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GEOLOGY
OF THE
AREA SOUTH OF MAGADI

DEGREE SHEET 58, N.W. QUARTER

(with coloured geological map)

by

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FOREWORD

The publication of the report on the geology of the area south of Magadi completes the account of the southern end of the Rift Valley as it occurs in Kenya. The Magadi area itself was described by Mr. Baker in Report No. 42 (1958). During the mapping of the continuation of the Magadi area the discovery of some critical exposures enabled the correction of an error of succession in the lower Pleistocene rocks that had been made during the survey of the Magadi area.

The area is wild and desolate, but of considerable interest scenically, with the western Rift wall a little beyond its west boundary, rugged hills of ancient rocks in the south-east and two prominent volcanoes, Lenderut and Shombole, rising from the Rift floor.

There is little mineralization in the area except kyanite in gneisses that outcrop prominently in the hills in the south-east. The content of kyanite does not, however, exceed 19 per cent in any of the samples tested, and in view of the low grade, inaccessibility and lack of water at the outcrops, the deposits are not commercially attractive.

Nairobi,
26th May, 1959.

WILLIAM PULFREY,
Ag. Commissioner (Mines and Geology).

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MAP

Geological Map of the Area South of Magadi; degree sheet 58, north-west quarter

(Scale 1:125,000) at end

ABSTRACT

The report describes an area 616 square miles in extent in the Kajiado District, south of Magadi. It is bounded by longitudes $36^{\circ} 00'$ and $36^{\circ} 30' E.$, and by latitude $2^{\circ} 00' S.$ and the Kenya-Tanganyika boundary. The area covers the southernmost part of the Rift Valley in Kenya.

A group of hills in the south-eastern part of the area rise to above 6,000 feet. The central part of the area is broken by numerous sub-parallel youthful escarpments and is at an elevation of 2,000 to 4,000 feet. The dissected remains of two volcanoes rise to 3,500 and 5,000 feet respectively.

Quartzites, biotite gneisses and kyanite gneisses referred to the Basement System, outcrop in the hilly south-eastern corner. Tertiary and Quaternary volcanic rocks comprising trachytes, nephelinites, olivine basalts, andesites, tephrites and basanites, and lacustrine and fluvial sediments occur in the remainder of the area. The volcanic, tectonic and sedimentary history of the whole of the Magadi section of the Rift Valley is briefly described.

Sub-economic but large deposits of kyanite are mentioned and some aspects of the development of water-supplies are discussed.

GEOLOGY OF THE AREA SOUTH OF MAGADI

I—INTRODUCTION

General.—The area south of Magadi as defined for this report is the part of the north-west quarter of Degree Sheet 58 (Kenya: Sheet No. 171 of the Directorate of Overseas Surveys) north of the Kenya-Tanganyika interterritorial boundary. It is bounded by longitudes $36^{\circ} 00'$ and $36^{\circ} 30' E.$ and by latitude $2^{\circ} 00' S.$ and the Kenya-Tanganyika boundary and is approximately 616 square miles in extent.

Owing to the similarity between the present area and the Magadi area to the north (Baker, 1958*), the two reports should preferably be read together, especially as the opportunity has been taken to summarize the geological history of the whole of the Magadi section of the Rift Valley in the present report.

The area south of Magadi falls into the Kajiado administrative district of Southern Province, and is inhabited by nomadic and pastoral Masai. The only buildings are two African shops at Alangarua at the northern foot of Shombole mountain, and a third shop at the foot of Lesiri hill in the eastern part of the area.

The only produce of the area is hides and skins, but a small fishing industry is centred on Alangarua, where catfish are caught and sun-dried on a small scale. Sales of stock organized by Government do not seem to have begun in this area as they have elsewhere, probably on account of the poor communications.

Communications.—There are no roads in the area, only a few motorable tracks developed by intermittent use by traders and prospectors. The principal track leads southwards from Magadi to the south end of the lake and thence generally south-westwards to Alangarua. A further track made by a prospector to gain access to a magnesite deposit on the Tanganyika side of the boundary leads from the south end of Lake Magadi south-south-westwards across the area. A very rough and scarcely noticeable track leads from this magnesite deposit and enters Kenya due south of the Lenderut hills and, after reaching the Lesiri shop in the east by a circuitous and rocky route, proceeds north-eastwards and eventually joins the Kajiado-Turoka-Mile 46 road north-east of the present area.

A motorable route from Singaraini station (outside the north-east corner of the area) to Lake Kabongo is also shown on the map (at end). This old track is exceedingly rough and so little used that it is not visible over the greater part of its length.

Some of the larger soil-filled valleys are motorable along part of their length, namely Rekereien, Sereata, Narsurana and the greater part of the Ngare Nyiro plain outside the swampy areas. The lower Pagasi river and the southern end of the Kirikiti escarpment can be reached by crossing the Ngare Nyiro by the steel bridge west of Magadi and driving southwards along the foot of the Nguruman escarpment.

In spite of the lack of maintained roads and the roughness of the few existing tracks it was found that no part of the area is more than a few hours walking from the nearest motorable route.

Climate.—The greater part of the area is semi-arid in climate, with temperatures commonly exceeding $100^{\circ} F.$ and moderate humidity, the latter rising to an uncomfortable level during and after rainstorms. Towards the south-east the ground rises steadily from 2,000 feet to over 6,000 feet among the Losirua and Kileu mountains. Here, and along the plain extending along the foot of the mountains the climate is pleasant with more moderate temperatures and lower humidity.

Maps.—The only existing topographical map of the area available at the time of the survey was that of the Anglo-German Boundary Commission (Uhlig, 1909, pp. 9–10) whose map—Sheet 4, scale 1:100,000—was found to be inaccurate. The writer made a hasty plane-table survey based on three major triangulation stations outside the area to the north—Olorgesailie, En Doinyo Nyiro and Ol Doinyo Nyegi. The map accompanying this report was then compiled using aerial photographs. Altitudes were measured by a single aneroid barometer and locally differed appreciably from the barometer observations made by the Anglo-German Boundary Commission. The writer's altitude work was based on Lake Magadi, which has recently been determined as 1,973 feet above mean sea-level.

*References are quoted on p. 26.

The northern margin of the geological map (at end) does not correspond exactly with the southern margin of the geological map of the area to the north (Magadi area, Baker, 1958) due to the fact that the latter was based in part on the Anglo-German Boundary Commission map referred to above, which the writer found to be inaccurate. The lack of correspondence with the map to the east (Namanga-Bissel area, Joubert, 1957) is due to the same cause.

Previous Work.—Several early explorers passed along the base of the Nguruman escarpment, this being a well known route from the earliest days of exploration. The first was Fischer in 1883 (see Gregory 1921, p. 179) and later Kaiser, but their observations were probably made to the north of the present area. C. Uhlig and F. Jaeger in 1904 entered the area from the south and visited Shombole mountain and the Pagasi river area (Uhlig and Jaeger, 1942, pp. 31–43). They described the geography of the Nguruman escarpment and noted arfvedsonite trachyte overlain by yellow tuffs and boulder beds at the southern end of the escarpment south of the Pagasi river. Mention was made of the Ngare Nyiro plain (op. cit., pp. 37–39) and the swamp, and they described westward-dipping tuffs and lavas on Melil hill. They also observed the beach terraces on Melil. A full description of the topography of Shombole was given (op. cit., pp. 41–43) and the northern face of the mountain recognized as composed primarily of tuff and nephelinite lava. The rock collection made by Uhlig and Jaeger is listed in an appendix (op. cit., pp. 181–188). The rocks collected from the present area were trachytic tuff and trachytes from Ol Doinyo Lengorale, the southernmost hillock of the Nguruman escarpment immediately south of the Pagasi river (op. cit., p. 181) and nephelinite lavas and tuffs from Shombole (op. cit., p. 182).

Capt. G. E. Smith (1907) passed through the area and carried out much surveying *en route*. He gave a general description of the Nguruman escarpment (pp. 256–7) and the hot springs at the south end of Lake Magadi (p. 258). Smith regarded the floor of the Rift Valley as broken “by numerous dykes of hard lava”, which he thought gave rise to the horst and trough topography.

P. Walther (1922) described the trona in Lake Magadi and found saline incrustations some 25 miles south of Magadi, presumably in the area of the Ngare Nyiro swamp. They were reported as consisting of sodium bicarbonate, but when the samples were examined after a considerable interval they were determined as trona. Walther also reported having detected carbon dioxide gas escaping from numerous fissures in soil and rocks.

II—PHYSIOGRAPHY

The area can be divided into three physiographic units, the mountainous country in the south-east together with the gently-sloping soil pediment to the west of it, the central lava area consisting of many narrow horsts and troughs, and the Ngare Nyiro plain together with the southernmost and lowest part of the Nguruman escarpment.

The mountainous south-east corner of the area is dominated by the Kileu ridge and Kaku mountain, which reach altitudes of nearly 7,000 feet. The Kileu ridge is composed largely of resistant quartzites striking to the north-north-east, and a few miles north-west are the Losirua hills, more or less rounded in outline and reaching nearly to 6,000 feet. North of Losirua are smaller residual quartzite hills such as Lesiri and Lenkijabe. Regarded in a broader setting the Kileu ridge is the southern continuation of the Luanji hills which extend far to the north-east, and the Losirua group and its surrounding hills occur as “outliers” of the main hilly area. These hills have steep slopes and are at a late-youthful stage of dissection. They are margined to the west by a gently-sloping plain covered with grass and patches of acacia forest. This plain, of which M’balbal Ormeresho is a part, slopes down from 4,500 to below 4,000 feet, the soil cover becoming thinner westwards, till basalts of the Rift Valley emerge from beneath it.

The central part of the area, which is composed of alkali trachytes and basalts, is closely grid-faulted along lines trending approximately 15 degrees east of north, the resulting topography being that of elongated ledges, platforms and troughs bounded by rocky escarpments which are generally vertical in the upper part. Erosion has made little impression on these fault-blocks, but lake beds or swampy soils frequently occupy the floors of the troughs. The Lenderut hills, whose summits rise 1,500 feet above the surrounding grid-faulted country, represent the remnants of a denuded volcano, the lower parts of which have been engulfed

by the alkali trachytes and basalts that cover the Rift Valley floor. The average level of the grid-faulted area descends from 4,000 feet in the east to below 2,000 in the central and western parts, where the lavas pass beneath alluvium and lake beds belonging to Lakes Natron and Magadi. This westward slope is the result of the tilting of many of the fault blocks to the west, and is also due to the greater cumulative throw on west-facing fault escarpments.

The Torosei river and its tributary the Sinya Landari descend from the western and northern faces of Losirua Mountain and run westwards across the grid-faulted topography to end in the Narsurana valley, in the lowest part of which there is a seasonal swamp. The river traverses the Torosei, Kisielib and Narsurana valleys, which it has partly infilled with its detritus, and breaks through the intervening lava horsts in narrow gorges which are as much as 200 feet deep. Other rivers descending from the high ridges east of Lesiri and Lenkijabe hills traverse the plain but end in it. The Turoka river, however, enters the area in the north-east corner and following the south-south-westerly trending fault troughs, ends in Lake Kabongo, which occupies a fault-trough. A further, unnamed, river drains the eastern slopes of the Lenderut hills and the broad dip slope of lava east of Oldomut. It skirts the eastern Lenderut foothills and ends in the Oldomut plain, the site of a former lake, which overflowed to the north-west into the south-eastern lagoon of Lake Magadi.

The principal fault-troughs are Kisielib, the long, narrow and deep Sereata-Kiambu valley, Nasurana, the Lesoit-Rekereien trough which is the southern continuation of the Lake Magadi trough, and the broad Ngare Nyiro depression. Kibangaini, a large flat-floored dried lake bed, is largely in Tanganyika—only its northern tip occurs in the present area.

The Ngare Nyiro plain and swamp are a few tens of feet above the present level of Lake Natron and, in their southern part west and north-west of Shombole, the plain is composed of lake beds deposited when the lake stood at a higher level. To the north the lake beds are masked by more recent alluvium brought down by the river. Overlooking the plains and swamps on the south is the old volcano Shombole, rising 3,000 feet to a little less than 5,000 feet. In spite of erosion that has cut precipitous, radially-arranged canyons on all sides of the mountain in the soft tuffs and shattered nephelinites of which it is composed, the volcano-like profile is clearly discernible at a distance. The flat top of the mountain is composed of flat-lying tuffs that originally lay in the wide crater. The cliffs that surround much of the summit plateau occur near the inner crater wall, the flat-lying tuffs of the crater evidently being more resistant to erosion than the dipping beds of the crater rim.

West of the Ngare Nyiro plain is the southern tip of the Kirikiti platform (cf. Baker, 1958, Fig. 1, p. 5) which is the lower step of the composite Nguruman escarpment. This lower escarpment, which is composed of basalts, is high and precipitous to the north, but slopes at approximately one and a half degrees southwards and passes below the Ngare Nyiro plain and the boulder beds to the west of it just south of the Pagasi river. A few miles west of the Kirikiti escarpment, and just outside the present area, is the main Nguruman escarpment and its southern continuation the Ol Doinyo Sambu escarpment, both of which form the impressive western margin of the Rift Valley and rise to heights in excess of 7,000 feet.

The summits of the Kileu ridge and Kaku are at levels of approximately 6,500 to 6,600 feet, and may represent an extension of the end-Cretaceous erosion surface recognized in the Namanga-Bissel area (Joubert 1957, p. 4). The mature valleys on all sides of Kaku hill seem to have been graded to a level of approximately 5,500 feet, and this corresponds with the levels ascribed by Joubert to sub-Miocene peneplanation in the south-west part of the Namanga-Bissel area. The summit ridges of the hills Lenkijabe, Lesiri, Loldorobo, and the south-west shoulder of Losirua may represent remnants of an erosion bevel at altitudes between 4,500 and 4,700 feet. This surface would be approximately 1,000 feet below the sub-Miocene surface a short distance to the east, making it necessary to postulate a fault downthrowing approximately 1,000 feet to the west between Losirua and Kaku.

The gently sloping Sinun plain west of Losirua extends north-eastwards along the foot of the Basement System hills into the Namanga-Bissel area and on into the area west of Turoka. South-east of Njoro Sindio in the Namanga-Bissel area the plain extends as a broad embayment eastward into the undulating Basement System country around Matumbatu. The plain consists of sandy soils with dark clay soils in swampy areas. The western

part of the plain certainly overlies the basalts in the Rift Valley, and to the east they overlie Basement System rocks. The plain is due largely to the aggradation of alluvial sediment discharged by rivers descending from the high ground to the east. It is likely, however, that the sub-volcanic surface in the Sinun, Torosei and Njoro Sindio areas is an erosion bevel sloping to the north-west, the slope of the surface being approximately 110 feet per mile in the Njoro Sindio region. This erosion surface is earlier than the basalt vulcanicity of the Rift Valley floor and is considered to be of low to moderate relief on account of the rarity of inliers of Basement System rocks projecting above the Rift Valley volcanics. The eastern or exposed part of the erosion surface is at an elevation of 3,800 to 4,000 feet at Sinun, and slopes upwards towards the north-east till it occurs at an altitude of 4,700 to 5,000 feet in the Njoro Sindio area. The vertical interval between this surface and the sub-Miocene erosion surface is approximately 700 feet in the Losirua-Sinun region, and the lower erosion surface forming the Sinun-Torosei plain is tentatively regarded as end-Tertiary in age.

III—SUMMARY OF GEOLOGY

The oldest rocks in the area are gneisses, quartzites and schists of the Turoka Series, a formation which is considered to be of Precambrian age. They are folded on axes plunging gently to the north-east, and have suffered regional metamorphism and slight granitization. They contain such minerals as kyanite, garnet and graphite.

There is no geological record of Palaeozoic or Mesozoic rocks in the area; the main period represented is the latter half of the Tertiary and the Quaternary, when vulcanicity, faulting, and later, lake and river sedimentation associated with the Rift Valley took place.

The two central volcanoes Shombole and Lenderut represent the first vulcanicity to take place in the area, possibly during the Miocene period. These volcanoes consist of nephelinite and tuff, and trachyte and basalt respectively. Plateau eruptions of olivine basalt followed the initial period of rift faulting along the Nguruman escarpment, and are represented by the Kirikiti Basalts and basalts in the eastern half of the area. There was then a second movement on the Nguruman fault and quartz trachytes were laid down as a thick series in the floor of the Rift Valley. During the eruption of these lavas a series of pebble beds and sands were laid down on the Kirikiti platform. The quartz trachyte vulcanicity ended with the formation of small ash and scoriaceous lava cones.

Two series of lacustrine sediments were laid down on the lava surface—the Chert Series and the Oloronga Beds. The deposition of these was followed by widespread grid-faulting which broke up the floor of the Rift Valley into a series of parallel raised and sunken blocks. The High Magadi Beds and contemporaneous beds in the Natron Basin, were deposited in two larger fault depressions and other deposits, largely unexposed, were laid down in the smaller fault-troughs.

Following erosion of these beds alkaline spring activity in the Magadi and Natron troughs gave rise to the Evaporite Series which is in process of deposition at the present day. Kunkar limestones, gravels, wind-blown sands, alluvial and fluvial silts and clays comprise the superficial deposits.

The tabulation below summarises the succession in the present area, and the area to the north. The relative ages of the Olorgesailie, Shombole and Lenderut volcanics is not known, nor is it known what the relative ages of the Ol Keju Nero Basalts, the Kirikiti Basalts and the basalts of the eastern half of the area are. There is strong evidence, however, that the basalt series are younger than the volcanics of the central volcanoes. The remainder of the succession is well established. The only firm dating by fossil evidence is of the Olorgesailie Lake Beds, which are upper-middle Pleistocene in age (Baker 1958, p. 37). Recent work in the area to the west of Magadi has shown that the Kirikiti Basalts rest on the sub-Miocene erosion surface, the inference being that they are Miocene or post-Miocene in age.

In the report on the Magadi area (Baker 1958, p. 16) the basalts of the eastern side of the Rift Valley were tentatively correlated with the Kirikiti Basalts. It has, however, been suggested above that the eastern basalts rest on an erosion surface of end-Tertiary age, implying an upper Pliocene or Pleistocene age for the lavas. For the purpose of the present report the basalts of the eastern half of the area are tentatively regarded as Pleistocene in age, and as being younger than the Kirikiti Basalts.

GEOLOGICAL FORMATIONS IN THE MAGADI AREA AS A WHOLE

Recent	Loess; fluvial pebbles Evaporite Series (140 ft.)*
Upper Pleistocene	High Magadi Beds and sediments at north end of Lake Natron (> 40 ft.)
Middle Pleistocene	Olorgesailie Lake Beds (c. 175 ft.)
Lower Pleistocene	Pebble beds and sands of Pagasi (c. 100 ft.) Oloronga Beds (c. 70 ft.) Chert Series (c. 70 ft.) Scoriaceous lava and ashes of vents Orthophyre-trachyte (c. 150 ft.) Plateau Trachyte Series (> 1,000 ft.) Lengitoto Trachyte and trachyte of Lengorale (> 75 ft.) Ol Keju Nero Basalts (c. 245 ft.) Basalts of the eastern half of the S. Magadi area (> 200 ft.)
Miocene and Pliocene?	Kirikiti Basalts (> 500 ft.)† Lenderut Volcanics (> 1,000 ft.) Shombole Volcanics (> 3,200 ft.) Olorgesailie Volcanic Series (c. 2,700 ft.)
Precambrian	Basement System (> 14,500 ft.)

*The figures in parenthesis indicate the maximum observed thickness of each formation. Where the total thickness of the formation is known to be greater than the observed thickness this is indicated by the symbol >.

†Only 500 feet of Kirikiti Basalts are exposed in the south Magadi area. In the Magadi area to the north the Kirikiti Basalts are known to exceed 1,500 feet in thickness.

IV—DETAILS OF GEOLOGY

1. Basement System—Turoka Series

The metamorphic rocks of the south-eastern corner of the area form a group of hills which are the western and southern extensions of the Metu and Luanji hills of the Namanga-Bissel area (Joubert, 1957). The lithology of these rocks is very similar to the Turoka Series as described by Parkinson (1913) and as more precisely defined by Joubert (op. cit.). The writer follows Joubert in treating the Turoka Series as part of the Basement System, though there is a suggestion that the Turoka Series may eventually be separable from the remainder of the Basement System on the grounds of different structure and degree of granitization and may deserve promotion to a higher grade in stratigraphical nomenclature.

The stratigraphy of the metamorphic rocks that form the Kileu-Losirua hills is not as firmly established as could be desired on account of indifferent exposures and rapid lateral variations in some of the rock types.

The following succession is established for the Kaku and Losirua hills:—

	feet
8. Quartzites of Losirua	1,500
7. Biotite gneisses	3,000
6. Biotite-garnet gneisses	800
5. Quartzite	150
4. Kyanite-biotite gneisses	400
3. Quartzites of Kileu	3,000
2. Biotite gneisses	2,200
1. Quartzites of Kaku	2,000

The succession west of the Losirua fault, between the Losirua and Loldorobo hills, is as follows:—

								feet
10.	Quartzites of Loldorobo	..	..	..	..	..	..	1,500
9.	Limestone	..	..	..	..	..	..	300
8.	Quartzite	..	..	..	..	..	..	
7.	Muscovite-biotite gneisses	..	..	..	..	..	..	1,500
6.	Quartzite	..	..	..	..	..	..	400
5.	Biotite gneiss	..	..	..	..	..	..	
4.	Quartzite	..	..	..	..	..	..	
3.	Kyanite-biotite gneisses	..	..	..	..	..	..	1,000
2.	Quartzites	..	..	..	..	..	..	1,000
1.	Biotite gneisses	..	..	..	..	..	..	1,000

These rocks are folded on axes plunging gently to the north-north-east. The stratigraphical relationship between the two sequences is not known with certainty, though there is a possibility that the kyanite-biotite gneisses can be correlated. Such a correlation would require a movement of the Losirua fault downthrowing approximately 5,000 feet to the east and the quartzites above and below the kyanite gneisses would have to be regarded as thickening markedly eastwards.

Three separate bands of kyanite gneisses outcrop on the ridge south-east of Ropet, the bands being separated by biotite gneisses and the whole underlain by a massive quartzite. Although the kyanite gneisses are closely comparable to those outcropping elsewhere in the area the succession differs from that in the adjacent hills. The Ropet area is therefore separated from the remainder by a tentative fault drawn through a zone of vertical foliation south-west of Losirua.

This succession invites comparison with the succession discovered by Joubert (1957, p. 32) in the adjacent Namanga-Bissel area, but beyond the fact that there is a general similarity between the rocks of the present area and the Quartzite Group (i.e. the lower part) of the Turoka Series, it is not possible to effect any more precise correlation. The absence in the present area of the hornblende rocks which characterise the middle part of the Quartzite Group in the Namanga-Bissel area is a notable factor, and one that reinforces Joubert's belief that the hornblende rocks may be of volcanic or intrusive origin and thus likely to be restricted in occurrence.

(1) QUARTZITES

Quartzites outcrop on nearly every ridge and summit on the Kileu and Losirua hills, and quartzite rubble covers the hill slopes and obscures exposures of other rock types. Kaku hill is composed of massive quartzites dipping east and west from the summit ridge of the hill and defining an anticline plunging at a shallow angle to the north-east (*see* Fig. 1). The rocks are buff- or reddish-weathering, coarse-grained and without prominent bedding partings.

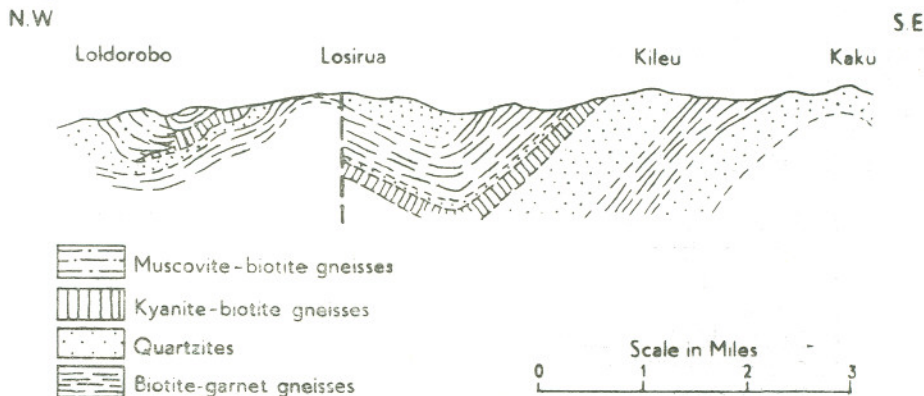


Fig. 1.—Vertical section showing structure between Kaku and Loldorobo hills.

The whole of the Kileu ridge is built of thin well-bedded quartzites separated by narrow impersistent beds of quartz-muscovite schist. The formation marked on the map should be regarded as a zone in which quartzites are predominant. At the southern end of the ridge the quartzites dip at approximately 50 degrees to the west-north-west, but at the northern end they are vertical and form narrow wall-like outcrops. At the upper (western) margin of this quartzite group there are muscovite schists locally and these contain vein quartz segregations containing large blue kyanite crystals. A further quartzite group is found in the western limb of the Kileu syncline on the east slopes of Losirua hill—each quartzite forms a distinctive feature.

Quartzites outcrop on Ropet hill and on the next ridge to the east, where they underlie kyanite gneisses. The uppermost quartzite is a poorly-bedded very coarse-grained rock comparable to that forming the ridge of Lesiri hill. These quartzites have grains one centimetre in diameter and weather to a coarse reddish grit.

Two coarse quartzites, with muscovite flakes near the base, outcrop on the hills around the north-west flank of Losirua and in the axis of the Kileu syncline three miles east of Losirua. At the upper contact they grade into massive muscovite gneisses containing ribs of coarse quartzite.

Loldorobo hill, Lesiri, Lenkijabe and isolated hills north of Losirua are also composed of quartzite, often of very coarse texture, resting in some cases on muscovite gneisses. Their position in the succession is uncertain, but they may be tentatively assigned to a position above the muscovite gneisses of the north-west flank of Losirua.

(2) KYANITE GNEISSES

Biotite gneisses with kyanite and muscovite in variable proportions form widespread and easily recognisable marker horizons. They occur on the west slopes of the Kileu ridge, on the north and west slopes of Losirua, and on the ridge east of Ropet. In each case abundant kyanite float crystals occur below the outcrops, which are also distinctive on the aerial photographs because of the small-scale mamillated topography to which they give rise.

On the northern and western slopes of Losirua the kyanite gneisses are particularly well exposed. Where no quartzite intervenes they grade upwards into the biotite-garnet gneisses. The uppermost kyanite gneisses are massive, sometimes flaggy biotite gneisses, rarely with sparse small garnets, and with narrow beds containing pale greenish blue kyanite prisms up to half an inch long. Muscovite frequently accompanies the kyanite and clearly replaces it along certain layers. The upper 200 feet of the kyanite gneisses are of this type—the lower 60–80 feet, however, are massive poorly foliated kyanite-biotite gneisses in which muscovite is rare or absent. Below the massive beds are thin kyanite-muscovite-graphite schists and these overlie a thin bouldery quartzite. The kyanite gneisses are from 200 to 400 feet in thickness on the northern and north-western sides of Losirua and are cut off to the east by a fault (*see* Fig. 3).

Two kyanite gneiss beds occur in the low hills east of Ropet, and are interbedded between biotite gneisses. Both contain minor amounts of muscovite and garnet. The more westerly of the two beds is the more homogeneous and contains the most kyanite, in the form of easily visible green prisms.

The kyanite gneisses that outcrop extensively on the west slopes of the Kileu ridge are essentially similar to those already described. Muscovite is a ubiquitous constituent and the kyanite content decreases from the top of the bed towards its base.

(3) BIOTITE GNEISSES AND BIOTITE-GARNET GNEISSES

These rocks are best seen in the core of the Kileu syncline and above the kyanite gneisses on the northern and western flanks of Losirua. They are inhomogeneous rocks varying from light-coloured felspathic gneisses with sparse minute garnet granules to dark well foliated schistose types with garnets in well defined layers. The occurrences in the hills east of Ropet are not garnetiferous but contain thin quartzite layers. They are separated locally from the kyanite gneisses below by one or two thin quartzites. The biotite gneisses appear to be altogether absent on the col one and a half miles north-west of Losirua summit and at the north-western end of the Kileu ridge.

The kyanite gneisses and the biotite (garnet) gneisses together represent a pelitic or semi-pelitic stage within a predominantly arenaceous succession. The variations of lithology within this stage have very likely been governed by original variations in the composition of the sediments from which they are derived and to a lesser extent by granitization.

A group of biotite gneisses that is stratigraphically and lithologically distinct occurs in the core of the Losirua anticline below the kyanite gneisses. The group consists of gneisses that locally contain garnet and are migmatitic in appearance, irregular feldspathic streaks, veins and zones of varying texture differentiating them from the other biotite gneisses described above. Between them and the quartzite above them is a thin but widespread bed of fine-grained muscovite-biotite schist too narrow to be shown on the map. There is a sharp distinction between the migmatitic appearance of these rocks and the non-migmatitic character of the higher beds and it is possible that they represent the upper part of a different series or system. This question could be resolved by detailed mapping.

(4) MUSCOVITE GNEISSES

Muscovite gneisses occur above the upper quartzite group on the north-west flank of Losirua. They are massive coarse-grained feldspar-rich rocks containing thin coarse quartzites. Similar rocks also occur below the quartzite on Lesiri and the other outlying hills to the east.

(5) LIMESTONE

A thin medium-grained limestone outcrops on the north slope of the small isolated hill south of Loldorobo. No other limestones were seen in the area.

(6) GRAPHITE SCHISTS

Isolated exposures of kyanite-graphite schist and muscovite-graphite schist were seen near the base of the kyanite gneisses on the north slope of Losirua. This horizon cannot be traced far because of the abundance of quartzite rubble on the hill sides.

2. Tertiary and Quaternary Rocks

(1) VOLCANIC ROCKS

It is inferred from evidence obtained elsewhere in Kenya that the volcanic activity connected with the Gregory Rift Valley did not begin till some time in the Miocene (*see p. 20*). A general lower limit is set for the vulcanicity in the present area by this inference and an upper limit is set by the fact that all lava eruptions are known to have ceased by the time the Olorgesailie Lake Beds of the Magadi area were laid down, that is, by the upper Middle Pleistocene. Minor pyroclastic activity persisted into the upper Pleistocene.

The volcanic activity in the present area began with the formation of the central volcanoes Lenderut and Shombole. The denuded condition of these two volcanoes suggests that they date from at least the Pliocene, or perhaps even the Miocene period.

(a) Lenderut Volcanics

The Lenderut hills are formed of the denuded remnants of a central volcano which pre-dates the surrounding quartz trachytes of the Plateau Trachyte Series. The general structure of the volcano is indicated by the radial dips shown by its component lavas about a centre approximately one and a half miles north-west of the summit of Lenderut. The volcanics consist of andesites, tephrites and basanites which were erupted in the order written.

Andesites are represented by specimens 58/238* from the ridge south-west of Oldomut, and specimens 58/248 and 58/236A from the north-eastern and eastern margins respectively. These rocks contain sparse andesine, brown hornblende and pyroxene microphenocrysts set in a trachytoid matrix of intermediate or sodic plagioclase, minute rods of pyroxene and much iron ore. In specimen 58/238 some small euhedra of apatite are visible.

Specimens 58/244 and 58/236 are from the north-central and western part respectively of the summit ridge of the hills, and are similar to the andesites described above, but contain small amounts of a mineral of low birefringence and low refractive index in the matrix.

*Numbers prefixed by 58/ refer to specimens in the regional collections of the Mines and Geological Department, Nairobi.

This mineral may be analcite or a related mineral, and the rocks are classed as tephrites. A more basic tephrite is represented by specimen 58/235 from the inlier of Lenderut lavas south-east of the main area. This rock is highly porphyritic, with purplish augites and zoned basic plagioclases set in a fine dense matrix of plagioclase prisms, abundant iron ore granules and rare green pyroxene grains. The matrix contains small altered nephelines.

Porphyritic basanites form the prominent dark hills at the northern margin of Lenderut and on the summit ridge. They contain labradorite, augite and olivine phenocrysts, the latter usually partly or completely altered to iddingsite. There are numerous patches of clear analcite in specimen 58/237, and in specimen 58/234 there are small ill-defined patches possibly representing an alkaline mesostasis.

(b) *Shombole Volcanics*

Shombole volcano rises approximately 3,000 feet above the surrounding country and is scarcely recognisable as a volcano on account of the deep canyon-like valleys eroded into its sides. At close range, however, the volcanic structure is especially clear—the banded cliffs illustrate the radial dip of the lavas and pyroclastics and the horizontal attitude of tuffs and agglomerates that fill the original crater is obvious. The average angle of dip of the volcanics on the south and north ridges of Shombole is 19 degrees. The prominent hog-back ridge east of the main mountain is due to the upfaulting of a portion of the eastern flank of the volcano. Shombole is notable for the steepness of its slopes and the treacherous nature of the rubbly lavas and pyroclastics of which they are composed. Thorn bush on the upper slopes is unusually thick and difficult to penetrate.

The mountain consists largely of yellowish brown tuffs, with thin agglomerate horizons and rare thin nepheline lavas. The crater region, which is composed of horizontal tuffs appears to contain no lavas. The lavas and associated dykes are very much alike, being greenish grey to olive rocks rarely showing vesicles and often having visible phenocrysts of yellowish brown nepheline and prismatic pyroxene.

Typical of the nephelinites on the mountain are specimens 58/241 and 58/242 from the east ridge. These rocks contain abundant idiomorphic nepheline phenocrysts up to four millimetres in diameter containing zeolites in cracks. Green pleochroic aegirine-augite microphenocrysts, and rarer sphene microphenocrysts, occur in a microcrystalline matrix which seems to consist largely of pyroxene granules and microphenocrysts and granules of analcite.

Thin sections of two dykes on the southern part of Melil hill, specimens 58/232 and 58/233 are similar to the nephelinites described but 58/232 has a finer-grained matrix and is richer in strongly zoned aegirine-augite prisms. Specimen 58/233 contains many fewer nepheline phenocrysts, the pyroxene being correspondingly more abundant, though in smaller crystals. Analcite crystals are not so obvious in thin section, but pools of analcite are present.

(c) *Kirikiti Basalts*

The main features of the Kirikiti Basalts have been described in connexion with the Magadi area (Baker 1958, pp. 16–18). They are exposed along the face of the precipitous lower part of the Nguruman escarpment and on the lower Kirikiti platform. In the present area the ledge of basalts which forms this platform slopes southwards and passes below the level of the more recent sediments which occur in the Ngare Nyiro—Lake Natron basin. Not more than 300 feet of the basalts are exposed in the face of the escarpment north of Ol Doinyo Lengorale, and these are dark grey mottled equigranular olivine basalts (specimen 58/275). An exception to this type was collected half way up the escarpment at the northern boundary of the area. It is a greenish grey olivine basalt (specimen 58/276) containing much greenish blue chlorite in the matrix. The olivine granules alter to an unidentified dark greenish grey substance.

(d) *Olivine Basalts of the Eastern Half of the Area*

The olivine basalts outcropping over a wide area in the eastern part of the area occur also in the Namanga-Bissel area to the east (Joubert 1957, p. 33) and are also equivalent to the basalts occurring in the south-east corner of the Magadi area (Baker, 1958, p. 16).

Little can be added to Joubert's description of these rocks. They are characterized by bouldery outcrops and occasionally exhibit a facies with small visible felspar phenocrysts. They are assumed to rest directly on the Basement System rocks. The thickness is unknown but it is unlikely to exceed 200 feet along the eastern margin of the outcrop; the lavas are likely, however, to thicken toward the west. It is of interest to observe that the olivine basalts can be shown to be much younger than the Kapiti phonolite of the Turoka area (cf. Gregory 1921, pp. 180-183).

(e) *Plateau Trachyte Series*

The Plateau Trachytes are the most widespread lavas in the Magadi region and have been fully described previously (Baker 1958, pp. 18-22). They rest conformably on the olivine basalts in the east and on the Kirikiti Basalts in the west. The thickness of the series is unknown but is certainly in excess of 600 feet and is likely to be of the order of 1,000-1,500 feet being thicker in the west than in the east. The present eastern margin of the series is close to the former limit of extension of these lavas, little erosion having taken place since their eruption. No vents from which they may have erupted are known and they are regarded as due to fissure eruptions for this reason. In outcrop they are characterized by broadly spaced horizontal partings giving the loose weathered rocks a flaggy appearance. The trachytes are dull greenish grey, frequently with a sheen due to the presence of many felspar micro-phenocrysts. The matrix is rough to the touch and the only megascopically visible constituents are rare yellowish alkali felspar phenocrysts up to one centimetre long.

In thin section the trachytes of the present area can be broadly divided into two varieties; the microporphyrritic Loloitikush type represented by four specimens, three from the Loloitikush plateau (58/230, 251, 252) and one from the south-west side of Lesoit nearby (58/240), and an "orthophyre" variety, which is more widespread. Small amounts of interstitial quartz have been identified in both types, as was found in some of the trachytes of the Magadi area (Baker 1958, p. 19).

The Loloitikush variety is porphyritic with 2 to 5 millimetres-long soda-orthoclase phenocrysts and green aegirine-augite microphenocrysts in a fine-grained matrix consisting mainly of alkali felspar prisms, aegirine granules and brown glass interstitial to the felspars. An alkali amphibole pleochroic in shades of olive-brown is noticeable in most slides. Calcite occurs in vesicles and in patches in the groundmass. In one thin section (58/230, from the northern end of the Loloitikush plateau), there is much fine chalcedonic quartz in the groundmass.

The orthophyre variety contains the same minerals and some of the alkali felspars are microphenocrysts. The felspars of all generations are, however, short prisms with a zone of dusty inclusions near their borders. The matrix is much coarser-grained than in the Loloitikush type and contains more green aegirine-augite, often in the form of ragged microphenocrysts. Skeletal ophitic kataphorite is common and quartz in isolated clear grains occurs in half the slides. Reddish brown to greenish brown glass occurs as intersertal wedges throughout the slides.

Examples of the orthophyre variety of alkali trachyte were collected from the eastern edge of the Oloronga plateau, near the northern margin of the area (58/227); from two miles west of Ndamo (58/229A); from the west side of the Kiambu valley three miles east of Oldomot (58/239); from one mile west of Ngadalat (53/249); from the edge of the trachyte outcrop three miles north-west of Torosei wells (58/261); from the west side of the Sereata valley, three miles west of the south end of Lake Kabongo (58/262); and from the plateau two miles west of Olonguruan wells.

The trachytes of the Loloitikush variety are very similar to the soda trachytes of Gibeles type described by Campbell Smith from the Kikuyu and Kedong escarpments (Campbell Smith 1931, pp. 220-222), and the orthophyre trachytes are comparable with the pantelleritic trachytes (op. cit. pp. 222-224).

It is of interest to note that the rocks forming Ol Doinyo Lengorale hill in the western part of the area rest directly on the Kirikiti Basalts and are quartz trachytes. There is thus a strong parallel with the situation at the north end of the Nguruman escarpment where a

single trachyte, the Lengitoto Trachyte, rests on the basalts. It is on this evidence that the second movement of the Nguruman fault is regarded as having taken place after the beginning of the plateau trachyte vulcanicity (Baker, 1958, pp. 18 and 62-63).

(f) *Ash and Scoriaceous Lava of Alasho*

Ol Doinyo Alasho is a low hill situated east of Shombole, composed of ashes, tuffs and glassy scoriaceous trachyte, the latter being confined to the upper part of the hill. The broad open col between the eastern ridge of Shombole and Alasho is covered by yellowish brown crudely bedded pumice tuffs to a depth in excess of 60 feet. These tuffs represent the first pyroclastics ejected from the vent which is on the hill itself. At the foot of the hill, and forming an outlier a little distance north-west of it are reddish brown tuffs resting on the ashes. The tuffs on the hill grade upwards into agglomeratic beds and finally the upper part of the hill is composed of scoriaceous brown glassy trachyte. This trachyte (specimen 58/231) consists of reddish brown partly devitrified glass containing small alkali felspar phenocrysts. The Alasho volcanics are correlated with the ash and scoriaceous lava vents common in the Magadi area (Baker, 1958, p. 25), which are regarded as having brought the plateau trachyte vulcanicity to an end.

The yellowish brown ashes that occur on the Alasho-Shombole col appear to grade northwards into bedded fluvialite and finally lacustrine beds, which are closely comparable with the Oloronga Beds.

(2) LACUSTRINE AND FLUVIATILE SEDIMENTS

The sedimentary deposits of the present area closely resemble and are correlated with those already mapped in the area to the north (Baker 1958, p. 26). The more recent work has required that some modification be made to the succession originally established for the Magadi area (*see* Baker, 1958, appendix p. 81). The Chert Series was, at first, tentatively regarded as younger than the Oloronga Beds and equivalent to the Olorgesailie Lake Beds, but it is now known to be older, and to pre-date the grid-faulting episode. A part of the Ngare Nyiro plain is underlain by lake beds deposited when Lake Natron stood at a higher level, and these are believed to be the equivalents of the High Magadi Beds. Additional information gained in the present area makes it possible to give a brief account of the geological and climatic history of the Magadi area as a whole (pp. 20-22).

As in the area to the north the sedimentary rocks are largely confined to the fault-troughs, either due to their having been deposited only in troughs or due to their being down-faulted and protected from erosion. Useful sections are usually only found in the older lake beds—the Chert Series and Oloronga Beds, since these are affected by the grid-faulting and are exposed on or near fault escarpments.

The revised generalized succession of sedimentary rocks for the whole Magadi region is given in the following table:—

Ngare Nyiro Basin	Magadi trough	Legemunge-Koorra trough
High Magadi Beds of the Natron basin and High terrace	Evaporite Series High Magadi Beds	Boulder trains and sands
Ngare Nyiro Beds	(Lake beds, unexposed but probably occurring in the Lesoit, Sereata, Narsurana valleys etc.)	Olorgesailie Lake Beds
Pebble beds and sands (Pagasi)		
Oloronga Beds and the ash beds of Alasho	Oloronga Beds Chert Series	

Rift Valley lavas (mostly quartz trachytes and olivine basalts)

(a) Chert Series

The principal outcrops of the Chert Series are in the vicinity of Lake Magadi, only small patches being seen in the present area near its northern margin between Oloronga and Rekereien. The chert beds invariably rest directly on lava and are variable both in thickness and lithology. Cherts are exposed on the crests of the low escarpments along the motor track north-west of Rekereien. Often the only indication of these beds is the presence of a gravel of chert containing casts of *Viviparus* shells but elsewhere, such as on the brow of the first escarpment west of the Rekereien-Magadi valley, by the motor-track, there are outcrops of massive fossiliferous cherts resting on lava, and a little lower down the slope a chert breccia. A little further to the north the *Viviparus* limestone is partly silicified and outcrops at intervals and locally overlies olive-grey silicified clays. None of the sections are more than a few feet thick. Just north of the road, near a group of trees is the following section:—

	feet
4. Massive <i>Viviparus</i> chert	2-4
3. Chert breccia with chalcedony veins	2 (<10)
2. Grey friable volcanic silt	<4
1. Pale buff laminated clays	6

Further to the north, about one and a half miles south-west of the hot springs at the south-west end of Lake Magadi, a series of sections exposes the Chert Series resting on quartz trachyte lavas and overlain by the Oloronga Beds. The *Viviparus* chert caps the low escarpment locally and is seen to overlie a poorly exposed sequence of cherty clays and silts not more than 20 feet thick. Two hundred yards west of the brow of the escarpment the contact of the Chert Series and Oloronga Beds is well exposed. All the beds dip at 4° to 5° to the west; the general sequence is as follows:—

	feet
Oloronga Beds	8. Thick kunkar limestone c. 3
	7. Clay with honeycomb structure >3
	6. Poorly bedded yellow-brown silty clay 28
	5. Yellow-brown well bedded silts with chert and lava gravels 4
	4. Nodular kunkar limestone ½
Chert Series	3. <i>Viviparus</i> chert 4
	2. Pale green-grey conglomerates c. 5
	1. Cherty silts and clays c. 10 (Quartz trachyte lavas)

In the face of the low escarpment that forms the eastern margin of the Oloronga plateau at the point where the motor-track crosses, is a further section in Chert Series overlain by six and a half feet of Oloronga Beds:—

(Oloronga Beds)	feet
6. Banded buff or pale green chert with <i>Viviparus</i> casts	3
5. Pale olive green volcanic clay	c. 5
4. Grey volcanic gravel	1½-2
3. Green-grey silt	4
2. Thin platy kunkar	¾
1. Grey-green friable volcanic silt	5
(Scoriaceous trachyte lava)	

In the immediate vicinity of the western set of hot springs at the northern margin of the area, and forming a series of low flat-topped hillocks to the south, are poorly exposed cherts capped by kunkar limestone. The plain surrounding these hillocks consists of High Magadi Beds deposited on an uneven surface of cherty rocks and the surface of the ground is littered with a gravel of chert plates derived by erosion. These cherts are probably similar to those described at the south end of the ridge east of the south-western lagoon of Lake Magadi. (Baker 1958, p. 29).

One mile due north of the junction of the Gelai and Oldomut motor-tracks, north-west of the Lenderut hills, lake-beds with cherts are exposed in a gorge leading through a long narrow fault-block of lava. The beds dip at three degrees to the north-west and are confined to a narrow fault-trough; the succession is as follows:—

	feet
(Unconsolidated chert gravel)	
Chert gravel cemented by kunkar limestone	1
Chert bed—in irregular rounded lumps	3
Tough pale brown clays	8
Yellow-brown fine silt	18
Lava boulders in grey earth	6

Lithologically the outcrops of Chert Series in the present area closely resemble those already described for the Magadi area to the north; the rocks are clays and silts of volcanic derivation and the sequence frequently culminates with a fossiliferous limestone which is usually silicified. The patchy distribution of the series is due primarily to post-depositional erosion, a large part of which probably took place before the deposition of the Oloronga Beds, since the latter are frequently observed resting directly on lava.

(b) *The Oloronga Beds*

The Oloronga Beds were originally established on the basis of poor exposures on the Oloronga plateau in the area to the north (Baker 1958, pp. 27), but much more satisfactory outcrops were found at the southern end of Oloronga during the present survey. At the south-eastern edge of the outcrop of these beds on the Oloronga plateau, just north of the motor-track, six and a half feet of bedded brown silts rest on the Chert Series. Further north on the same escarpment the Oloronga Beds rest directly on lava, having a thin lava conglomerate at the base. At the northern boundary of the area the Oloronga plateau has a smooth surface of kunkar limestone sloping together with the beds it overlies at two degrees to the west. The Oloronga Beds together with the overlying kunkar pass beneath the later sediment filling the Ngare Nyiro basin. Between the Shombole motor-track and the northern boundary of the area the Oloronga Beds are exposed in a series of low hillocks, the unusual dissection of the plateau being due to a river which formerly drained the low-lying ground east of Oloronga and which cut through the Oloronga plateau and ended in the Ngare Nyiro basin. The lake-beds exposed total some 60 to 70 feet in thickness and are homogeneous light to dark brown silts showing little or no bedding. Occasional gravel layers are seen in the middle part of the sequence and near the top is a resistant porous clay.

East of Oloronga the westward-tilted lava-blocks are covered by a thin layer of Oloronga Beds and kunkar limestone, but exposures are poor and it is only on the two low escarpments overlooking the northern end of Rekereien that useful sections are found. On the face of the higher of the two escarpments between one and three miles north of the Shombole motor-track a number of sections show Oloronga Beds resting on Chert Series rocks. The two best sections are as follows:—

	feet
Oloronga Beds { Grey silts and volcanic sands	10
{ Brown silts with rare lava pebbles	5
Chert Series { Massive olive-green chert	2
{ Laminated olive clays and siltstones	12
{ Pale green to buff cherty limestone	1½
{ Yellow-brown ripple-marked silts	8
(Trachyte lava)	
Oloronga Beds { Brown silts	c. 10
{ Lava conglomerate in silt	c. 2
{ Yellow-brown coarse sands with clay lenses	c. 8
Chert Series { <i>Viviparus</i> limestone	0-3
(Trachyte lava)	

A little further to the north-east, between the two escarpments, is the section of Oloronga Beds and Chert Series tabulated on p. 12. Here 31 feet of poorly bedded brown silts with a thin conglomerate at the base rest on an eroded undulating surface of *Viviparus* chert, the latter being covered by a layer of chert pebbles cemented by kunkar limestone. The beds dip at five degrees to the west.

The Oloronga Beds are also exposed west of Loloitikush and north of Ol Doinyo Alasho, where they dip gently north-westwards towards the Ngare Nyiro swamp. Four miles north of Ol Doinyo Alasho five feet of brown conglomerate consisting of rolled ash fragments are exposed in streams, and at intervals down the slope to the swamp. One mile further north the Shombole motor-track crosses a low ridge of yellowish green clays and silts dipping at three degrees westward. All the exposures of these beds are capped by a thin kunkar limestone which slopes north-westwards.

There are no exposures over the greater part of the slope of the broad *col* between Ol Doinyo Alasho and the eastern part of Shombole. Three miles north-west of Ol Doinyo Alasho shallow stream-sections expose four to six feet of conglomerate consisting of ash fragments and lava pebbles up to a quarter of an inch in diameter in a brown silty matrix. Small oyster shells occur in these beds which, towards Shombole, grade into cemented pebble-beds derived from the Shombole lavas, overlain by coarser loose pebbles of more recent date. One mile north-west of Ol Doinyo Alasho stream gullies expose well bedded bright yellow-brown ashes which can be seen to underlie the red-brown tuffs that form the lower slopes of the hill. These ash beds cover the whole of the saddle between Alasho and Shombole, dipping gently north or north-west to the north of the saddle and dipping south to the south of it. A good river section on the south side three miles south-west of Alasho yields the following section:—

	<i>feet</i>
Kunkar-lava gravel	1
Hard buff gritty earth	1½
Platy kunkar limestone	½
Brown earth with rounded pebbles of kunkar and lava	6
——eroded contact——	
Homogeneous brown unbedded pumice tuff	45–50

The ash and tuff beds were derived from Ol Doinyo Alasho and appear to have been deposited sub-aerially in the vicinity of that volcano, and to pass into the lacustrine and fluvial reworked ashes and finally into typical Oloronga Beds further to the north. For this reason they are equated with the Oloronga Beds.

Oloronga Beds outcrop immediately south of Ol Doinyo Lengorale at the southern end of the Kirikiti escarpment, where they occur banked against the trachyte of Lengorale, and are overlain by the pebble beds and sands of the Pagasi. They consist of the typical brown silts with rare thin gravel beds. Bedding is poorly shown, but locally they seem to dip steeply to the east and are affected by minor north-south faults. It is because of the faulting that it is impossible to determine the thickness of the succession exposed, but it must exceed fifteen feet.

The occurrence of the Oloronga Beds resting on the Kirikiti Basalts is of importance in so far as the dating of the movements of the Nguruman fault is concerned. This matter is discussed in the section dealing with geological history (p. 20).

(c) *Pebble Beds and Sands of the Pagasi*

Unconsolidated pebble beds and sands occur on the Kirikiti platform west and north-west of Ol Doinyo Lengorale and are well exposed in the gorge cut by the Pagasi river. They rest on the upper surface of the Kirikiti Basalts and reach a maximum thickness of approximately 100 feet, thinning towards the north. Banks of pebbles rest on the Oloronga Beds and surround outcrops of the Lengorale trachyte. The pebbles are well rounded and consist of Basement System quartzites and pegmatites, in a matrix of sand. Bedding is extremely

poorly developed and many of the sandy beds are sandy earths. These beds together with the basalts on which they rest are cut off by the Nguruman fault, but much of the unconsolidated material has been swept over the escarpment by the Pagasi river and redeposited in alluvial fans.

The pebble beds and sands are of fluvial deposition and were laid down on the Kirikiti platform as a result of the rapid erosion of the precipitous Nguruman escarpment two miles to the west. Similar accumulations of pebbles and sands were laid down in the vicinity of the Oloibortoto gorge further north during the eruption of the Kirikiti Basalts (Baker, 1958, p. 16).

(d) *Sediments in Fault-troughs*

The sediments described in preceding sections were laid down previous to the episode of grid-faulting which broke up the Rift Valley floor. A further series of sediments were deposited in the depressions formed by this faulting.

Most of the larger fault-troughs in the area are floored by sediments, but it is comparatively rare that they are exposed. Study of stereoscopic pairs of air photographs shows clearly, however, that those fault-troughs that have no outlet for surface drainage are partly filled by lacustrine or fluvial sediments, and it is noticeable that in some cases the troughs have been filled to the level of the lowest part of the surrounding escarpments, and have then overflowed into adjacent troughs at lower level. This is particularly conspicuous in the case of those troughs crossed by the Torosei and Turoka rivers.

Light-coloured clays and silts with occasional thin gravels are exposed at the south-west side of the Rekereien valley and in the centre of the Lesoit trough. Elsewhere only red clay soils, light-coloured dusty soils and, in swampy areas, dark clay soils occur in the floors of the troughs, the largest of these being the Oldomut basin, which overflowed in the past into the south-eastern arm of Lake Magadi. The Kibangaini depression and the long Sereata-Kiambu valley are similarly floored with sediments. Further to the east, on the olivine basalt outcrop, the soils in the troughs are generally brown and glutinous when wet, and full of basalt boulders, and it seems likely that few if any sediments were deposited on the basalts.

The Nasurana, Kisilib, Torosei and Ologuruan basins and valleys are in a different category, for they have all been traversed by rivers originating on the high gneiss country to the east of the Rift Valley. They are partly filled by poorly bedded fluvial quartz sands which are of comparatively recent date.

Similar sedimentary infillings of fault-troughs occur in the Magadi area to the north, and in the absence of evidence to the contrary it was suggested that they are the equivalents of the Oloronga Beds (Baker 1958, p. 27). Although the Oloronga Beds may be preserved in the deeper fault-troughs of the western part of the area it is now considered that the unexposed lake-beds confined to fault-troughs are almost certainly later than the grid-faulting and must be correlated with the Ologesailie Lake Beds and the High Magadi Beds. The uppermost beds in the fault-troughs are almost certainly equivalent to the High Magadi Beds, for they were clearly deposited after all faulting and tilting had ceased. Some features of these sediments are discussed below.

(e) *High Magadi Beds and Equivalent Beds of the Natron Basin*

The High Magadi Beds that outcrop on the eastern side of Lake Magadi have already been fully described (Baker, 1958, pp. 37-39) and little can be added to that account for only a few exposures of these beds are found in the present area, in the northern part of the Rekereien valley. Equivalent beds connected with Lake Natron have, however, not been recognized previously, but as a result of the present work their presence is now established at the northern margin of the Lake Natron basin and in the area of the Ngare Nyiro swamp.

Both these groups of beds represent the higher levels of Lakes Magadi and Natron, and they were deposited after tectonic movements ceased in this part of the Rift Valley. In the Magadi basin the beds were deposited up to a level of 40 feet above the present lake-level, and are represented by yellow-brown poorly bedded silts overlying laminated clays with fish remains. They pass below present lake-level and occur flooring the dry southern arms of the lake, two of which extend into the northern part of the present area.

Two exposures of the High Magadi Beds occur banked against the lava ridge on the east side of the north Rekereien valley. In the more northerly some 25 feet of clays and silts without fossils are poorly exposed, 12 feet of laminated buff and brown clays resting on deep brown unbedded silts. Similar silts outcrop to the south, and on both these occurrences there is a thin skin of saline efflorescences. A little further to the south, in the centre of the Rekereien valley are low heaps of shingle with beds of fluviatile gravels which mark the original southern shore of the High Magadi lake. The shingles and gravels appear to pass laterally into the pebble beds of the alluvial fan of the Orkajolasaien river. Close to the western margin of the south-western lagoon of Lake Magadi, some 200 yards north of the present area there is one of the few places where the High Magadi Beds are seen resting on older lake-beds. A small exposure in the banks of the stream that exposes the best section of Chert Series (Baker, 1958, p. 30, fig. 6, section A) shows the following section:—

							<i>inches</i>
Unconsolidated chert-kunkar-lava gravel							6
Kunkar limestone							6
High Magadi Beds	{	Deep brown silts	..	..	..	..	24
		Brown clay with fish remains	..	..	..	..	4
Chert Series	{	Chert pebbles cemented by kunkar	..	..	..	..	2
		Olive-green coarse sands	..	..	..	..	24

The High Magadi Beds here rest with unconformity on eroded and dipping Chert Series rocks.

At the foot of the north-west slopes of the Lenderut hills there are outcrops of fluviatile beds at a level somewhat higher than the upper limit of the High Magadi Beds. They are exposed in shallow stream-courses near the junction of the Oldomut and Gelai motor tracks, where sections show brown silts and clays containing thin lenses of lava conglomerate. About one mile to the east a further section 20 feet thick of volcanic pebble beds with silt matrices is seen. In each case the beds are overlain by grey loessic soils covered by kunkar limestones. The beds dip at angles of up to one and a half degrees northwards but the dips are probably depositional.

These beds are tentatively correlated with the High Magadi Beds and are regarded as fluviatile deposits laid down at the base of the Lenderut hills during the maximum development of Lake Magadi. They are overlain locally by coarser pebble beds of more recent date.

The beds deposited in the High Natron lake extend over a wide area to the north of Lake Natron and are seen on the Ngare Nyiro plain as far as the northern boundary of the area. Exposures are poor as the beds have not been exposed to any depth by erosion, and in many places the surface of the plain is covered by friable clays and wind-blown accumulations of light colour. On the plain immediately north and east of the outwash fan of the Pagasi river there are many low hummocks of fine grey or brown loess overlying compacted brown silty clays showing poor bedding and having scattered efflorescences of salts. The limit of exposures of these beds is only roughly marked on the map, for they are overlain by more recent alluvial and loess deposits to the east.

The furthest extension of these beds is unknown, but it is likely that they underlie the whole of the Ngare Nyiro plain as far east as the Oloronga plateau, and probably extend for a mile or two north of the northern boundary of the area. The highest level reached by Lake Natron is not known precisely, but is likely to have been between 50 and 100 feet above its present level, as is suggested by the presence of poorly preserved beach levels on Melil hill ranging from the base of the hill to about 50 or 60 feet above present lake-level.

The possibility that many of the other fault troughs contain beds of High Magadi age has been put forward in the preceding section. The sediments occupying these troughs are built up to a level surface and are clearly unaffected by faulting or tilting. This suggests that they are younger than the Olorgesailie Lake Beds, which are affected by minor faults. In any case it would be surprising if no beds contemporaneous with the High Magadi Beds were laid down in other troughs, for beds were clearly deposited under pluvial conditions.

(3) SUPERFICIAL DEPOSITS

The nature of the soils in the area is controlled largely by topography and drainage. The soils of the valley flats are usually light-coloured, fine and dusty when dry, and dark and clay-like when wet. They vary from light to dark grey, the latter being similar to the "black-cotton soils" of poorly drained areas. The latter are particularly common on the olivine basalts outcrops in the east of the area. In the Ngare Nyiro plain the soil is largely loess, sometimes redeposited by water. It is usually grey, structureless, and occurs in hummocks. On the lava horsts soils are generally thin and patchy, of red-brown colour and of the consistency of clay.

In complete contrast are the sandy soils of the Narsurana, Kisielib, Torosei and Olonguran valleys. Here the valleys have been covered by alluvial sands discharged by seasonal torrents of the Torosei and Turoka river systems and derived from the predominantly quartzo-felspathic Basement System rocks to the east. Sandy soils also occur on the eluvial slope westwards from the base of the gneissic hills of Losirua, Lesiri and Lenkijabe.

Pebble beds and boulder beds of fluvial origin are found around all hills of moderate to steep relief, and a pediment of such beds completely surrounds Shombole Mountain and to a lesser extent the Lenderut hills. The Pagasi alluvial fan is notable in that the greater part of the material of which it is composed is derived from a series of fans of considerably greater age.

Kunkar limestone is widespread in the area, and occurs in several forms, the two most important of which are "platy" kunkar and "nodular" kunkar. The former is not common and occurs principally in stream-beds and on old land-surfaces between the older series of lake beds. The "nodular" kunkar occurs either as nodules in soil or lying loose on the surface or as cemented nodules. The latter is the commonest variety and is extensively developed on the Oloronga plateau, between Oloronga and Rekereien, north-west of Ol Doinyo Alasho, and more rarely on lava horsts such as Loloitikush.

The cemented nodular kunkar of the Oloronga-Rekereien area is of interest since it seems to be of composite age. On the Oloronga plateau it forms the upper surface of the Oloronga Beds and slopes down westwards and passes beneath the Ngare Nyiro alluvium and the Natron equivalents of the High Magadi Beds. East of Oloronga, however, a similar kunkar overlies the Oloronga Beds and passes over the escarpments and descends into the Magadi-Rekereien trough and terminates a few feet above the present level of Lake Magadi. This relationship is seen repeatedly on both sides of Rekereien—the kunkar lies on an eroded surface of High Magadi Beds and on older formations. This episode of kunkar formation can be dated as early in the deflation of the High Magadi Beds. It seems that an early kunkar formed on the Oloronga Beds, probably shortly after their deposition, and was instrumental in preserving them from erosion on the Oloronga plateau, and that there was a second period of formation after the deposition of the High Magadi Beds. This younger kunkar has been eroded in the recent past to form kunkar gravels usually mixed with chert fragments and lava.

Superficial gravels occur as thin sheets resting on the younger kunkar limestone surface and on High Magadi Beds at the southern end of the south-western lagoon of Lake Magadi and along the base of the lava ridge on the east side of Rekereien. Similar gravels are often found resting on lake-beds in many of the small fault-troughs of the area, particularly at the north end of the Kibangaini depression. Wherever they occur they are found on the surface or overlain by grey loess-like dusty soils. A typical sequence of superficial deposits in the central part of the area is:—

4. Grey loess soil
3. Unconsolidated gravel
2. Kunkar limestone
1. Lake-beds or river deposits

The southernmost tip of the south-west lagoon of Lake Magadi and a group of feeble springs occur at the northern boundary of the area. Both the lagoon and the springs (numbers 13 and 14) have been fully described previously (Baker 1958, pp. 52–55).

V.—STRUCTURE

The structure of the area closely resembles that of the Magadi area to the north (Baker 1958, p. 61) and little can be added to the account given previously.

The metamorphic rocks in the south-east corner of the area are folded on axes plunging gently to the north-north-east. Three folds are recognized, the Ropet syncline, the Losirua anticline and the Kileu syncline. These folds are asymmetrical with gently dipping easterly limbs. The few lineations and minor folds that were observed are co-axial with the major folds and define a structural style with monoclinic symmetry. The lineations are therefore b-lineations. A few lineations on Kaku hill on the eastern boundary of the area trend east-north-east, and may indicate a swing of the fold axes in that direction. These structures contrast with those deduced by Joubert (1957, pp. 75–83) for the Namanga–Bissel area to the east, and those deduced by Weiss (1958) for the Turoka area.

The Losirua fault is inferred on stratigraphical grounds and was not seen in the field. On the basis of a tentative correlation between the stratigraphical sequences on either side of the fault, a downthrow of 5,000 feet to the east is inferred.

The remainder of the area is dominated by fault tectonics associated with the Rift Valley. The pattern is apparent on Fig. 2, which shows the numerous parallel faults that characterize the valley in the Magadi region. Little need be added to the account already given (Baker 1958, pp. 61–63) with the exception of additional comment on the Nguruman fault system. The Nguruman fault, which first moved in mid-Tertiary times, was rejuvenated not once but probably twice. A second movement occurred after the deposition of the Kirikiti Basalts and previous to the eruption of the bulk of the quartz trachytes. A third movement must be postulated during the grid-faulting episode to allow for the cut-off of the Oloronga Beds. In any case post-quartz trachyte movements on the Nguruman fault at the same time as the grid-faulting are strongly suggested by the fact that the quartz trachytes dip towards the fault to the north and east of the Ngare Nyiro plain.

The pattern of grid-faulting is well shown on Fig. 2. A feature of the structure is the repetition of fault-blocks tilted to the west and with prominent east-facing escarpments. These mirror the structure of the rift on the larger scale and strongly suggest that the mechanism that originated rift movements continued to operate throughout the tectonic history of the area. The Koora, Kordjya–Magadi and Ngare Nyiro–Natron troughs illustrate the larger depressions formed by block-faulting and westerly tilting. In each case east-facing escarpments occur with down-faulted westerly-tilted blocks to the east of them. In each case the faults bounding these depressions to the west are slightly transverse to the trend of the majority of smaller grid-faults, being orientated north-south or even west of north.

The larger number of grid-faults trend a little east of north, and form a structure consisting of narrow blocks showing step or horst and graben structure. Few individual faults are longer than ten miles and fault systems are characterized by fractures arranged *en échelon* with ramps between the ends of adjacent faults. This is well shown in the Koora trough south of Olorgesailie.

The fault-planes themselves are invariably hidden by scree, but there is little doubt that they are normal faults, for the pattern will allow of no other interpretation (cf. Bain and Beebe, 1954, pp. 750–754). It also follows that the faulting was produced as a result of crustal tension (op. cit.) for compressive or torsional forces produce quite different patterns. The role of the underlying Precambrian structures is difficult to evaluate. To the east and west of the Magadi section of the Rift Valley the regional strike of the metamorphic rocks is close to the trend of the rift structures. It has been suggested that this and other observations lend support to the hypothesis that the site of the Rift Valley has been subject to shearing, faulting or rift faulting of pre-Tertiary age (Dixey 1956, pp. 26–29). There is no evidence of this in the Magadi area, nor to the writer's knowledge, anywhere else in Kenya. It is reasonable, however, to suppose that the Tertiary and Quaternary rift structures were influenced to a greater or lesser extent by the pre-existing structural lines of the metamorphic foundation.

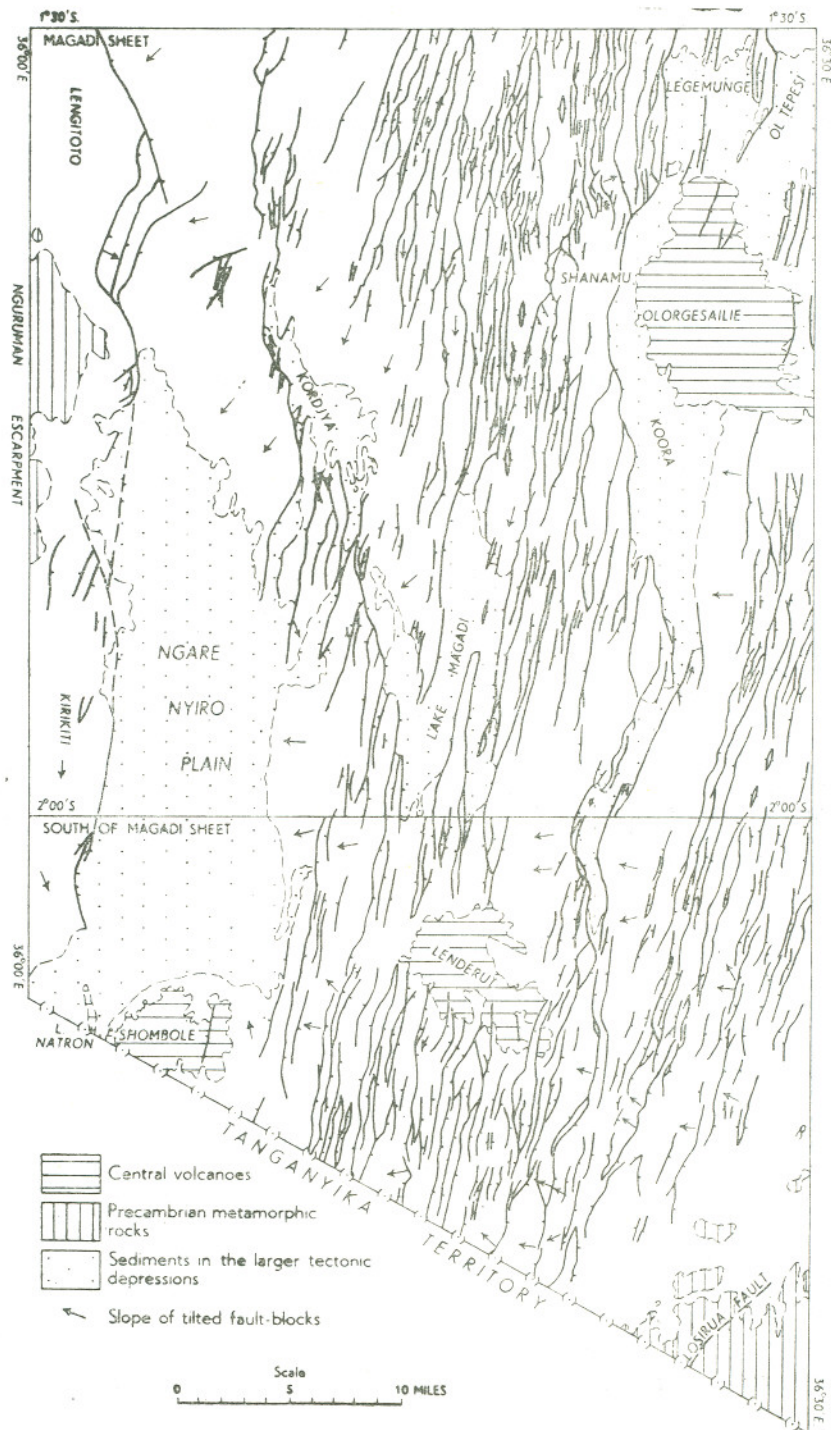


Fig. 2.—The pattern of faulting in the Magadi region.

VI—GEOLOGICAL HISTORY OF THE MAGADI SECTION OF THE GREGORY RIFT VALLEY

The southern part of the Gregory Rift Valley in Kenya differs in several important respects from the other parts to the north and south, but also forms the link between the dissimilar but related Tanganyika section and the more widely known central part in the Naivasha-Nakuru area. Whereas many of the older rift volcanics and the structures associated with them are blanketed by comparatively recent volcanics in the areas to the north and south, in the Magadi area the greater part of the volcanic succession is exposed.

The metamorphic rocks of the Basement System, which are believed to be Precambrian in age, form the foundation on which the Rift Valley geology is built. The post-Cambrian history of the area is one of repeated uplift and erosion, and erosion surfaces of end-Cretaceous and sub-Miocene age have been recognized on the east shoulder of the Rift Valley (Joubert 1957, pp. 9-10). The sub-Miocene peneplain is believed to have extended from the area north of Kajiado and Turoka, where it is well developed and overlain by the oldest rift volcanics, across the present day valley and to have been continuous with an erosion surface near the top of the Nguruman escarpment west of Magadi. Certainly there is no evidence here or elsewhere in the Gregory Rift Valley of any rift-faulting or plateau vulcanicity preceding the formation of the sub-Miocene peneplain (cf. Shackleton 1951, pp. 371-373). The sub-Miocene surface, at a present-day elevation near the crest of the Nguruman escarpment of 6,300 feet, is in a youthful state of dissection. It slopes gently westwards away from the Rift Valley and appears to be continuous with the sub-volcanic surface further north, in the Sotik area, (Schoeman, 1949, pp. 5-28). It lies beneath the phonolites at the base of the Isuria escarpment (op. cit. p. 28) and is up-faulted by the Isuria fault. The observation that the lowest plateau lavas of the Rift Valley, generally phonolites, occur on an erosion surface of sub-Miocene age which has been gently warped and faulted is a common one (Shackleton 1946, p. 45), and serves to give a lower age limit for Rift Valley faulting and vulcanicity generally.

Following the eruption of the earliest of the Kirikiti Basalts, some of which occur on the upper part of the Nguruman escarpment, a simple graben was formed by opposed normal faulting on the Nguruman fault to the west and the Turoka fault to the east. The throw of the former was approximately 2,000 feet and of the latter much less, perhaps between 600 and 1,000 feet, the throw of the latter decreasing southwards till in the vicinity of Torosei no evidence of rift faulting was observed by the writer, although Joubert (1957) shows rift faults in the adjacent area.

The first volcanic events in the Magadi area were the eruptions of the central volcanoes Olorgesailie, Shombole and Lenderut which probably pre-date the earliest rift-faulting. Following the building of these volcanoes there occurred the olivine basalt plateau vulcanicity which flooded the floor of the graben and covered the lower slopes of the central volcanoes. Contemporaneous vigorous erosion of the Nguruman escarpment is suggested by the occurrence of interbedded conglomerates in the Kirikiti Basalts along the base of the escarpment. The basalt eruptions were followed by the first of the Plateau Trachyte flows (Lengitoto and Lengorale), which is seen only on the Kirikiti platform for, after the eruption of the first trachytes, a second major movement of the Nguruman fault took place, effecting a further downthrow of the Rift floor by at least 2,500 feet. This rejuvenation of the Nguruman escarpment resulted in the formation of a ledge of the Kirikiti Basalts on the face of the older fault escarpment.

The Plateau Trachyte vulcanicity continued on the lowered Rift Valley floor, which at this time sloped gently to the west since there was no rejuvenation of the Turoka fault on the east to compensate for the second large movement on the Nguruman fault. The trachytes are therefore thickest in the west and thin to the east and probably never covered the whole width of the Rift, at least in the southern part of the Magadi area. The trachyte vulcanicity was brought to a close with the eruption of a distinctive orthophyre-trachyte in the north, a lava that seems to have originated from the Suswa region, and will prove valuable when correlation of the Magadi succession with sequences to the north is attempted.

The final volcanic phase was the formation of small scattered cones of scoriaceous lava and ash. This activity appears to have continued intermittently for some time, for the ashes of Alasho are contemporaneous with the Oloronga lake-beds.

With the close of volcanic activity the floor of the Rift Valley can be visualized as a practically flat expanse of trachyte lava with the olivine basalts outcropping to the east. A number of small ash cones and the upper parts of the old central volcanoes rose above the level expanse of lava. On this surface the Chert Series was deposited as a comparatively thin layer of clays and silts, culminating in a fossiliferous limestone. These beds were then eroded and a thin kunkar limestone deposited locally and the Oloronga Beds laid down. These beds are poorly bedded silts and gravels and were formed largely by the redeposition of tuffs in shallow lakes and by streams. There then ensued an arid period of climate, the conglomerates of Pagasi were deposited as torrential deposits on the southern end of the Kirikiti platform and a thick kunkar limestone was formed on the Oloronga Beds.

Following the deposition of the Chert Series and the Oloronga Beds came the grid-faulting, which broke the Rift floor into many parallel blocks and fault-troughs. This phase of faulting can only be likened to differential collapse of the Rift floor along sub-parallel fractures. It was accompanied by a second minor rejuvenation of the Nguruman fault, for the Oloronga Beds and conglomerates of Pagasi are truncated by it. This grid-faulting episode must have taken place quite rapidly, for there was virtually no erosion of the escarpments during the faulting, nor has there been much since.

A third phase of lacustrine deposition occurred subsequent to the grid-faulting—these are represented by the Olorgesailie Lake Beds, which have been studied in detail on account of the vertebrate fauna and artefacts found in them. These beds are approximately 175 feet thick and rest on an eroded surface of volcanics. They represent a period of lacustrine deposition during which there were many recessions of the lake margin and during which Acheulian man camped and hunted along the lake shore. Reddening of part of Bed L8 (Baker, 1958, p. 34) suggests that at one time at least the emergence of the bed was of sufficient duration to allow the formation of a soil profile. Deposition in the Legemunge basin was almost certainly brought to an end by a phase of minor faulting which affects the lake-beds and caused local rejuvenations of the grid-faults. The Ol Tepesi depression was formed at this time and deepening of the Koora trough to provide an outlet for the lake is suggested by the presence of hanging valleys on the east side of the Shanamu escarpment. The Ol Keju Nero, which previously had been the main affluent of the lake which formerly occupied the Legemunge basin, then cut across the lake beds at the base of the northern slope of Olorgesailie mountain. A series of coarse boulder beds were deposited on terraces at an early stage in the erosion of the Ol Keju Nero valley. With the rejuvenation of the Ol Keju Nero a considerable amount of brown alluvial, and some fluvialite, material was laid down in the northern part of the Koora trough.

Following the period of minor faulting a phase of lacustrine sedimentation took place in the Magadi trough. The High Magadi Beds were laid down on an eroded surface of older lacustrine beds and lavas. Kunkar limestone is almost ubiquitous on the land surface beneath these beds and is suggestive of a period of aridity preceding the onset of lacustrine sedimentation. The High Magadi Beds were built up to a level 40 feet above present lake-level, where a well marked strand-line exists with a talus accumulation above. Equivalent beds were deposited in the Natron basin up to approximately 60 feet above present lake-level. A lake also existed in the Kibangaini depression south of Magadi, but unlike lakes Magadi and Natron, it has dried up completely. Much of the sediment which clearly fills the multitude of fault depressions in the region was also deposited during this phase; the few poor exposures indicate that the smaller depressions were little more than swamps and are filled by alluvium and fluvialite material of various kinds. Wind deflation must be invoked to account for the partial excavation of the Magadi trough to allow the deposition of the Evaporite Series, which is probably stratigraphically continuous with the High Magadi Beds in the centre of the trough. The deposition of the Evaporite Series is connected with the onset of alkaline spring activity and is not necessarily due to a change in climate, for no positive evidence of such a change is found outside the Magadi trough. The interbedded clays of the evaporite sequence were almost certainly derived from the erosion of the High Magadi Beds and the building up of the series to the present-day level of the lake is largely the result of crystallization of trona and the deposition of clays in alkaline lagoons in comparatively small depressions on the High Magadi Beds. The deflation of the latter would very likely be assisted by the fact that the alkaline waters would inhibit the growth of vegetation on the lake flats. During the period of deflation coarse poorly sorted boulder beds were deposited at various levels at the margins of the Magadi trough. The gravel sheets spread over the surface of

the lake flats at the southern end of Lake Magadi and the grey silty loess-like accumulations in the lee side of the trough suggest that the arid conditions which caused the lowering of the High Magadi lake and the erosion of its deposits have persisted substantially unchanged to the present day.

VII—PLEISTOCENE CHRONOLOGY AND CLIMATE

As a result of the work of Leakey, Wayland, Nilsson and others on the Pleistocene deposits in East Africa a faunal and cultural sequence has been evolved and used to date various deposits. On the evidence of the lithology of various fluvial, lacustrine and sub-aerial deposits and their contained fauna a climatic sequence for the Pleistocene has also been worked out, and a series of four pluvials and corresponding interpluvials of varying length and character have been postulated. Terms that were originally proposed for pluvial phases have now achieved stratigraphical significance (cf. Zeuner, 1952, pp. 249–252) and this tendency has recently culminated in the acceptance of the terms Kageran, Kamasian, Kanjeran and Gamblian as stratigraphical units (3rd Pan-African Congress on Prehistory, 1955, pp. 31–32). These terms refer to the deposits laid down during a pluvial period together with the succeeding interpluvial period and are defined (op. cit.) as “stratigraphic climatic divisions”. A stratigraphical nomenclature based on a hypothetical climatic sequence is of necessity imprecise and controversial, especially when the geology of the type localities on which it is based has not been adequately described, and when what is known of these areas can often give rise to conflicting climatic interpretations. In spite of these considerations suggestions of a glacio-pluvial correlation with Europe have been made (Cole, 1954, pp. 51–55), and correlations based on climatic deductions have been repeatedly made in the past.

Cooke (1955, p. 51) has recently drawn attention to these problems and has urged caution in accepting a glacio-pluvial correlation (op. cit. p. 53). It is the writer's opinion that the evidence for the climatic sequence in East Africa is in need of re-examination before a stratigraphical sequence based on climate is to be of value.

The evidence from the Magadi region supports the concept of the Gamblian pluvial, and an indifferent case can be made for a Kanjeran pluvial, but the evidence in favour of the latter is inconclusive. The Ologesailie Lake Beds are the only firmly dated deposits in the Magadi region, and are regarded as comparable to Bed IV of the Olduvai sequence and to the Kanjera Beds by Leakey (1952, p. 209; 1951, pp. 29–30; Kent, 1942, pp. 125–127). These beds are also correlated with diatomaceous lake-beds at Kariandusi and Munyu wa Gicheru (Shackleton 1955, pp. 259–260). These beds are upper middle Pleistocene in age. The succeeding High Magadi Beds and their Natron equivalents are not positively dated but can reasonably be compared with the former greater extensions of Lakes Naivasha, Elmenteita and Nakuru which have been referred to the Gamblian climate phase, which is regarded as being upper Pleistocene in age (Cole 1952, pp. 49–50, 60).

The Chert Series and Oloronga Beds are therefore earlier than upper middle Pleistocene in age and are tentatively placed in the lower Pleistocene. No correlation with other lower Pleistocene beds is possible because of the lack of fauna or stone tool cultures in them and no climatic evidence of regional significance can be deduced from them.

The High Magadi Beds and their Natron equivalents must be regarded as having been deposited during a period of appreciably higher rainfall than that obtaining at present, and so accumulated under pluvial conditions in the sense of Wayland (1952, pp. 59–61). The evidence for dry conditions before and after the deposition of these beds has already been mentioned. The evidence for pluvial conditions during the formation of the Ologesailie Lake Beds is poor, for deposition may well have been brought to an end by tectonic means. In addition, evidence for dry conditions immediately previous to the deposition of the Ologesailie Lake Beds is scant. It is notable, however, that in closed basins in the Magadi area which have a similar form to the Ologesailie lake basin and which have a similar rainfall no lakes exist under present-day semi-arid conditions. This suggests that the rainfall may have been higher in Ologesailie Lake Beds times than at the present day, but since the existence of the Ologesailie lake was to a large degree dependent on the formation of suitable basin by tectonic means i.e. the grid-faulting, then the initiation and the ending of lake deposition may well have been controlled largely by tectonic movements.

The evidence for climatic change before and after the deposition of the High Magadi Beds and their equivalents is good, and that pluvial conditions existed in Gamblian times. The evidence for climatic changes previous to these in the Magadi area are, however, inconclusive.

VIII—MINERAL DEPOSITS

An exclusive prospecting licence (E.P.L. No. 103) is held by the Power Securities Corporation Limited, Nairobi, over the whole of the area south of Magadi, excluding the areas underlain by Basement System rocks. The southern part of the area leased by the Magadi Soda Company Limited, falls into the present area, and includes the land bounded by latitudes $2^{\circ} 00'$ and $2^{\circ} 05' S.$, and longitudes $36^{\circ} 10' E.$, and $36^{\circ} 20' E.$ Under the terms of the lease the Company has the rights to work and dispose of deposits of sodium carbonate and other salts mixed with it, but has no rights over any other mineral (cf. Baker, 1958, p. 64).

1. Kyanite

Kyanite gneisses outcrop prominently among the hills in the south-east of the area and occur in three main beds, along the western slopes of the Kileu ridge, on the northern and western slopes of Losirua mountain, and on the ridge east of Ropet. In each case the rocks are biotite-kyanite gneisses with variable quantities of muscovite, quartz and feldspar. Only the Losirua kyanite beds have been studied in detail from an economic point of view, but the similarity between the three occurrences suggests that the conclusions reached for the Losirua occurrence can be applied in a general way to the others.

The Losirua kyanite bed is approximately 300–400 feet thick. Only the lower 50 or 60 feet contain appreciable quantities of kyanite; the upper part consisting of thin kyanite-bearing layers in biotite and biotite-muscovite gneisses. The lower kyanite-rich bed is homogeneous and contains greenish kyanite prisms up to half an inch in length. A series of grab samples were taken at various localities on this bed by A. L. Stewart, Government Metallurgist, and the proportion of kyanite estimated by means of separations in heavy liquids and by electro-magnet. The localities are marked on the sketch-map, Fig. 3, which also shows the geology and form of the deposit.

The percentages of kyanite estimated by Mr. Stewart are as follows:—

<i>Sample No.</i>	<i>Kyanite</i>
	%
220/1	12.4
220/2	9.8
220/3	18.6
220/4	18.4
220/5	12.8

The lowest 120 feet of the kyanite gneiss at the locality of grab sample 220/4 appears to be the best part so far located. The same horizon sampled at 220/2 gives a low kyanite percentage in spite of promising indications in the field.

Three further grab samples were taken, in the Kileu band of kyanite gneisses immediately east of the closure of the synclinal structure, three and a quarter miles east-north-east of the summit of Losirua. Kyanite percentages were determined by Mr. Stewart as follows:—

<i>Sample No.</i>	<i>Kyanite</i>
	%
220/6	9.7
220/7	10.4
220/8	8.4

The proportion of muscovite in these gneisses is generally higher than in those on Losirua. More comprehensive sampling of the Kileu kyanite beds is required, however, before an opinion of their economic possibilities can be expressed.

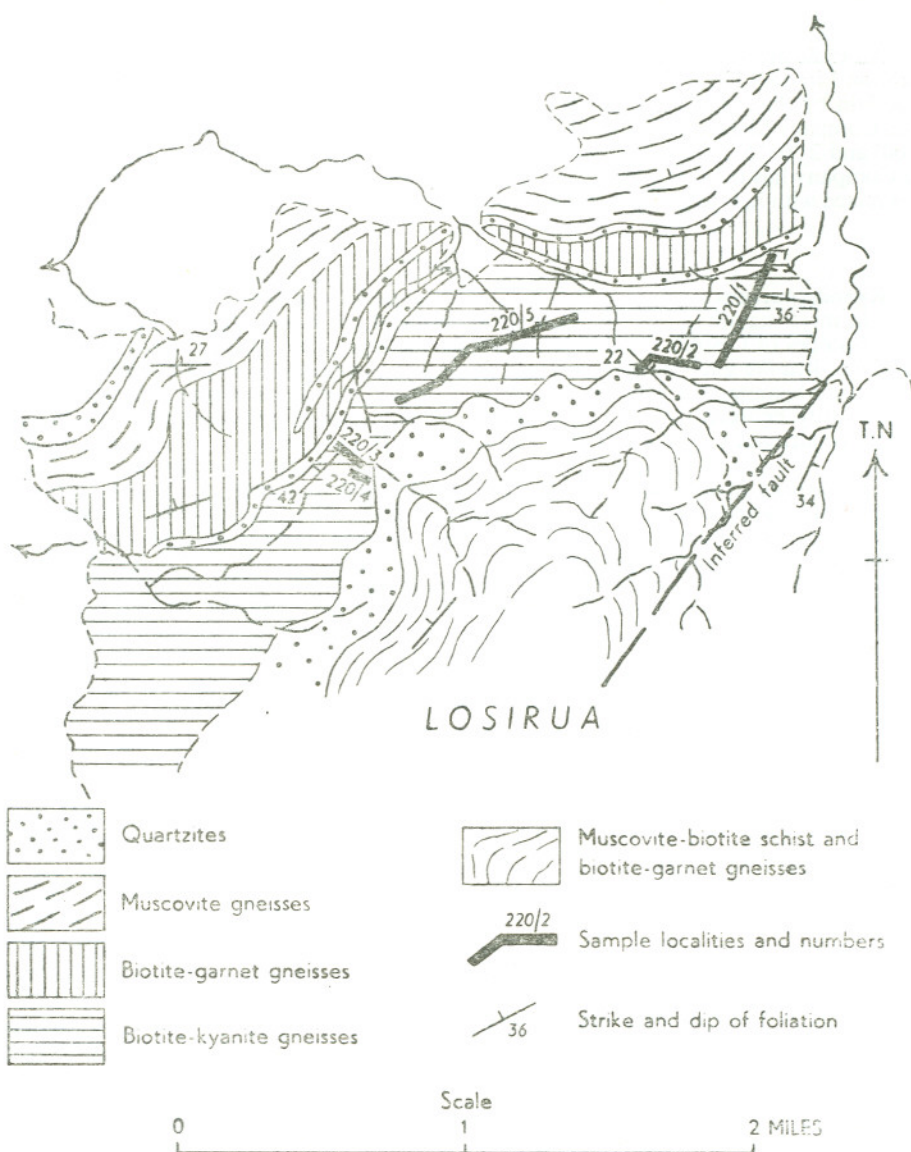


Fig. 3.—Geological sketch-map of the Losirua kyanite deposit.

The kyanite gneiss occurrences on the ridge east of Ropet were hastily examined and it is clear that only the western bed is likely to be of economic interest. The bed is homogeneous, moderately coarse-grained and very similar to the lower part of the Losirua kyanite gneiss.

These figures quoted above indicate that the kyanite gneisses are less rich than might be suggested by field estimations and that the deposits would be a sub-marginal economic proposition under present economic circumstances. The economic potentialities of the deposits are also adversely affected by the distance to the nearest railway, which is approximately 40 miles, and the absence of a natural water-supply. The deposits are, however, large, and should there be an improvement in the price and demand for kyanite and mullite it may well be profitable to carry out a full-scale investigation on them.

2. Graphite Schists

Kyanite-graphite schists occur near the top of the quartzite at the base of the kyanite gneiss on Losirua. Few exposures are seen and no estimate of the thickness of the graphitic bed can be made. The graphite occurs in flakes up to 5 millimetres in diameter and locally forms perhaps 20 per cent of the rock by volume.

This occurrence, however, is not likely to be economic, but could be investigated by pitting should there be a revival of interest in the neighbouring kyanite deposits.

3. Water Supply

There are several perennial sources of water in the South Magadi area, and in this respect it is somewhat better supplied than the area to the north. The Ngare Nyiro and the swamp north of Shombole provide ample water and also good grazing to the many herds of Masai cattle that crowd there in the dry season. The lower reaches and the out-wash fan of the Pagasi river also provide water, except in very dry seasons, but this area is apparently avoided by the Masai, possibly because some of the forest there contains *tsetse* fly. The other major watering place is Lake Kabongo, which has been perennial since the unusually heavy rains in 1951, but which the Masai state dried up seasonably before that date. This water is normally extremely foul because of the large numbers of cattle who crowd into it in the dry season. As many as ten or twelve herds can be seen watering at one time in the dry months while others are struggling over the escarpments that bound this lake on three sides. A further supply is obtained from wells dug in the Torosei river near its junction with the Sinya Landari. A large number of wells are dug here each year into the sandy river-bed, which has been partly dammed by a low concrete wall dug at the point where the river enters a gorge. These wells are likely to be perennial except in unusually dry years.

Seasonal water-supply is obtained from a number of small, undeveloped natural pans, from rock basins in river beds, and from wells in the bed of the Turoka river. Pools of water occur in the southern part of the Kiambu valley after rain, and also along impersistent shallow watercourses on the M'balbal Ormeresho plain.

The movements of the Masai are controlled entirely by the necessity for finding grazing and water, and during the dry season they concentrate around the few reliable water sources, with resulting serious overgrazing of the surrounding country. The Losirua and Kileu hills, on which there is good grazing, are neglected on account of the lack of water, and the northern part of the M'balbal Ormeresho is undergrazed for the same reason. Since future development in the area is likely to be in the form of grazing control, a planned augmentation of the existing water-supplies will be necessary also. The problem is to keep the Masai away from the potentially better grazing areas, such as the Ngare Nyiro plain, the ground around Ol Doinyo Alasho and the larger valleys such as Lesoit, Oldomut and Narsurana, until grass can re-establish itself in these areas. This can only be done by control and the provision of additional water-supplies.

Initially the quickest and cheapest methods of increasing water-points would be the construction of "tanks" or artificial deep pans in suitably chosen spots. The best sites are those already occupied by natural pans and by places receiving appreciable run off and which have reasonably impervious soil of adequate depth. Many of the valleys of the central part of the area are floored with clay soils of considerable depth and transient streams flow into them. Tanks could be constructed at the points where these streams disappear, and could be so arranged that the streams flow into them. Such tanks would, however, be short-lived on account of sediment carried into them.

There are many suitable sites for tanks on the Ilkoritoriti and Ormeresho plains, on the brown clay soil of that region. Similar promising areas are at the southern end of Oldomut, at the southern end of the Sereata valley, at the northern end of Rekereien and in the Lesoit valley.

No bore-holes have been drilled in the area, but one drilled a few miles north-east of Ilkoritoriti proved to be dry. The chances of success in the Sinun vicinity and south-east of Lenkijabe are good, if the bore-holes penetrate the basalts to the sub-volcanic surface. Any bore-holes drilled in the western half of the area are likely to encounter saline water.

4. Economic Possibilities in the Area

The only mineral likely to be of economic interest is kyanite, which has been discussed above. Future developments in the area will probably be in the direction of improving water-supply, implementing grazing control and in the provision of better motor-tracks. The area south of Magadi is likely to remain very much as it is at present for many years to come.

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