalline limestone and graphitic schist which, although recrystallized, are unaffected by granitization. Through the Basement System areas of Kenya, layers of marble particularly, on scales ranging from regional to that of an outcrop, follow the trend of the foliation, indicating that the foliation is closely related to the original sedimentary bedding.

A trace of an additional plane, transverse to the foliation, is to be seen in some exposures. Specimens 19/18 and 19/51 from the Mara range contain traces of transverse planes, and appear to be generally similar to the tectonites described by Turner and Verhoogen (1951, p. 544).

Lineation is well developed in all but a few of the rock bands in the area, the best developed types being the elongation of micas, the growth of trains of mica flakes, the elongation of amphiboles in the foliation planes of pelitic or amphibolite rocks, and the orientation of augen in the augen gneisses. In some marbles the lineation consists of a fine ribbing. Most of the measured lineations plunge gently to just east or west of north, or in the reverse direction slightly east or west of south. As these lineations are parallel to the direction of the fold-axes they conform with the definition of b-lineation described by Turner and Verhoogen (1951, p. 534).

Traces of a-lineation can be observed in some of the rare exposures of slickensided thrust-planes along the eastern limits of the area. This lineation is present as polished streaks, with a tendency to development of ragged, rod-like felspars.

The orientation of the major folds described was confirmed statistically by plotting poles to foliation, lineation and minor fold-axes on a Schmidt equal area net (*see* Fig. 4).

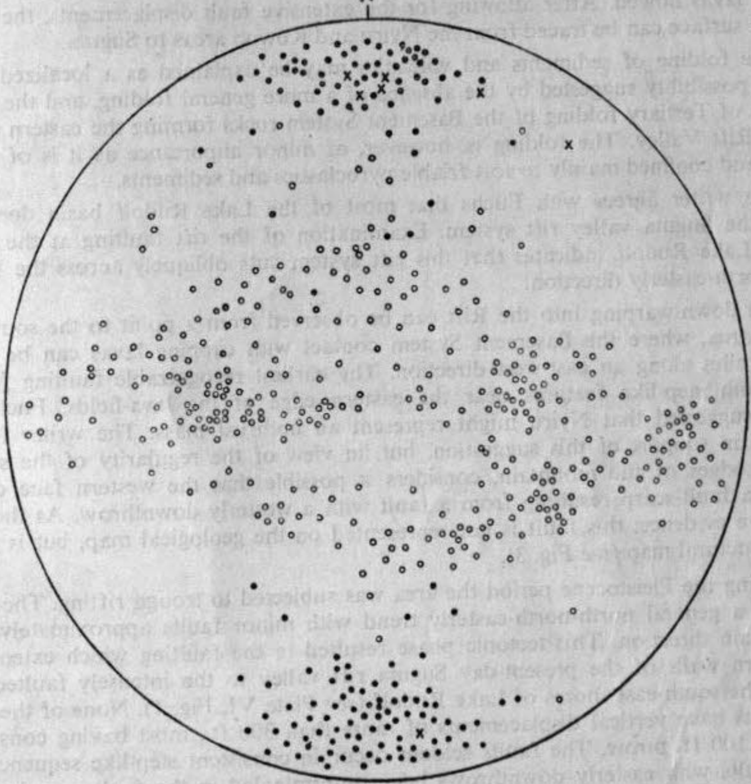

Fig. 4—Structural data from the Basement System rocks plotted on the lower hemisphere of a Schmidt equal area net

The area may be described as typified by homogeneous folds with roughly north-south, almost vertical axial planes. It must be concluded that the area was subjected to predominant east-west pressures.

2. Tertiary to Recent Structures

There is no evidence in the present area to suggest a definite age for the earliest tectonic disturbances. It is known, however, that the earliest lavas flowed out on sediments that have been identified as Miocene, and the writer believes that the lava was released from fault fractures. Fuchs (1939, p. 266) considered the oldest rift faults of the Lake Rudolf area to be of late Oligocene age.

Fuchs (*op. cit.*) described gentle folding of the Tertiary sediments and volcanics along approximate north-south axes to the north-east and west of the present area. He considered this folding to be indicative of a compressional origin of the rift faulting which produced the valley, including Suguta and the southern end of Lake Rudolf.

The writer, however, considers that the Suguta valley was formed by tensional trough faulting. It is considered likely that the earliest movement took place as gentle down-warping to form a trough-like depression along a north-north-easterly direction. This movement was followed by fracturing which it is believed initiated the first plateau-lava outpourings in the area. Evidence of this down-warping is provided by the situation of the original surface of Basement System rocks and Tertiary sediments over which the earliest lavas flowed. After allowing for the extensive fault displacements, the convexly curving surface can be traced from the Nyiru and Kowop areas to Suguta.

The folding of sediments and volcanics may be explained as a localized relief of load, a possibility suggested by the absence of a more general folding, and the complete absence of Tertiary folding of the Basement System rocks forming the eastern shoulders of the Rift Valley. The folding is, however, of minor importance as it is of a limited nature and confined mainly to soft friable pyroclastics and sediments.

The writer agrees with Fuchs that most of the Lake Rudolf basin does not lie within the Suguta valley rift system. Examination of the rift faulting at the southern end of Lake Rudolf indicates that this rift system cuts obliquely across the lake in a north-north-easterly direction.

The down-warping into the Rift can be observed from a point to the south of the present area, where the Basement System contact with capping lavas can be seen for several miles along an east-west direction. The earliest recognizable faulting forms the north-south step-like features near the eastern edge of the lava-fields. Fuchs (1939, p. 266) suggested that Nyiru might represent an upthrust mass. The writer found no evidence in support of this suggestion, but, in view of the regularity of the scarp-like westerly edges of the mountain, considers it possible that the western face of Nyiru may be a fault-scarp resulting from a fault with a westerly downthrow. As there is no conclusive evidence, this fault is not represented on the geological map, but is included in the structural map (*see* Fig. 3).

During the Pleistocene period the area was subjected to trough rifting. The faulting followed a general north-north-easterly trend with minor faults approximately normal to the main direction. This tectonic phase resulted in the faulting which extends from the eastern walls of the present-day Suguta rift valley to the intensely faulted Latarr area on the south-east shores of Lake Rudolf (*see* Plate VI, Fig. 1). None of the Pleistocene faults have vertical displacements of more than 300 ft., most having considerably less than 100 ft. throw. The faults seldom occur in consistent step-like sequence, occasional faults with easterly downthrows being intermingled in the fault complex. While most of the lavas have been progressively tilted to the west, lavas on the north-eastern shoulders of Suguta, faulted by the most recent trough rifting, have been tilted to the east.

The collapse of the Nagaramasainia caldera took place by two subsidences, the earlier collapse occurring along an arc to the west of the present caldera. The second collapse, which formed the caldera, followed the pattern of the first in that the largest displacement took place on the western side. There appears to have been a slight rejuvenation of collapse movement in recent times.

In the wind-deposited sands exposed in the Losergoi river there is evidence of recent faulting. The faults, most of which have westerly downthrows of about 3 ft. to 5 ft., are of limited extent and can only be observed in river sections. It is possible that such faults may be related to the recent movements in the caldera, or the recent rejuvenation of volcanism on the Barrier.

No recognizable folding took place during the Tertiary period within the limits of the present area, but gentle folds in the Upper Pleistocene beds exposed in the Losergoi valley can be observed. The fold axes are aligned approximately east-west and the amplitude of the folds does not exceed about 200 ft. The alignment of these folds suggests gentle north-south pressures during the late Upper Pleistocene period.

VIII—MINERAL DEPOSITS

The area is remote. The nearest railhead is at Thomson's Falls about 210 miles to the south, while the road as far as Maralal includes several bad sand-river crossings, extremely steep gradients and generally poor surfaces. Any mineral occurrence would have to be sufficiently valuable to cover the expense of long, difficult hauls by road.

No mineral occurrences worth exploitation in present circumstances were discovered during the course of the survey. The following are the minerals of economic interest recorded in the South Horr area.

1. Graphite

The graphitic schists and gneisses of the South Horr valley were described in a previous chapter (*see* p. 18). The most important band is the folded schist exposed on the western slopes of Mara. The lower hillside is a dip-slope on the western limb of the Mara anticline, and yields an exposure of the schist about 1,000 yards wide at its widest point. The band narrows sharply to the south. In the hand-specimen the schist appears to contain a high percentage of graphite. Tests on two representative samples, however, gave 15.43 and 16.8 per cent for the carbon content, as determined by loss on ignition (*Analyst*: *Mrs. R. Inamdar*).

Flotation in the presence of phosocresol "A", conducted by A. Stewart, Metallurgist, provided the following information regarding the size of the graphite flakes:—

Product	Weight in grams	Carbon percentage
Calculated feed	234	16·8
Concentrate + 100 mesh BS	42	14·3
Concentrate − 100 mesh BS	78	31·9
Tailings + 100 mesh BS	65	8·0
Tailings − 100 mesh BS	49	6·8

The results show that the schist would be difficult to upgrade by the standard methods and that it would require grinding to at least 100 mesh (150 microns) in order to release the graphite. The flakes are too fine for crucible grade. There is also sillimanite in the schist and it would be easy to separate, but it accounts for about 3 per cent only of the total rock composition.

The occurrence is, therefore, of no value in present conditions because of the costliness of transportation and beneficiation, and the low price of small-flake graphite.

2. Mica

No saleable mica was discovered in the area, but as in the Baragoi area to the south, some of the complex pegmatites might yield mica. Prospecting for mica in complex zoned pegmatites should be directed towards the centre of the pegmatite, around the quartz cores, as most mineralization occurs in the zone immediately enclosing the quartz core.

3. Nickel

All intrusives of ultra-basic composition in the area, qualitatively tested, proved to contain nickel. There is no chance of exploitation of the limited intrusives, which contain small quantities of nickel only, but it is possible that they may be related to an undiscovered larger, mineralized intrusive body. See pages 13, 24, 25.

4. Asbestos

Several pits dug by prospectors in the central South Horr valley have revealed the presence of poor quality anthophyllite associated with a small ultra-basic intrusion. The asbestos reaches a maximum fibre length of about 2 in. but is friable and of generally poor quality.

5. Evaporites

The evaporite deposits in the Suguta valley, while unlikely to prove commercially exploitable, play an important part in the life of the Turkana tribe. Although the composition (*see* p. 39) of this salt is unlike the trona from the Magadi salt lake in southern Kenya, it is used for the same purposes as unprocessed trona, namely, as an addition to finely ground tobacco to produce snuff, which is extensively used by most African tribes in Kenya. Turkana tribesmen travel for considerable distances to collect supplies of the salts.

As a stock salt-lick the evaporite is much sought after.

6. Heavy Minerals

Examination of panned concentrates from various parts of the area failed to reveal the presence of even minute quantities of valuable minerals. In view of the presence of the ultra-basic intrusives, careful attention was paid to the heavy mineral residues collected from their proximity, but the concentrates proved to be devoid of the heavy rare metals sometimes associated with such rocks.

7. Water

In relation to the vegetation available as food for stock, the western portion of the area has a sufficient water supply for the indigenous population. Permanent and semi-permanent water is found in most of the river-courses cut through the lava-fields and in some parts of the Suguta valley, such as at the mouth of the Losergoi river. Lake Rudolf water, while not palatable, is apparently fit for human and animal consumption although the fluoride content is excessive (*see* table). The following analyses of water samples from Lake Rudolf show a high percentage of matter in solution. In most cases the sodium content was not determined, but it is safe to assume that nearly all of the carbonate and bicarbonate is present as sodium salt.

COMPOSITION OF LAKE RUDOLF WATERS
Parts per 100,000

	1	2	3	4	5	6	7	8
Alkalinity (as $CaCO_3$)—								
Carbonate	30·8	Nil	32	60	50	13	24·8	50
Bicarbonate	82·3	15·6	76·5	45·8	59·9	37·6	91·2	82
Ammonia—								
Saline	n.d.	n.d.	n.d.	n.d.	0·048	0·016	0·032	0·05
Abuminoid	n.d.	n.d.	n.d.	n.d.	0·08	0·012	0·072	0·036
Chlorides (as Cl)	44	2·8	41·2	40·3	43·1	19·3	42·8	52
Sulphates (as SO_4)	4	trace	2·4	3·2	2·1	trace	1·5	5
Nitrites (as NO_2)	n.s.	n.s.	trace	n.s.	n.s.	present	n.s.	present
Nitrates (as NO_3)	n.s.	n.s.	n.s.	n.s.	n.s.	present	n.s.	present
Calcium (as Ca)	0·5	1·1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Magnesium (as Mg)	0·79	0·66	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Iron (as Fe)	n.d.	n.d.	n.d.	n.d.	0·014	0·03	0·14	0·07
Silica (as SiO_2)	n.d.	n.d.	n.d.	n.d.	trace	6·3	0·7	0·3
Total hardness	4·0	5·0	3·5	3	3	2	2	2
Total solids	n.d.	n.d.	n.d.	n.d.	199	103·5	203	230
Fluorides (parts per million)	12·5	1·0	17·2	11·3	9·3	3·8	9·2	8·6
pH.	10·3	7·6	10·6	n.s.	10·4	8·7	8·5	8·5

n.d. = not determined.
n.s. = not stated.

	9	10	11
Alkalinity expressed as Na_2CO_3 equivalent	—	—	139·92
CO_2	149·5	17·4	Not determined
Cl	45·2	13·4	49·77
SO_4	14·3	12·0	2·2
Na	122·8	19·1	Not determined
Ca	1·0	2·6	0·70
Mg	0·6	4·9	0·38
Al-Fe	0·8	0·2	0·28

1. Lake Rudolf, Todenyang.
2. Omo River, northern end of Lake Rudolf.
3. Lake Rudolf.
4. Lake Rudolf near Lokitaung.
5. Lake Rudolf.
6. Lake Rudolf.
7. Illeret, Lake Rudolf.
8. Ferguson Gulf, Lake Rudolf. *Analyst: Government Chemist.*
9. Hot spring near Lake Rudolf.
10. Lake Rudolf. *Analyst*: Mrs. J. A. Stevens.
11. Lake Rudolf, about eight miles south of Loyangalani. *Analyst: Mrs. R. Inamdar.*

There is little chance of growth of stock herds as the inhospitable, rocky arid nature of the country prevents the growth of more than sparse vegetation, which consists mainly of stunted thornbush.

The South Horr valley is adequately supplied by three river-courses draining the eastern slopes of Nyiru. Water is obtainable at certain points in these river-courses even during the driest months of the year. There is little hope of increasing the water supply in the barren, desert-like plains in the eastern part of the area. The plains are mantled with sandy soils incapable of holding water for more than a day or two after heavy rain. The sinking of boreholes is generally inadvisable in arid areas but may be of value if holes are widely spaced. Water might be conserved by the construction of deep, narrow dams with relatively small surface areas to minimize evaporation. The dams could only be built in some of the rocky river-courses draining the inselbergs dotted about the plain. It must be pointed out, however, that there is little point in increasing the water supply in this region as the supply of vegetation available as food for stock is strictly limited.

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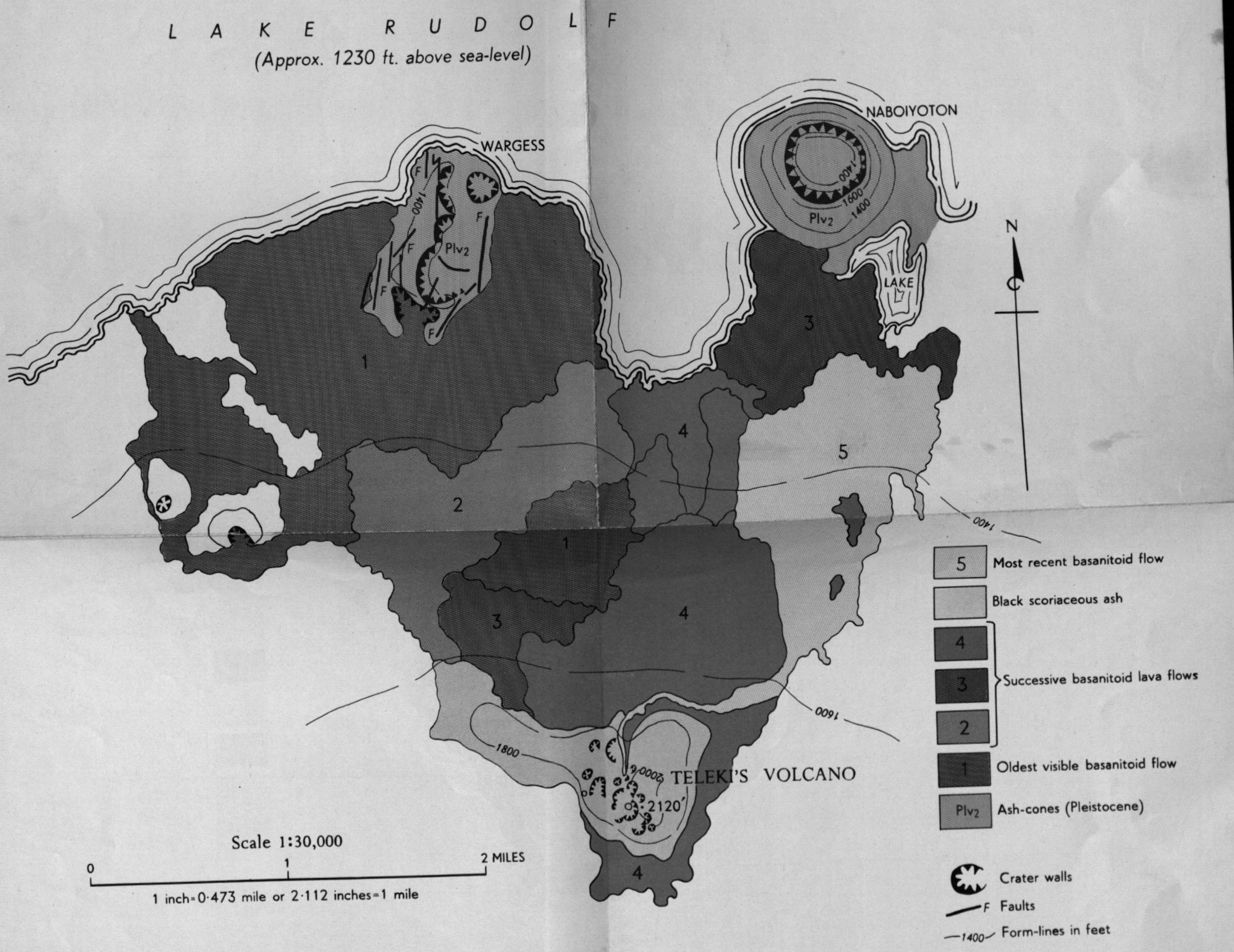
G.P.K. 483—800—2/61

TELEKI'S VOLCANO, WITH RECENT LAVA-FLOWS



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