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GEOLOGY OF THE ELDAMA RAVINE-KABARNET AREA

DEGREE SHEET 34 S.E. QUARTER
(with coloured geological map)

by

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Chief Geologist

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ABSTRACT

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A reappraisal of the sediments of the Kamasian type area is made, and they are proved to consist of two separate groups of widely differing ages. The lower group is renamed the Chemeron beds, and the upper group the Kapthurin beds.

The structure and tectonics of the area are described, and a time-scale suggested for the deposition of the various rock types and episodes of faulting which have produced the Rift Valley as it is seen today.

Sections are devoted to hot-springs and carbon dioxide occurrences related to volcanic activity, and the water supplies and economic minerals of the area are discussed.

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The report describes an area of about 1,225 square miles in the central part of the Kenya Rift Valley, bounded by the Equator and parallel 0° 30′ N. and meridians 35°30′ and 36°00′ E.

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I.—INTRODUCTION AND GENERAL INFORMATION

General

The area described in this report is of approximately 1,225 square miles, and is bounded by the Equator and parallel 0°30'N., and meridians 35°30' and 36°00'E. It lies in the Rift Valley Province of Kenya, and comprises parts of four districts: Uasin Gishu, Elgeyo-Marakwet, Baringo and Nakuru. Uasin Gishu and Nakuru districts are mainly areas of large farms and plantations and some forest reserves, and Elgeyo-Marakwet is an area of smallholdings, again with forest reserves. Baringo district is mainly a grazing area. The gazetted forest reserves in the area are so numerous that their boundaries are omitted from the geological map for the sake of clarity, but all are marked on the 1 : 50,000 maps of the Survey of Kenya enumerated later.

Kabarnet, in the north of the area, is the District Headquarters of the Baringo District, and at Eldama Ravine (known locally simply as "Ravine") in the south is the office of the District Officer in charge of the southern part of the Baringo District. It is interesting to note that the township of Eldama Ravine lies in the Nakuru District, several miles from the Baringo border, an anomaly resulting from many changes of boundaries since the beginning of the century, when Eldama Ravine was the headquarters of a much larger district of the Uganda Protectorate, and Kabarnet a very new and minor substation to Eldama Ravine. Chepkorio is the District Officer's headquarters administering the southern (Elgeyo) part of the Elgeyo-Marakwet District, the District Commissioner having his headquarters at Tambach, a few miles north of the map area.

The main tribes of the area are the Tugen (also known as the Kamasia tribe) who inhabit the Baringo District, and the closely related Elgeyo in the Elgeyo-Marakwet District. Lesser tribes are the Njemps who live in the extreme north-east on the low ground north and east of Marigat, where a few Pokot from the north are also found, and Nandi on the Uasin Gishu Plateau in the west.

Both the Tugen and Elgeyo tribes can be subdivided into the hill dwellers and lowland dwellers of the tribes, by an accident of geography rather than on ethnic grounds. The hillmen are mainly agriculturists with only a few stock, and those in the dry lowlands subsist almost entirely upon their domestic stock, cattle, goats and sheep, with only rare smallholdings in river valleys where seasonal rainfall allows maize to be grown. Little land is wasted, and huts and maize plantations are often sited on hillsides the slopes of which were measured on more than one occasion and found to be up to 45°. (Plate I.)

In the Kamasian Hills maize is almost the only crop grown, but on the high ground in Elgeyo intensive agriculture is practised in smallholdings of a few acres each, all neatly fenced or hedged, which give the landscape an appearance of parts of southern England. Crops include cereals such as barley and wheat in addition to maize, and excellent vegetables, among them potatoes, cabbages, onions and tomatoes.

Near Marigat is the Perkerra Irrigation Scheme, where the waters of the Perkerra River have been diverted to irrigate large areas of the fertile but barren flats of the ancient Baringo-Hannington Lake. Irrigation is not new in this area, the Njemps having practised it long before the coming of Europeans to this part of Africa, though until the opening of this scheme the art had been almost forgotten.

Climate and Vegetation

Rainfall statistics kept in many places in the area, and in many stations close by, enable a fairly accurate diagram of average rainfall to be drawn (Fig. 1). It will be seen that rainfall amounts are controlled largely by altitude.

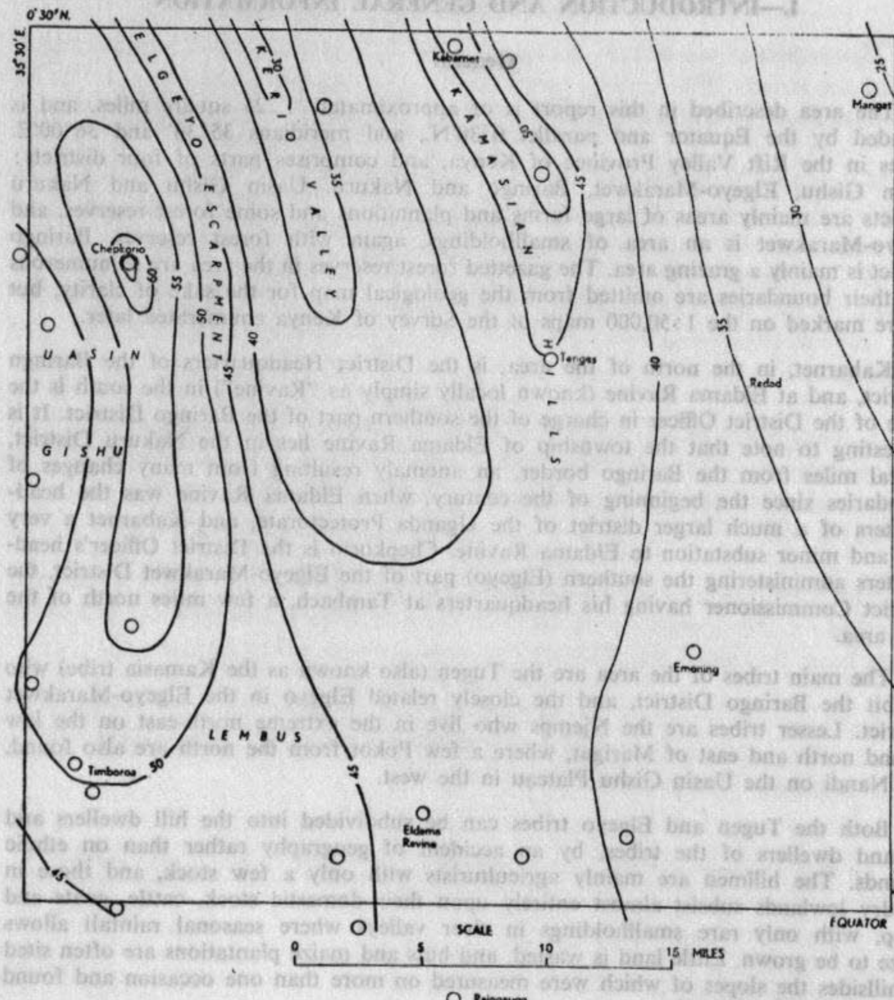

Fig. 1—Isohyet diagram of average annual rainfall in inches

Rainfall is heaviest between March and September, with peaks in April and August, the former month usually having a slightly higher average than the latter. Of the other months in the year December is the wettest, most of the stations showing rainfall during this month amounting to approximately half the totals for April or August.

Like rainfall, temperatures are controlled largely by altitude, the highest parts of the area in the west being relatively cool during the day, with early morning mist very common, and night temperatures sometimes falling below frost level. The Kerio Valley and the rift floor in the east, particularly the low ground in the north-east, are hot by day and generally warm by night.

All the ground below about 5,000 ft. O.D. supports a poor thorn scrub, mainly species of acacia with succulents, and larger trees only along watercourses. Above 5,000 ft., with increasing rainfall, patches of indigenous forest still remain. These are interspersed with rolling grassy plains, which have resulted from forest clearing, though some may have been original. Even in the early years of the present century all the higher ground of the Kamasian Hills, Lembus and the Uasin Gishu supported forest, and those patches which still remain are logged for podo, cedar and musumboria, cleared areas in forest reserves being replanted with various species of conifer. In the cleared forest lands soil cover often exceeds 30 ft. in depth, always very fertile and protected from soil erosion by a good grass cover maintained by the high rainfall. In the lower areas soil is thin or locally entirely absent, such grass cover as there is being scant and seasonal. The whole of the lower ground is heavily over-grazed, and only in the past few years has any determined attempt been made at stock control. Around Emening the land has been divided into large grazing areas, securely fenced and patrolled, and only a limited number of licensed stock are allowed to graze, being rotated from plot to plot so that each block is grazed for three months and then rested for a year. After only a few months rest even the most barren and rocky patches regain a good grass cover, and experiments are continually progressing to further improve the land by reseeding.

Game is now very scarce throughout the area, the only big game left being a herd of a dozen elephant in the eastern part of the Kaptagat Forest. The few common game animals elsewhere are dik-dik in the lower ground, with a few impala around Emening and zebra and ostrich near Marigat. Snakes are very common, especially in the lower ground, and there is an unusual concentration of tortoises, up to three feet long, around Emening. It is not unusual to meet 20 or 30 in a day's walking in rainy periods. Colobus monkeys are fairly common in the forests of Lembus and the steep forested upper slopes of the Elgeyo Escarpment. Crocodiles are numerous in the Perkerra and Molo rivers.

On the higher ground most of the streams and rivers are perennial, but from 5,000 ft. downwards only the largest rivers, notably the Molo, Perkerra and Kerio and their main tributaries, contain water throughout the year.

Lake Baringo, a fresh-water lake, lies a few miles north-east of Marigat, and Lake Hannington, a soda lake, a few miles south-east of that place. Lake Narasha in the south-west of the area is little more than a marshy pond, and is exceeded in size by many of the bodies of water impounded by dams near by. Lelen Swamp, in the east, is a lake during the wetter months of the year.

Communications

The Uganda line of East African Railways cuts the southern border of the area in two places, and follows the western border for many miles. The most important road is the Nakuru-Eldoret road, which cuts across the south-western corner. Other main roads are those from Nakuru to Kabarnet via Mogotio and Marigat, and that from Kabarnet to Tambach and Eldoret, which crosses the Kerio River at Chebloch Bridge. Sclater's Road, cut in the last years of the nineteenth century to extend the Mombasa-Kibwezi road to Lake Victoria, enters the area at the Equator near Esageri, and runs via Eldama Ravine to Timboroa and beyond. That part of the road east of Eldama Ravine is metalled and maintained as a first-class road, but between Eldama Ravine and Timboroa the road is now neglected, and passable only with difficulty.

The most important of the secondary roads is that running south from Kabarnet along the Kamasian Hills to Eldama Ravine. It is kept in very good repair, but running as it does for many miles as a mere shelf on extremely steep hillsides it is dangerous in wet weather even to a four-wheel-drive vehicle. At other times it is passable to vehicles of up to five tons loading. The roads along the Kerio Valley and that through Sabur and Bekibon are generally passable only to four-wheel-drive vehicles, and then only with difficulty. But perhaps the most spectacular of all is the short road from Sigoro, on the eastern side of Lembus Forest, to Sirwa, which has been cut into the steep mountainside east of Chemorogok. It is only wide enough for one vehicle, often with no passing places for several miles, and a driver is well advised to ascertain before leaving Sigoro that there is no other car on the road ahead.

Maps

The area is covered by four maps on a scale of 1 : 50,000 prepared from R.A.F. aerial photographs, and numbered 104/I to 104/IV. All the sheets except that covering the north-west quadrant are contoured by Multiplex at 100-foot intervals; contours have been redrawn at 250-foot intervals on the final geological map to avoid overcrowding. The north-west quadrant was contoured during the survey using a single three-inch aneroid barometer controlled by available spot-heights and suitably corrected for diurnal variations, and contours there must be considered as only approximate. Field mapping was done directly on to aerial photographs at a scale of approximately 1 : 30,000 and plotted on the 1 : 50,000 sheets, the draft of the final map being drawn at a scale of 1 : 83,333 for mechanical reduction to the printed scale of 1 : 125,000.

Acknowledgements

The writer is indebted to Prof. B. C. King (Bedford College) and Dr. A. T. J. Dollar (Birkbeck College) of the University of London, who visited the area after the first draft of this report was written, and discussed with the author many doubtful points of interpretation.

II.—PREVIOUS GEOLOGICAL WORK

Joseph Thomson (1885*) was the first traveller to have left a record of his work in the area. In November 1883 he walked from Njemps in the Baringo Basin east of Marigat westwards across the Kamasian Hills and the Kerio Valley to the Uasin Gishu Plateau. He followed the line of the present road from Marigat to Kabarnet, from there westwards passing two or three miles north of the northern boundary of the present area to climb the Elgeyo Escarpment between that boundary and Tambach. He referred (p. 463) to the Kamasian Hills as being " . . . of a metamorphic rock composed of a white striated felspar, a little quartz, and black mica in minute scales". No crystalline rocks are known to outcrop anywhere in this part of the Kamasian Hills, and it is probable that he confused his notes of this area with those made elsewhere. On page 464 of his account he gave a good geological description of the Elgeyo Escarpment, and noted a thick deposit of volcanic debris between the metamorphic rocks and the overlying lava, a reference to the Miocene sediments which outcrop immediately to the north of the present map.

The next reference to the geology of the area comes from J. W. Gregory (1896, pp. 137-138) who followed the same route as Thomson as far as Doenyo Lubikwe (easily identifiable as the hill now known as Tarambas, with its higher northern extension of Marop) a few miles east of Kabarnet. He made further reference to parts of the area in his later book (1921), dealt with at greater length in a later section of this report.

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* References are quoted on page 47.

G. T. Prior (1903) described many of Gregory's rock specimens from Kamasia and others from Elgeyo, the latter from a collection of rocks from the Uganda Protectorate (to which Elgeyo belonged in those days) sent to the British Museum by Sir Harry Johnston.

E. E. Walker (1903) in 1902 traversed the area from Eldama Ravine to Marigat, and later followed Thomson's route from Marigat to Elgego (Elgeyo). He mentioned an abundance of opals and agates on the west side of the Tigrish (Perkerra) River, but this site was not found during the present survey, though the same minerals were found on the east side of the river at Isanda. He further mentioned patches of lava *in situ* at the foot of the Elgeyo Escarpment. Thomson (1885, p. 464) had thought these to be enormous masses of rock "crashed headlong from the upper precipices".

The Swedish Geological Expedition to East Africa in 1927/28 covered much of the Rift Valley, but apparently only visited the eastern margin of the present area. Nilsson's thesis (1932, pp. 68-71) discussed the extent of the ancient Lake Baringo-Hannington, whose sediments are shown on the present map to follow closely Nilsson's sketch map, Fig. 60.

In 1929/30 Bailey Willis visited East Africa, and his book on the area was published in 1936. On pages 283-286 he discussed the Kamasian Hills and the origin of the Ndo (Kerio) Valley and the flanking Elgeyo Escarpment. He made the rather surprising statement that the latter is not a fault scarp, but an erosional feature. The writer makes more detailed reference to Bailey Willis' work in the structural chapter of this report.

R. Murray-Hughes wrote a short report on western Kenya (1933) which covered the whole area in very broad detail. On page 6 of that work he made a brief mention of the sediments in the Elgeyo Escarpment at Tambach.

F. C. Bullard (1936) made a lengthy series of gravity readings in East Africa, and in a summary of his findings (pp. 513-517) stated that all the available evidence pointed to a compressional origin for the Gregory Rift Valley, explaining the negative Bouguer anomaly in the rift as being due to the sunken portion being forced downwards by the shoulders of the rift along reversed faults.

The Expedition de l'Omo of 1932/33 followed the Nakuru-Eldoret road on its journey north and C. Arambourg (1935 pp. 30-33) gave a brief description of some of the lavas of the Uasin Gishu Plateau, and included a chemical analysis and a microphotograph (*ibid*. Plate I, Fig. 1) of a specimen from Lake Narasha.

In 1938 V. E. (Now Sir Vivian) Fuchs and D. G. McInnes visited the Baringo Basin (Fuchs, 1950), and made some interesting calculations about the earlier extent of the old lake. Whilst much of this work was of great value, the present writer shows later that Fuchs was in error on several points of detail, and confused sediments of very different ages.

R. M. Shackleton (1950) gave a detailed account of the Kavirondo Rift Valley which lies immediately west of the present area, and in the same paper gave the first detailed description of the sediments at Tambach, and was able to date them as Miocene. It will be seen later in this report that the age of these sediments has an important bearing on the dating of the Rift Valley as a whole.

F. Dixey, in a review of the East African rift system (1956), enlarged upon Gregory's views that a marked topographic high existed along the line of the present-day Rift Valley, and pointed out the marked parallelism of the Elgeyo Escarpment and the foliation of the crystalline rocks in that escarpment, and stated that the rift system seems to have arisen from some ancient weakness of the crust, dating back to Precambrian times.

The area immediately west of the present one was surveyed by D. J. Jennings (1964), and that to the east was surveyed by G. J. H. McCall (1967) currently with the present survey.

III.—PHYSIOGRAPHY

The area can be divided into the following physical units (Fig. 2): (1) the eastern edge of the Uasin Gishu Plateau in the west, followed eastwards by (2) the Kerio Valley, (3) the Kamasian Hills and (4) the floor of the Rift Valley proper. The high ground of the south-west quadrant is a continuation of both the Uasin Gishu Plateau and the Kamasian Hills, around the head of the Kerio Valley.

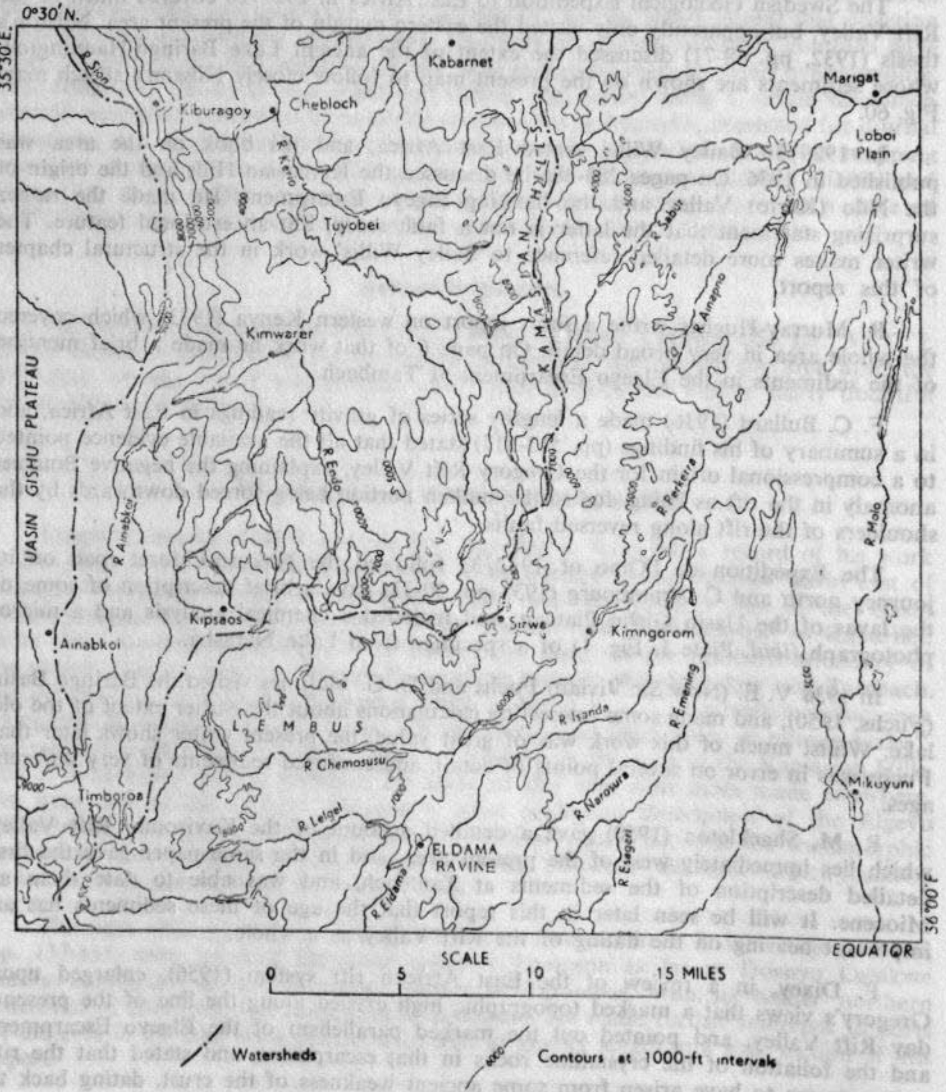

Fig. 2—Physiography of the Eldama Ravine-Kabarnet area

Drainage on the Uasin Gishu Plateau is to Lake Victoria, the watershed following the lip of the Elgeyo Escarpment, except in the extreme north where it passes west of the Sion River. This river drains into the Kerio Valley just north of the area, falling over the lava precipice at the top of the escarpment in a single drop exceeding 1,000 ft. South of the escarpment the watershed swings south-west round the head of the Nabkoi River system and from there southwards it is traced out by the line of the railway. Drainage east of this line is to Lake Rudolf via the Kerio River, or to Lake Baringo, the watershed between the latter two drainage systems running north-north-east from Timboroa to near the lip of the Kerio Valley south of Kipsaos, thence eastwards to Sirwa, and thence northwards along the summit line of the Kamasian Hills.

The Kerio River, which is perennial, draws its water mainly from the Ainabkoi and Nabkoi rivers and lesser streams draining the northern end of Lembus Forest, and short seasonal streams on the western flanks of the Kamasian Hills. Many of the headwater tributaries of the Kerio, particularly those high up on the surrounding valley sides, are tapered streams, perennial in their upper reaches but losing water underground and by evaporation before reaching the main river. From Kimwarer northwards the Kerio meanders in a fairly flat plain of bouldery wash and sediment from the surrounding hills, sometimes laying down small flats of sandy alluvium. Along much of its length it has cut down deeply enough to expose the underlying Samburu basalts, and where it meets the Kabarnet trachytes at Tuyobei and again at Chebloch Bridge it has cut steep-sided gorges, an excellent example of superimposed drainage, the river having cut down through the former thicker sediment cover. At Chebloch Bridge the road crosses the river by a bridge less than 20 ft. across but over 60 ft. above the surface of the water. From the bridge northwards the river cuts down in a light brown sandy clay, an ancient alluvial deposit, being bounded by cliffs of that material exceeding 60 ft. in height. Along that stretch the only boulders seen are those in the bed of the river which have been carried downstream from the gorge and south of the gorge.

Lembus Forest forms an extensive drainage basin, almost circular in shape, with radial streams uniting to form the Perkerra River north of Eldama Ravine. The latter is named after the steep-sided gorge cut by the Eldama River a mile north of the township which, when joined by the Chemosusu River a few miles downstream, is nearly 1,000 ft. deep, with precipitous sides. The steepest faces are those cut in the Eldama Ravine tuffs, below which the underlying phonolites and basalts are exposed in many places. At Kimngorom the valley floor opens out and alluvial flats extend for four miles downstream until the valley sides again close in, and the river flows in a steep-sided gorge, controlled mainly by the pattern of grid-faulting, until it debouches on to the Loboi Plain at Marigat through a final short canyon.

East of the Perkerra River, running from south to north just inside the map margin, is the Molo River, also perennial, which northwards from Mikuyuni is controlled by the fairly recent grid-faulting and flows for most of its length in deep gorges, as does the Perkerra. After flowing out on the Loboi Plain it joins the Perkerra River at Logumkum (Njemps) Swamp, a few miles east of Marigat, whence it drains into Lake Baringo.

In the eastern half of the area the only perennial rivers other than the Perkerra and Molo are the Emening and its two tributaries, the Narasura and the Esageri. All the others are seasonal and flow for only a few days or hours after rain, though in the largest, notably the Ainapno and Sabur, water can be obtained for most of the year by digging a few feet down into the river bed.

No ancient erosion surface is recognizable in the area, though the presence near Tambach of Miocene sediments between the Basement System rocks and the Uasin Gishu phonolites proves the latter to lie on the sub-Miocene erosion bevel. The deposition of the Miocene sediments, which reach 500 ft. in thickness below Tambach and yet are missing six miles south of that place, indicates that the plain had undergone considerable disturbance before the deposition of the sediments and the overlying lava. The elevation of the Basement-lava contact is at its highest at Kiburagoy—7,625 ft., dropping northwards to 6,550 ft. at the northern margin of the map, and again southwards from Kiburagoy to 5,890 ft. west of Kimwarer.

IV.—SUMMARY OF GEOLOGY AND GEOLOGICAL SUCCESSION

The oldest rocks exposed in the area are the metamorphosed sediments in the Elgeyo Escarpment, which belong to the Basement System, of Precambrian age. At the line of Section AA on the geological map they are seen to reach 14,000 ft. in thickness, and it is inferred that they extend eastwards a further 10,000 ft. under the Quaternary deposits of the Kerio Valley, before being covered by lavas. Many of the rocks exposed are hornblende gneisses, with lesser bands of quartzo-felspathic gneisses (which differ from the hornblende gneisses only in a diminution of their melanocratic mineral content, and often grade into hornblende gneisses) and crystalline limestones, with minor amounts of quartzites and biotite gneisses. They are vertical or near-vertical over the whole outcrop, and no evidence was found to indicate which flank of the outcrop is the bottom of the succession. There appears to be no tight folding, the only repetition of beds being due to faulting.

The next highest rocks in the succession are the basalts of the *Samburu series* (Tvb_1), first named by Shackleton (1946, p. 30) which in this area are largely of a fine-grained, hard, black non-porphyritic type, with lesser amounts of Kijabe type basalt, a rock with a fine-grained purplish or dark grey base supporting large, flat plagioclase phenocrysts. A third type, much less abundant than those already mentioned, is a porphyritic basalt with a fine-grained black groundmass supporting phenocrysts of olivine and pyroxene. This rock is identical with the overlying Elgeyo basalt, and the few exposures seen might be remnants of the latter and not part of the Samburu series. In the relatively flat and low-lying country around Sabur the Samburu basalts are so deeply weathered that generally only small fragments of solid rock are to be found in a deep weathering product which becomes a tenaceous clay when wet, with striking colour variations over very small areas. In a distance of 200 yds. near Sabur the colour is seen to change from yellow to brown, red, mauve and purple. Most of the yellow patches seem to be derived from tuffs, though this could not be determined with certainty. The only undoubted tuffs recognized within the series are a 20-foot lens of yellowish fine-grained tuff a mile south-east of the shops at Sacho in the Kamasian Hills and a deep-red rotted tuff east of Chini ya Malima where the Marigat-Kabarnet road crosses the Chomokut River.

The next highest rocks are the *Elgeyo basalts* (Tvb_2), porphyritic olivine-augite basalts which overlie the Samburu basalts and reach their maximum extent at the southern end of the Elgeyo Escarpment.

Overlying the Elgeyo basalts in the same part of the area are the *Kimwarer sediments* (Tm), which the writer considers to be equivalent to the Miocene sediments near Tambach already referred to, and described in detail by Shackleton (1951, pp. 371-373). Shackleton (1946, pp. 27-29) described similar sediments in various parts of the Nanyuki-Maralal area, and in his succession (*ibid.* p. 3) showed them to be older than the Samburu basalts, though he nowhere found the two in contact. In Miocene sediments to the west and south-west of the present area volcanic tuffs occur (Shackleton 1950, pp. 363-367, Binge 1962, p. 19, and Jennings 1964, p. 20). In one of the Miocene exposures in the Nanyuki-Maralal area Shackleton records lapilli and tuffs. It therefore seems probable that the deposits of tuffs and sediments (Tvf_1) at the base of the Uasin

Gishu phonolites in the present area are also equivalent in age to the Tambach sediments, the occurrence of a fine-grained greenish, sandy clay at Kaisok at the base of the Tvf_1 tuffs, identical in appearance to some of the Tambach beds, adding further weight to the hypothesis. The Kimwarer sediments rest on Elgeyo basalts, and the Tvf_1 beds rest on Samburu basalts, and if the correlation of both of these groups with the Tambach sediments is valid then the Samburu and Elgeyo basalts are both older than the sediments.

The Uasin Gishu phonolites in some exposures can be subdivided into a lower, generally non-porphyritic type, and an upper porphyritic lava. The distinction is clear in some parts of the Elgeyo Escarpment and in the east of the area around Gobat and Arus, but elsewhere the two types are found to alternate both horizontally and vertically and the concept of a lower and upper series can no longer be substantiated. For this reason only one symbol, Tvp_1, has been used for this lava.

The Tinderet volcanics which overlie the Uasin Gishu phonolites have their origin in the Tinderet Volcano to the south-west of the present area (Binge 1962, pp. 23-25). Only two members of the suite occur in this area, a nephelinitic phonolite (Tvpn) and a melanocratic porphyritic phonolite (Tvp_2). In the area immediately to the west Jennings (1964) further subdivided the upper division into a lower melanocratic phonolite (Jennings' Tvp_3) and an overlying Tvp_4, phonolitic lavas with subsidiary ashes and tuffs. No justification could be found in the present area for such a division, and the only tuffs found in the area covered by the Tinderet volcanics are demonstrably very much younger than the lavas.

The Eldama Ravine tuffs and sediments are next highest in the succession, and are seen to overlie the Tinderet volcanics in the west of their outcrop. Elsewhere they rest directly on the Uasin Gishu phonolites or the Samburu or Elgeyo basalts. The deposit is predominantly tuffaceous, varying from only poorly consolidated ashes to hard, streaky welded tuffs, often closely resembling lava flows. The sediments are mainly riverine, sometimes lacustrine, and occur at the base of the deposit in the north-east, where they wedge out near Radad, and sometimes intercalated with the tuffs, and have unconformable junctions either below or above the sediments, sometimes both. The harder tuffs are worked in small quarries at many locations near Eldama Ravine and yield an excellent building stone.

The Kwaibus olivine basalts (Tvb_3) overlie the Eldama Ravine deposits at several points in the eastern part of the map area, and are named from Kwaibus peak a few hundred yards outside the eastern margin of the area, where they attain their greatest thickness. Much of the basalt is a grey, fairly coarse-grained rock, with macroscopic phenocrysts of felspar, olivine and pyroxene. Near Marigat the upper part of the basalt is a purplish, non-porphyritic rock with large drawn-out vesicles, often lined with yellow zeolites.

The Chemeron beds, which overlie the Kwaibus basalts at a few localities near Marigat, are a series of tuffs, tuffaceous earths and silts, with subordinate diatomites. In an exposure in the Kapiswa River a thin sheet of basalt similar to Kwaibus basalt is intercalated with the sediments. It is possibly a sill-form intrusion, but the possibility remains that the Chemeron sediments may have been initiated before the close of the extrusion of the basalts. The Chemeron beds are the lowest part of the Kamasian beds first described by Gregory (1921, pp. 112-113), though not named by him, and further studied by later writers. A detailed appraisal of the Kamasian type locality is made later in this report.

The Kabarnet trachytes (Tvt) with their associated tuffs and sediments (Tvf_4) are nowhere seen in contact with lavas later than the Uasin Gishu phonolites and their relative age cannot be proved. For reasons detailed later they are considered to be of

Middle Pliocene age. Tuffaceous sediments and tuffs are found underlying the trachytes east of Kabarnet, and further small lenses of exactly similar materials were found in several parts of the outcrop. The trachyte has a coarse-grained groundmass and is usually lacking in macrophenocrysts. Quartz was found in one of the slides examined.

The Lake Hannington phonolites, named by McCall (1967) in the course of his work in the area immediately to the east, overlie the Chemeron beds, and overstep to the south and west to rest on lower rocks of the Tertiary succession. In the present area it was found possible to subdivide the phonolites into a lower porphyritic (Tvp_3) and an upper non-porphyritic type (Tvp_4), though the division in a few localities, as at Soui west of Marigat, is not a firm one, since the upper division sometimes contains lenses and flows of porphyritic lava identical with the lower division. Felspathoids (under which term the writer includes analcite) were not seen in all of the thin sections made of these lavas, the rock then being a trachyte. It is not known whether the trachytic parts of the lava are separate flows intercalated with the phonolites, or whether they are only small patches of phonolite lacking in felspathoids.

The Kapthurin beds (Pll) are seen to overlie the Lake Hannington phonolites and are presumed to be younger also than the Kabarnet trachytes. Their main constituent is a coarse bouldery torrent-wash, with subordinate silts and tuffs, the latter thickening considerably to the northwards, where they form a major constituent of the deposit a few miles outside the present area. These beds are the upper division of the Kamasian beds of the type area, the lower division being the Chemeron beds already referred to.

The Molo River tuffs (Plt_1) reach their greatest extent in this area in the extreme south-east, where they sometimes veneer the whole country, and sometimes fill or partly fill the grabens in the strongly faulted country. They are clearly younger than any of the lavas in their vicinity. They are characterized by their ubiquitous inclusions of featherweight black pumice, which in the south-east were seen to occur as blocks sometimes exceeding two feet in diameter, but which fall off in size to the north and west. Similar black pumice was seen in some of the tuffaceous sections in the Kapthurin beds, and it is possible that the Kapthurin beds and the Molo River tuffs are of the same age. No sediments or clearly waterlain tuffs were found in the tuff outcrop as mapped.

The tuffs of the Uasin Gishu Plateau and Lembus (Plt_2) are, like the Molo River tuffs, much younger than any of the rocks which underlie them, and occur only as valley infillings. They are generally pale grey in colour, rarely well compacted, and contain a high proportion of very fine material, perhaps due to their having been washed into valleys by rain, and tend to form areas of swamp. The relative ages of these tuffs and the Molo River tuffs could not be determined. It is clear that the former were laid down when the dissection of the Uasin Gishu Plateau was as it is today, and therefore they must be very young.

Quaternary deposits have been mapped under four different headings, and in what is considered to be decreasing order of age as follows:—

Red soils and torrent-wash of the Kerio Valley (Q) which are derived from both Basement System rocks and volcanics, cover the floor of the Kerio Valley to a depth exceeding 60 feet, as evidenced by gullies. In appearance they closely resemble the torrent-wash and earthy deposits of the Kapthurin beds, and in fact may be of equivalent age. They contain no tuff horizons.

The lacustrine silts of the Loboi Plain (Ql) are deposits formed in the last phase of development of the original Lake Baringo-Hannington before it dwindled to form the two separate lakes seen today. The silts are apparently unaffected by faulting and the almost total lack of boulders and pebbles, as contrasted to the earlier Chemeron and Kapthurin beds, suggests a period of quiet deposition.

Volcanic Soils (Qv) cover most of the volcanic outcrops, except where erosion is severe. Their symbol is used on the map only around Kures in the south-east where a wide expanse of such soil forms a partial swamp which totally obscures the underlying solid geology.

Alluvium as mapped indicates only very recent deposits of the rivers Kerio and Perkerra. None of the other rivers in the area has alluvium sufficiently extensive to be shown at the scale of the present map.

Correlation of the rocks of the present area with those to the west (Jennings 1964) and to the east (McCall 1967) is as shown in Table 1.

TABLE 1

Kapsabet-Plateau Area (Jennings 1964)	*Eldama Ravine-Kabarnet Area*	*L. Hannington-Thomson's Falls Area (McCall 1967)*
	Silts of Loboi Plain (Ql)	Silts of Loboi Plain (Ql_2)
		Various sediments of small extent (Qt_1, Qt_2, Qt_3 Qll)
	Uasin Gishu tuffs (Plt_2)	Solai lapilli tuffs and pumice beds (Plt_3)
	Molo River tuffs (Plt_1)	
	Kapthurin beds (Pll)	Kamasian sediments of type area (Pll_3)
		"Claystone" tuffs of Ol Arabel gorge (Tvf_5)
		"Claystone" tuffs of Iguamiti (Tvf_4)
	Lake Hannington phonolites (Tvp_3, Tvp_4)	Kinangop tuffs (Tn, Tvf_3) Lake Hannington phonolites (Tvp_3)
	Kabarnet trachyte group (Tvt, Tvf_4)	
	Chemeron beds (Tvf_3)	Sediments of Samburumburu Plateau (Tvf_2)
	Kwaibus basalts (Tvb_3)	Kwaibus basalts (Tvb_2)
	Eldama Ravine group (Tvf_2)	
Tinderet Phonolites (Tvp_4)		
Upper Tinderet volcanics (Tvpn, Tvp_3)	Upper Tinderet volcanics (Tvpn, Tvp_2)	
		Sipili trachytes (Tvt_1)
		Thomson's Falls phonolites (Tvp_2)
Uasin Gishu phonolites (Tvp_1, Tvp_2)	Uasin Gishu phonolites (Tvp_1 Tvf_1)	Rumuruti phonolites (Tvp_1)
Nephelinitic agglomerates (Tv)		
	Elgeyo basalts (Tvb_2)	
	Samburu basalts (Tvb_1)	Samburu basalts (Tvb_1, Tvf_1)
Basement System (X)	Basement System (X)	

V.—DETAILS OF GEOLOGY

1. Basement System

Crystalline rocks, which from their similarity to other rocks covering wide areas of Kenya have been assigned to the Basement System, considered to be of Precambrian age, are exposed on the lower slopes of the Elgeyo Escarpment in the north-west of the area. They underlie the Elgeyo basalts and Uasin Gishu phonolites, and exposures generally end close to the foot of the escarpment where they are covered by Quaternary deposits. Their outcrops form steep ridges and valleys, both parallel to and transverse to the strike of the rocks, which are vertical or near-vertical over their whole outcrop. They thus contrast strongly to the overlying phonolites, which form sheer cliffs. They weather to a light red sandy soil which is generally thin and sometimes absent due to the steep topography.

The main rock types represented are hornblende gneisses with a Shand colour index varying from over 30 to almost nothing, where they grade into quartzo-felspathic gneisses. They are of coarse grain, with a poor foliation marked by a tendency to alternate layering of the leucocratic and melanocratic constituents. A microscope slide of a typical specimen, 34/1013* shows anhedral crystals of brownish green hornblende intergrown with pale green diopside, yellow brown biotite and sometimes hyperthene pleochroic from pale green to pale pink. Opaque iron ore is fairly common. The hornblende is an alteration product of diopside and hypersthene and has itself partly altered to biotite, with iron ore being thrown out as a by-product of the transformation. In some parts of the slide elongated flakes of biotite are seen in contact with diopside, and suggest a direct alteration from diopside to biotite. The main leucocratic mineral is coarsely perthitic microcline, with lesser amounts of plagioclase felspar, determined as oligoclase-andesine, and rare quartz. Near Kiburagoy garnet is locally an important constituent.

The quartzo-felspathic gneisses vary in appearance from coarse, poorly foliated rocks, sometimes deeply iron-stained, and apparently a leucocratic facies of the hornblende gneisses, to off-white, almost schistose granulites. A specimen of granulite from Emsea, 34/1037, shows under the microscope a fine, granular texture, with all the constituents in anhedral form and drawn out as a result of crushing or shearing. Recrystallization has taken place in the quartz, which is generally in much larger blebs than the felspar and shows little strain. The felspar is mainly oligoclase, much of it untwinned, with trace amounts of microcline. Wisps of pale brown bleached biotite occur aligned along the foliation, always accompanied by opaque iron ore and a deep-brown limonitic product. A single grain of sphene occurs in the slide. 34/1034 from below Chororget is of much coarser grain, and heavily iron-stained. It consists of quartz, a great deal of strongly perthitic microcline and a small amount of oligoclase. Accessory minerals are anhedral fractured salmon-pink garnets with iron-staining marking the fractures, much opaque iron ore and patches of brown limonite, sometimes flanked by small flakes of a deep-green mineral tentatively identified as chlorite.

The outcrops of crystalline limestone shown on the map have been somewhat simplified to suit the scale of the map. The larger outcrops all contain bands and lenses of quartzo-felspathic gneiss and less often, hornblende gneiss, varying in width of outcrop from a few inches to up to 50 feet. The colour of the limestones is usually white, speckled with grey or green minerals, sometimes off-white with yellowish iron-staining, and sometimes rose-pink. Minerals identified in thin sections include, in addition to calcite, quartz, felspar (both orthoclase and oligoclase), colourless tremolite, forsterite and diopside. Hand specimen 34/1032 from Naon contains visible specks of bornite with typical "peacock" discoloration.

Quartzites are few and small in volume, the only outcrops large enough to show at the scale of the map being two bands north-east of Kiburagoy. Specimen 34/1040 from the more westerly of the two is of coarse grain, off-white and grey in colour, with fine parallel streaks of tiny flakes of bleached biotite marking the foliation. Small patches of kaolin, derived from felspar, are scattered through the rock. In the thin section of the same rock no felspar occurs, and it is probable that all the small original

* Numbers 34/1013, etc., refer to specimens in the regional collection of the Mines and Geological Department, Nairobi.

felspar content has been kaolinized. The section shows the quartz to be a mesh of coarse interlocking anhedral grains, with no strain shadow, which suggests recrystallization.

A single outcrop of biotite gneiss was found near Kimwarer. Its Shand colour index was never seen to exceed 15, and locally biotite gives way to graphite in small disseminated flakes.

No dykes or intrusions were found in the Basement System rocks other than rare quartz stringers, seldom more than one or two feet across, and often measured only in inches. Along the fault west of Kimwarer, large float blocks of red brown and yellow fault breccia material, closely resembling chert, are scattered over an area of several hundreds of yards on each side of the fault. Under the microscope the breccia, 34/1033, is seen as an extremely fine-grained mylonite, recognizable only with difficulty as quartz and chalcedony, the latter light red brown in colour, with small patches of opaque iron ore.

The Basement System rocks at this locality are all derived from sediments, and closely resemble the Turoka Series of Parkinson (1913). However, the type area of this series is separated from the Elgeyo outcrop by over 150 miles of volcanic rocks, and correlation of the two must remain conjectural.

2. Tertiary Volcanic Rocks and Sediments

(1) Samburu Basalts

These basalts outcrop over a total area of several hundred square miles in the centre and north of the area and form much of the Kamasian Hills and their flanks in the Kerio Valley to the west and the rift floor to the east. On high ground and steep slopes they are generally well exposed, but in the lower areas they are often masked by scree and soil cover, and in the rift floor in particular are so deeply weathered that solid rock is confined mostly to stream cuttings, or to small scattered float. The weathering products are however very distinctive due to their bright and varied colours, varying from the most common deep purple brown to browns, reds, yellows and greys. Over the more porphyritic types the soil is rich in fragments of white felspar which, where grass cover is absent, gives the impression of the aftermath of a hailstorm. After rain the wide grass-free expanses so typical of the area become stretches of glutinous mud and tenaceous clay which make walking across them a slow misery.

The Samburu basalts can be subdivided into three main types, plus a lesser tuff phase: (1) a dark grey or black, fine-grained non-porphyritic variety with rare vesicles coated or infilled with white zeolites, (2) a strongly porphyritic variety, the only prominent phenocrysts being large but thin plates of felspar, (3) a porphyritic variety with phenocrysts of olivine, augite and plagioclase, and (4) minor intercalations of tuff. It was found impossible to map the different varieties separately as no definite succession could be recognized. The second variety, characterized by large plagioclase phenocrysts, appeared to occur fairly high up in the succession, but this was not proved. The few exposures of tuff appeared to occur haphazardly throughout, as did the variety with olivine and augite phenocrysts. The latter type is identical with the overlying Elgeyo basalt, and small relict outcrops of the Elgeyo basalt may have been mistaken for Samburu basalt.

The non-porphyritic variety is by far the most common type found in the area, being especially abundant in the Kamasian Hills. A typical example, specimen 34/940 from Cheplambus, is very dark blue-grey in colour with a grain just coarse enough to be seen with the naked eye, and a few phenocrysts, one or two millimetres across, scattered through the rock at such wide intervals that a normal sized hand specimen shows only seven or eight on its surface. The thin section of the same rock shows abundant microphenocrysts averaging 0.2 mm. across, mainly of olivine and plagioclase felspar, with rarer and smaller brownish-grey augite grains. The olivine crystals are often euhedral in outline, and where partly altered the alteration product is a dark grey-green mineral resembling chlorite, not the more common iddingsite. The felspar phenocrysts are elongated laths of andesine. The groundmass is a fine-grained aggregate of andesine, almost colourless augite, and olivine, with a high proportion of opaque iron ore in tiny anhedral grains. The content of magnetite in many outcrops of the basalt is sufficiently high to deflect a compass needle through several degrees of arc. Small cavities, now totally infilled with white analcite, are scattered throughout the rock, tending to concentrate in small patches each a few inches across. No analcite was identified in the body of the rock.

In many of the other slides of this variety of basalt taken from various places over the outcrop the felspar is andesine-labradorite, and in two slides, 34/805 from near Chini ya Malima and 34/817 from two miles east of Sabur, the felspar is oligoclase. In 34/805 a few microphenocrysts of anorthoclase occur in addition to oligoclase, and green aegirine-augite occurs in the groundmass in addition to colourless augite. The rock thus tends towards a trachybasalt.

The second variety of Samburu basalt is easily recognized by the large size (often exceeding 30 mm. across while seldom more than 2 mm. in thickness) and abundance of the platy felspars, which are set in a fine-grained matrix usually of a purple shade but sometimes dark grey. In some exposures the rock is highly vesicular, with yellow and green zeolites lining the vesicles. Phenocrysts of olivine occur in addition to felspar, but always greatly subordinate in numbers. In thin section the felspar plates were identified as andesine-labradorite, being always close to An_{50}. Olivine is always partly or wholly altered to red-brown iddingsite. The fine-grained groundmass consists of plagioclase identical in composition to the phenocrysts, iddingsitized olivine, a little colourless augite and an abundance of magnetite. A few patches of secondary calcite occur. Typical specimens are 34/900 from Kimngorom and 34/967 from Cheberen. This rock is very similar to the Kijabe type basalt, named from Kijabe Hill 35 miles north-west of Nairobi, and described by Shand (1937, pp. 265-267). Shand identified the plagioclase phenocrysts of the type rock as medium labradorite (An_{60} and An_{65}), rather more calcic than those of the present area.

The groundmass of the third variety of Samburu basalt is almost black in colour, sometimes with a purple or brown tinge, with abundant phenocrysts averaging 4 to 5 mm. across. The microscope slide of a sample from Sigoro, 34/992, shows phenocrysts of olivine sometimes euhedral but more commonly rounded and cracked, often altering to iddingsite, and pale purple-brown augite, usually euhedral and sometimes showing alteration from the centre outwards to a red-brown mineral closely resembling the iddingsite in the same slide, but which may be limonite. Much less abundant are smaller phenocrysts of felspar, identified as andesine-labradorite. The groundmass is of medium-grain size, with augite, andesine-labradorite and iddingsitized olivine, with three or four per cent (by volume) of opaque iron ore. A few vesicles occur in the slide, each with a thin lining of a red-brown mineral, again probably limonite, and a central infilling of calcite.

Tuff outcrops in the basalt are rare and small, the only one readily identified being a 20-foot thick lens a mile south-east of the trading centre of Sacho. This rock is a compacted mass of fine, yellow ash. At the river crossing east of Chini ya Malima a lens of tuff about 30 ft. across and 10 ft. thick occurs in flaggy non-porphyritic basalt. It is of very fine grain, soft and crumbly to the touch, and of a deep reddish-purple colour. Its appearance suggests that it was deposited in a depression on the top of a flow and covered by a later flow. Its softness is probably due to a high earth content which would result from ash and other debris being washed into the depression after falling to earth as a fine dust. Other yellow and purple patches of earth near Sabur probably also represent tuffs, but the fineness of the material after deep weathering makes exact identification impossible.

No centre of centres of extrusion of the basalts were found in the area, nor are any known over the wide extent of the same basalts mapped in other areas to the north-east and east, and the rock must have had its origin in fissure eruptions. The only feeder dykes found in the basalts were of the younger phonolites.

(2) ELGEYO BASALTS

These basalts are so named by the writer since they reach their greatest thickness, above 1,500 ft., at the southern end of the Elgeyo Escarpment. Where their contact with the underlying Samburu basalts is exposed it is always uncomformable, sometimes marked by a baked red soil layer from a few inches up to three or four feet thick, and sometimes the underlying Samburu basalt is seen to be dipping steeply and planed off by erosion. The base of the Elgeyo basalt commonly contains rounded and semi-rounded blocks of Samburu basalt and Basement System rock, a notable locality being at Chof where blocks of Samburu basalt occur throughout the bottom 600 ft. of Elgeyo basalt, with blocks of Basement system rock appearing in addition in the lowest 100 ft. The nearest exposure of Samburu basalt is several miles away to the south-east, and it appears that the earliest flows of Elgeyo basalt flowed over Basement System rocks, with only float of Samburu basalt on them. Later flows came from further afield and swept up huge quantities of rubble from the lower basalt and perhaps plucked blocks out of the solid rock. The pattern of the outcrops of the Elgeyo basalts, which thin out rapidly to the east and north-east, suggests that their main centre of eruption was somewhere to the west or south-west of Chof.

The contact between Elgeyo basalts and the overlying Uasin Gishu phonolites in the Elgeyo Escarpment usually forms a marked shelf. (Plate II.)

In appearance this basalt is identical with the olivine-augite porphyritic variety of the Samburu basalts, but whereas the latter occurs only as small patches in other varieties of basalt the Elgeyo basalt remains constant in appearance over the whole of its outcrop. It has a black or very dark grey fine-grained groundmass supporting numerous phenocrysts of yellow-green olivine and black augite, and sometimes a few glassy felspars. The size of the phenocrysts remains remarkably constant everywhere, never exceeding 8 mm. across, and averaging 4 to 5 mm. Typical specimens, taken from widely separated outcrops, are 34/937 from Cheptunyo in the Kamasian Hills, 34/981 from Theloi near Eldama Ravine, and 34/1043 from the Elgeyo Escarpment near Chof. The dominant phenocryst in all these thin sections is augite of very pale purple-brown colour, often darkening in zones towards the edges of the crystals. Olivine occurs as phenocrysts in slides 34/981 and 34/1043, but not 34/937, where however, it is visible in the hand specimen. Olivine is always more or less altered, sometimes to iddingsite, sometimes to a dark grey-green mineral resembling chlorite, sometimes both, when the iddingsite is rimmed by the green mineral. Plagioclase phenocrysts are prominent in 34/981, and have the composition of andesine-labradorite, with only very minor amounts of altered olivine, and much magnetite. Patches of secondary calcite occur in slides 34/981 and 1043, and the latter also contains a mineral of very low birefringence resembling analcite. This mineral appears to be a primary constituent of the rock, which may therefore be a basanite rather than a true basalt.

(3) KIMWARER SEDIMENTS

Exposures of these sediments are confined to a large outcrop stretching three miles south-east from Kimwarer and two much smaller outliers on fault blocks south-west of Kimwarer. Exposures are too poor either to establish a true section through them, or to measure their total thickness, but they certainly exceed 100 ft., and may be a great deal thicker. Near to Kimwarer the rock is generally a cream or yellow siltstone, and under the microscope a slide of such rock (34/1030) is almost wholly isotropic, apparently consisting of a pale, reddish-brown silicate with minute grains of quartz. A test with dilute acid gave no carbonate reaction. Layers of light brown chert an inch or so thick mark some of the bedding planes of the siltstone. Near the centre of the largest outcrop a steep gully gives a fairly good succession, in just over 100 ft. of sediments at that place. The upper layers are light-coloured sandstones or siltstones similar to those just described, still with cherty layers, gradually darkening in colour downwards through grey and purple clays and agglomerates with scattered boulders to the contact with the underlying purple Kijabe type Samburu basalt. The basalt is here so rotted that it is difficult to decide where lavas end and the sediments begin. All the lowest 40 ft. is clearly derived from Samburu basalt, and in it were found no boulders or fragments of any rock other than Samburu basalt. The high silica content of the upper part of the succession suggests derivation from Basement System rocks. At a 40-ft. section in the bank of the Endo River at Chepsiri only the lighter-coloured sediments are exposed, and there coarse fragments of quartz and felspar, derived from Basement System rocks, far outweigh the few basalt fragments found. The lowest bed seen in that section is a fine, grey waterlain ash, poorly consolidated, overlain by fine white clays, off-white grits with a large proportion of rounded pebbles up to half-an-inch in diameter, and lenses of grey-brown, non-pebbly grits. Layers of yellow chert up to two feet in thickness are common, following the bedding planes and in dyke-like bodies oblique to the bedding, showing them to be younger than the sediments themselves. No trace of organic remains could be found at any of the exposures visited. Diatoms were looked for in the white clays, but none found.

In parts these sediments bear a close resemblance to the Miocene sediments below Tambach on the Elgeyo Escarpment a few miles north of the boundary of the map, and the writer considers it probable that these occurrences are of the same age, though no such sediments occur anywhere in the escarpment between the two outcrops. At Tambach basalts are missing and the Miocene sediments rest directly on Basement System rocks and are overlain by Uasin Gishu phonolites. The Kimwarer sediments everywhere rest on Samburu or Elgeyo basalts, but their relationship to the Uasin Gishu phonolites could not be determined. The smallest of the three outcrops rests on Elgeyo basalt, and only a few hundred yards to the south a sharp contact of Elgeyo basalt with Uasin Gishu phonolite is exposed, with no sediments between them, which can be explained if the shoreline of the original basin of deposition lay between the contact and the present sedimentary outcrop.

(4) Tuffs and Sediments at the Base of the Uasin Gishu Phonolites

Outcrops of these deposits are small and scattered, their greatest concentration being in the southern part of the Kamasian Hills, approximately centred on Tenges. In all the exposures in which sediments occur they are subordinate in amounts to tuffs, and usually take the form of tuffaceous earths. The only exception is on the eastern flank of Kaisok, where a green clay identical with parts of the Tambach Miocene succession underlies a red-speckled grey and cream tuff, and forms more than half of the 25-foot succession exposed. To the north of the ridge the sediments lens out and tuffs thicken to 80 ft. On the western flank of the same ridge a total thickness of 180 ft. of tuff with only thin intercalations of tuffaceous earth was measured. Two miles south of Tenges the deposit attains a thickness of 200 ft., again with only very thin earthy bands. There the tuff is quarried for building stone. On the north-east slopes of Tingwa, at the southern end of the Elgeyo Escarpment, the deposit is represented by 40 ft. of fine-grained purplish pumice tuff. If, as their position immediately underlying Uasin Gishu phonolites suggests, these tuffs and sediments are equivalent to the Tambach sediments, they must be of Miocene age, and equivalent also to the Kimwarer sediments just described.

(5) Uasin Gishu Phonolites

The outcrops of these lavas have the greatest extent of any in the area, reappearing at intervals from the west of the area to the east (where they are the equivalent of McCall's Rumuruti phonolites) and from the northern to the southern border. Where their junction with the underlying Samburu basalts is exposed there is always a strong unconformity. This is particularly marked on the eastern side of the Kamasian Hills, where phonolites dipping generally only three or four degrees to the east rest on Samburu basalts dipping eastwards at 30 degrees or more. To the west Jennings (1964) divided the phonolites into a lower, generally non-porphyritic facies, and an upper porphyritic facies. While this division holds good in the present area in some outcrops, notably along the Elgeyo Escarpment and around Gobat and Arus in the east, at many places the lowest exposures of the phonolite are strongly porphyritic, as at Tenges where non-porphyritic phonolite is both underlain and overlain by the porphyritic variety. On this account it was not possible to differentiate the phonolites over large parts of the area and only one symbol, Tvp_1, has been used for the whole sequence. It should be noted that throughout this report the term "non-porphyritic" refers to rocks in which no phenocrysts are visible to the naked eye, or visible phenocrysts are extremely rare. In many of the rocks termed "non-porphyritic" microphenocrysts can be distinguished in thin sections.

Anorthoclase felspar occurs in all of the rock slides examined, sometimes as phenocrysts in thin glassy plates up to 10 mm. in length and seldom exceeding 2 mm. in thickness, as microphenocrysts, and always as an important constituent of the groundmass. The range of axial angles of the majority of those crystals which were measured was 40-45°, but rare examples have axial angles less than 25°, suggesting sanidine. All values fall within the range of the sanidine-anorthoclase cryptoperthite series of MacKenzie and Smith (1956, p. 406).

Nepheline, like anorthoclase, occurs as phenocrysts, microphenocrysts and as a groundmass mineral, but in those slides in which it occurs as phenocrysts or microphenocrysts it is always subordinate in numbers to anorthoclase. As a groundmass mineral its common form is in tiny grains of square and hexagonal cross-section. Often it is replaced by analcite, but the latter mineral is more common as a primary constituent of the rock in minute interstitial grains and laths, usually colourless but occasionally pale yellow or pale green. Sometimes the analcite is truly isotropic, but more often it has slight birefringence, and between crossed nicols is dark grey.

The most common coloured mineral in the phonolites is aegirine-augite, which occurs in the groundmass of all the slides examined, and more rarely as phenocrysts. It is green or yellow-green in colour, and pleochroic. In a few of the slides the mineral approaches aegirine in composition, with almost parallel extinction.

The next most abundant coloured mineral is cossyrite, which occurs in the groundmass of more than three-quarters of the slides made, always accompanied by aegirine-augite and usually subordinate in quantity to that mineral. It is strongly pleochroic from light to very dark purple-brown. Other sodic amphiboles occurring as groundmass minerals are riebeckite, pleochroic from light to medium yellow-brown, and (rarely) barkevikite, pleochroic from pale green to pale brown.

Small and widely scattered phenocrysts of red-brown biotite were seen in some exposures of the porphyritic phonolite and in about one quarter of the specimens collected. One phenocryst of olivine occurs in specimen 34/889 from Molo Siriwe.

Specimen 34/944 from Chereremet in the Kamasian Hills is typical of the non-porphyritic variety. It is greenish-black in colour, of so fine a grain as to appear almost waxy. A few small phenocrysts are scattered at wide intervals through the rock. In thin section it shows rare microphenocrysts, up to 0.5 mm. across, of anorthoclase and nepheline set in a groundmass of trachytic texture, with a mesh of anorthoclase laths enclosing masses of yellow-green aegirine-augite, deep purple-brown cossyrite and lesser amounts of grey-blue riebeckite. Throughout the slide are anhedral grains of very pale grey analcite and tiny squares and hexagons of nepheline, both locally showing replacement by calcite.

Specimen 34/939 from south-west of Tenges is of the porphyritic variety, the groundmass being dark grey in colour and of very fine grain, supporting numerous phenocrysts varying in length from less than 1 mm. to 10 mm. Phenocrysts are mainly of anorthoclase and nepheline, with a few of aegirine-augite and biotite (the latter not appearing in the thin section). The groundmass is of fine trachytic texture, with anorthoclase, aegirine-augite, a small proportion of cossyrite and rare grains of riebeckite. Small grains of nepheline occur in the groundmass, far outweighed by interstitial primary analcite.

An interesting and attractive variety of the rock was found as float near Kimngorom and in the tuffs near Isanda. It consists of a fine-grained yellow groundmass speckled with black radiating dendritic clusters. In thin section (34/896) the lighter portions of the rock are seen to consist wholly of anorthoclase, and the dendritic clusters to be discrete aggregates of blue green aegirine-augite and barkevikite, strikingly pleochroic from brownish-green to purple brown. Although the separate minerals in the aggregates appear to have a random orientation all the grains in any cluster of barkevikite change their absorption colours together as the microscope stage is rotated, i.e. are in paralled optical orientation. Small amounts of riebeckite and nepheline also occur in the slide.

Specimen 34/993, taken from the Sirwa motor track at Makrip, has a very fine-grained off-white groundmass speckled with fragments of Kijabe type basalt ranging in size from mere specks to several feet in diameter, often partly remelted and drawn out in streaks. Two slides were made of this specimen, and one shows patches of free quartz, despite the fact that nepheline is present in quantity. The explanation is probably that the lava flowed across an old land surface of Samburu basalts, picking up fragments of the basalt and partly resorbing them, and at the same time picking up fragments of chert or opal, which are sometimes to be found on the basalt surface, the silica recrystallizing as quartz without being wholly assimilated by the lava.

At the base of the phonolite at Sigoro a band of coarse trachyte, approaching syenite, is seen. In hand specimen 34/1002 it is streaked in bands of light grey and brown, suggesting flow, and of a grain size coarse enough to be easily distinguished by the naked eye. In thin section the rock is seen to be a coarse trachytic mesh of anorthoclase laths, with some three per cent of barkevikite and trace amounts of aegirine-augite and riebeckite. The outcrop, seen in one side only of a steep gorge, is 50 ft. long and up to 20 ft. thick and may be a sill-form intrusion rather than a sub-aerial flow. No thermal effects were noted at the junctions.

In some exposures the phonolite is thoroughly glassy in thin section. One such specimen, 34/995 from Soror, is medium grey in colour with fine scoriae marking flow lines. Its thin section shows fragments of anorthoclase in isotropic glass. 34/867 is a very dark green glass taken from one of the obsidian boulders which litter the scarp south-east of Gobat. In thin section it shows small phenocrysts and microlites of sanidine-anorthoclase with a 2V of about 30°, and rare microlites of aegirine-augite.

In the outcrops of Uasin Gishu phonolites in low-lying areas where soil erosion is intense weathering of these rocks consists of the formation of a brownish or greyish skin, seven or eight millimetres thick, on spheroidal boulders or solid rocks. On the higher ground, where soil cover is generally thick, as in Lembus Forest, the rock weathers to a pink or pale brown and grey clay, seen in places to exceed 30 ft. in depth. When dry the weathered rock is not unlike a fine-grained tuff in appearance and weight, but the outline of every phenocryst can still be seen, though the phenocrysts are as deeply rotted as the rock which supports them. Very occasionally the deeply weathered phonolites show spheroidal cores of unaltered rock a few inches in diameter. Specimens 34/994 from Sirwa and 34/1000 from Gaisamu are good illustrations of this deep weathering.

The phonolites are of the plateau type, with no single centre of eruption. Dykes of this phonolite were found in some exposures of the Samburu basalts where erosion has removed the overlying phonolite sheet. They were noted at Loguk where a dyke nearly a mile long but never more than eight feet in width forms the crest of a steep ridge. A parallel dyke downhill to the east was noted, but its full length was not traversed. On the steep slope at the head of the Kerio Valley in Metkei Forest a dyke of Uasin Gishu phonolite 85 feet wide cuts the corner of a fault block, with a second six-foot-wide dyke parallelling it 20 ft. away.

In the east of the area some fault-scarp sections of the phonolites can be seen to consist of successive flows. Perhaps the best example is the peak of Gobat which is built up of horizontal flows each about 60 feet in thickness. The junction between successive flows is sometimes marked by a blocky under-surface to the upper flow, often finely vesicular and purple in colour for the lowest one or two feet. Some of the junctions however, while very clear from a distance, could not be distinguished when walking over them.

On the south-eastern flank of Gobat a deposit of red-brown coarse tuffaceous earth, very poorly consolidated, divides two flows. Only a few hundred feet in lateral extent, it nevertheless reaches a thickness of 150 ft. at its greatest depth and is clearly an infilling to a channel in the underlying flow which was buried by a later flow. A similar band of sediment was seen at Kabarak on the eastern flank of the Kamasian Hills. There the deposit is only five feet in thickness, and as at Gobat the sediment wedges out on either flank and the lava then shows no evidence of any lapse of time between the successive flows.

Gregory (1921, pp. 113-114) pointed out the similarity between these phonolites and the Kapiti phonolites which cover wide expanses of the country south of Nairobi.

(6) Upper Tinderet Volcanics

Only the upper part of the Tinderet succession is present in this area, the lower part outcropping around the Tinderet volcanic centre south-west of Timboroa (Binge, 1962) and in the Kapsabet-Plateau area to the west (Jennings, 1964). The lowest facies present on the Uasin Gishu Plateau in the west of the map area is a nephelinitic phonolite well exposed in the cliffs of the Elgeyo Escarpment. It reaches its greatest thickness of over 650 ft. in the Nabkoi Valley, thinning out to about 350 ft. in the north of the area. On the high ground of the Uasin Gishu Plateau and Lembus it appears only as occasional semi-rounded float boulders in thick soil, and its contact with other rock types as shown on the map is only an approximation. It is readily identified in the field by its abundance of grey and white nepheline phenocrysts of square and hexagonal cross-sections often exceeding 10 mm. across. On weathered surfaces the nephelines are eroded away more rapidly than the fine-grained groundmass, leaving a surface pocked with angular pits. Anorthoclase felspar occurs also as phenocrysts in a proportion of less than one for every ten nephelines. In thin sections 43/1016 from south of Kimwarer and 34/1028 from Tingwa only nepheline phenocrysts are seen, set in a groundmass of narrow laths of anorthoclase with aegirine-augite, cossyrite, barkevikite and pale red-brown biotite. Nepheline occurs in the groundmass but is far outweighed in amount by pale grey interstitial analcite. 34/1028 is studded with small vesicles which are filled with white zeolites, tentatively identified as analcite and stilbite.

Overlying the nephelinitic phonolite, with no evidence of erosion between the flows, is a melanocratic porphyritic phonolite very similar in appearance to the porphyritic facies of the Uasin Gishu phonolites. The Tinderet phonolites tend to be richer in nepheline phenocrysts, being about equal in number to anorthoclase, whereas in Uasin Gishu phonolites nepheline phenocrysts are almost always greatly inferior in numbers to those of anorthoclase. In areas where nephelinitic phonolite outcrops the rocks above and below can be identified with certainty, but elsewhere, as in the southern part of Lembus, the differentiation between Tvp_1 and Tvp_2 on the map must be accepted with some reservations.

The unweathered rock has a dark blue-grey, sometimes black, fairly fine-grained groundmass, usually slightly coarser than that of the Uasin Gishu phonolite, set with numerous phenocrysts of nepheline and anorthoclase up to 10 mm. across, and rarer small flakes of biotite. A typical specimen, 34/1011 from Kaptagat Forest, has macro-phenocrysts of nepheline and anorthoclase in about equal numbers, and the slide shows microphenocrysts of pale green aegirine-augite. The groundmass is of medium grain, with a trachytic mesh of anorthoclase laths enclosing grains of aegirine-augite and cossyrite in equal amounts by volume, and lesser proportions of barkevikite. Tiny grains of nepheline are common, and analcite is a primary interstitial mineral, being also present as an alteration product of some of the nepheline. Riebeckite, which is fairly common in the Uasin Gishu phonolites, was not seen in any slide of Tinderet phonolite.

The Tinderet phonolite weathers very deeply on the flatter ground. A recently blasted section in a road cutting at Lake Narasha shows a clean 50-foot section, of which only the bottom 10 ft. is unweathered (34/979), grading upwards into a further 10 ft. of semi-weathered rock in which the groundmass is of a medium grey colour (34/978). This in turn passes upwards into a light brown clayey aggregate in which outlines of phenocrysts can sometimes be distinguished, and which contains rare spheroidal cores of clearly recognizable phonolite. The uppermost 10 ft. of the section is in red soil. At other recently cut sections along the realigned parts of the Nakuru-Eldoret road around Timboroa on which grass cover was not yet established when studied, the rocks exposed appeared to be unconsolidated red and white tuffs with sedimentary layers up to 2 ft. thick. Closer examination showed them to be of deeply rotted phonolite, the apparent sediments being of the same weathered phonolitic material which had been thoroughly mixed by slumping, probably when in a water-logged condition.

Arambourg (1935, p. 33) gave the chemical composition of the phonolite at Lake Narasha as follows:—

SiO_2	53.44	or	29.47
Al_2O_3	17.20	ab	34.71
Fe_2O_3	2.71	an	3.89
FeO	4.41	ne	10.15
MnO	0.23	di	7.09
MgO	0.97	ol	2.85
CaO	2.68	mt	3.94
Na_2O	6.66	il	1.37
K_2O	4.97	hl	0.47
TiO_2	0.68	th	0.14
P_2O_5	tr		
H_2O+	3.03		
H_2O-	2.57		
Cl	0.27		
SO_3	0.10		
CO_2	0.13		
	100.05		

analyst—M.F. Raoult.

Plate I—Hill dwellings on the slopes of the Elgeyo Escarpment near Kiburagoy

Plate II—Shelf feature between the Elgeyo basalts and the overlying Uasin Gishu phonolites at Chof on the Elgeyo Escarpment

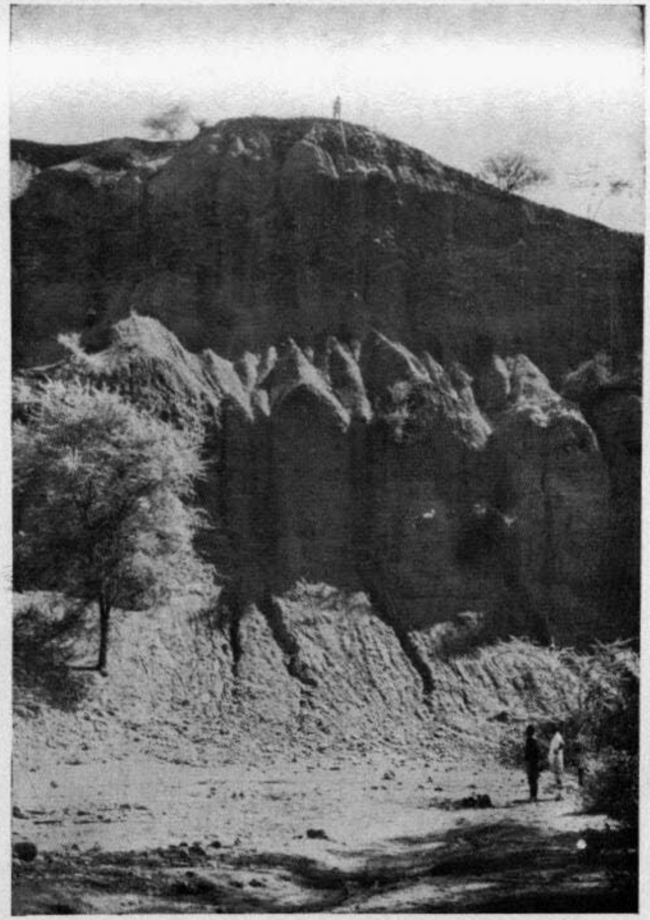

Plate III—Kapthurin sediments with boulder beds in 113-foot section on the Chemeron River north of Marigat

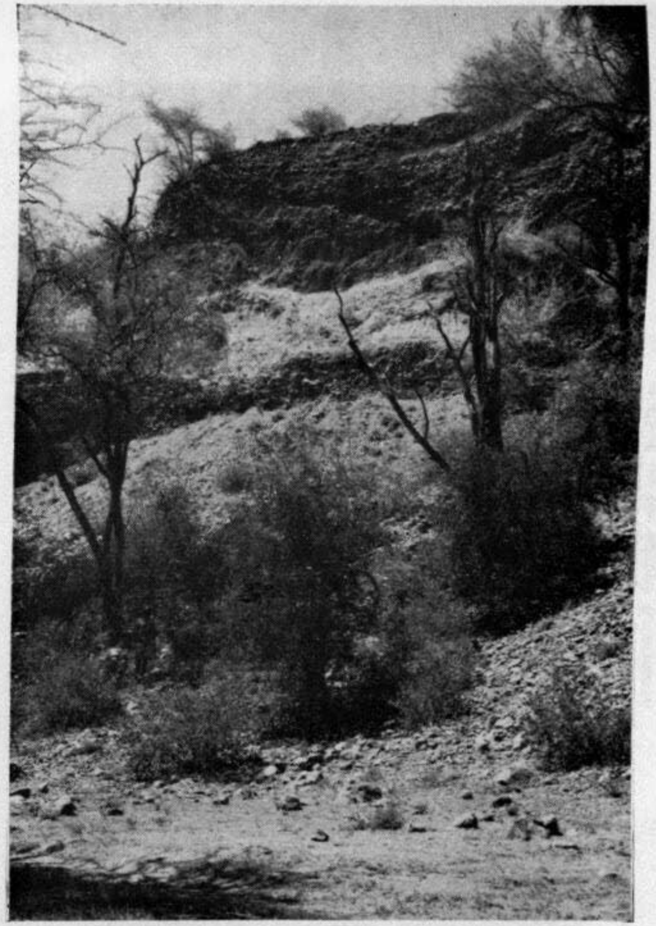

Plate IV—Typical torrent-wash of the Kapthurin sequence exposed in the south bank of the Chemeron River. The section rises a little over 100 feet from the river bed

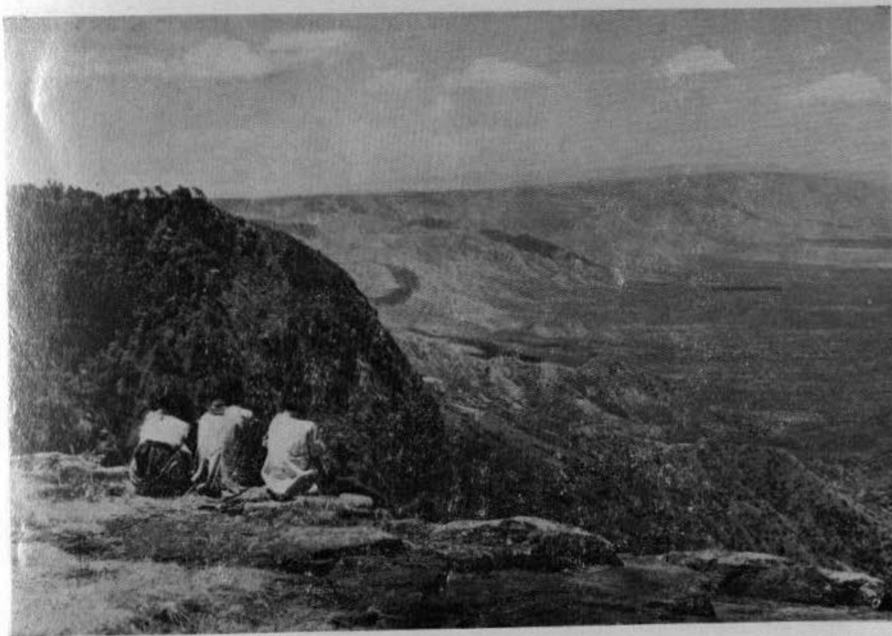

Plate V—The Elgeyo Escarpment and Kerio Valley looking north from Chororget

[*Photo: Kenya Information Service*

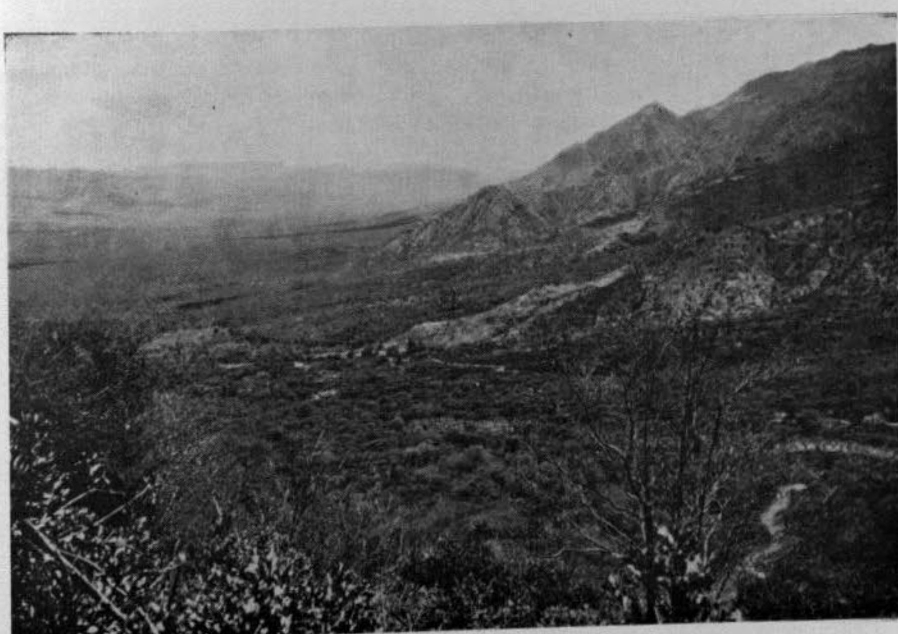

Plate VI—The Elgeyo Escarpment and Kerio Valley looking south from Tambach. Kiburagoy Peak breaks the skyline on the right of the picture

Plate VII—Gorge of the Perkerra River cut in Lake Hannington phonolites at Marigat

Plate VIII—Grid-faulting in the floor of the Rift Valley looking north-west across the Molo Valley north of Kwaibus. The Kamasian Hills appear in the left distance

(7) Eldama Ravine Tuffs and Sediments

This series reaches its greatest development in the area in the south, where the thickness exceeds 1,000 ft. at the map edge. Sediments form only a small fraction of the total and usually consist of reworked tuffaceous material laid down in quiet periods between tuff showers. An exception is in the gorge of the Perkerra River north of Tigeri, where the series dies out to the north-east. Fig. 3 shows a section of the southern side of the gorge at that point. Only 40 ft. thick there, the deposit is wholly

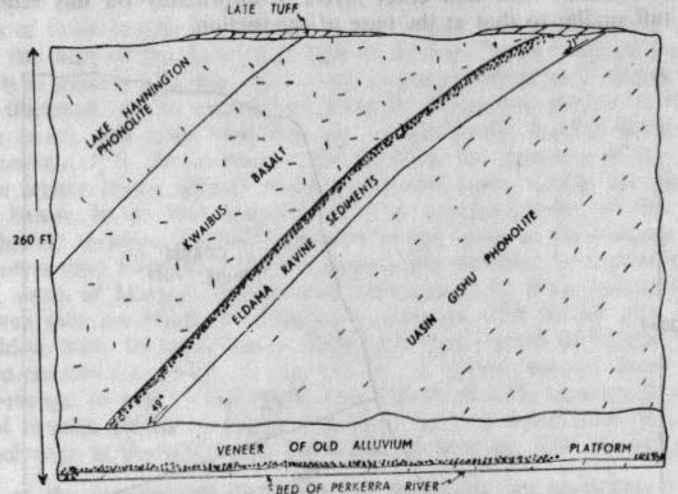

Fig. 3—Diagrammatic section of the Eldama Ravine sediments in the Perkerra Gorge north of Tigeri

waterlain and represents an outwash of material from the main deposits farther south. The bottom few feet consist of yellow fine-grained waterlain ash passing upwards into a bright red deposit consisting of the same fine ash but with a greater admixture of earthy material, with some thin and discontinuous pebble bands. At the top of the succession is a band exceeding 10 feet in thickness of unsorted rubble and boulders, often well rounded, of material derived from Samburu basalts and Uasin Gishu phonolites. The bright red coloration is due to baking of the deposit by the overlying Kwaibus basalt. The smaller pebbles in the rubble band are baked and reddened right through but the larger boulders, which reach six feet in diameter, have a reddened outer skin two to three inches thick surrounding cores of unaltered rock. The tuff capping of the section is part of a discontinuous layer, never exceeding 20 ft. in thickness, which rests on an eroded surface of Lake Hannington phonolite and Kwaibus basalt. It is much younger than any of the rocks near by, and is considered to be a small outlier of the Molo River tuffs. The areas of this late tuff are too small to be shown on the final map. The bottom of the section is obscured by a veneer of later river deposits lying against the walls of the gorge. The present-day Perkerra has cut down through this earlier alluvium without completely removing it, and has exposed a platform of Eldama Ravine sediments and lava into which the river has cut an even younger channel five feet deep.

A further section on the Perkerra River two miles upstream shows a total thickness of 150 ft. of hard grey-green tuff with only four to five feet of fine yellow current-bedded tuffaceous sediments exposed at its base. Here the Kwaibus basalt is missing and Lake Hannington phonolite lies directly on an unbaked surface of tuff. A mile and a half farther south-east, at the outlier of Lake Hannington phonolite east of Tigeri and away from the river, a discontinuous layer of bouldery sediments locally separates the grey-green tuff from the overlying phonolite, and between this grey-green tuff and the fine basal sediment is a coarse white and cream tuff which farther to the south-east occurs to the exclusion of the sediments.

In the Perkerra River a mile north of Isanda sediments mark a discontinuity in the white tuffs (Fig. 4). An eroded surface of tuff has been covered by a torrent-wash deposit of dark red-brown earth with unsorted but rounded pebbles and boulders. The flat upper surface of the torrent-wash is overlain by six feet of fine whitish water-lain tuffaceous material with thin chert layers. Conformably on this sediment lies a coarse white tuff similar to that at the base of the section.

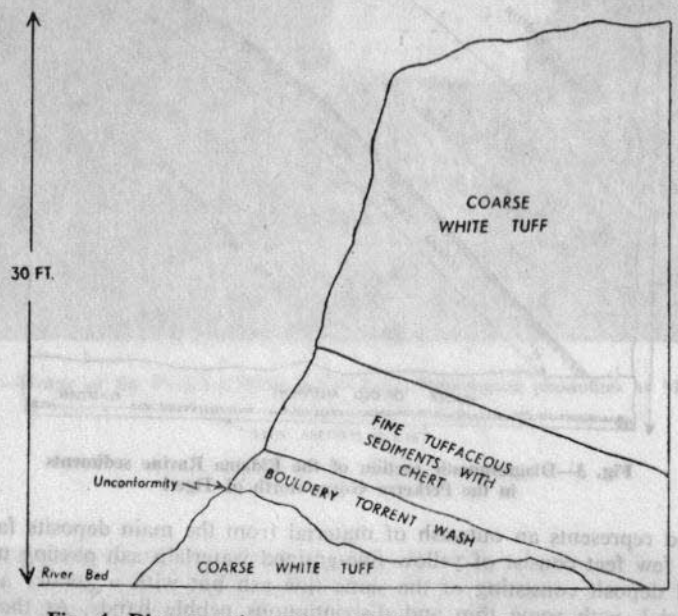

Fig. 4—Diagrammatic section of Eldama Ravine tuffs and sediments in the bank of the Perkerra River, north of Isanda

As the series thickens towards Eldama Ravine the tuffs become harder, and many small quarries have been opened for building stone. A mile east of the township several small hills mark the remnants of a sheet of true welded tuff, too hard to be cut profitably, which rings when struck with a hammer. A typical specimen, 34/780, has a pale grey, fine-grained groundmass enclosing fragments of anorthoclase and angular fragments of pumice and phonolite. Elsewhere inclusions may be absent, and the fine hard matrix shows fluxional streaks suggesting an ignimbritic origin. Between Kimngorom and Terte a small quarry works a well-consolidated crystal tuff of an attractive purple colour (34/974). Exposures near by show this purple tuff to be at the base of the tuff series, being underlain directly by Uasin Gishu phonolite. The upper surface of the purple tuff is eroded, marking an unconformity between it and the overlying coarse off-white tuff. Both the purple and off-white tuffs are cut by siliceous bands a few inches thick, which are red in the purple tuffs and white in the others.

The increase in thickness of the tuffs towards the south of the area and the occurrence there of welded tuffs, some possibly of ignimbritic origin, suggest a point of origin of the tuffs farther to the south, probably either or both of the volcanoes Loldiani (Londiani) and Kilombe. Of the two only Kilombe was visited during the present survey, with Dr. G. J. H. McCall (McCall, 1964). The crater was found to be partly filled with a tuff similar in appearance to much of the Eldama Ravine deposit but it was decided by the writer and McCall (admittedly on slender evidence) that the crater tuff was younger than the Eldama Ravine tuffs, and probably was not a product of Kilombe Volcano at all, but had settled in the crater from an eruption elsewhere and had been preserved from erosion by the lack of outflowing drainage from the crater. An outflow exists at the present day, but the steep sides of the gorge through which the main stream flows show it to be of very recent origin.

(8) KWAIBUS OLIVINE BASALTS

Outcrops of these basalts are confined to the eastern and south-eastern parts of the map area, in the floor of the Rift Valley and its western flanks south of the Kamasian Hills. At the type locality Kwaibus, on the eastern margin of the map, basalt approaches 1,000 ft. in thickness. In its commonest form it is medium purple in colour, very rough to the touch, and often vesicular, the vesicles locally having linings of yellow and orange zeolites. It is always heavy, and much harder than any of the other rocks mapped. The writer broke several wooden hammer hafts during the survey, every one on this basalt. In its commonest form it is non-porphyritic to the naked eye, though porphyritic varieties are fairly common in the north of the outcrop where they are seen in alternating flows with the non-porphyritic varieties. In a good river section at Chabaran, south of Marigat, the alternate flows are 15 ft. thick, but no such regular alternation was seen anywhere else—generally outcrops tend to fall into one type or the other, seldom both. In the ravine on Denning's Farm, north of Eldama Ravine, the vesicular non-porphyritic variety is exposed in an almost vertical face, in separate flows each between 10 and 15 feet thick. The bottom of each separate flow is marked by a layer of basaltic rubble a foot or two thick, an auto-brecciation phenomenon. A thin baked selvedge in the underlying tuff marks its junction with the basalt.

Typical of the non-porphyritic variety of the basalt are specimens 34/874 from Matebei and 34/980 from an outlier north-east of Eldama Ravine, between the Perkerra and Cheptilatil rivers. Both are purple-grey in colour with no visible phenocrysts, 34/874 being coarsely vesicular, and 34/980 having small patches of finely vesicular material. In thin section both show microphenocrysts of iddingsitized olivine and andesine-labradorite felspar set in a medium-grained groundmass of felspar laths enclosing pale purple-grey augite, olivine and iddingsite, and much opaque iron ore.

Specimen 34/832, from Kaptim, is a sample of the porphyritic facies. In appearance it is very similar to the non-vesicular non-porphyritic phase (though the porphyritic lava too is often vesicular) but is studded with phenocrysts up to 5 mm. across of pale greenish-yellow olivine, and a few glassy felspars. In the thin section phenocrysts of olivine are abundant, together with one large phenocryst of andesine-labradorite with eroded crystal faces, indicating a small degree of resorption by the groundmass magma, and numerous small inclusions of augite and magnetite. The groundmass consists of andesine-labradorite laths and augite grains in equal amounts, with an abundance of semi-altered olivines and two or three per cent of magnetite. Augite is an abundant constituent of the groundmass of all the rocks examined in thin section, but is very rare as phenocrysts or microphenocrysts. In most specimens the felspar is andesine-labradorite, but labradorite occurs in three of the slides and andesine in one.

All of three specimens of Kwaibus basalt collected in the southern part of the outcrop, 34/979 and 34/979a from Esageri and 34/909 from Saos, are alkali basalts. 34/979a and 34/909 differ in appearance from the basalts just described. Both are dark blue-grey in colour with only rare macrophenocrysts and are non-vesicular, while 34/979 is exactly similar in appearance to the purple-grey vesicular type described above, even to the yellow linings to some of the larger vesicles. The former two have microphenocrysts of both andesine and anorthoclase, and anorthoclase also appears as an important constituent in the groundmass, together with aegirine-augite and augite. 34/979 contains a small amount of anorthoclase in the groundmass and much interstitial analcite as a primary constituent.

The whole extent of the Kwaibus basalt at Begamoi in the south-east is very coarsely vesicular, and weathers to rounded boulders with deep identations. The writer and McCall (who mapped the eastern extension of the same outcrop) were struck by the resemblance of many of the boulders to skulls, and found the term "Death's head basalt" a very apt description.

(9) Chemeron Beds

For reasons which are given later details of the Chemeron beds are included with those of the Kapthurin beds on page 27.

(10) Kabarnet Trachytes

In the present area outcrops of Kabarnet trachytes and associated tuffs and sediments are confined to the vicinity of Kabarnet, though they were seen to extend for many miles along the Kamasian Hills north of the area.

The tuffs and sediments associated with the Kabarnet trachytes reach their greatest extent of outcrop at Kituro, east of Kabarnet, where they underlie the trachyte. No continuous section was found to enable their true thickness to be measured, but this appears to exceed 150 ft. The Kituro deposits consist mainly of coarse grey or yellow tuffs with fragments of black pumice, and bands of fine, grey tuffaceous sediments, seldom more than a foot or two in thickness, intercalated with the coarse tuffs. Much of the tuff is soft and friable, but a small quarry opened in it beside the Kabarnet-Marigat road produces a building stone of adequate strength for single-storey buildings. At Kiptimim, five miles west of Kabarnet, an outlier of trachyte rests on 50 ft. of coarse yellow tuff, containing black pumice and additionally blocks of black obsidian up to 10 in. across. The junction between the tuff and trachyte is marked by three feet of red soil. Many artifacts of chert or opal (but, oddly enough, none of obsidian) were found on the surface of the tuff at that locality, but none were seen embedded in the tuff, and it is unlikely that they were derived from there. The base of the tuff is obscured by red soil, and it could not be determined whether the tuff lies at the base of the trachyte or intercalated between flows.

Several other sedimentary exposures were seen, all intercalated between trachyte flows. At Chesolop, midway between Kabarnet and Kiptimim, 50 ft. of tuff are exposed in a steep hillside of trachyte, the lower 25 ft. being identical in appearance to the Kiptimim exposure, overlain by a further 25 ft. of fine, white tuff. South-east of Chebloch, near the Kirumbopso River, 35 ft. of coarse, yellow and green tuff, overlain by red soil, is seen between two trachyte flows. The last sedimentary exposure noted lies in a road cutting south of the peak of Kimojoch, where a 12-ft. band of river gravel and tuffaceous silt occurs in the lava, its top 10 in. baked bright red by the overlying flow. This exposure affords evidence of an old river channel cut during a pause in deposition of the lavas.

Where tuffs and sediments are lacking no evidence could be found of successive separate flows of the trachytes except in the steep northern slope of the Kibaino Valley at Chesolop, just outside the map area, where from across the valley four separate flows can be distinguished, each about 200 ft. thick. The base is not seen. On climbing the hill the only feature marking the junctions between successive flows is a slight shelf where a sparse vegetation can find root, as contrasted with the almost bare faces above and below.

The trachyte is of coarse grain, and grey or greenish-grey in colour, the greenish tinge being due to fairly deep weathering which in many exposures completely obscures the unaltered rock. It is generally non-porphyritic except in a few exposures south-east and south of Kabarnet, where glassy anorthoclase felspars up to 6 mm. in length occur. One specimen from Kabarnet, 34/920, shows red biotite phenocrysts two or three millimetres long. Under the microscope most specimens were seen to be microporphyritic, with microphenocrysts of anorthoclase set in a coarse, trachytic-textured groundmass of anorthoclase, aegirine-augite, cossyrite and a small amount of riebeckite. Some specimens, as 34/943 from Kimojoch, have a groundmass showing granular texture. Neither nepheline nor analcite occurs in any slide but 34/925, from Chesolop, contains blebs of quartz as a primary constituent.

No sources of extrusion of the trachytes were found, but viewed from the high ground to the south or west the main outcrop west of Kabarnet is seen as a sheet which has flowed down the dip-slope of the Kamasian Hills, and was later tilted to the south-west. The main source of the lava appears to lie on the crest of the hills a few miles north of Kabarnet. The isolated horizontal outcrop at Kimojoch stands considerably higher than the level of the trachytes at Kabarnet, and although there is faulting between the two points such faulting is demonstrably largely older than the trachytes, major faults in the older formations seldom displacing the overlying trachytes by more than 30 or 40 ft. as a result of later renewals. The Kimojoch outcrop must therefore have originated from a separate source, probably a fissure or fissures now buried beneath the lava.

In the present area no trachytes were found east of the main Kamasian Ridge. Two explanations can be put forward to account for this, either that only little of the lava flowed eastwards, and that small amount has since been removed by erosion, or that at the time of extrusion of the lava the summit line of the Kamasian Hills lay to the east of the present summit line, and the trachytes were extruded on the western slopes of the ridge. The much steeper eastern slopes have eroded faster than the western slopes, cutting back the summit line to its present position at the trachyte sheets.

(11) Lake Hannington Phonolites

Named by McCall (1967) from Lake Hannington, a few miles east of the present area, along the shores of which they reach their greatest known thickness, these phonolites outcrop widely in the east and south of the present area. McCall maps only one type, a fairly coarse-grained rock with only rare phenocrysts, but over much of the present area a clear division between the upper, generally non-porphyritic lava (Tvp_4) and a lower coarsely porphyritic facies (Tvp_3) can be mapped. In some outcrops, notably at Soui in the north-east, a good deal of porphyritic lava is intercalated with the non-porphyritic, but where the phonolite can be proved to belong to the lower division the rock is invariably porphyritic. Thus any outcrop in which both types are found to be intermixed was mapped as Tvp_4. The lower porphyritic facies is here included with the Lake Hannington lavas of McCall since nowhere was evidence found of any lapse of time between the outpourings of the two types, and the evidence in the present area points to a beginning of extrusion in the west of the present outcrop followed closely by extrusion of the non-porphyritic type from sources farther to the east. The present map suggests that the lower lavas may never have extended into the area to the east.

In the field the Lake Hannington lava is clearly distinguished from the Uasin Gishu phonolites, even where their stratigraphic relationship is not immediately obvious, by the much coarser grain of the Lake Hannington rocks. They are usually dark grey or black in colour except at the bottoms of flows, which sometimes have a deep purple colour. Large vesicles are common locally, especially in the north of the area, sometimes with linings of white zeolites.

Typical of the porphyritic facies is specimen 34/819 from Kaptim. The glassy phenocrysts, up to 10 mm. in length, were identified in thin section as anorthoclase felspars falling in the sanidine-anorthoclase cryptoperthite range, set in a groundmass showing trachytic texture, consisting of a felted mass of laths of anorthoclase enclosing grains of bright green aegirine-augite, a small amount of pale greenish brown augite, purple-brown cossyrite and primary analcite. In most other specimens studied analcite is common, and small crystals of nepheline were identified in some slides, occasionally showing partial or complete alteration to analcite. Ragged flakes of red-brown biotite occur as phenocrysts in one specimen, 34/895 from Isanda, which also contains a small amount of riebeckite in the groundmass.

In the Perkerra Gorge, south of Radad, many float blocks of light yellow-brown coarse-grained syenite were found, apparently having fallen from the outcrop of the Tvp_3 phonolite on the lip of the gorge, though none could be found *in situ*. They appear to be blocks of already solidified rock carried from depth in the phonolite magma. In thin section (34/879) the rock is seen to consist mainly of large anorthoclase crystals with interstitial aegirine-augite, cossyrite and riebeckite, and a dark green isotropic mineral tentatively identified as stained analcite. Some opaque iron ore with limonite also occurs in the slide.

The non-porphyritic facies of this lava is identical in thin section with the porphyritic, except that phenocrysts are rare or absent, though microphenocrysts of anorthoclase are not uncommon. In two of the slides examined, 34/907 from Sagat and 34/1008 from Turner's Farm, between Sagat and Eldama Ravine, neither analcite nor nepheline was identified, and the rock is therefore a trachyte rather than a phonolite. Not enough specimens were collected from those places to determine whether the trachyte occurs as separate flows between phonolite flows, or whether it represents small areas lacking in felspathoids.

A low ridge 500 yds. long and about 100 yds. across trending north-north-westerly stands above the surface of the Tvp_4 phonolite at Kabarichan, near the northern border of the map. The rock which forms the ridge is dark purplish grey in colour, of very fine grain, and locally finely scoriaceous. In thin section 34/831 it appears as an almost opaque glass with small clusters of zeolite filling cavities and a single microphenocryst of pale green aegirine-augite. Its identification as phonolite is therefore only tentative, and it may be a later lava extruded from a fissure in the Lake Hannington phonolite. No similar rock was found elsewhere in the area.

Some of the porphyritic phonolite was extruded from Kabuot, a cone over a hundred feet high with an almost circular crater nearly a mile across. The crater itself is completely filled with lava and appears as a flat-topped hill, but aerial photographs show two distinct flows running to the north and north-east, a lower broad flow and an upper much smaller flow overlying the former. In the field the two flows are distinguished only with difficulty, there being no difference between the rock types, and no clearly defined junction between them. At the north-eastern limit of the larger flow the Lake Hannington phonolite abuts against an older scarp of Uasin Gishu phonolite which for most of its length rises above the later flow. At its western margin the flow oversteps from Uasin Gishu phonolite on to Elgeyo basalt and finally on to Samburu basalt, forming a marked escarpment along its whole length. It is doubtful whether lava extruded from Kabuot extended more than a mile or so south of the crater, and the bulk of the lava to the south probably had its origin in scattered fissures. One such fissure is marked by an east-west dyke of phonolite ten feet in width cutting Samburu basalts north of Isanda, eight miles south of Kabuot. No source was found of the upper non-porphyritic phonolite, which is a typical plateau lava and was almost certainly extruded entirely from fissures

(12) Kapthurin and Chemeron Beds

The writer and G. J. H. McCall made a series of traverses between the north-east of the present area and Lake Baringo with the object of reappraising the sediments first described by Gregory (1921, Chapter IX) and later re-examined by Fuchs (1950, pp. 149-174). Various sediments elsewhere in the East African Rift Valley system have been correlated with these sediments, and all given the name "Kamasian".

The present re-examination was made because the writer discovered that two sedimentary successions of different ages are present in the Kamasian type-area, and these had been treated by earlier writers as a single unit. The older sediments were renamed by the writer and McCall the Chemeron beds, from the Chemeron River (known in its upper reaches as the Nasagum), which cuts the northern border of the map, and where the sediments attain their greatest known extent. The younger group were named the Kapthurin beds from the river of that name which runs from west to east roughly parallel with the Chemeron and about five miles to the north of that river. Since in the past both groups have been treated as one stratigraphic unit it is convenient to consider both together in this report in order to point out the differences between the groups, and the evidence for their differing ages. The following account is the joint work of the writer and McCall, and closely follows the account already published (McCall, Baker and Walsh, 1967). Only the parts of that paper referring to the present area are drawn on here, and therefore the Kapthurin section is only briefly mentioned.

(*a*) *The Chemeron-Nasagum River Section* (*Fig.* 5).—At the point where the road from Marigat to Kampi ya Samaki, on the west shore of Lake Baringo, meets the Chemeron River (about one mile north of the map margin) sections of torrentwash only are exposed, associated with brown, earthy silts. A thickness of 113 ft. of these sediments is seen in section on the north bank of the river (Plate III). To the east however, near the junction of the Chemeron with the Ndau River, thickly bedded tuffs, which form mesas, are intercalated in the torrentwash. Air photographs clearly reveal minor faults trending roughly north-south dislocating these sediments near to the road.

To the west of the 113-ft. section thin bands of tuffaceous sediments showing slump structures were recognized, intercalated in the brown, earthy silts. Passing westwards up the Chemeron Valley there is a stretch of about a quarter of a mile with no exposures until a narrow rocky gorge occurs, which is cut in lava of the Lake Hannington phonolite series. The surface of the lava flow dips some 15° to the east and is overlain by bouldery torrentwash dipping at up to 2° east. There is a well-marked fault bounding this tilted block of lava on its west side, and there is no reflection of this fault in the torrentwash which passes over the tilted fault-block of lava without any disturbance. Small faults also affect the lava in the gorge but not the overlying torrentwash.

To the west of this gorge, in a 100-ft. section on the south bank of the river, is a succession of brown, clayey soil-like sediments interspersed with bouldery torrentwash (Plate IV), but showing no evidence of lacustrine origin. To the west of this section the river passes through another gorge cut through two eastward-tilted fault-blocks of the same lava as that in the first gorge. These blocks tilt to the east at about 6° and are overlain by nearly horizontal torrentwash. Under the lava are exposures of finely bedded yellowish soft silts which, like the higher series of sediments, contain black pumice inclusions. Unconformable on these sediments are some torrentwash deposits composed of boulders and earthy silt apparently brought down by the present-day river, but which are indistinguishable from the previously described torrentwash deposits. The fine, yellowish tuffaceous silts under the tilted lavas are clearly quite distinct from the upper series of coarse torrentwash which passes over the top of the fault-block undisturbed, and the name "Chemeron group" has been given to this older sedimentary formation. The dip of the sediments under the lava was found to be

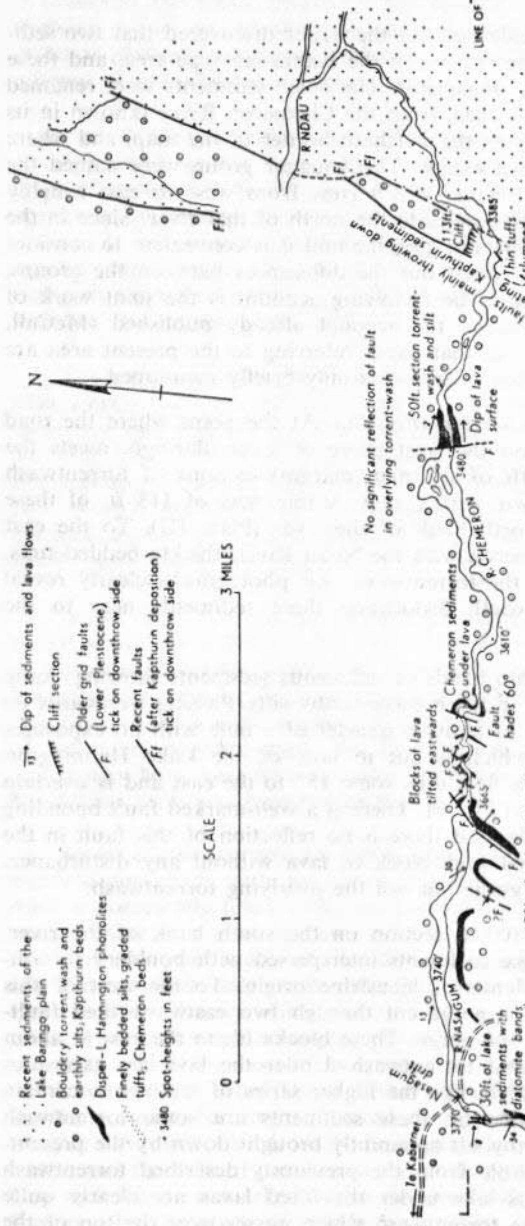

Fig. 5—Sketch map and section of exposures near the Chemeron-Nasagum River

18° E.S.E. A few yards to the west of the margin of the fault-block another small fault can be seen, which throws the lava down to the west. The fault plane is exposed and is that of a normal fault hading at 60°. The overlying torrentwash does not appear to have been displaced by this fault. A few yards even farther to the west another eastward-tilted lava fault-block is seen to overlie soft, finely bedded sediments which are there conformable with the lava. The base of the latter is markedly vesicular, suggesting flow over wet lake beds.

In a gully between two high-standing lava hills on the south side of the river is a section exposing the Chemeron group of sediments under the Lake Hannington lava. There a thickness of approximately 130 ft. of sediments appear to underlie about 70 ft. of lava, which is in turn mantled by torrentwash. The Chemeron sediments dip east at about three degrees and are separated from the lava by a red brick-earth layer which marks an old land surface. In the bed of the Nasagum River near by, the Chemeron sediments are seen without any lava capping. The lava either thinned rapidly to the west or has been removed by erosion. The Chemeron sediments still dip east at three degrees and are overlain unconformably by the flat-lying bouldery torrentwash.

At the Nasagum Drift, where the Kabarnet road crosses the river, massive white fairly pure diatomite outcrops within the Chemeron sediments in beds a foot or more thick. Above the drift are further good sections of sediments, thinly bedded clayey silts and tuffs, and thin diatomites dipping east under Lake Hannington lavas at up to 34°. A very good section showing small normal faults throwing down to the west is also seen there.

The Chemeron sediments in the Nasagum River appear to become thicker and more diatomaceous in a westerly direction, and this is repeated in the Kapthurin and the Kapiswa river sections. The overlying lava appears to thin out westwards, the sediments emerging from under the lava and being seen in contact with the overlying torrentwash formation.

(*b*) *The Kapiswa River Section* (*Fig.* 6).—(The Kapiswa River is that referred to by Fuchs (1950, p. 155) as the Marigat River.)

The town of Marigat consists of a few shops and a police post at the ford of the Perkerra River (the original settlement) and a recently established administrative centre about a mile to the north-east. Between the District Officer's headquarters and the old settlement, at "Pole Pole corner", the road cuts a section in some well-stratified and cross-bedded tuffs carrying black pumice inclusions up to three inches in diameter. The sediments dip 7° E., are cut by a small, vertical fault throwing down about two inches to the west, and are overlain by torrentwash of the Kapthurin series. A single artifact of Levallois type was found on the surface of this bouldery deposit. The lower sediments in the section are probably also part of the Kapthurin series despite their unusually high dip, which may be explained by the fact that they lie in the eastern zone of late faulting. They closely resemble tuffs seen elsewhere in this upper series.

The Recent poorly stratified silts of the Baringo Plain (the Loboi silts) form high sections in the Perkerra River below Marigat Ford which, as Nilsson shows (1932, map p. 68), marks the highest limit of the recognizable extensions of Lake Baringo.

Above the ford is a great wall of lava belonging to the Lake Hannington phonolite sequence, a fault scarp through which the river emerges in a narrow gorge only a few hundred yards long (Plate VII), where a most interesting section is seen. At the bottom of the lava a rubbly band rises westwards from the river bed, soon becoming separated from the lava by a few feet of sediments including diatomites. This rubble band, resembling many seen in and near Menengai, a huge caldera near Nakuru, is composed of green angular lava fragments cemented in a fine-grained groundmass of similar material. The rubble band, believed to be due to autobrecciation, thickens westwards

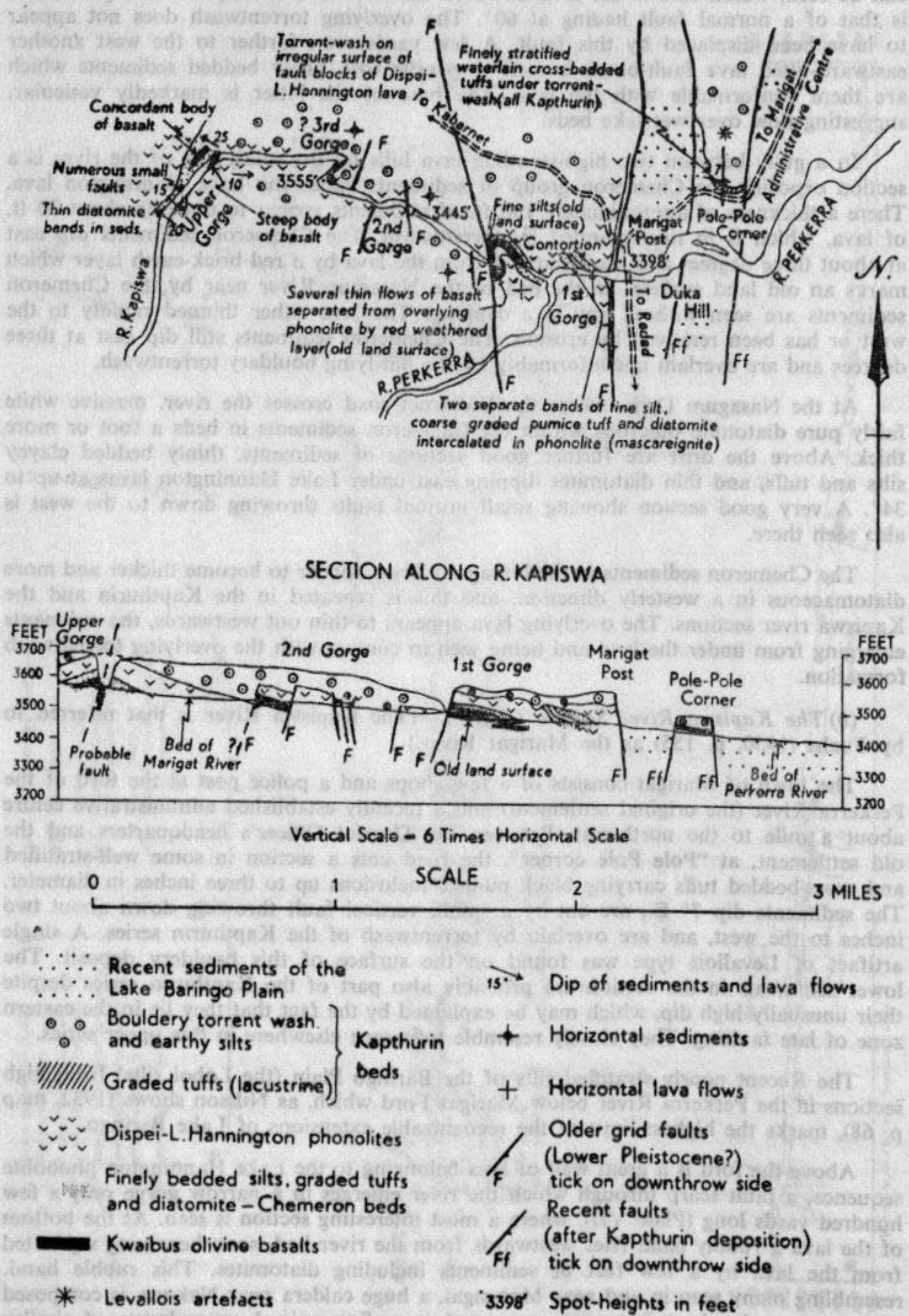

Fig. 6—Sketch map and section of exposures near the Kapiswa River

to about 20 ft. and includes diatomite lenses. Below it are sediments with a dark brown, baked top surface. These sediments include diatomites and coarse pumice beds, in massive units like those of the Kapthurin series, but in this case marked by abundant fossilized reeds or grasses. There are also some yellowish fine-grained tuffaceous silts, identical in appearance with those of the Chemeron group, which from their position under faulted Lake Hannington lavas and their appreciable eastward dip must be assigned to the Chemeron succession. They are underlain by another flow of the Lake Hannington lavas, which also shows a rubbly bottom. Opposite the confluence of the Perkerra and Kapiswa rivers this flow is remarkably contorted and this contortion brings up the overlying rubble band, without intervening sediments, a fact which reveals the degree of lateral variation in these formations.

To the west of the river junction sediments are again seen under the Lake Hannington lava south of the river. The under surface of the lava is vesicular and strikingly fluted (McCall, 1964B). Beneath it there is a compact black baked layer, showing columnar jointing, and merging downwards into a friable old land surface deposit which overlies very soft yellowish silts and tuffs, the characteristic sediments of the Chemeron group. To the west the lava is brought down to river level in an abrupt flexure, but to the north of the river the same succession is repeated, though the sediments are thinner and a massive vesicular basalt emerges beneath them. The base of the overlying lava is again vesicular. The river now takes an abrupt turn south along the line of a fault throwing down to the west. On the east bank there is a fine section of two basalt flows with reddened top surfaces, overlain by Lake Hannington lava showing a rubbly base. The absence of sediments here demonstrates their lateral impersistence once again. The upper phonolitic lava is contorted into a boudin-like mass. Such contortions are not uncommon in the Lake Hannington lavas, and are probably primary flow structures and not tectonic in origin. The phonolite and underlying basalt are concordant, and mapping farther south establishes that these basalts are part of the Kwaibus group. At the south end of this gorge the river turns once again west and Lake Hannington lava is seen to be faulted down in relation to the rocks west of the fault. Immediately west of this torrentwash and silts of the Kapthurin sequence appear above the lava.

There follows a section illustrated by Fuchs (Second Marigat Gorge) in which a series of eastward-tilted blocks of Lake Hannington lava are overlain by coarse bouldery torrentwash (Kapthurin sediments) that has fallen down into spaces between the blocks. No true lacustrine sediments are present. In sections farther west the basalt reappears under the Lake Hannington phonolite, with no sedimentary intercalation between the flows. It is overlain by a mantle of bouldery torrentwash but no lacustrine sediments are seen.

Next the river flows through a narrow gorge cut in Lake Hannington phonolite that dips 10° E. Once again the river turns abruptly south, along a fault zone in which it has cut a gorge flanked by steep cliffs, called by the writer and McCall the West Marigat George, as Fuch's "Third Marigat Gorge" could not be exactly located. This latter appears to be part of a now slumped and overgrown section lying farther to the east. In the West Marigat Gorge thinly bedded silts, tuffs and diatomites of the Chemeron group underlie lava of the Lake Hannington sequence. They are cut by small faults and show dips up to 15 degrees. There are two bodies of basalt in the gorge, one a near-vertical wall-like mass on the river bed resembling a dyke and the other a conformable body in the sediments. These basalts could be late intrusions, but it would appear that the Chemeron sediments are also locally represented with the Kwaibus basalt flows, and the steeply tilted body of basalt in the river bed is therefore thought to be a highly deformed sliver of originally flat-lying basalt lava situated in the fault zone.

(c) *The Molo River Section and Duka Hill.*—At the crossing of the Molo River south-east of Marigat there is a 50-ft. section of unstratified earthy silts—the Loboi silts—which form a flat expanse of Recent sediments between Lake Baringo and Lake Hannington. Beneath these silts are thick, horizontal beds of pumice tuff, identical with those in the Kapthurin River section and containing similar enclaves of black pumice. At Duka Hill torrent gravels and graded tuffs of the Kapthurin succession abut a horst of Lake Hannington lava.

(d) *Conclusions.*—The Kamasian sediments are generally referred to as "faulted sediments", following Gregory's earliest description. In fact they are now seen to consist of two groups, the Chemeron and Kapthurin. The Chemeron group is strongly faulted, being deposited before the last two episodes of rift faulting referred to later in this report. The Chemeron beds underlie the strongly grid-faulted Lake Hannington lavas, and from the description already given it is clear that they form an integral part of a complex horst and graben structure. By contrast the Kapthurin sediments are only very weakly faulted in the eastern part of their outcrop near Marigat, and are unfaulted farther west. This minor faulting is part of the last episode of Rift Valley faulting in the Baringo Basin which, minor though it was, and confined to a narrow zone in the centre of the rift, lowered the base level, forming a shallow hollow in the Kapthurin Lake beds and allowed a further accumulation of sediments, represented in the present area by the Loboi silts. This slight subsidence explains the fact that these later infillings occur below the level of the Kapthurin exposures near Marigat. There is no possible mechanism which could have removed the Kapthurin sediments from the floor of the Baringo Basin after deposition—wind deflation is discounted—and they must underlie the Recent sediments, though faulted down to a lower level subsequent to their deposition. There are many normal faults with steep hades exposed in the type-area section near Marigat. No evidence of reverse faulting was seen.

There is no firm evidence for referring the outcrops south of Marigat to the Kapthurin sequence. They are so assigned because they are younger than the Lake Hannington phonolites and resemble the earthy silts of the Kapthurin type-area, though the bouldery deposits so common farther north are represented by only a few thin pebble sheets.

(13) Molo River Tuffs

These tuffs (Plt_1) reach their greatest extent in the extreme south-east of the map area, and exposures die out to the north-east. They are characterized by inclusions of black and yellow pumice in sizes varying from a fraction of an inch to two feet in diameter. Specimen 34/852 was taken from a large angular block of black pumice in the bank of the Molo River north of Mikuyuni. It is light enough to float on water, with vesicles up to an inch across, and contains rare fragments of glassy oligoclase felspar. The tuff is generally pale brown or brownish-grey in colour, light in weight and fairly soft—too soft to make a good building stone. In it was found no evidence of sorting or stratification, and all of it is believed to have been deposited on dry land. The tuffs fill or partly fill many of the graben in the strongly faulted country in which they are exposed. Although stereoscopic pairs of aerial photographs suggest strong faults in the Kwaibus basalt north of Lomolo Sisal Estate continuing as vague ridges in the tuffs, no such ridges or other evidence of faulting could be seen on the ground.

The distribution of the Molo River tuffs in the present area and in areas to the south suggest that they may have had their origin in the volcano of Menengai, near Nakuru.

(14) Tuffs of the Uasin Gishu Plateau and Lembus

These tuffs, Plt_2 on the map, are generally of fine grain, yellow or grey in colour, sometimes containing yellow and grey pumice and occasionally fragments of phonolite and rare small crystals of anorthoclase. Most of the outcrops are clearly layered, apparently as a result of secondary deposition in river valleys. Such layered tuffs are generally soft and poorly consolidated, but a few outcrops of the rock are hard enough to be cut for building stone. One such building stone, 34/1023 from Kamwosor, is pale yellow-grey in colour with large and small fragments of pumice and phonolite streaked out in horizontal layers, and shows no evidence of redeposition. Where the tuffs extend for long distances along river valleys their upper surfaces incline downstream with the same gradient as that of the valley shoulders. On this account the writer considers the tuffs to have been deposited over the whole area in which they now outcrop as a thin mantle, and to have been washed into the river valleys where they were consolidated to a greater or lesser degree. They occur at the present day as flat swampy floors in valleys of original V-shaped transverse section, and all the evidence points to a very recent date of deposition as the dissection of the terrain at the time of deposition must have been substantially as it is today. At Kipkabus Downs Estate, on the western margin of the map, shallow roadside cuttings show a tuff layer only one or two feet thick underlain by red soil identical to the soil which overlies the tuff. Lake Narasha, near Timboroa, lies on one of the tuff outcrops, and is no more than a swampy pond which almost disappears in dry seasons.

3. Quaternary Deposits

(1) Red Soils and Torrentwash of the Kerio Valley

This deposit, marked on the map with the symbol Q, covers a wide area on either side of the Kerio River and in the Kibaino Valley. The main constituent is a red or pale yellow-brown fine, earthy silt, with numerous layers of coarse ill-sorted bouldery material occurring at all levels. The bouldery strata were not seen north of Chebloch Bridge, though the present-day bed of the Kerio at that point is composed largely of boulders carried downstream from south of the bridge. Near Kimwarer, in the south of the outcrop, one gully exposes a depth of 45 ft. of soil and boulders, and north of Chebloch a thickness exceeding 60 ft. was noted, the base not being seen in either case. The deposit is derived from both Basement System and volcanic rocks, and was laid down at a time of much greater precipitation than now, as all indications point to degradation at the present time, with soil being removed by erosion much faster than material is added by occasional heavy storms. The bouldery exposures in the south closely resemble the torrentwash deposits of the Kapthurin sequence around Marigat, but bedded tuffs are absent in the Kerio deposit. However, in the western outcrops of the Kapthurin sediments tuffs are lacking, and it is possible that the Kerio and the Kapthurin sediments are of the same age.

The Kerio River is at present cutting down into the deposit, and in the north of the area is flanked by nearly vertical cliffs 60 ft. high, while near Kimwarer at the south of the valley the slopes are much less steep and generally do not exceed 25 ft. The trachyte tongue at Chebloch Bridge marks a knick-point in the river profile, and is reducing the rate of downcutting of the river upstream. The position of the river cutting this lava tongue rather than flowing to the west of the exposure (the surface of the sediments between the bridge and the shops 400 yds. to the west is 30 ft. lower than the lava surface at the bridge, though still some 30 ft. above the normal river level at the bridge) is a clear demonstration of superimposed drainage, the earlier river having cut down through a much greater thickness of sediments than is seen at the present day. Similarly the position of the river cutting the trachyte outcrop four miles upstream from the bridge may be attributed to a gradual lowering of the surface of the sediments, incising the river into the underlying lava.

No fossil remains were found in these sediments and the few artifacts found by the writer were all lying on the surface, with no indication that they had been derived from the deposit itself.

(2) Lacustrine Silts of the Loboi Plain

The silts of the Loboi Plain in the extreme north-east of the map area are deposits marking the last extension of the original lake (Gregory's "Lake Kamasia") which has now dwindled to form lakes Baringo and Hannington. The silts are of a light yellow-brown colour, poorly stratified, with only rare pebbles. No faulting is seen in the silts, and erosion is so slight, despite a total lack of grass cover over most of the plain, that no deep gullies have developed, and a car may be driven at will between Marigat and Lake Baringo. The Perkerra River below Marigat ford cuts down into the silts and exposes sections 25 ft. in height resting on Kapthurin sediments.

(3) Volcanic Soils

Volcanic soils, indicated by the symbol Qv on the map, are shown only in one area in the south-east, around Kures, where they completely obscure the underlying rocks. Much of this deposit is of black soil which for much of the year is a swamp supporting a poor stunted thorn scrub. Marginally, where the ground is better drained, the soils grade from brown to red. Elsewhere in the area the soils, whether derived from basalt, phonolite or trachyte, are bright red or reddish-brown, and where their thickness and rainfall amounts allow cultivation, they are very fertile and will yield ten or more successive crops of maize before being allowed to lie fallow. On the high ground of the Uasin Gishu Plateau, where heavy forests covered much of the land only 50 years ago, soils are seen exceeding 30 ft. in depth, and with the good husbandry of the Elgeyo farmers crop yields are as high as anywhere in Kenya.

(4) Alluvium

On the map the symbol for alluvium is used only for deposits laid down by rivers in their present-day courses. Thus while much of the torrentwash of the Kerio Valley is an ancient alluvium, only those sandy patches laid down after the river had cut down into the earlier deposits are shown under the alluvium symbol. Many of the rivers of the area have narrow bands of alluvium in and close to their beds, but the only deposits large enough to be shown at the scale of the map are those of the Kerio River and a four-mile flat on the Perkerra River. In each case the deposit is of fine sand derived from the surrounding rocks, with thin pebble bands marking flood conditions and occasional lines of coarse boulders marking older river courses. Some of the bands are poorly cemented with calcium or other salts.

VI.—HOT SPRINGS

Hot springs occur at Arus on the Molo River and at Kureswa on the escarpment which faces north down the Kerio Valley. The Arus hot springs rise along fissures in the very steep eastern bank of the Molo River. When visited (June 1959) the springs were seen as jets which up to four feet above river level spouted water at about 85°C., and above four feet spouted only steam at well above atmospheric pressure. The springs occur along a fault line, and very close to a junction between three separate grid faults. For a distance of nearly two miles upstream from Arus the river closely follows one of these faults, and samples of water taken from the springs and the river at the same spot show close affinities, as is seen in the analyses in Table 2. The only significant differences are the amounts of silica, which has doubled in the spring water owing to the amount of silica dissolved out of the country rock by the hot water, and the drop in iron content in the water of the springs. This can be explained by the large increase in saline ammonia (reflected in the decreased pH value) in the spring water, which has precipitated some of the iron originally held in solution and redeposited it as bright red siderite on the rocks around the vents. The occurrence of small amounts of sulphur around the vents suggests that the drop in sulphates in the spring water is due to fixing of free sulphur by bacteria.

TABLE 2

	1	2	3	4
		Parts per million		
Alkalinity (as $CaCO_3$) Carbonate	—	—	35	30
Bicarbonate	42	31	355	425
Ammonia Saline	0.04	1.46	—	—
Albuminoid	0.82	0.53	—	—
Oxygen absorbed 4 hrs. at 80°F.	4.0	2.2	—	—
Chlorides (as Cl)	5	4	16	16
Sulphates (as SO_4)	5	Nil	36	33
Nitrites (as NO_2)	Nil	+	Nil	Nil
Nitrates (as NO_3)	Nil	+	Nil	Nil
Calcium (as Ca)	—	—	7	7
Magnesium (as Mg)	—	—	1	1
Iron (as Fe)	2.8	1.4	0.02	0.02
Silica (as SiO_2)	30	60	90	90
Total hardness (as $CaCO_3$)	10	20	20	20
Permanent hardness	Nil	Nil	—	—
Temporary hardness	10	20	—	—
Carbonate hardness (as $CaCO_3$)	—	—	20	20
Excess alkalinity (as Na_2CO_3)	—	—	390	460
Free carbon dioxide	—	+	—	—
Total solids	165	255	570	630
Fluorides (as F)	0.8	0.4	16	17
pH	7.3	6.3	8.3	8.3

1. Arus–Molo River } *Anal. B.D. Patrick, Government*
2. Arus–Hot springs } *Chemist, Nairobi.*
3. Kureswa hot springs—west } *Anal. N. Kirby, Government*
4. Kureswa hot springs—east } *Chemist, Nairobi.*

The non-condensible gas from the Arus Springs has the following analysis:—

H_2	0.4 per cent by volume
CH_4	0.14
N_2	51.9
O_2	13.3
A	0.62
CO_2	34.0
He	0.01

Anal. A. H. Turnbull, A. E. R. E. Harwell.

The proportions of nitrogen, oxygen and argon are those of air, leaving virtually pure carbon dioxide, which also occurs in boreholes at Esageri, just over 10 miles south-east of Arus, as discussed in a later section.

From available evidence it is clear that the hot springs result from river water which enters fault fissures and meets at depth emanations from a cooling magma, being forced to the surface again under the pressure of gas and steam developed by the heating.

The hot springs at Kureswa emerge at intervals over a length of 100 yds. on a steep hillside at an elevation of 6,000 ft. O.D. The water bubbles upwards out of vertical fissures only a fraction of an inch in width. Two steep-sided V-shaped gullies cut the hillside across and at right angles to the spring line, but both are dry, the water issuing from the crests of the interfluves and flowing down the flattened ridges to the river a hundred feet below. A small amount of gas, which was not sampled, bubbles quietly out with the water. The supply of water reaches several thousands of gallons per hour, and people living near by say that the volume of water remains constant whatever the weather conditions. The water has no smell and no noticeable taste, and its temperature at the fissures is 65°C. Two samples of water, one from each end of the line of springs, were analysed and the results are tabulated in Table 2, columns 3 and 4. The analyses are consistent with groundwater that has travelled for some distance through rock and picked up some of the more soluble constituents in it. The summit of the dissected country of Lembus Forest occurs 3,000 ft. above the springs immediately to the south, and the relatively heavy rainfall on the thickly forested plateau would be more than sufficient to supply the springs as well as the surface streams of the district.

VII.—STRUCTURE AND TECTONICS

The main structural features of the area are, from west to east: (1) the Uasin Gishu Plateau rising to almost 10,000 ft. O.D. and its south-eastern extension into Lembus; (2) the Elgeyo Escarpment marking the eastern edge of the plateau and falling to (3) the Kerio Valley, much of which lies below 4,000 ft.; (4) the Kamasian Hills which rise to nearly 8,000 ft. at Kimojoch, and (5) the floor of the Rift Valley proper, which falls gradually from 5,000 ft. in the south of the area to below 3,500 ft. in the north.

Fig. 7 shows the fault pattern of the area, together with the outcrops of deposits which post-date the faulting and obscure the underlying structure. It is clear that no major faulting occurs on the Uasin Gishu Plateau, although minor faulting may be present but obscured by the generally deep soil cover. Similarly the thick forests and paucity of outcrops in the Lembus area make it difficult to decide whether faulting is more pronounced there than the figure suggests. The absence of faults shown in the north-south belt of country around Sabur is due to the difficulty in recognizing faults in the deeply weathered Samburu basalts. It is highly improbable that this belt could have escaped faulting. However, the pattern of closely spaced grid-faulting on the eastern margin of the map never extended as far west as Sabur, since these faults are so recent that had they existed in this locality they would still give rise to very pronounced features.

The Elgeyo Escarpment, a mile in height, when viewed from a distance gives the impression of resulting from a single major fault (Plate V). However, only relatively minor faulting could be recognized in the escarpment, downthrowing a total of less than 1,000 ft. The occurrence of Samburu basalt outcrops in the bed of the Kerio River at the 4,000 ft. contour, and the occurrence of Basement System gneisses up to 7,625 ft. in the escarpment to the west, suggests a hidden fault under the Kerio sediments with a downthrow exceeding 3,500 ft., if it is assumed that the volcanics were laid down on a plane surface of gneiss. But all the evidence indicates that the land surface here was not a plane surface at the time of the first volcanic activity. At Tambach, only a few miles north of the area, are 500 ft. of fresh-water Miocene sediments lying directly on Basement System rocks, and the surface of the latter is taken to be a part of the sub-Miocene peneplain which covered much of Kenya. By the very definition of a peneplain no depression could exist which would allow of deposition except after tectonic disturbance. For reasons mentioned earlier the writer considers that the Miocene sediments post-date the Samburu basalts which are so extensively developed east of the escarpment. A study of the sub-Miocene erosion bevel in Kenya (Pulfrey, 1960) shows the site of the present-day Rift Valley to have been uplifted by many thousands of feet after the development of the sub-Miocene surface. In a discussion of the origin of the Rift Valley, Pulfrey (*ibid.* pp. 12-13) points out that it is sited along a topographic low (relative to the flanking high hills and mountains) that existed in Miocene times, and must have been the site of powerful rivers. The evidence therefore points to an uplift of the flanks of the valley, together with a possible

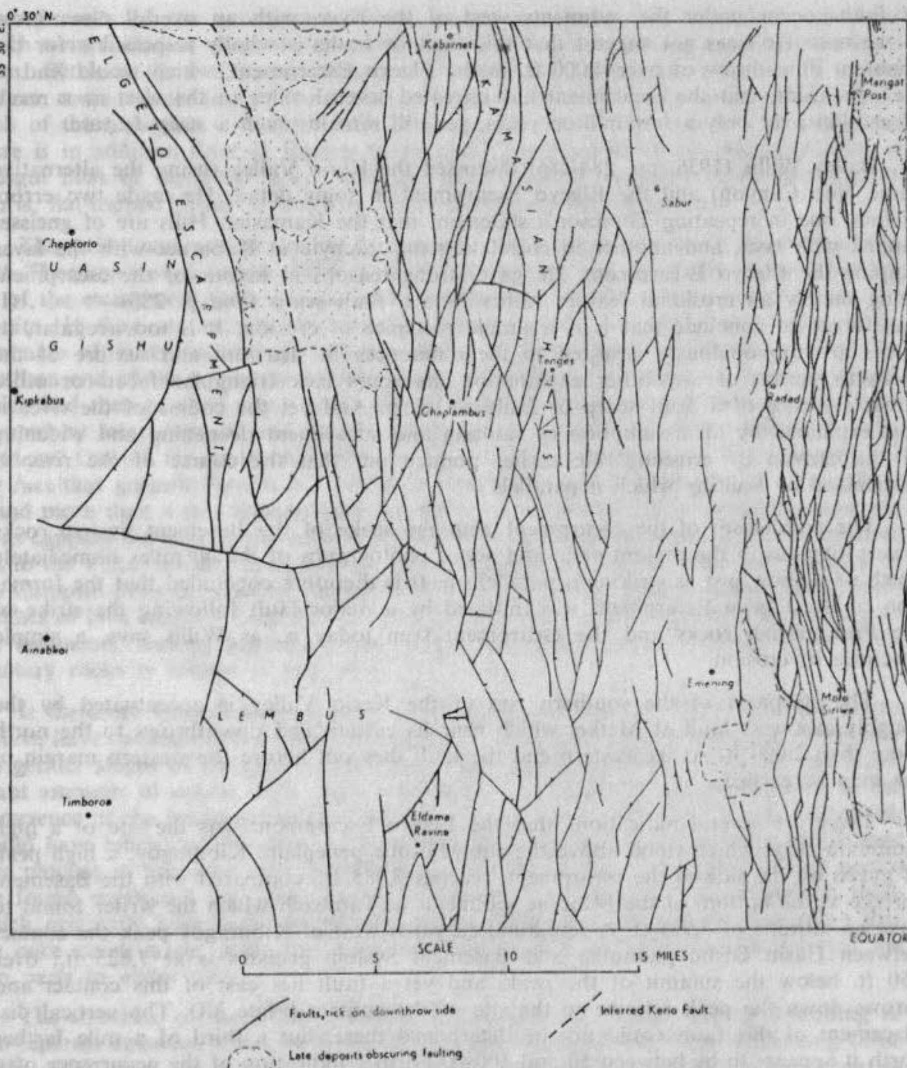

Fig. 7—Pattern of faulting in the Eldama Ravine-Kabarnet area

down-warping of the central area, unaccompanied by major faulting, which led to the outpouring of the Samburu basalts and their filling the then relatively shallow central zone and locally overspilling its higher flanks. Shackleton's map of the Nanyuki-Maralal area (1946) shows Samburu basalts north of Maralal many miles east of the eastern shoulders of the Rift Valley, and in the present area they are found at nearly 9,000 ft. at Metkei, south of the Kerio Valley. It is noteworthy however, that these basalts do not appear in the Elgeyo Escarpment. It seems that the Samburu basalts exposed in the bed of the Kerio flowed up against a ridge of gneisses and feathered out between the river and the present-day escarpment. Strong north-south faults at the head of the Kerio Valley disappear under late sediments, and it must be assumed that they continue northwards as there is no reason to suppose that in such a faulted area the Kerio Valley escaped disturbance. The writer therefore suggests that a strong fault or series of faults occur under the sediments west of the river, with an overall downthrow to the east. He does not suggest that this fault or faults is wholly responsible for the apparent downthrow of over 4,000 ft. in the Elgeyo Escarpment, which would lead to the conclusion that the escarpment has retreated several miles to the west as a result of erosion over only a few million years, yet still remains such a steep feature.

Bailey Willis (1936, pp. 284-286) discussed the Kerio Valley (using the alternative name Ndo Canyon) and the Elgeyo Escarpment in some detail. He made two errors of fact, one in repeating Thomson's statement that the Kamasian Hills are of gneisses capped with lava, and another in correlating the trachyte at Kabarnet with the lavas capping the Elgeyo Escarpment. He gave strong reasons in favour of the escarpment being mainly an erosional feature rather than a fault scarp (*ibid* p. 285)—" . . . (I) was forced to conclude that is is a simple precipice of erosion. It is too irregular, its forms are too obviously adjusted to the differences in structure and texture of the rocks to permit of any other explanation. Its spurs lack triangular facets or other direct evidence of a fault scarp or faultline scarp. And yet the course of the river is best explained by an assumption of faulting and subsequent deepening and widening of the canyon by erosion." He earlier pointed out that the course of the river is determined by faulting which it parallels.

The parallelism of the escarpment with the strike of the Basement System rocks is very obvious in the present area, and aerial photographs of the 40 miles immediately north of it show just as striking a parallelism. It is therefore concluded that the formation of the Elgeyo Escarpment was initiated by a major fault following the strike of the Precambrian rocks and the escarpment seen today is, as Willis says, a simple precipice of erosion.

The steepness of the southern rim of the Kerio Valley is accentuated by the roughly east-west fault at Metkei which near its eastern end downthrows to the north more than 2,000 ft. At its western end the fault dies out before the western margin of the map is reached.

There are several indications that the Elgeyo Escarpment was the site of a high mountain ridge which stood above the sub-Miocene peneplain. Kiburagoy, a high peak of gneiss on the side of the escarpment, reaches 7,985 ft., compared with the Basement surface at the bottom of the Miocene sediments at Tambach which the writer found to have an altitude of 5,925 ft. A few hundred yards west of Kiburagoy peak the contact between Uasin Gishu phonolite and Basement System gneisses is at 7,625 ft., over 350 ft. below the summit of the peak, and yet a fault lies east of this contact and throws down the peak relative to the site of the contact (Plate VI). The vertical displacement of this fault could not be determined there, but a third of a mile farther north it appears to be between 50 and 100 ft. Further indication of the occurrence of a high ridge is the fact that above the Uasin Gishu phonolite at the top of the escarpment many hundreds of feet of Tinderet volcanics form almost vertical cliffs. Despite the fact that the original depression at the site of the rift may have been completely filled by Samburu basalts, such a fluid lava as a phonolite (Walsh (1963, pp. 6-9) shows the single flow of phonolite which forms the Yatta Plateau in southern Kenya to have flowed 180 miles down a grade of less than 10 ft. per mile) would have spread far to the east of the present escarpment, and would now still be found in extensive and thick sheets. With the exception of some float of Tinderet nephelinitic phonolite at the base of the escarpment, discussed in the next paragraph, no Tinderet lavas are found east of the escarpment, which is further supporting evidence for the likely former presence of a barrier ridge.

At the foot of the escarpment are five patches of lava which fill old valleys in the Basement System rocks, and slope downhill at angles varying between 10 and 14 degrees, slopes which are of the same order as the overall slope of the Basement

System rocks of the escarpment. These occurrences have the appearance of flows which were spilled or erupted into valleys when the escarpment had reached its present form. Between these five occurrences are numerous valleys cut into the Basement System rocks which contain no trace of lava or lava float. The main rock type in each of these patches is Uasin Gishu phonolite. At the Emsea and Kapsoi exposures there is in addition float of Elgeyo basalt and Tinderet nephelinitic phonolite, and at Musgut float of the latter only. Although much of each exposure takes the form of debris, flat-topped sheets as much as 50 ft. across are not uncommon.

The writer was at first unable to reconcile the evidence shown in these exposures with Thomson's explanation (1885, p. 464) that they are masses of lava fallen from the lip of the escarpment, and was inclined to agree with Walker (1903) that the lavas are *in situ*. If they are *in situ* this can be explained only by considering them to be remnants of fairly widespread but thin sheets of lava which had flowed around the southern end of the mountain barrier and mantled the lower slopes of the escarpment, which had then reached much of its present stage of dissection, and subsequently been covered by later deposits and now re-excavated, a postulation rather difficult to substantiate. One of the main objections to regarding the exposures as fallen material is the fact that gneissic float is not found in any of the lava exposures, nor is lava float found more than a few hundred feet downhill on the metamorphic terrain between the lavas capping the escarpment and the lower masses of lava. Professor King has pointed out to the writer the similarity between these occurrences and the numerous landslips of the Campsie Fells in Scotland (Bailey, 1925, p. 241). These latter landslips result from patches of lava capping a sedimentary escarpment breaking off and riding downhill over the sediments, leaving immense trails of volcanic debris in which float of the sedimentary rocks is seldom if ever seen.

It therefore appears that each exposure marks an immense landslip, where sheets of lava have broken off the sheer cliffs capping the escarpment and have slid down over the gentler slopes of the underlying metamorphic rocks without picking up any significant amounts of debris from these lower rocks. It is possible that at the time of the occurrence of the landslips the gneisses had some extent of soil cover which, when wet, would have lubricated the soles of the slides. King also points out that the two largest lava patches in this area (more occur along the foot of the escarpment farther north) are found north-east and south-east of Kiburagoy, a remnant of the mountain ridge which originally held back the plateau lavas capping the escarpment, suggesting that the once much larger peak may have split the original sliding mass and diverted the two parts to either side.

The structure of the Kamasian Hills is controlled by rather open grid-faulting of two separate episodes, since the faults in the Kabarnet trachytes, while continuing those in the older lavas, are of much lesser magnitude, pointing to a renewal of movement in the older fault pattern. The eastern side of the hills is more strongly faulted than the west, and the overall picture is one of a steep and strongly broken eastern face contrasted to a more gentle western slope which approaches a true dip slope on the outcrop of the Kabarnet trachytes. The overall dip of the main outcrop of the trachytes is 4° to the south-west (a slope of approximately 300 ft. per mile), although locally the dip steepens to as much as 9°. If it is assumed that the original rest-level of the lava upon extrusion was at a slope of just over 1° (100 ft. per mile) the then existing fault along the Kerio Valley must have been renewed and thrown down more than 1,500 ft. to the east subsequent to the extrusion of the trachytes, probably during the second period of major rift faulting in the Lower Pleistocene.

The writer contends that in this part of the Rift Valley the western wall, which is clearly the Elgeyo Escarpment farther north, dies out at the head of the Kerio Valley, and the system of grid faulting east of the Kamasian Hills is relayed to the east to become the new western wall. Such relaying (*en echelon* faulting on a grand scale) is a feature of the Rift Valley throughout its length. The western wall becomes much less distinct east of Eldama Ravine and farther to the south is somewhat obscured by the volcanoes of Loldiani (Londiani) and Kilombe, south of which it reappears as the eastern boundary of the Mau, west of Lake Nakuru. Thus the floor of the Rift Valley proper in this area is the country extending eastwards from the foot of the Kamasian Hills at Sabur to the foot of the Laikipia Escarpment east of lakes Baringo and Hannington.

East of Radad a belt of much more recent close grid-faulting occurs, forming as it were a rift within the rift. The western margin of this newer faulting runs from south to north as far as Radad, and then swings slightly eastwards through Marigat Post to near the western shore of Lake Baringo. This newer system of grid-faulting, well shown in Plate VIII, is itself impressed on the older and more open grid pattern, as evidenced west of Marigat Post. A mile or more west of the post the grid-faults disappear under the Kapthurin sediments without disturbing them, but at the post and eastwards the Kapthurin beds themselves are faulted, and form almost vertical cliffs upwards of 100 ft. in height overlooking the Loboi Plain. The newness of the faulting in the sediments is evidenced by the very poorly consolidated nature of the beds, which crumble too readily to allow the faces of the cliffs to be climbed, yet these are nevertheless almost vertical faces. Where the newer faults cut lavas the fault faces are again vertical or near-vertical with little or no vegetation and very little scree at the foot. Just west of Lake Baringo this grid-faulting is referred to by Gregory (1921, p. 109) as the "Clapham Junction type", from the resemblance to successive platforms separated by sunken railroads.

Almost all the faults have a roughly north-south alignment parallelling the adjacent walls of the Rift Valley. Notable exceptions are the east-west fault, downthrowing some 2,000 ft. to the north, which marks the southern end of the Elgeyo Escarpment and the Kerio Valley, and a shorter east-west fault, downthrowing some 400 ft. to the south, on the western flank of the Kamasian Hills. The fault of north-easterly trend in Lembus Forest makes only a small feature on the ground, and it is doubtful whether its throw exceeds 100 ft.

All of the faults of which the nature could be seen clearly are normal faults with steep hades, generally between 65° and 90°. Nowhere was reverse faulting seen which could have resulted from compression. Fault breccias are unexpectedly rare, among those recognized being that in the Precambrian gneisses at the southern end of the Elgeyo Escarpment already described, a coarse breccia in the Uasin Gishu phonolites outcropping in the gorge of the Perkerra River at Radad, and a very similar occurrence in the Lake Hannington phonolites 4½ miles north-east of Gobat Peak. Probably many more breccias exist but are masked by scree and soil cover.

Gravity

A gravimetric survey of the present area was made, using a Worden gravimeter, jointly by the writer and McCall in order to extend the work of the latter in the Nakuru-Thomson's Falls-Lake Hannington area (McCall, 1967) and adjacent areas of the Rift Valley. The interpretation by the present author of the Bouguer anomalies derived by plotted readings obtained during the whole survey are shown in Fig. 8. E. C. Bullard's readings, made in 1933-34 (Bullard, 1936), are included in the diagram with the subscript B. These are generally a little lower in absolute values than those calculated during the present survey due to a different base station being used. This diagram also appears in McCall's report. The main points of interest are the markedly low values recorded at Chebloch Bridge and south of Eldama Ravine. The low at Chebloch (which may not be the lowest value in that part of the area since readings were made at widely spaced stations) strongly suggests a major fault under the alluvium of the Kerio Valley, as postulated earlier. On the other hand the area of low values

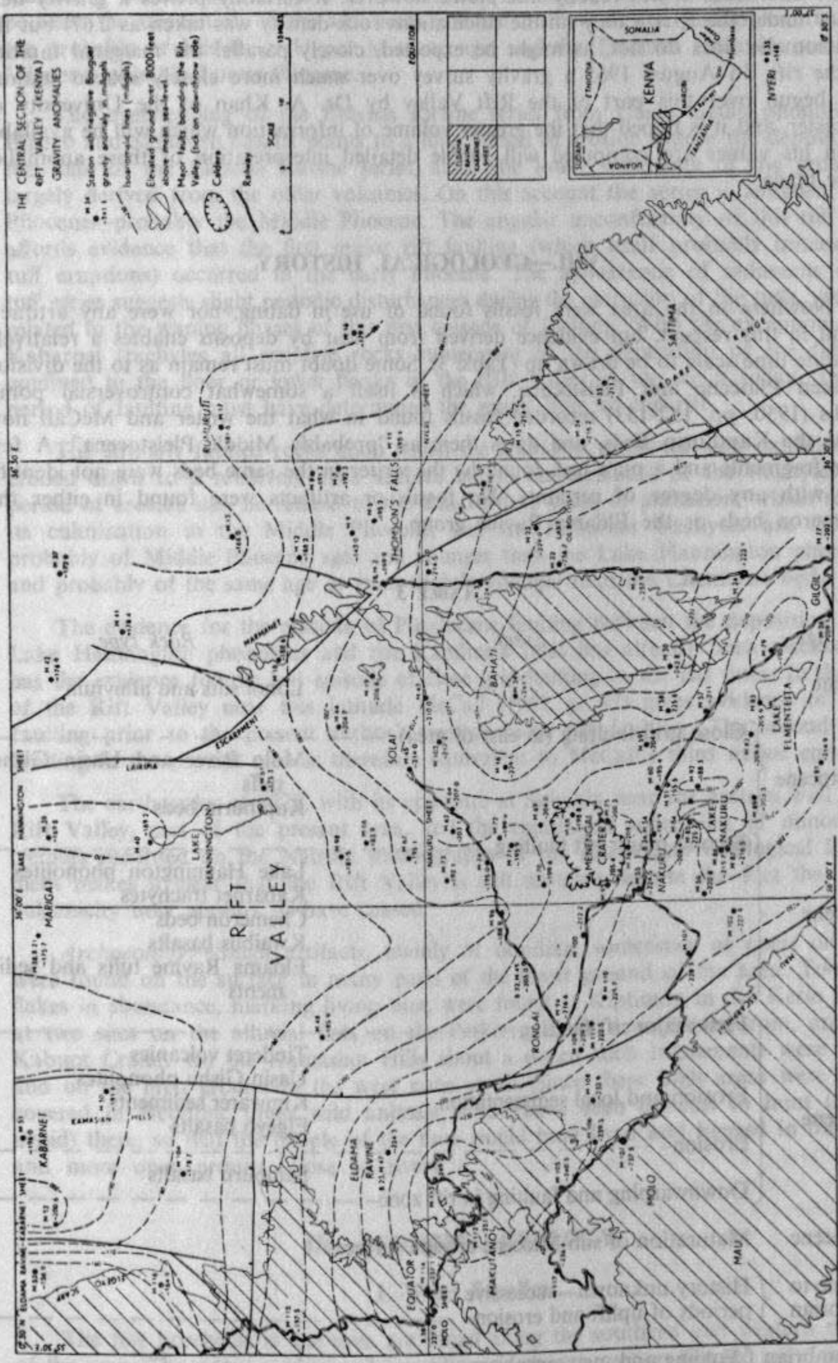

Fig. 8—Lines of equal Bouguer anomaly in the central part of the Kenya Rift Valley

south of Eldama Ravine is ascribed by McCall to the Kavirondo Rift Valley, with its associated strong negative values, entering the area from the west. The overall pattern of the anomalies is not readily interpreted however. It certainly proves a gravity deficiency under the Rift Valley (in the calculations rock density was taken as 2.67) but the iso-anomalic lines do not, as might be expected, closely parallel the marginal faulting of the rift. In August 1965 a gravity survey over much more closely spaced stations was begun over this part of the Rift Valley by Dr. A. Khan of the University of Leicester, and it is hoped that the greater volume of information which will be available when his values are computed will enable detailed interpretation of these anomalies to be made.

VIII.—GEOLOGICAL HISTORY

Nowhere in the area were fossils found of use in dating, nor were any artifacts useful in this respect, but evidence derived from near by deposits enables a relatively accurate time scale to be drawn up (Table 3). Some doubt must remain as to the division between Pliocene and Pleistocene, which is itself a somewhat controversial point. Fuchs (1950, pp. 152-153) recorded fossils found in what the writer and McCall now name the Kapthurin Beds, and dates them as "probably Middle Pleistocene". A few bone fragments and a pig's tusk found by the writer in the same beds were not identifiable with any degree of certainty. No fossils or artifacts were found in either the Chemeron beds or the Eldama Ravine group.

TABLE 3

Age	*Event*	*Rock type*
Recent		Loboi silts and alluvium
Pleistocene	Close grid-faulting (in east of area)	
		Molo River and Uasin Gishu tuffs Kapthurin beds
Pliocene	Second major rift faulting	
		Lake Hannington phonolites Kabarnet trachytes Chemeron beds Kwaibus basalts Eldama Ravine tuffs and sediments
Miocene	First major rift faulting	
	Erosion and local sedimentation	Tinderet volcanics Uasin Gishu phonolites Kimwarer sediments Elgeyo basalts
	Erosion	
		Samburu basalts
	Downwarping and faulting in rift zone	
Oligocene	Maturation of sub-Miocene erosion surface	
Eocene to Cambrian	History unknown—successive periods of uplift and erosion	
Precambrian	Folding and metamorphism Sedimentation	Basement System

The Uasin Gishu phonolites at Tambach (Shackleton, 1950 p. 373) overlie beds, which contain an undoubted Miocene fauna, which the writer correlates with the Kimwarer sediments. As there is no evidence of any prolonged period of erosion between the deposition of the sediments and the outflow of the phonolites, the latter are probably of Middle or Upper Miocene age, and the Tinderet volcanics are Upper Miocene, possibly Lower Pliocene.

The overstepping of the Eldama Ravine series from Uasin Gishu phonolites to Elgeyo and Samburu basalts points to a long period of erosion before the deposition of the tuffs of the Eldama Ravine series, since the lower sediments of the group are largely derived from the older volcanics. On this account the series is assigned to the Pliocene—probably the Middle Pliocene. The angular unconformity of this tuff series affords evidence that the first major rift faulting (which itself probably initiated the tuff eruptions) occurred in the early Pliocene. The appearance of sediments in the tuff series suggests slight periodic disturbances during the extrusion of the tuffs, probably related to the waning phases of this first episode of faulting. With the exception of the Kabarnet trachytes all eruptive rocks subsequent to the deposition of the tuffs are confined to the floor or lower flanks of the Rift Valley as we see it today, and this period of faulting must have determined the major lines of the rift.

The strongly faulted rocks upon which the Kabarnet trachytes were extruded were eroded down to a relatively even surface before emplacement of the trachytes. This period of erosion can be related to the end-Tertiary cycle of planation, which reached its culmination in the Middle Pliocene, and the Kabarnet trachytes are therefore probably of Middle Pliocene age, and younger than the Lake Hannington phonolites, and probably of the same age or even slightly younger than the Chemeron beds.

The evidence for the episode of Pleistocene faulting between the deposition of the Lake Hannington phonolites and the Kapthurin beds has already been discussed, as has the evidence for the last episode of close grid-faulting in the rift floor. In the west of the Rift Valley near this latitude McCall (1967, p. 97) gives evidence of major faulting prior to the present author's second major rift faulting. The second major faulting in the present area is therefore equivalent to McCall's third major episode.

The earthquake of 1928, with its epicentre at Subukia near the eastern wall of the Rift Valley, east of the present area, and the continuous succession of minor local tremors recorded on the Nairobi seismographs of the Mines and Geological Department makes it clear that the Rift Valley is still unstable despite the fact that active vulcanicity now appears to have ceased.

Archaeology.—Small artifacts, mainly of obsidian, sometimes of chert or agate, were found on the surface in many parts of the lower ground of the area. Tools and flakes in abundance, marking living sites, were found at Kiptimim in the Kerio Valley, at two sites on the alluvial flats on the Perkerra River near Kimngorom, and near Kabuot Crater. On the Kamasian Hills about a dozen such implements were found, and on the high ground in the west none at all. Since these high areas were forest-covered in Neolithic times wild animals would have been difficult to hunt (and to avoid) there, so that the people of the time would have lived and hunted in the lower and more open ground, close to rivers.

IX.—ECONOMIC GEOLOGY

1. Water Supplies

The few boreholes in the area are found along the southern and western margins of the map. The water-producing bores (those producing carbon-dioxide are dealt with in the next section) listed from east to west and then north, are shown in Table 4.

TABLE 4

Borehore No.	*Locality*	*Depth (ft.)*	*Water Struck (ft.)*	*Rest level (ft.)*	*Tested yield in gallons per 24 hours*
C781 ..	.. Lomolo	525	525	448	50,000
C795 ..	.. Lomolo	532	510	456	53,000*
C1406 ..	.. Legetetwek	469	375+445	284	48,000*
C616 ..	.. Sagasaket	315	185 (main supply) 353 to 265	152	54,000
C1280 ..	.. Esageri Factory	368	307 to 350	225	8,000*
C626 ..	.. Pearson's Farm, Eldama ..	500	400+460	396	24,000
C722 ..	.. Eldama Ravine Boma ..	460	424	165	45,600
C2124 ..	.. Moore's Farm, Torongo ..	440	230	200	17,280
C1838 ..	.. Foster's Farm, Kipkabus ..	360	162+246 (main)	240	21,600

*Warm water

McCall (1957, pp. 39 and 46) points out that the water table in the extreme south-east of the present area around Lomolo and Kampi ya Moto is at a great depth, and it is doubtful whether drilling even to 1,000 ft. would produce water in many locations. Even then no appreciable sub-artesian rise could be expected. In that locality up to 1957 only five out of 13 boreholes were successful.

Approaching Eldama Ravine and continuing westwards there is no record of an unsuccessful borehole. There are few bores in the farming areas because rainfall conditions are good and sufficient water can generally be obtained from surface streams, storage against dry periods being provided by stone or earth dams. Smallholdings east of Eldama Ravine, around Kabimoi and Esageri, are supplied with water from pipe-lines from the slopes of Kilombe, south of the mapped area, a project of the African Land Development Board (Aldev). Piped water is also available in the township of Kabarnet from a series of small dams near by.

Water for stock in the dry rift floor in the east of the area is augmented by a further Aldev project, the building of "Haifa tanks". Such tanks are fairly shallow depressions scooped out by small earth-moving machines and bounded by earth dykes, with further banks of earth angled out from the tanks to trap the run-off from a wide area around. Such tanks are sited on very gently sloping ground and away from marked stream channels to obviate the danger of the earth banks washing away in floods. Such a tank, an acre or more in area and perhaps 20 ft. deep when filled, will hold water from one rainy period to another and allow grazing in areas which would otherwise be used only during rainy periods when natural surface water could be relied on.

The Perkerra Irrigation Scheme, north-east of Marigat is a project, started by hand labour but later mechanized to a high degree, which taps the water of the perennial Perkerra River to irrigate many hundreds of acres of fertile silts in an area usually too dry to permit farming. The area of the present scheme is known to have been irrigated by the Njemps tribe long before the coming of the first Europeans, but the original work is said to have been abandoned when the Perkerra River changed its course in the latter part of the nineteenth century.

Irrigation is also practised to a small extent in the Kamasian Hills and the upper slopes of the Elgeyo Escarpment, where trenches only a foot wide and a few inches deep are cut to tap off water from streams and lead it to near-by smallholdings.

2. Carbon Dioxide

In 1946 several boreholes were sunk in the Esageri Location (which extends south of the southern margin of the map) for an agricultural scheme. Of the seven boreholes started in the original programme two were abandoned before completion, two (C616 and C1406 already referred to in the water section) produced water, and three (C525, C526, and C576) produced CO_2 (carbon dioxide) gas, C526 producing a small quantity of water in addition to gas. Borehole C576 lies one mile south of the area. Boreholes C525 and C576 were sealed off, but C526 was tapped by a two-inch pipeline which carries the gas to the factory of Carbacid Ltd., who lease the CO_2 rights. At the factory, built alongside the main road 3½ miles south-south-west of the borehole, the gas is compressed to be sold in liquid form or, after further treatment, as "dry ice".

All the gas-producing boreholes were sited in treeless grassy patches in bush country, probably in the belief that such bare patches marked an underground source of water. Examination of the terrain and of air photographs shows these grassy areas to occur only on fault lines. Gas bubbles are reported to occur in these areas after very heavy rain, when the surface is softened, and many cases have been reported of birds dropping dead when flying over them. It is extremely doubtful whether flying birds could be affected, but on visiting the producing borehole at a time when some of the gas was being allowed to escape several dead whydah birds were found, which were probably asphyxiated while feeding on the ground when wind conditions were too slight to disperse the blanket laid down by the escaping gas. In 1959, after the factory had been in operation for 12 years, the gas pressure at the wellhead had gradually fallen from over 60 p.s.i. to only 42, and complete stoppages had occurred due to water collecting in the borehole in sufficient quantity to seal off the gas. In an effort to clear the water plug a plastic pipe was inserted into the hole to the point where water was known to be seeping in, and left open to the atmosphere so that water was blown out by the gas pressure. It was under such conditions that the pressure of gas entering the pipeline fell as low as 42 p.s.i. The original hole was cased for only 191 ft. from the surface, and to prevent further pressure loss it was decided to case the bore throughout to keep out water, which enters at a higher level than the gas, and to prevent clogging by rock waste falling in from the sides of the bore. To avoid putting the factory out of production during the alterations, and to provide an alternative gas supply, a second borehole was sunk late in 1959, and completed before the original borehole was cleaned out and cased. McCall and the writer picked a site for the new borehole (C2928) on the same fault line 100 yds. away from the old. This site was chosen because it would be an easy and inexpensive matter to join the new hole to the existing pipeline to the factory, and it was considered very doubtful that the pressure of gas would show any noticeable decrease on tapping at a second point near by. In fact both boreholes now register the same pressure, just over 60 p.s.i. After choosing the site of the new bore the company obtained the advice of a water diviner who picked a spot within a few yards of that chosen by the geologists, stating that a borehole there would not encounter water. It did.

The two producing boreholes are shown diagramatically in Fig. 9, after McCall, with additions by the writer. The sediment at the top of each of the bores is of the Eldama Ravine group capped by gravels and soil, and its appearance above the younger Lake Hannington phonolite is due to the boreholes cutting the fault (the degree by which the boreholes diverge from the vertical at depth has not been measured) and continuing in the downthrown phonolites, again reaching the Eldama Ravine group at about 350 ft. in C526 and at 446 ft. in C2928. The varying thickness of both the lava and the tuff/sediment group in the boreholes is reflected in the rapid variations of thickness in their outcrops elsewhere. The lowest lava is believed to be the Uasin Gishu phonolite (identification was made from fragments obtained from percussion drilling) and the ten feet of basalt overlying it in C526 is a sill or dyke, since no basalt flows are known to occur between the Uasin Gishu phonolites and the Eldama Ravine group.

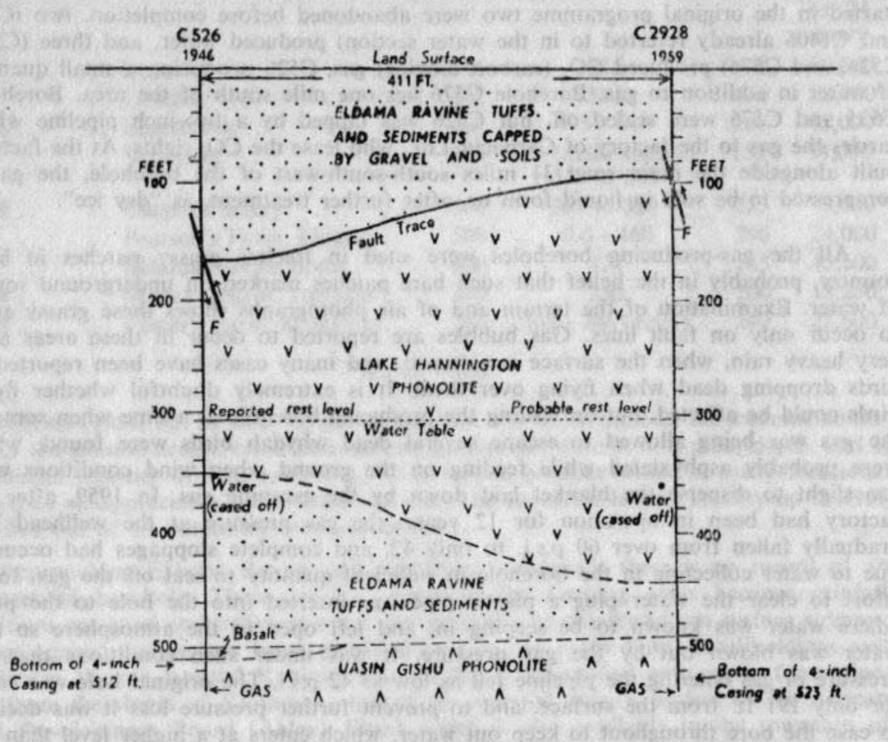

Fig. 9—Diagrammatic section of carbon-dioxide-producing boreholes at Esageri

The fact that the gas and water produced from the boreholes is noticeably warm indicates that the origin of the gas is closely connected with the hot springs and fumaroles found elsewhere in the present area, and in great numbers in the Lake Hannington area to the east. There the fumaroles are all aligned along visible faults. All of the Lake Hannington steam jets and fumaroles carry CO_2, and the large steam content is thought to be due to water from Lake Hannington seeping down the fault fractures and meeting hot juvenile gases rising from a deeply buried cooling senescent magma (McCall, 1967). The Esageri gas, in common with other neighbouring steam jets tested, shows abnormal radio-activity—about twice background when the ratemeter is placed in the escaping gas at the wellhead.

The pressure of the gas at Esageri is ascribed to the presence of sediments of the Eldama Ravine group which form a capping which allows the gas to seep upwards only very slowly, and the same sediments have clogged the fault fractures so that the gas can escape only with difficulty.

The CO_2 content of the gas is tested at the factory at regular intervals, and found to average 98.5 per cent of the whole, sometimes rising to above 99 per cent. The balance of the gas consists of Nitrogen 0.8 per cent, Hydrocarbons 0.6 per cent, Argon 0.02 per cent and Helium less than 0.01 per cent (calculated from an analysis by the Government Chemist, London).

3. Building Materials

Building stone of good quality is plentiful in the Eldama Ravine tuff series, and many small quarries are worked for local projects. The tuff at the base of the Uasin Gishu phonolites is generally too thin and small in accessible outcrops to be profitably worked, but a quarry on the road two miles south of Tenges produces a hard grey freestone which has been used to build many of the shops at Tenges, Sacho and Timboywo. In the northern part of the Kamasian Hills small quarries have recently been opened in the Kabarnet tuffs at Kituro for materials to build a single-storey school, but the stone is considered to be too soft for higher buildings. The late tuffs of the Uasin Gishu Plateau and Lembus are worked for building stone near Kamwosor, but they are generally too poorly consolidated for anything but top-dressing for roads.

Sand for building is generally scarce, but that in the Kerio Valley has a high quartz content and is used at Kabarnet and Tambach. Elsewhere in the area black volcanic sand can be obtained from some of the larger rivers, though only with difficulty due to the generally high boulder content of the deposits.

Where soil cover is deep over phonolites and trachytes the subsoil often makes a good brick-earth, and bakes to a good-quality, hard, red brick. Small brickworks, using wood for fuel, are operated at Kabarnet, Chepkorio, Kipkabus and at several sites along the Molo River near Mikuyuni. The Molo River sites are all on tuff bedrock, but the brick-earth is very different in appearance from the soil usually resulting from weathering of the Molo River tuffs, and is a flood-plain deposit of the river, derived from farther afield.

4. Other Materials

Diatomite occurs in thin bands and lenses in the Chemeron beds in the north-east, but the small size of the outcrops and their remoteness from any market makes it very doubtful that they will ever be worth working.

Graphite occurs in biotite gneisses near Kimwarer, but the small proportion of graphite in the rock, and again the remoteness of the outcrop, makes it of no commercial interest.

Opals were found in large quantities scattered over the surface at Isanda near the Perkerra River, and Walker (1903) mentioned a deposit on the west bank of the same river, which was not found during the present survey. In neither deposit were precious opals found.

Other economic minerals, none occurring in more than trace amounts, found in the Basement System rocks of the Elgeyo Escarpment are *garnets* in hornblende gneisses near Kiburagoy and *copper ore* (bornite) as specks in crystalline limestone near Naon. The *limestones* were not tested for suitability for cement making since their general inaccessibility makes them doubtful as a commercial product.

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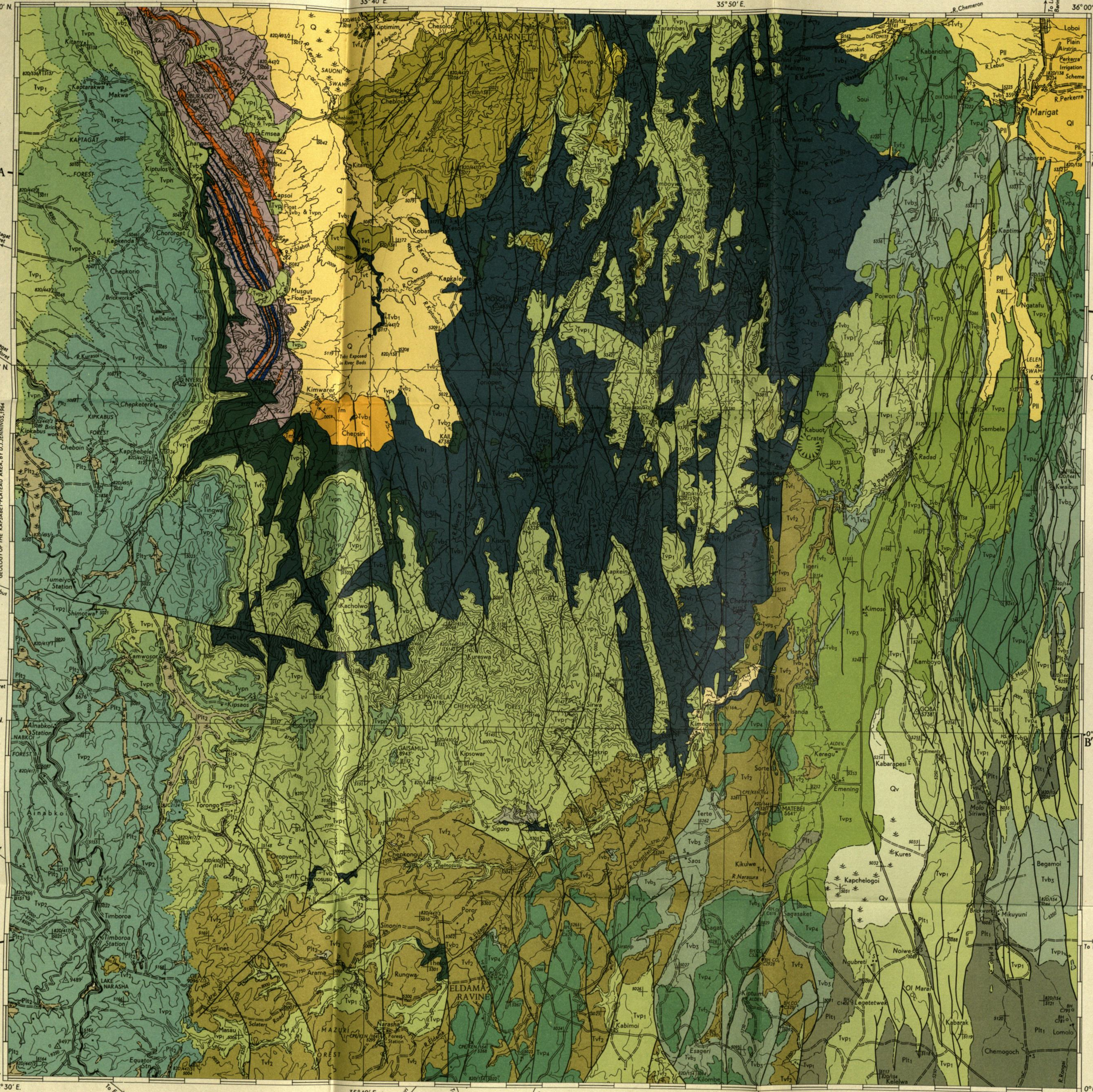
GEOLOGICAL MAP OF THE ELDAMA RAVINE - KABARNET AREA

To accompany Report No. 83

DEGREE SHEET No. 34. SOUTH-EAST QUARTER (Directorate of Overseas Surveys. Sheet No. 104)



EXPLANATION

QUATERNARY
- Alluvium
- Qv — Volcanic soils
- Ql — Lacustrine silts of Loboi Plain
- Q — Red soils and torrent-wash of Kerio Valley

PLEISTOCENE
- Plt₂ — Tuffs of Uasin Gishu Plateau and Lembus
- Plt₁ — Molo River tuffs with black pumice
- Pll — Kapthurin Beds-bouldery torrent-wash, silts and tuffs of Kamasian type area (part)

PLIOCENE
- Tvt — Kabarnet trachytes
- Tvf₄ — Sediments and tuffs associated with Kabarnet trachytes

LAKE HANNINGTON PHONOLITES
- Tvp₄ — Upper non-porphyritic Lake Hannington phonolites
- Tvp₃ — Lower porphyritic Lake Hannington phonolites
- Tvf₃ — Chemeron Beds-tuffs, silts and diatomaceous earths of Kamasian type area (part)
- Tvb₃ — Kwaibus olivine basalts
- Tvf₂ — Eldama Ravine tuffs and sediments

TINDERET VOLCANICS
- Tvp₂ — Melanocratic porphyritic phonolites
- Tvpn — Nephelinitic phonolites

MIOCENE

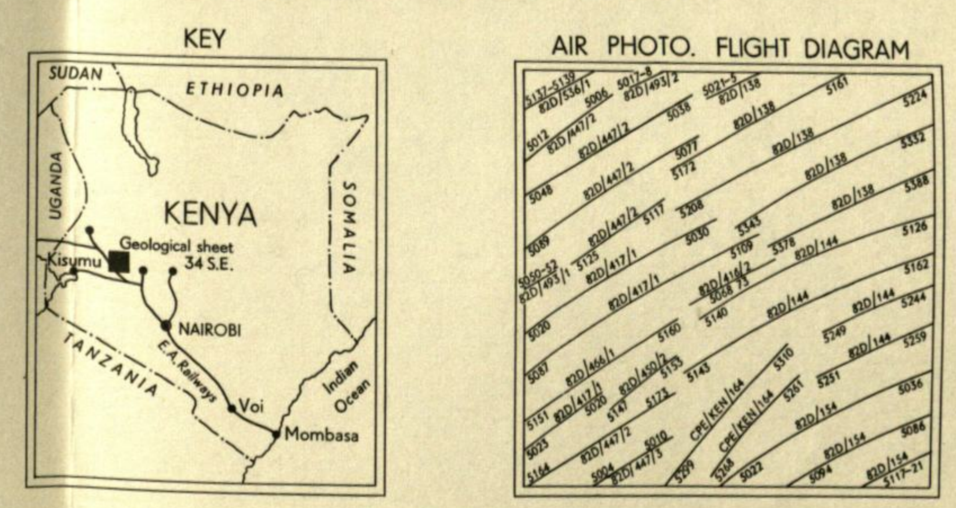
UASIN GISHU PHONOLITES
- Tvp₁ — Lower phonolite-generally non-porphyritic
- Tvf₁ — Tuffs and sediments at base of lower phonolite
- Tm — Kimwarer sediments
- Tvb₂ — Elgeyo porphyritic olivine basalts
- Tvb₁ — Samburu basalts

ARCHÆAN

BASEMENT SYSTEM
- Xq — Quartzites
- Xgg — Quartzo-felspathic gneisses
- Xb — Biotite gneisses
- Xhb — Hornblende gneisses
- Xl — Crystalline limestones
- X — Undifferentiated Basement System rocks (in section)

- Geological boundaries, observed and approximate
- Geological boundaries, inferred
- Fault with tick on downthrow side
- Fault breccias
- Dip of lavas and sediments
- Dip of foliation in metamorphic rocks
- Vertical foliation in metamorphic rocks
- Plunge of lineation in metamorphic rocks
- Mineral deposits
- Artifact localities
- Bore-hole (water)
- Bore-hole (Carbon Dioxide)
- Hot springs
- Water tanks
- Railways
- Main roads
- Secondary roads and motor tracks
- Contours at 250-ft interval
- Trigonometrical stations with heights in feet
- Spot-heights in feet
- Principal points of aerial photographs
- Swamps
- Dams
- Buildings: S-shop, D-dispensary, P-police post
- A—A' Line of section

Magnetic declination approximately 2°50' West



MINISTRY OF NATURAL RESOURCES & WILDLIFE
MINES & GEOLOGICAL DEPARTMENT
KENYA

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Scale 1:125,000

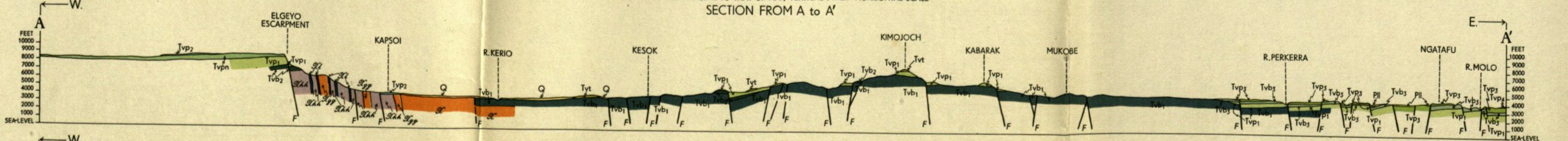
MILE 1 0 1 2 3 4 5 6 7 8 9 10 MILES

1 inch=1·973 miles or 1·014 inches=2 miles

SCALE OF SECTIONS EQUAL TO THAT OF MAP, VERTICAL SCALE=HORIZONTAL SCALE

GEOLOGICALLY SURVEYED BY J. WALSH, GEOLOGIST,
Between April 1959 and February 1960

SECTION FROM A to A'



SECTION FROM B to B'