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GEOLOGY OF THE MAU AREA

DEGREE SHEET 42, SE QUARTER
(with coloured geological map)

by

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MAP

Geological map of the Mau area (degree sheet 42, SE Quarter), scale 1:125,000 (at end)

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PREFACE

This report is one of several quarter degree geological sheet descriptions that have been awaiting publication for several years; since field work was completed in 1962 and the geological map, at a scale of 1:125,000, published in 1967.

The task of preparing the report for publication has been part of a UK-funded project under which geologists of the British Geological Survey have worked alongside Kenyan counterparts of the Mines and Geological Department. A major aim of this project is to reduce publication delays in the future so as to ensure the rapid application of geological data to the search for, and controlled development of, Kenya's mineral, groundwater, and energy resources.

A significant part of the report is a detailed description of a sequence of Tertiary volcanic rocks which cover almost the whole of the Mau area and form part of one of the world's largest lava and pyroclastic fields. Although couched in terms that may be no longer acceptable to modern volcanologists, the rock descriptions have much relevance to the economic mineral potential of the Mau area.

The best potential is for dimension stone and ballast and there are indications that residual clays have some promise as ceramic raw materials.

C.Y.O. OWAYO
Commissioner of Mines & Geology

J. WACHIRA
Chief Geologist

March 1991

EDITORS' NOTE

Volcanological Nomenclature

Since this report was written there have been major advances in volcanic rock terminology and it is clear that many of the terms employed by the author are not in accord with current practice. In cases where there is no doubt that more acceptable terms can be employed, these have been used but to completely update the terminology, in the absence of the author, would entail the editors' making subjective inferences from the author's rock descriptions, or a re-examination of selected rock units in the field. Neither option is satisfactory. In the interests of shortening the already long delay in publishing the report therefore, the author's original terminology, in most cases, is retained with some suggestions made in footnotes regarding more modern usage.

Units

The report contains a mixture of imperial and metric units. To fully metricate would make the report inconsistent with the (already published) geological map. The mixture is therefore retained as the better of two evils.

Stratigraphy and Chronology

Since this report was written (c 1970) much additional information (including many contributions by the present author) is available in both published and unpublished works, giving a more precise chronology of the volcanicity and tectonism in this part of the Rift. It is impossible to summarise this more recent work here, but important papers are listed below and have been incorporated into the reference list. Users of this report would be well advised to consult Baker *et al.*, 1988 for the broad stratigraphic and chronological framework of the area. Other important works are: Baker and Mitchell, 1976; Baker *et al.*, 1971; Crossley, 1976, 1979; Crossley and Knight, 1981; Fairhead *et al.*, 1972; Knight, 1976; Williams, 1970, 1978; and Williams *et al.*, 1983.

RD Walshaw and PN Mosley

British Geological Survey

ABSTRACT

The report describes the geology of an area of approximately 1,200 square miles situated in south-western Kenya, and enclosed by longitudes 35°30' and 36°00' E, and latitudes 0°30' and 1°00' S. The area lies mainly within the Narok District of the Rift Valley Province.

Little evidence is visible to deduce the extent and form of old erosion surfaces, but volcanic rocks some 1,500 feet thick are believed to rest on a warped sub-Miocene surface underlain by Precambrian metasediments.

Quartzites, gneisses and pegmatites belonging to the Kenya 'Basement System' are unconformably overlain by Miocene phonolites and ankaratrites which are in turn followed by various members of a welded pyroclastic sequence - the Mau Tuffs - of presumed Pliocene age. The Mau Tuffs are themselves overlain by poorly-consolidated pyroclastic deposits termed the Mau Ashes, which are provisionally assigned to the Middle Pleistocene. Late Pleistocene alluvial deposits and a variety of soils are also described.

The most important single structural feature is the SSW regional dip of the Mau Tuffs at about the average gradient of streams dissecting the Mau.

The chief economic deposit in the Mau area is building stone. Of particular interest are devitrified tuffs which closely resemble the well-known Nairobi stone.

I INTRODUCTION

This report describes the geology of an area of some 1,200 square miles, bounded by the meridians 35°30' and 36°00' E and parallels 0°30' and 1°00' S. It is situated mainly within the Narok District of the Rift Valley Province of Kenya, but includes small portions of the Kericho and Nakuru Districts. The area embraces the south-eastern quarter of degree sheet 42, corresponding to the Directorate of Overseas Survey sheet No. 132, and covers a large part of the densely-forested Mau range which rises to 10,000 feet above sea level and is composed of Tertiary to Pleistocene volcanic rocks. The fieldwork was carried out between July and November 1962.

Maps - The area is covered by four uncontoured preliminary plots on a scale of 1:50,000 prepared from aerial photographs taken in 1948. These maps were used as field-sheets during the survey, being modified where necessary by transferring information visible on 1961 air photographs that cover the entire area. Form-lines were drawn from spot-heights recorded with an aneroid barometer, and corrected for diurnal variation. Heights in the southern half of the area were based on an altitude of 6,191 feet for the District Commissioner's office in Narok (seven miles south-south-west of Rotian); form-lines in the northern half of the area were based on Elburgon (7,943 feet) and Njoro (7,114 feet) railway stations, some 12 to 14 miles beyond the northern boundary. Form-lines in the more inaccessible central parts of the Mau range were sketched from air photographs.

Communications - A north-south road linking Njoro with Narok crosses the Mau range and provides a useful line of access to the eastern parts of the area. The surface is generally good through the Mau Narok farming area in the north-east and is suitable for all traffic during dry weather, but the road is liable to be closed to heavy vehicles in the wet seasons. Southwards from Lengiberi, the condition of the road is variable: in dry weather the route is easily negotiable in saloon cars but after rain it should only be attempted in four-wheel-drive vehicles.

The road is best used in the mornings to avoid the regular afternoon rainstorms in the forest belt. A number of private farm roads branch from the main road in the Mau Narok district, but south of Lengiberi the route is flanked by dense forest, and with the exception of a few small tracks at Enabilibil the country is completely inaccessible to motor vehicles, and much of it can only be penetrated with great difficulty on foot. Cattle-tracks lead down to the Seyabei river at Rotian, Orengitok, Enabilibil, Saaiet and Enembeneyo, but no paths were found down to the Sigindirr (Ngusur) river north of Orengitok.

The high moorland in the north-eastern parts of the area is traversed by a dry-weather road linking Lengiberi with Elburgon. The northern part of the route, beyond Olokurto trading centre, is used by heavy vehicles from two sawmills and is liable to deteriorate rapidly after heavy rain. Logging tracks provide access to the forest fringe between Olokurto and Chapaltarakwa, and parts of the moorland are motorable in dry weather, though for many months in the year the grassland is completely waterlogged. Olenguruone is accessible from both Elburgon and Molo, though the latter route involves using a private road through Keringet Estate. The tracks throughout Olenguruone Settlement Area become extremely slippery after even light rain, and because of the steep gradients are suitable only for four-wheel-drive vehicles. A number of tracks, motorable in dry weather, penetrate the southern half of the area. In the south-east, a track commencing at

Seyabei Mission (about six miles south of the present area) runs northwards along the interfluve between the Olombori and Olchoro Lekilessi streams to Olchoro trading centre. The track continues north-eastwards towards the Mau Escarpment but the route is seldom used. A very rough track, linking Seyabei Mission with Entontol, crosses the extreme south-eastern corner of the area. Four tracks provide limited access to the south-western quarter of the area. One crosses the Uaso Ngiro river by a ford at Ololonga and is motorable for about seven miles to Ol Eshepani. Another track branches from the Narok-Ngorengore road near Masandare trigonometrical beacon (about half a mile south of the present area) and can be followed for about six miles to Eoutoud to the western banks of the Uaso Ngiro. A very rough motorable route to Olmirani hills barely penetrates the present area, where it finally becomes impassable on the hilltop overlooking the Amala river. This track commences at Kelusu school, near the Ngorengore-Kapkimolwa road, and involves travelling some six miles along the foot of the Olmirani range to reach the Mau area. North of the Amala river a narrow track provides a line of access to the forest edge from Chemaner trading centre, which is about a mile and a half outside the Mau area; the route is motorable only in dry weather.

Well-defined footpaths through densely-forested parts of the area are rare and it is advisable to employ a reliable guide for excursions into the forest. The paths that do exist generally follow interfluves and, unless the route traverses glades visible on air photographs, navigation can be very difficult.

Climate - The greater part of the Mau experiences a relatively cold and wet climate. Temperatures are generally related to altitude while rainfall is controlled mainly by the distribution of forest. There is a marked decrease in rainfall, from over 70 to less than 30 inches per year, both southwards and north-eastwards from the central parts of the Mau. The extreme southern parts of the area fall within the Narok-Loita Plains climatic zone, with the heaviest rain falling between March to May and December to January, though there is a less marked seasonal distribution than in many other parts of Kenya. In the northern parts of the Mau, rainfall maxima occur in May and August, the driest months being December to February.

Population - The area falls largely within the Narok District and the southern, south-eastern and north-central parts of the Mau are sparsely inhabited by semi-nomadic pastoral Maasai who are attracted to the well-watered grazing land, occasionally penetrating the forest fringe to utilize grassy glades.

Agricultural communities occur mainly in three widely separated parts of the area. In the north-east, full use is being made of the fertile Mau Narok farming district, an area of extensive settlement. This part of the country is also ideal for sheep farming and, in addition to the private farms, there exists a Government-run ranching scheme established to assist the local Maasai. Widespread cultivation is carried out by the Kipsigis in the west-central portion of the area near the Amala river. The Kipsigis intermingle with the Maasai as far east as Ol Eshepani, introducing to their neighbours a more static agricultural way of life. In the north-western part of the Mau, Olenguruone Settlement Area has been carved from the forest to provide land for displaced 'Wandorobo'.* Outside the main farming areas described above, smaller patches of cultivated land. are encountered, the most important being around the permanent settlements at Enabilibil and Ol Orkirkirae beside the Narok-Lengiberi road.

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* The name 'Wandorobo', derived from the Maasai language and meaning 'poor people' (i.e. without cattle), has now been superseded by the more culturally-specific 'Okiek' (Eds).

Small permanent communities exist around Olchoro and Olkiuliamon trading centres, and at Ol Razella Sawmills (Olokurto) and the Purko Timber Co-operative Society sawmill (Chapaltarakwa). Olkiuliamon comprises a Police Station, several small shops, a dispensary and an administrative centre. The densely-forested parts of the Mau are largely uninhabited and frequented only by small bands of 'Wandorobo' hunters.

II PREVIOUS GEOLOGICAL WORK

Although numerous references to 'the Mau' are to be found in geological literature, few authors actually visited the area or made any significant contribution towards a clearer understanding of the geology of this part of Kenya. Early and more recent workers alike were deterred by difficulty of access, so that the basic geology remained unknown; evidence from the surrounding areas indicated the likelihood of an important development of Miocene phonolites, overlain by Quaternary pyroclastic rocks.

The earliest references to the Mau in geological works date back to the last century (e.g. Toula, 1891, p. 552; Suess, 1891, p. 578; Gibson, 1893, pp. 561-563; Gregory, 1894, pp. 297 and 305) but the authors were merely drawing attention to the highland area lying beyond the western Rift scarps. Gorges (1900, p. 78) mentioned the Mau in his description of a journey from Lake Naivasha to Lake Victoria and it is possible that he cut across the southern part of the Mau area in his travels, following the route taken by Austin and Pringle in 1892-99 (see Atlas of Kenya, 1962). Schoeman (1949) worked along the western boundary of the Mau area in 1946-47 while undertaking a geological survey of the Sotik district. He shows an unbroken Tertiary volcanic cover along this boundary between latitudes 0°30' and 0°45' S, noting (p. 27) that the rocks are phonolites with very subordinate interbanded ashes or tuffs. The thick Pleistocene ash cover encountered during the present work was not recognized by Schoeman(1949), but it seems likely that some, if not all, of the ashes which he described are remnants of this cover, rather than intercalations in the Tertiary succession; further references to occurrences of ashes in the Sotik area are made in later sections of this report. Schoeman (1949, pp. 9 and 27) used the terms Mau Volcanic Series and, more specifically, Mau Phonolite in descriptions of the volcanic rocks, in view of their obvious derivation from the north-east.

The Naivasha area, lying to the east of the Mau, was geologically surveyed by Thompson and Dodson in 1955-56. Pyroclastic rocks and sediments mapped between the meridian 36°00' E and the Mau Escarpment were said (Thompson and Dodson, 1963, p. 11) to be composed of soft volcanic ashes and tuffs with only rare outcrops of agglomerate and lavas. These authors described (p. 37) a bed of welded tuff exposed in the lower slopes of the escarpment, and outcrops of trachyte near the base of the scarp; a Middle Pleistocene age was assigned to both the welded tuff and the lava.

A geological survey of the Narok area, to the south of the Mau, was carried out by Wright in 1959. North-east of Narok, and up to the boundary of the present area, ashes some 200 feet thick were found resting on a similar thickness of tuffs (from Wright's description some of these are eutaxitic welded tuffs), which in turn overlie alkali basalts. All these rocks were assigned to the Lower or Middle Pleistocene by Wright (1967, p. 8), a conclusion that is questioned in a later chapter of the present report (see also Williams, 1964A, p. 45).

The survey of the Molo area, north of the Mau, was undertaken by Jennings in 1962, at the same time as the fieldwork upon which the present report is based. A fair measure of agreement exists between the conclusions reached by Jennings (1970) and those put forward in this account.

III PHYSIOGRAPHY

1 Topography

The area described in the present report embraces a large portion of the Mau range, a densely-forested NNW-trending volcanic highland belt flanking the western margin of the Kenyan Rift Valley and rising locally to over 10,000 feet above sea level. In contrast to the other major volcanic mountain masses in East Africa, in distant view the Mau is notable for its regular outlines devoid of prominent peaks and craters. This regularity of profile is readily explained by the results of the present survey, particularly the evidence of a substantial cover of Pleistocene volcanic ashes over a gently-tilted succession of Tertiary lavas and welded tuffs.

The Mau range is bounded on the east and north-east by major scarps marking the main faults of the adjacent parts of the Rift Valley. Most of these fault scarps lie beyond the confines of the Mau area, though one prominent scarp passes through the north-eastern corner in the Mau Narok district. To the south and south-west, the Mau slopes steadily down to merge into vast plains (the Loita Plains) representing the sub-Miocene peneplain overlain by a comparatively thin cover of Tertiary and Pleistocene volcanic rocks; residual hills and inselbergs of Precambrian rocks are common. To the west, the Mau slopes away gradually into the dominantly volcanic areas of Kericho and Sotik, but northwards the regularity of the range is destroyed by the Tertiary volcanic centres of Tinderet and Mount Londiani. The average gradient of the ground surface, south-westwards from the highest point of the Mau in the present area, is about 80 feet per mile; the slope southwards is over 90 feet per mile. These figures are of interest when compared with the regional dip of the Pliocene pyroclastic rocks (see Chapter 7).

The apparent regularity of profile of the Mau range is, however, shown on closer inspection to be broken by numerous, deeply-incised V-shaped valleys, frequently more than 500 feet deep. The orientation of major valleys in the central and south-central parts of the area imparts a strong N-S grain to this portion of the Mau, whereas NE to SW directions are prominent in north-western parts of the area and near the eastern boundary. In cross-section, many of the major valleys have marked asymmetrical profiles, with eastern walls consistently steeper than the western, and it is concluded that the entire area was tilted gently eastwards after an early drainage pattern had become established on an inclined ash surface. It is interesting to note that grassy glades in forested areas tend to develop principally along the less steep western sides of the valleys, and also that better rock exposures are found on the western sides; presumably slumping of poorly-consolidated, deeply-weathered volcanic ashes tends to obscure outcrops of underlying formations along the eastern banks of the streams.

Despite the fact that the Pleistocene ash cover is deeply dissected, evidence of the flat nature of the original subsurface is still preserved in parts of the Mau. Views southwards from Olenguruone show particularly well the level ash surface on interfluves. Schoeman (1949, p. 6) noted the even line of the horizon in the north-western parts of the Sotik area, but attributed it to the original surface of the phonolites (volcanic ashes were not recognized), suggesting that the lavas are deeply weathered as a result of the high rainfall in this region.

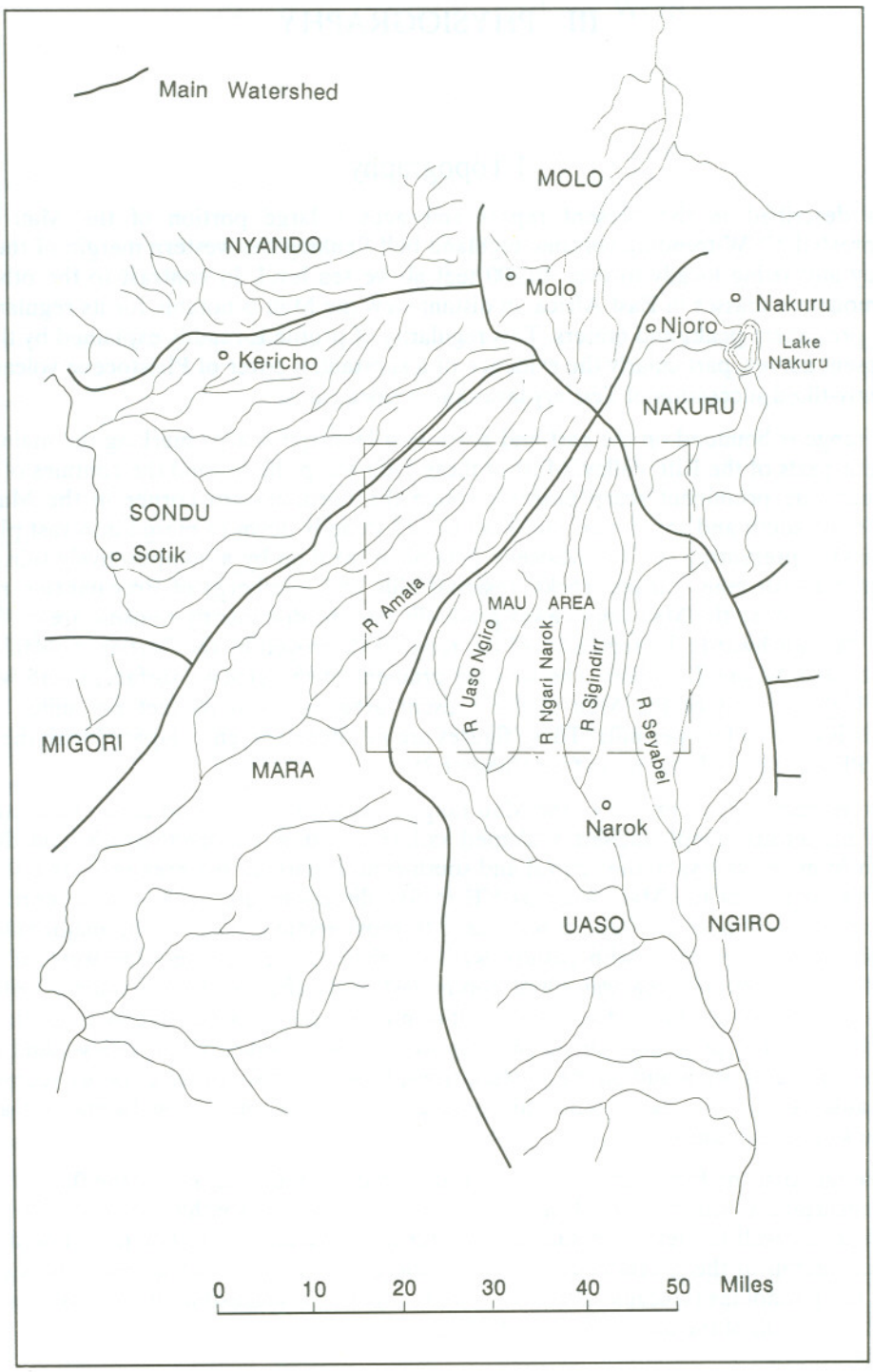


Figure 1 Drainage pattern in and around the Mau area

2 Drainage

The drainage pattern in and around the Mau area is shown in Fig. 1. Most of the streams draining the eastern and central parts of the Mau (the Seyabei, Sigindirr, Ngare Narok and Uaso Ngiro systems) unite to form the Uaso Ngiro in the Narok area, flowing south-eastwards and then southwards to Lake Natron in the Rift Valley. The head-streams of the Mara river, which reaches Lake Victoria at Musoma in Tanzania, traverse the north-western parts of the Mau area; the principal stream there is the Amala. Streams in the extreme north-western corner of the area feed the Sondu river, which flows to the Kavirondo Gulf of Lake Victoria. A sharp divide in the north-eastern part of the area separates the Uaso Ngiro and Nakuru drainage systems; streams belonging to the latter flow north-eastwards into the Rift Valley to Lake Nakuru. Because of the high rainfall experienced in the upper parts of the Mau, most of the streams shown on the geological map flow steadily throughout the year, though some very minor tributaries carry water only immediately after rainstorms. Waterfalls and rapids are more common where the Upper Welded Tuffs are still preserved.

The late eastward tilt of the entire area, which is inferred from the asymmetrical cross-sections of valleys, may have been responsible for the radial drainage pattern that now characterizes the Mau area. The initial drainage pattern on the ash surface probably consisted predominantly of south-westward flowing streams, so that the Uaso Ngiro and even the Seyabei head-streams may have flowed into a primitive Mara river. Downcutting by the Uaso Ngiro, as a result of eastward tilting of the area flanking the Rift Valley together with periodic rejuvenation due to faulting, evidently led to capture of many of the Mara head-streams between Narok and the present Uaso Ngiro-Mara divide.

Wright (1967, p. 5) recorded evidence of the development of lakes in the middle reaches of the Uaso Ngiro in the Early Pleistocene. Temporary damming of this sort, probably in Upper Pleistocene times, is also likely to have been responsible for the thick deposits of alluvium that now occupy parts of the Uaso Ngiro's course in the present area. Breaching of barriers in the river, perhaps during Recent times, resulted in rapid downcutting through some 40 feet of alluvial deposits in the Mau area.

3 Erosion Surfaces

The Mau area provides no direct evidence of the slope or altitude of the sub-Miocene bevel, which has been recognized in surrounding parts of the country, for dissection has not proceeded far enough to expose the sub-volcanic surface. Nevertheless, this account would be incomplete without a statement on the likely position and attitude of this surface.

The bevel is overlain by Miocene phonolites south and south-west of the Mau (Wright, 1967; Williams, 1964b) and at least some of these flows were derived from the present area. The bevel lies at an altitude of about 6,500 feet near the south-western corner of the Mau area and slopes to the south-west at some 35 feet per mile across the Mara river-Sianna area; between Narok and the Loita Hills the slope of the bevel is approximately eastwards at 47 feet per mile (see Pulfrey, 1960, map). It is unlikely that the axis of this warping extends into the Mau area, where the direction of dip of the Pliocene Mau Tuffs probably corresponds approximately to the slope direction of the

sub-Miocene erosion bevel and the phonolites which rest on it.* In the Mau area, the Mau Tuffs evidently dip at an average of 80-90 feet per mile to the SSW and it is considered likely that the base of the phonolite is inclined at an average of perhaps 60 feet per mile in the same direction. If warping of the sub-Miocene bevel does occur within the present area, it is much more likely to be about an axis situated close to the major faults in the Mau Narok district, where dip reversals in the Mau Tuffs are postulated to account for the distribution of the different pyroclastic beds (see section C-D, at the foot of the coloured geological map).

The main difficulty encountered in predicting the position of the sub-Miocene surface in the Mau area lies in the lack of knowledge about the existence or extent of hills and mountains on the sub-Miocene bevel. Pulfrey (1960, map) shows most of the Mau underlain by a pre-volcanic topographic high of this sort, and in a generalized section which cuts through the northern half of the present area he shows a crest on the sub-Miocene surface at nearly 9,000 feet; this is actually as high or a little higher than the modern surface along the line of section, so the present work enables a correction to be made to Pulfrey's profile. Taking the altitude of the present surface as 8,500 feet (at 0°40' S, 35°50' E) and the minimum thickness of Miocene-Pleistocene volcanic rocks as 2,000 feet (i.e. Mau Ashes 500 feet; Mau Tuffs about 800 feet; Mau Phonolite unknown, but likely to be at least 700 feet thick since the flows probably originated near the present Rift margin), the sub-Miocene surface cannot be placed higher than 6,500 feet at this point. The author is not convinced, therefore, that it is necessary to postulate extensive mountainous areas on the sub-Miocene bevel beneath the volcanic rocks forming the Mau range; warping of the bevel about an axis close to the faults in the north-eastern corner of the present area could equally well explain the main topographical and geological features.

The lower Amala section is of some interest, for no phonolite occurs between 'Basement System' gneisses and Pliocene welded tuffs. This indicates prolonged erosion after the extrusion of the phonolite and before deposition of the Mau Tuffs; the phonolite was either stripped from the vicinity of the Amala, or 'Basement System' rocks were planed off in an area where phonolite never flowed.

'Basement System' quartzite hills in the south-western part of the Mau area are clearly residual masses on the sub-Miocene surface. They possibly represent reduced remnants of the end-Cretaceous bevel recognized, for instance, in the Sotik (Schoeman, 1949, p. 5) and Mara river (Williams, 1964B) areas.

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* This assumption refers only to the direction of slope and cannot be extended to the gradient, for the Mau Tuffs are separated from the sub-Miocene surface by phonolites which probably thicken towards their source somewhere to the north-east. (Author).

IV THE ADOPTED CLASSIFICATION OF PYROCLASTIC ROCKS

Because pyroclastic rocks are of widespread occurrence in the Mau area and and their nomenclature is somewhat controversial it is necessary to define the terms used in the descriptions that follow.

The classification of Fisher (1961), as summarised in Table 1, is used to a large extent but some definitions are drawn from other workers as detailed below.

Table 1 Size classification of pyroclastic fragments (Fisher, 1961)

Grain size (mm)	Pyroclastic fragments		Corresponding epiclastic fragments
+256	Coarse	Blocks and bombs	Boulders
-256 + 64	Fine		Cobbles
-64 + 2	Lapilli		Pebbles
-2 + 1/16	Coarse	Ash	Sand
-1\16	Fine		Silt and clay

The textural term **eutaxitic** is applied to welded tuffs characterized by a banded appearance due to the alignment of collapsed pumice lapilli.

The term **agglomerate*** is used here to describe pyroclastic rocks in which the majority of the fragments are of block and bomb grade (i.e. larger than 64 mm); the term **lapilli-tuff** is applied to consolidated deposits in which fragments range from 2.0 to 64 mm; consolidated ashes are referred to as tuffs, though an important group of fine-grained, poorly-consolidated deposits are described as ashes, to avoid confusion with older, harder rocks.

Ash-flow is defined (Ross and Smith, 1961, p. 3) as 'a turbulent mixture of gas and pyroclastic materials of high temperature, ejected explosively from a crater or fissure, that travels swiftly down the slopes of a volcano or along the ground surface. The solid material in an ash flow is dominantly of particles of ash size (less than 4 mm in diameter)** but generally contains different amounts of lapilli and blocks'.

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* The term 'agglomerate' is best restricted to pyroclastic rocks, with demonstrable volcanic bombs, that occur within, or very close to, a vent and should not be applied to remote pyroclastic-flow deposits or other deposits that do not contain demonstrable bombs. 'Volcanic breccia' would be a more acceptable term (Eds).

** This size is in accordance with the Wentworth and Williams (1932) classification (Eds).

Ash-flow tuffs are the consolidated deposits resulting from an ash flow and they 'may or may not be either completely or partly welded' (Ross and Smith, 1961, p. 3).

The term **ignimbrite** ('fiery rain cloud rock') was introduced by Marshall (1935) to describe deposits derived from immense clouds or showers of intensely-heated, generally minute fragments of volcanic origin. He evidently intended it to be used as a name for tuffaceous rocks of acid composition formed by fall of material from clouds produced during *nuée ardente*-style eruptions.* Smith (1960A, pp. 802-804) drew attention to ambiguity in the use of the term nuée ardente and stressed the sometimes overlooked fact that descriptions of observed *nuée ardente* eruptions indicate the existence of two parts - a basal avalanche (the ash flow) and a spectacular, overriding cloud of gas and dust. Because Marshall's definition of ignimbrite inferred derivation from the cloud rather than the basal avalanche portion of the *nuée ardente*, many workers (e.g. Smith, 1960A; Ross and Smith, 1961) prefer the term ash-flow tuff; others have modified the original definition and now use ignimbrite as general name for at least the welded products of ash flows.

Workers in Kenya have referred to fragmental eutaxitic volcanic rocks as welded tuffs, ignimbrites or ash-flow tuffs. McCall (1962 a,b,1964,1967) has suggested that some Kenyan eutaxitic rocks are unrelated to *nuées ardentes*, but are the products of **froth-flows** by a process of vesiculation, expansion and frothing on release of volatiles from glassy lava. McCall's hypothesis was based chiefly on studies in the Nakuru area north-east of the Mau but he clearly favoured a froth-flow mechanism to explain the fragmental eutaxitic rocks of a much wider region, including the then-unmapped Molo and Mau areas. Jennings (1970) subsequently described the fragmental rocks around Molo as ash-flow tuffs and suggested that variations probably indicate exposure of different zones of the same ash-flow unit. **Pumice flows** contain a conspicuous proportion of pumice fragments of lapilli or block size and the term is synonymous with '**lapilli flows**', '**block flows**', '**scoria flows**' and '**block and ash flows**' of various authors.

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* It is highly unlikely that the very extensive pyroclastic deposits of the Mau area are the products of nuées ardentes eruptions. Such eruptions produce small-scale block and ash deposits by lava dome collapse (Eds).

V SUMMARY OF GEOLOGY

The oldest exposed rocks in the Mau area are quartzites and gneisses forming part of the Kenya 'Basement System'. Absolute age determinations carried out on 'Basement System' rocks from other parts of the country show that regional metamorphism took place in late Precambrian times but the age of the sediments is unknown. The sedimentary origin of the rocks has been established in areas farther south and south-west, where ripple-marks, graded-bedding and current-bedding are locally preserved. The quartzites, which are probably the reduced remnants of an end-Cretaceous erosion surface, form two prominent ranges of hills south of the Amala river and represent the eastward extension of major quartzite bands mapped in the Sotik area (Schoeman, 1949). Occasional pegmatites cut the gneisses exposed in the Amala river.

No Palaeozoic or Mesozoic rocks occur within the Mau or the surrounding map areas, so that there is little or no record of events between the metamorphism of Precambrian sediments and the extrusion of vast sheets of phonolitic lavas (the Mau Phonolite) of unknown thickness in mid-Tertiary times. The lavas are referred to the Miocene because they are seen to rest on the sub-Miocene erosion bevel in areas farther south and south-west. The sub-Miocene surface was warped about a N-S axis during late Tertiary times, but little evidence of these physiographic events is available from the Mau area itself because of the widespread Pliocene-Pleistocene pyroclastic cover. The phonolites exposed along the western boundary of the area provide a link between lavas of the Mara river and Narok areas, and the phonolites described in the Sotik, Kericho and Molo areas. A single occurrence of ankaratrite (tentatively assigned to the Miocene) in the south-western Mau is the only indication of felspar-free lavas in the area.

The Mau Tuffs consist essentially of upper and lower formations of eutaxitic welded tuffs separated by agglomerates and lapilli-tuffs which are characterized by the uncollapsed nature of the constituent pumice fragments. Mapping shows that the beds dip to the SSW at an angle not markedly different from the gradient of major streams dissecting the Mau, so that only a limited part of the succession is exposed in any one part of the area; the total thickness is believed to be no greater than 800 feet. The Mau Tuffs are ash-flow deposits of probable Pliocene age. The source of the ash flows is not clearly demonstrated, but is likely to have been related to fissures close to the present Rift margin.

The welded tuffs are overlain by a thick mantle of poorly-consolidated pyroclastic material of Pleistocene age, collectively described in this report under the term Mau Ashes. Attaining a maximum thickness of more than 750 feet, the ashes and subordinate agglomerates and lapilli-tuffs effectively conceal the Tertiary lavas and welded tuffs over the greater part of the Mau, so that exposures of the older rocks are confined to nearly-continuous stream sections.

In the southern parts of the Mau, the Uaso Ngiro occupies a course incised in alluvial deposits, locally more than 40 feet thick. These sediments, which occur only in the Uaso Ngiro and Ndorroboni valleys, were probably deposited during temporary damming of the river in Late Pleistocene times.

Superficial deposits in the area are mainly clayey soils derived by deep weathering of volcanic ashes in a region of high rainfall. Dark brown soils give way to reddish varieties in the more densely-forested parts of the area. Sandy soils are encountered in the vicinity of outcrops of 'Basement System' rocks, particularly quartzites.

VI 'BASEMENT SYSTEM' ROCKS

'Basement System' metamorphic rocks, of presumed Precambrian age, are exposed only in the extreme south-western parts of the Mau; elsewhere in the area they are concealed by Tertiary and Pleistocene volcanic rocks. They are subdivided as follows:

1 Quartzites and micaceous quartzites

2 Feldspathic biotite gneisses

3 Pegmatites

1 Quartzites and micaceous quartzites

A variety of quartzitic rocks form the two NE-trending ridges known as Olmirani and Kuto. The shape and orientation of both are controlled by structures in the 'Basement System' rocks, described in Chapter 9.

The commonest rocks at Olmirani are reddish-brown granular quartzites containing a sprinkling of muscovite, and bearing lenses of white massive quartzite some 90-125 cm long and 60 cm wide. More definite layers of white and pinkish massive quartzites also occur, but all varieties have been combined on the geological map. A whitish muscovite quartzite (specimen 42/1071*) collected from Olmirani shows a mosaic of quartz grains having marked parallel elongation. Numerous small shreds of muscovite exhibit a similar parallel orientation.

The rocks at Kuto are mainly white massive quartzites, though subordinate reddish-brown granular types are also found. Muscovite is most prominent towards the eastern end of the hills. In the Engito stream massive quartzites are overlain by minor developments of pale grey muscovite-biotite quartzites bearing thin, intercalated quartz-muscovite schists. A thin section of a micaceous quartzite (42/1065) from this locality shows abundant quartz, xenoblastic grains of microcline, numerous tiny flakes of muscovite, and occasional shreds of biotite. A marked foliation is imparted by elongation of quartz grains and parallel arrangement of the micas. The rocks in the inlier at Lubi are essentially muscovite quartzites. Specimen 42/1058 from that locality is a brownish, medium-grained rock composed of small flakes of muscovite set in a mosaic of interlocking quartz grains.

2 Feldspathic biotite gneisses

Near the western boundary of the area, well-foliated biotite gneisses are exposed in the Amala river, though within a short distance upstream the 'Basement System' rocks are obscured by overlying eutaxitic welded tuffs of presumed Pliocene age. The gneisses probably underlie the quartzites exposed at Olmirani for the Amala evidently flows along the axial region of an anticline shown by Schoeman (1949, Fig. 3), and indicated in the present area by opposing dips at Olmirani and the Amala.

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* Numbers prefixed by 42 refer to specimens in the regional collection of the Mines and Geological Department, Nairobi.

3 Pegmatites

The feldspathic biotite gneisses of the Amala section are cut by a number of narrow pegmatites which trend approximately N-S, and locally contain hornblende crystals 25-50 mm long.

VII TERTIARY AND QUATERNARY VOLCANIC ROCKS

Tertiary and Quaternary volcanic rocks are present over almost the whole area of the Mau Quarter Degree Sheet. For details of how they have been stratigraphically subdivided the reader is referred to the geological map.

1 Mau Lavas

The Mau Lavas comprise two units: phonolite and ankaratrite.

(a) Mau Phonolite (Miocene) (Tvp1)

Distribution - The Mau Phonolite is the south-western part of a very extensive sheet of Late Miocene flood phonolite that has been mapped in many areas in central and southern Kenya (Table 4). The term Mau Phonolite was applied to these lavas by Schoeman (1949, p. 27) and they have also been referred to as the plateau phonolites (Williams, 1970). The group is perhaps currently the most reliably dated in the succession of Rift volcanics. Determinations by the potassium-argon method consistently indicating ages of about 11 to 13 Ma (Bishop *et al.*, 1969). The phonolites probably originated from fissures in the Nakuru area north-east of the Mau, and near the source region the flows attain thicknesses of at least 3,000 feet.

The sheet is only a few hundred feet thick in the Mara River area south-west of the Mau (Williams, 1964b) but it is said to be more than 1,000 feet thick in the Sotik and Kericho areas west and north-west of the Mau (Schoeman, 1949; Binge, 1962). 500-600 feet of phonolite is exposed at one locality in the Molo area (Jennings, 1970) but the total thickness is presumably much greater. In the northern parts of the Rift valley in Kenya, the plateau phonolites are underlain by considerable thicknesses of Miocene basalts, but there is no evidence to prove that the basaltic flows ever extended far south of the latitude of Nakuru. In southern Kenya the plateau phonolites rest directly on Precambrian rocks on both sides of the Rift valley; they undoubtedly occur in the Rift floor where they are covered by later volcanics. Thin flows of olivine basalts are intercalated locally in the plateau phonolites of the Molo area (Jennings, 1970) but no basic lavas were found among the limited phonolite outcrops in the Mau.

The maximum thickness of phonolite in the Mau area cannot be estimated with accuracy because the flows are largely obscured by overlying pyroclastics. In constructing sections across the geological map accompanying this report, a maximum thickness of 1,000 feet of phonolite has been assumed; this is probably a very conservative estimate.

The main phonolite outcrops in the Mau area are found along valley floors west of the Amala and Cheptuich rivers, forming a direct extension of the lava sheets mapped in the Sotik district to the

west (Schoeman, 1949), in the Kericho area to the north-west (Binge, 1962) and in the Molo area to the north (Jennings, 1970). The Pleistocene ashes (now largely altered to clays) which effectively conceal the greater part of the phonolite outcrop in the north-western part of the present area were not recognized in the Sotik and Kericho areas, so that a sharp discord exists, in particular, between the geological maps along the meridian 35°30'. In the north-western part of the Mau area, phonolites are overlain by members of the Pliocene pyroclastic succession in the upper stretches of the Loseni stream and in the headwaters of the Panda river; elsewhere in this corner of the area the lavas are known, or inferred, to be directly overlain by Pleistocene ashes.

South of the Amala river, phonolites are exposed in the Engito stream and in the small stream south of the Kuto hills. At one locality in the Engito stream the lava visibly overlies 'Basement System' rocks, and is overlain farther downstream by Pliocene welded tuffs which are in turn covered by Pleistocene ashes. The continuation of the phonolite mapped in the Engito stream is not shown on the geological map of the adjacent Sotik area; the lava extends nearly to the Narok-Kapkimolwa road. South of the Kuto hills, only ashes were mapped overlying the phonolite.

Apart from these occurrences, phonolite was encountered at only one other locality in the Mau area - in the Sigindirr stream near Rotian, where an inlier of lava is overlain by eutaxitic tuffs constituting a basal member of the exposed Pliocene pyroclastic succession. The phonolite at this locality represents a northward extension of the lavas mapped by Wright (1967) in the Narok and Ngusur rivers (Ngare Narok and Sigindirr of the present survey) and is the only lava occurrence in the eastern two-thirds of the Mau area; it does suggest, however, that phonolites may underlie later pyroclastic rocks over part, if not all, the Mau area.

Mineralogy and Petrography - The phonolites are dark grey, strongly-porphyritic lavas with a characteristic splintery fracture. Feldspars are the most prominent phenocrysts, ranging up to about 20 mm in length, though smaller, euhedral, greenish-grey, waxy nephelines are visible in every specimen. Small flakes of bronzy biotite occur in the lavas west of the Amala river and also in the phonolite exposed in the Sigindirr stream; no mica was found in phonolites in the south-western part of the area. Biotite is an extremely rare constituent of phonolites in the Mara river-Sianna area south-west of the Mau (Williams, 1964b) and was seen in only a few outcrops in the Sotik district to the west (Schoeman, 1949). The mica becomes more common in phonolites north and north-west of the Mau area (Jennings, 1970; Binge, 1962).

Specimens of the Mau Phonolite show only minor variations in thin section. The rocks contain sanidine and nepheline phenocrysts in a fine-grained groundmass of sanidine laths together with crystals of green soda-pyroxene, purple-brown kataphorite and intensely-pleochroic, reddish-brown cossyrite. The interstitial material in the groundmass is nepheline, analcime or sanidine, or combinations of these minerals. Ore occurs in some of the rocks as tiny grains in the groundmass and, more rarely, as small insets. Pyroxene attains microphenocryst dimensions in several of the rocks examined. In specimen 42/1081 from the Engito stream, about a mile from the western boundary of the area, the pale green microphenocrysts are optically positive with $Z \wedge c = 35°$, suggesting a diopsidic composition; pyroxene in the groundmass is evidently aegirine or aegirine-augite, and sanidine laths display a spherulitic habit in this rock. Microphenocrysts of pale green pyroxene in specimen 42/1064, from the stream south of the Kuto hills, are marked by tiny overgrowths of bright green soda-pyroxene. In both the above specimens the microphenocrysts bear small euhedral inclusions of apatite. Some of the larger pyroxenes in the groundmass of the phonolites are strongly zoned, with cores of augite or aegirine-augite mantled by pleochroic aegirine.

Two of the phonolites collected are noteworthy on account of vug-like occurrences of calcite and zeolites. In specimen 42/1064, from the stream south of the Kuto hills, irregular vugs up to 1.0 mm long consist of a discontinuous marginal zone of clear trapezohedral analcime, the remainder of the vug being infilled with calcite. Other pools in the groundmass are composed only of analcime. Closely associated with some of the vugs are patches of green and brown mesostasis that penetrate the groundmass of the lava. The composition of this mesostasis is not determinable by optical methods, but the colour suggests a high iron content. Specimen 42/1082, from the Isei stream at the western boundary of the area, contains numerous pools of zeolite (having the unusual extinction associated with chabazite), locally fringed by clear trapezohedra of analcime. The vugs in these phonolites are too irregular in shape to be regarded as vesicle infillings and, in mineralogical composition and general appearance, they closely resemble the vugs in ngurumanite, a recently-described alkaline rock from the Nguruman escarpment west of Magadi (Saggerson and Williams, 1963; 1964).

Chemistry - There are no chemical analyses of phonolite specimens actually collected within the Mau area, but the plateau phonolites of the surrounding areas belong to the same eruptive phase and are likely to be very similar chemically to the Mau lavas. The first four analyses quoted in Table 2 are of plateau phonolites from the Sotik, Mara River and Kericho areas; specimen W.428 was collected in the Isei River only about a mile downstream from the western boundary of the present area. This specimen and the one from the Kericho area (42/289) contain biotite whereas the Mara phonolites (50/60 and 50/93) lack mica. This slight mineralogical difference between the plateau phonolites north and south of the Amala River is accompanied by only small differences in the major element chemistry. The biotite-bearing phonolites north of the Amala have higher Fe_2O_3 and FeO, slightly higher SiO_2 but lower TiO_2 and P_2O_5. The other analyses in Table 2 are of plateau phonolites from the eastern side of the Rift valley and phonolites of the same age from the Kisumu area near Lake Victoria. Of particular interest are the very similar SiO_2 contents of all these lavas.

The occurrence of enormous volumes of phonolitic and trachytic volcanics in central and southern Kenya poses a major petrogenetic problem. Attention has been drawn to the fact that fractional crystallization alone fails to provide an adequate explanation for the relative proportions of the various rock types. Another problem stems from the lack or scarcity of plateau volcanics of compositions intermediate between flood basalts and the abundant salic lavas and the rather abrupt change from plateau phonolite to plateau trachyte at the end of Miocene times, i.e. at about the time of major Rift faulting. Wright (1963, p. 172) has drawn attention to evidence suggesting that phonolites west of the Rift Valley were derived from a melanephelinitic parent magma.In a discussion of the petrogenesis of Tertiary to Recent alkaline rocks in southern Kenya and northern Tanzania, Saggerson and Williams (1964, p. 76) proposed an ankaratritic parental magma for a strongly alkaline series including melanephelinites and phonolites, and a basaltic source for the alkali olivine basalt-trachybasalt-alkali trachyte series. A more detailed study of some of the Kilimanjaro volcanics by the author (Williams, 1969) indicates that rare phonolites were probably derived from ankaratritic magma but most of the Kilimanjaro phonolitic lavas evidently represent differentiates of the much more abundant alkali olivine basalt magma.

Table 2 Chemical analyses of Kenyan phonolites

	A	B	C	D	E	F	G	H	I	J	K	L	M
SiO_2	54.34	54.76	54.17	54.28	54.58	55.48	54.73	56.58	55.32	54.38	54.70	54.66	54.24
Al_2O_3	18.81	19.97	20.02	19.86	19.42	18.70	18.86	17.20	16.44	18.34	19.62	20.03	20.12
Fe_2O_3	2.06	2.21	1.98	1.81	1.87	3.53	2.35	4.72	5.90	3.09	2.98	1.87	2.25
FeO	3.29	3.00	2.56	2.83	3.17	2.08	2.87	3.53	2.97	2.53	3.04	3.42	2.94
MgO	1.46	0.80	0.90	1.13	1.42	1.75	1.22	0.47	0.51	0.64	0.45	0.77	0.94
CaO	1.73	1.26	1.60	1.70	1.53	2.17	2.12	2.05	1.88	1.54	1.90	1.88	1.76
Na_2O	7.02	8.32	9.03	7.90	7.77	7.04	6.15	6.00	7.18	8.23	7.71	7.50	6.77
K_2O	5.44	5.72	5.70	5.49	5.00	4.85	6.00	5.00	4.95	6.09	5.47	5.56	6.13
H_2O+	3.46	2.28	2.66	3.35	2.95	3.31	3.66	2.89	2.17	1.79	1.50	2.47	2.19
H_2O-	0.74	0.36	0.23	0.46	0.64	0.19	1.38	1.16	1.60	1.13	1.50	0.43	0.73
TiO_2	0.74	0.60	0.91	0.91	0.80	0.70	0.62	0.32	0.42	0.30	0.92	0.60	0.58
P_2O_5	0.11	0.13	0.23	0.23	0.33	0.24	0.09	0.05	0.14	0.07	0.04	0.14	0.17
CO_2	0.36	0.12	0.03	0.00	-	-	-	-	-	0.06	-	-	0.06
MnO	0.32	0.21	0.25	0.25	0.23	0.12	0.33	0.29	0.43	0.33	0.11	0.16	0.15
Cl	-	0.03	-	-	0.01	tr.	-	-	-	0.31	-	0.00	0.07
F	-	0.14	-	-	0.10	-	-	-	-	0.04	-	-	-
S	-	-	-	-	0.04	-	-	-	-	-	-	-	-
SO_3	-	-	-	-	-	-	-	-	-	0.14	-	-	-
-O eqv	-	0.07	-	-	0.04	-	-	-	-	0.08	-	-	-
	99.86	99.84	100.27	100.20	99.82	100.16	100.38	100.26	99.91	99.01	99.94	99.49	99.10

A. Biotite phonolite (W.428), Isei River near Kibiosi, Sotik area. Anal. H Lloyd. (Mau Phonolite).

B. Biotite phonolite (42/289), Numek, Kericho area. Anal. WP Horne and J Furst. (Kericho Phonolite; Binge 1962, p. 36).

C. Phonolite (50/93), Ololorok, Mara River area. Anal. H Lloyd. (Mara/Mau Phonolite).

D. Phonolite (50/60), Motorogie, Mara River area. Anal. H Lloyd. (Mara/Mau Phonolite).

E. Phonolite (NLB.255), Kapiti Plains near Kapiti station, south-south-east of Nairobi. Anal. RB Ellestad. (Kapiti Phonolite; Bowen, 1937, p. 14†).

F. Phonolite (B.M. 1947, 200(1), 12 miles north-east of Kajiado station, Kajiado area. Anal. MH Hey. (Kapiti Phonolite; Smith, 1950, p. 5†).

G. Phonolite (35/1201), Uaso Narok flows, Marmanet Forest, Thomson's Falls - Lake Hannington area. Anal. Min.Res.Div. OGS (Rumuruti Phonolite; McCall, 1967, p. 19†).

H. Phonolite (35/1102), Iguamiti flows, Chui Peak, Subukia, Thomson's Falls-Lake Hannington area. Anal. Min.Res.Div. OGS (Rumuruti Phonolite; McCall, 1967. p. 19†).

I. Phonolite (35/589), Jorokikwa flows, Tarabunyan, Thomson's Falls. Lake Hannington area. Anal. Min.Res.Div. OGS (Rumuruti Phonolite; McCall, 1967, p. 19†).

J. Phonolite (41/934), south of Kisumu Yacht Club, Kisumu area. Anal. WP Horne. (Kisumu phonolite; Saggerson, 1952, p. 24†).

K. Phonolite (GN 349), Kisumu-Kaimosi road, south-west of brickyard at Kibos River, Kakamega area. Anal. WH Herdsman. (? Kisumu phonolite; Smith, 1931, p. 235†).

L. Biotite phonolite (41/858), near Rara, Kisumu area. Anal. WP Horne. (Kisumu phonolite; Saggerson, 1952, p. 24†).

M. Biotite phonolite (41/715), Nyakach Mission, Kisumu area. Anal. WP Horne. (Kisumu phonolite; Saggerson, 1952, p. 24†).

Ankaratrites and other melanephelinites in the Mau, Narok and Loita areas are not accompanied by salic differentiates, which appear most commonly at major central volcanoes rather than among the products of nephelinitic fissure eruptions or closely associated lines of small vents. The plateau phonolites are not considered to be genetically related to the ankaratrites because they differ mineralogically from phonolitic lavas that are found with nephelinites elsewhere, and also because the plateau phonolites are far too abundant to have been derived from ankaratritic magma which is represented by a very small volume of exposed volcanics. A similar volume anomaly exists if an ankaratritic source is proposed for the Mau Tuffs. Moreover, the ignimbritic rocks have silica-rich compositions which render them unlikely derivatives from highly undersaturated magma.

(b) Ankaratrite (?Miocene) (Tvu)

Distribution - The stratigraphic position of ankaratrites (biotite-olivine melanephelinites) in the southern Mau cannot be deduced from the field evidence but they are tentatively regarded as being of post-phonolite and pre-Mau Tuffs age. Wright (1967) recorded various occurrences of olivine-melanephelinites in the Narok area. Flows of this composition in the Kishalduga district were referred to the Miocene and mapping showed that the lavas underlie phonolite; Saggerson (1966) reported ankaratrites in the Kishalduga flows examined in the Loita Hills area. Other scattered outcrops of olivine-melanephelinites in the Narok area were regarded as plugs of Lower Pleistocene age (Wright, 1967, p. 24), though the relationships with surrounding rocks are not clearly demonstrated. It should be noted, however, that olivine melanephelinites at Mutunyi north of Narok evidently cut or overlie both Late Miocene phonolites and representatives of the Mau Tuffs (Wright, 1967, map) so that a Pliocene age is by no means unlikely.

Table 3 Chemical analyses of melanephelinites from the Mau, Narok, Magadi and Amboseli areas

	A	B	C	D	E	F
SiO_2	40.30	40.03	39.24	40.70	39.72	39.98
$Al2O_3$	9.55	9.10	9.58	10.42	9.49	12.27
Fe_2O_3	5.16	5.32	8.72	9.33	6.88	5.82
FeO	8.90	7.30	5.47	4.49	6.88	7.57
MgO	14.07	14.22	9.52	8.59	12.20	8.25
CaO	11.97	12.41	15.35	13.78	16.73	15.47
Na_2O	3.27	5.38	3.18	2.81	1.32	2.49
K_2O	1.40	2.06	1.07	1.40	1.09	0.74
H_2O+	2.17	0.96	3.62	2.94	1.35	1.72
H_2O-			0.61	1.32	0.00	0.61
TiO_2	2.33	2.75	3.02	3.20	3.83	3.85
P_2O_5	0.68	0.50	0.57	0.52	0.69	0.68
CO_2	-	-	0.16	0.16	0.22	0.06
MnO	0.16	0.16	0.21	0.21	0.15	0.22
BaO	-	-	-	0.30	-	-
	99.96	100.19	100.32	100.17	100.46	99.73

A. Ankaratrite (42/1060), Ol Doinyo Ngiro, Mau area. Anal. CP Wood.

B. Olivine melanephelinite (50/536), Morijo Narok, 2 miles south of Narok township, Narok area. Anal. CP Wood.

C. Ankaratrite (51/731), Nguruman Escarpment, Magadi area. Anal. Min.Res.Div. OGS (Saggerson & Williams, 1964, p. 67).

D. Ankaratrite (51/727E), Nguruman Escarpment, Magadi area. Anal. Min.Res.Div. OGS (Saggerson & Williams, 1964, p. 67).

E. Analcime-zeolite ankaratrite (59/482), south-west of Lemongo, Amboseli area. Anal. J Furst. (Williams, 1969, p. 7†).

F. Analcime ankaratrite (W.372), east of Naiperra, Amboseli area. Anal. H Lloyd. (Williams, 1969, p. 7†).

Only a single occurrence of ankaratrite was mapped in the Mau area, the outcrop covering a small area of high ground known as Ol Doinyo Ngiro (Ndunyagerro trigonometrical beacon) on the Uaso Ngiro-Ndorroboni interfluve. The occurrence is of interest not only because of the composition of the rock, but also in view of the rarity of outcrops of hard volcanic rocks on interfluves in the Mau area.

At Ol Doinyo Ngiro, thick beds of ashes (thought to be Middle Pleistocene) are evidently banked against the ankaratrite. No baking of the poorly-consolidated pyroclastic material was observed, as might be expected if the ankaratrite be regarded as an intrusive plug; and no melanephelinitic flows were found capping the Pleistocene ashes. On the contrary, there is every indication that ankaratrite boulders are mixed with the pyroclastic deposits.

Mineralogy and Petrography - The ankaratrite at Ol Doinyo Ngiro is extremely tough and is most commonly dark grey, though dark purplish-grey tinges characterize boulders of the same material a few hundred yards from the trigonometrical beacon. A thin section of the rock (42/1060) shows numerous subhedral microphenocrysts of colourless olivine (the mineral is optically positive, indicating a forsteritic composition) and many small irregular ore grains. Orange biotite (X = nearly colourless; Y = yellow-orange; Z = bright orange) occurs in anhedral plates, poikilitically enclosing groundmass minerals. The groundmass comprises small aegirine-augite prisms ($X \wedge c = 40°$), tiny ore granules and interstitial nepheline.

Chemistry - A chemical analysis of the ankaratrite from Ol Doinyo Ngiro (42/1060) is given in Table 3 together with analyses of other melanephelinites from several localities in southern Kenya. Of particular interest are the high MgO/CaO ratios for the Mau ankaratrite and the olivine melanephelinite (50/536) from the neighbouring Narok area. MgO rarely exceeds CaO in nephelinitic lavas in East Africa; the only other example known to the writer is an ankaratrite from Mt. Elgon (King, 1965, p. 76†) having 26.48% MgO and 8.23% CaO. The melanephelinite from the Narok area (analysis B) is marked by high total alkalis and low Al_2O_3. Some nephelinites from Mt. Elgon (Searle, 1952†) and from Kericho area (Binge, 1962) have total alkalis of well over 9%, but Al_2O_3 ranges from 11.5-15%.

2 Mau Tuffs (Pliocene)

Exposures of consolidated pyroclastic rocks, provisionally assigned to the Pliocene, are confined to more or less continuous sections along the lower parts of all the deeper valleys that dissect the Mau range. It has been neccessary to exaggerate greatly outcrop widths of all the Pliocene pyroclastic rocks so that they can be represented on the scale of the geological map. Similar rocks have been described from several surrounding areas, though a variety of different ages have been suggested. Evidence for a tentative Pliocene age is discussed in a later section of the report but it must be stressed here that the final solution to the age problem will probably not be found in the Mau area and will depend ultimately on detailed correlations with volcanic successions in areas flanking the Rift Valley.

A notable feature of the Mau Tuffs is that a comparatively small total thickness, of some 600-800 feet, is spread over an area of many hundreds of square miles. This is thought to be largely attributable to an overall dip of about 80 to 90 feet per mile to the SSW, a gradient corresponding closely with that of streams dissecting the Mau. The widespread distribution of individual thin members in the succession, with little indication of lateral variation in appearance or thickness, is of great significance and is one of the features supporting the conclusion that most, if not all, of the

Pliocene pyroclastic rocks are ash-flow tuffs.(See Chapter 4 for details of the system of pyroclastic nomenclature used in this report)

The Mau tuffs are subdivided as follows:

3 Upper Welded Tuffs

2 Ndorroboni Agglomerates and Chapaltarakwa Lapilli-Tuffs

1 Lower Welded Tuffs

(a) Lower Welded Tuffs (Tvf_{1-3})

With only a few exceptions, the oldest pyroclastic rocks exposed in the area show clear signs of welding and complete or near-complete collapse of constituent pumice fragments. Although the rocks described here as the Lower Welded Tuffs vary somewhat in general appearance, they all contrast strongly with immediately-overlying agglomerates and lapilli-tuffs that are often poorly welded and which are marked by, at most, only early stages of pumice collapse.

The Lower Welded Tuffs are well exposed in all major streams dissecting the south-eastern quarter of the area, and although the base of the unit is generally not seen, at one locality in the Sigindirr stream welded tuffs rest on Mau phonolite. Farther west, rocks assigned to the Lower Welded Tuffs crop out in the Ndorroboni stream and at one locality in the Uaso Ngiro, being concealed along the greater part of the latter river by thick alluvial deposits. Most of the welded tuffs exposed in the Amala river, in a number of its tributaries and in the Loseni and Amogong streams in the north-western quarter of the area, are tentatively correlated with various members of the Lower Welded Tuffs; the rocks were seen overlying both Mau phonolites and 'Basement System' gneisses. Representatives of the Lower Welded Tuffs are not well exposed in the north-eastern quarter of the Mau area, where they are effectively concealed by younger pyroclastic rocks, both welded and non-welded.

The Lower Welded Tuffs are further subdivided as follows:

3 Eutaxitic tuffs and 4 dark friable tuffs

2 Purple and grey devitrified tuffs

1 Basal eutaxitic tuffs

(1) Basal eutaxitic tuffs (Tvf_1)

Basal members of the Lower Welded Tuffs are characterized by strong eutaxitic textures caused by the collapse and alignment of pumice fragments, which results in dark, glassy, disc-like fiamme lying in a matrix of material of ash grade. Exposures of these eutaxitic welded tuffs are found in the north-western, south-western and south-eastern parts of the area, but the rocks from each of these districts are best described separately since their correlation is at present tentative and involves postulating some lateral variation in appearance. It should be noted that eutaxitic tuffs of very similar appearance and composition crop out in other parts of the Mau, but they are clearly younger than the types under immediate discussion.

The basal eutaxitic tuffs probably attain a maximum thickness of about 150 feet in the north-western Mau. They are certainly more than 50 feet thick in the south-eastern parts of the area. Though evidence is lacking, a figure of 100 feet is used in the construction of a section (Fig. 2).

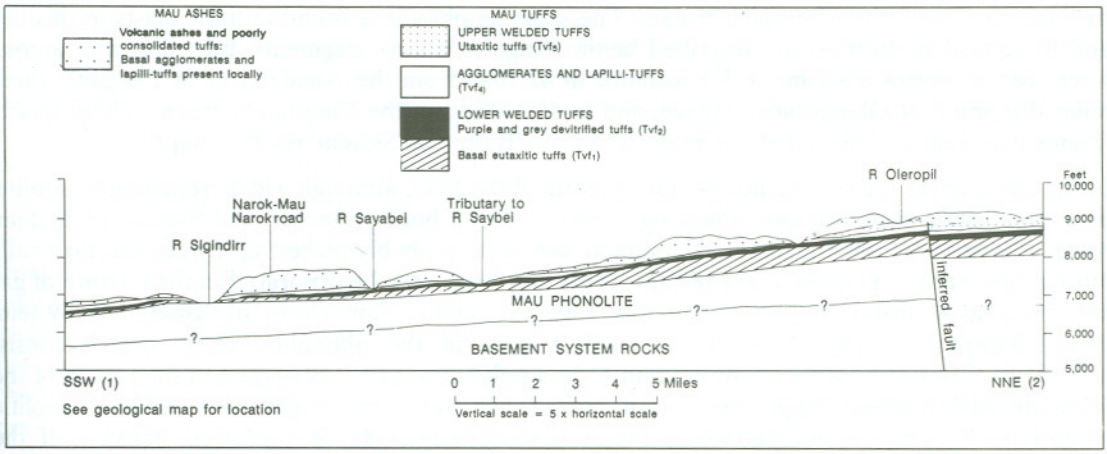


Figure 2 Section across the south-eastern part of the Mau area, showing the SSW dip of the Mau Tuffs

North-western Mau - In the Amala river and that part of the area lying to the north-west, many of the pyroclastic rocks are coarse, welded tuffs that show a striking degree of collapse and flattening of pumice lapilli. The lapilli, which are commonly 25-50 mm long and occasionally twice that size, are seldom more than 5.0 mm thick, and are black or dark grey and glassy, with streaks of yellowish, powdery material. Many break readily into small ovoid lumps along perlitic cracks. These glassy lapilli are accompanied by small, sub-rounded lithic clasts that vary in colour from greenish-grey or grey to shades of yellow-brown, and range from 2-12 mm in diameter. The grey matrix in these rocks bears numerous small, flattened, black glassy fragments similar to the lapilli and tiny feldspar crystals 1.0-2.5 mm long. The rocks are frequently marked by crude polygonal jointing, dividing weathered surfaces into units about two metres across, in contrast to finer jointing that characterizes overlying grey or purplish devitrified tuffs described later. Rapids and small waterfalls often develop over the better stream exposures of the eutaxitic tuffs, a fine example occurring near the bridge over the Cheptuich stream two miles west of Olenguruone village.

Thin sections of the eutaxitic welded tuffs from the north-western parts of the Mau show many of the black lapilli to be completely-collapsed pumice, in which all trace of original vesicularity has been destroyed during welding into a compact glass. However, flow-like patterns and frayed ends in other lapilli preserve pumice structure and clearly demonstrate the origin of the fragments; perlitic cracks are common. In some rocks, for example specimen 42/1108 from the Cheptuich stream four and a half miles downstream from the road bridge, total elimination of internal pumice structure is indicated by occasional patches of structureless pale brown glass. In this specimen, the extreme plasticity of much of the pumice during welding is shown by numerous lobes around the edges of the lapilli and by local the inclusion of portions of the groundmass.

All the eutaxitic welded tuffs contain sub-rounded lithic clasts and crystals. The commonest are small euhedral crystals of feldspar, identified as sanidine by small optic angles ($-2V = c.10°-20°$). Rare small prisms of aegirine occur in most of the thin sections examined; the mineral has $\dot{X} \wedge c = 2°-3°$ and is strongly pleochroic with X = brilliant green, Y = grass green, Z = pale yellow-green, and with $X > Y > Z$. A strongly-pleochroic amphibole of the barkevikite-kataphorite series occurs as rare small zenocrysts in a coarse, eutaxitic tuff (42/1074) collected from an exposure 220 feet above the level of the Amala river and four and a quarter miles downstream from

its confluence with the Cheptuich stream. The same amphibole is found in lithic clasts in this tuff and its optical properties are described below. Angular quartz fragments, up to 0.5 mm across, were seen in several specimens, for instance in 42/1096 from the Amala river at Lengabe, three miles due south of Olenguruone village, and in 42/1108 from the Cheptuich stream. These quartz fragments are most likely to have been derived from 'Basement System' rocks at depth.

Lithic clasts in the tuffs of the north-western parts of the Mau, although widely replaced by zeolite, have contrasting compositions indicating derivation from both phonolite and 'Basement System' rocks. Phonolitic clasts are the most common and were probably picked up by the ash-flow tuffs during their eruption across a lava surface; some may have been incorporated in the mixture of gas and pyroclastic material before eruption, together with a few clasts of 'Basement System' quartzofeldspathic rocks. Nepheline is seldom seen in the phonolitic clasts, which consist essentially of sanidine, soda-pyroxenes and soda-amphiboles, and it is suggested that much of the feldspathoidal material might have been melted out but some might have suffered zeolitic alteration. An origin from phonolite, rather than soda-trachyte, is preferred because of the abundance of lavas of the former composition, and scarcity of the latter, in, and immediately north of, the Mau area. Phonolitic clasts, in a specimen (42/1074) from the Amala river mentioned above, contain an amphibole having the following optical properties: -2V small to moderate; $Z \wedge c = 8°\text{-}20°$; pleochroism X = yellow-green to yellow-brown, Y = dark purple-brown, Z = olive green with $X > Y > Z$. In composition, this amphibole is considered to lie between kataphorite and barkevikite. Another partly-altered lithic clast in this specimen contains albite and could have been derived from a 'Basement System' rock. More convincing clasts of 'Basement System' origin are found in specimen 42/1090, from the Cheptuich stream near the road bridge, where quartz and oligoclase occur together. Quartz grains also occur in extensively-altered lithic clasts in specimen 42/1099 from the Amala river due east of Olenguruone village. In most of the tuffs the clasts display partial or complete alteration to aggregates of natrolite.

The groundmass in the eutaxitic tuffs consists of welded and distorted shards which form an isotropic base. No significant devitrification of either groundmass or pumice lapilli was observed.

South-western Mau - Welded tuffs, characterized by strong eutaxitic structures due to complete collapse of pumice lapilli, crop out in the Amala river and the Engito stream in the south-western part of the area. The rocks, which rest on 'Basement System' gneisses in the Amala and on Mau phonolites in the Engito valleys, are very similar to the types described above from the north-western Mau, though alteration of the matrix tends to give the tuffs a more yellowish overall colour; grey pumice lapilli are generally about 25 mm long.

South-eastern Mau - Welded tuffs, showing less striking eutaxitic structures than those described above, occur in many of the stream sections in the south-eastern quarter of the Mau area. They are well exposed in the Seyabei river at Enabilibil, Ol Orkirkirae and near Rotian, and in both the Sigindirr and Ngare Narok streams. At all these localities the eutaxitic rocks underlie purple devitrified tuffs, described later; the base of the eutaxitic tuffs is normally not exposed, but in the Sigindirr stream near Rotian they overlie phonolite. Welded eutaxitic tuffs exposed in the Olombori and Enambadad streams, both tributaries to the Seyabei, are very similar to the rocks discussed here but they are clearly younger,

The commonest eutaxitic tuffs in the south-eastern Mau are grey, brown or khaki-coloured compact rocks. Flattened pumice lapilli are generally smaller and less abundant than those in the rocks already described from the north-western parts of the area, but nevertheless they occasionally attain lengths of 25-35 mm as in specimen 42/1042 from the Ngare Narok stream north-north-west

of Naisoya trigonometrical beacon. Lapilli 15 mm long are, however, more typical of these rocks. The pumice fragments usually show complete collapse and thorough welding to a dark glass but in some tuffs, for instance 42/1039 from the Seyabei at Rotian, most of the lapilli retain their vesicular nature in spite of marked flattening. Lithic clasts, in the form of brown pellets 2.0-5.0 mm across, are found in all the tuffs together with small feldspar crystals.

Thin sections of the rocks show varying degrees of collapse and devitrification of pumice lapilli. In specimen 42/1045, collected from a 30-foot-thick bed of eutaxitic tuff near the Seyabei river at Enabilibil, no pore space remains in the lapilli, which are composed of compact glass. Most of the pumice is completely collapsed in specimen 42/1046, from a 20-foot-thick tuff bed immediately underlying the one described above, but original vesicularity is preserved in some fragments though the pores are elongated as a result of flattening. No devitrification of the glass is visible in either of these specimens, but a eutaxitic tuff (42/1039) from the Seyabei at Rotian is characterized by partial devitrification of both pumice and groundmass shards; this rock is also marked by incomplete collapse of the pumice. Parallel intergrowths of the devitrification products result in typical axiolitic structures similar to those illustrated by Ross and Smith (1961, Figs. 71-74).

All the feldspar crystals have very small optic angles, leading to their identification as sanidine. Strongly-pleochroic amphiboles occur as small crystals in some of the tuffs, notably specimens 42/1045 and 42/1046 from the Seyabei river at Enabilibil. Both contain an amphibole pleochroic from olive green to purple-brown and similar to that identified as a member of the barkevikite-kataphorite series in a rock from the north-western Mau; in addition, small crystals of arfvedsonite ($X \wedge c = 15°$ and X = deep bluish-green, Z = pale violet) were seen in specimen 42/1046.

Small lithic clasts in the eutaxitic tuffs are evidently of phonolitic compostition, being composed of sanidine, soda-pyroxene, kataphorite, cossyrite and unconfirmed nepheline. No quartzofeldspathic clasts of possible 'Basement System' origin were seen in the tuffs in the south-eastern parts of the Mau.

(2) Purple and grey devitrified tuffs (Tvf_2)

In the south-eastern quarter of the Mau area, the basal eutaxitic welded tuffs described above are overlain by a bed of hard devitrified welded tuff which, in spite of its extensive outcrop, is probably little more than 30 feet thick. The rocks of this distinctive marker bed are all characterized by pale purplish or purplish-grey tints and outcrops are found in the Seyabei southwards from Ol Orkirkirae and in the lower reaches of most of the tributaries to this river. Similar tuffs are exposed in the Sigindirr stream and the Ngare Narok. North-east of Ololonga, hard, purplish tuffs crop out near the Uaso Ngiro and in the Ndorroboni stream, and are tentatively correlated with those of the Seyabei section though the base is not exposed. In the north-western parts of the Mau, eutaxitic welded tuffs are overlain by up to 100 feet of devitrified varieties that only locally develop a purplish tinge, and differ from those of the Seyabei in being rather more porous. In view of their stratigraphic position, however, they are provisionally correlated with the harder rocks farther south and are described separately to demonstrate the lateral variation.

South-eastern and south-central Mau - These rocks vary only slightly in general appearance, fresh surfaces ranging in colour from purplish-grey or purplish-brown to distinct purple or mauve tints; most are marked by strong conchoidal fracture. The pyroclastic origin of the rocks is generally evident on close examination but, although small flattened and aligned devitrified pumice fragments are often visible, eutaxitic structures are never as striking as those in the underlying tuffs

where lapilli are typically glassy. In the devitrified tuffs, brown or grey pumice lapilli are seldom more than 6.0-12 mm long, and because of devitrification and intense welding, boundaries between the fragments and groundmass are usually indistinct. Apparent vesicularity in the lapilli is invariably attributable to recrystallization and the production of minute spherulites, rather than the preservation of pores in the pumice. At some localities, for instance in the Sigindirr stream near Orengitok, the tuffs are extremely fine grained with only occasional fragments attaining lapilli grade. Throughout the exposures examined, the commonest crystals are tiny feldspars seldom more than 2.0 mm long; many of the tuffs also contain small flakes of dark brown biotite. Sub-rounded lithic clasts are sometimes recognizable by their pale colour and faint crystalline texture, though often they are not easily differentiated from devitrified pumice. These clasts rarely exceed 5.0 mm in diameter. Exposures of densely-welded tuffs in the Olombori stream, south-east of Olombori trigonometrical beacon, are marked by crude columnar jointing, a feature that was also noticed elsewhere.

Pale grey, porous welded tuffs exposed in the Ndorroboni stream, immediately below its confluence with the Ol Eshepani, are of interest because they closely resemble devitrified welded tuffs of the north-western Mau; farther downstream, however, these rocks grade into mauvish tuffs, typical of those found at other localities in the southern and south-eastern parts of the area.

In thin sections, hard purplish tuffs from the southern parts of the Mau show only minor variations. Pumice fragments in all the rocks examined are completely collapsed, flattened and well aligned; all display extensive devitrification with characteristic axiolitic and spherulitic structures.In some specimens, for instance 42/1027 from the Olchoro Lekilessi stream three and a half miles south of Olchoro trading centre, small grains of cossyrite and aegirine are intergrown with the devitrification products of the pumice. This specimen is also marked by extensive calcification, generally confined to the devitrified areas of the rock. Groundmass shards display varying degrees of devitrification. All the rocks are characterized by minute grains of strongly-pleochroic cossyrite evenly distributed throughout the groundmass, and this mineral is undoubtedly responsible for the distinctive colour of the tuffs.

Sanidine ($-2V = 10°$-$30°$) is present in all the rocks as small euhedral to subhedral crystals up to 1.5 mm long. In specimen 42/1027 the alkali feldspar bears small inclusions of brown biotite. In specimen 42/1053, from the Ndorroboni stream, sanidine is accompanied by rare crystals of oligoclase. Small flakes of biotite, 0.25-0.5 mm long, occur in about half the specimens examined and the mica is not confined to the rocks in any particular part of the area. The mineral is pleochroic from straw brown to dark brown or dark reddish-brown. Pyroxenes are occasionally present as small crystals 0.25-0.5 mm long; most common are crystals are of green aegirine. In specimen 42/1054, from the Ndorroboni stream immediately below its confluence with the Ol Eshepani, the aegirine is strongly pleochroic with X = brilliant green and Z = drab yellow-green. Crystals are zoned, centres having extinction $X \wedge c = 14°$ and rims $X \wedge c = 4°$. Green pyroxene in specimen 42/1038, from the Kerrerie river two and a half miles upstream from its confluence with the Olchoro Lekilessi, shows extinction $X \wedge c = 35°$, while non-pleochroic pyroxene crystals in 42/1032, from the Enambadad stream west of Olombori beacon, have $Z \wedge c = 35°$ and a moderate $+2V$. Small crystals of opaque ore occur in some of the tuffs.

Lithic clasts in the devitrified tuffs are usually sub-rounded and about 2.0 mm in diameter. A common mineral association is sanidine, aegirine-augite, kataphorite, cossyrite and sometimes biotite; interstitial analcime and unconfirmed nepheline occur in some rocks. Optical properties of the green pleochroic aegirine-augite are variable, both optically positive and negative varieties being present in addition to occasional crystals showing $2V = c.90^{\circ}$. Kataphorite displays

pleochroism from pale yellow-green or olive green to pale purple-brown. Reddish-brown to nearly opaque cossyrite has $Z \wedge c = 43°$ in a specimen (42/1025) from the Olombori stream, south-east of Olombori trigonometrical beacon. Biotite is pleochroic from pale brown to reddish-brown. Fragments containing identifiable nepheline or analcime were derived from phonolitic lavas. Where feldspathoid is absent, an origin from soda-trachyte must be entertained though lavas of this composition have not been recognized underlying the welded tuffs.

North-western Mau - Rocks that are tentatively correlated with the welded tuffs described above crop out in the upper Amala section, in the Olpusimoru stream and at several other localities in the Olenguruone Settlement Area. These welded tuffs of the north-western Mau are characterized by pale grey or mauvish-grey colours, a more porous texture than their counterparts farther south and even less distinct eutaxitic structures. Pumice fragments are very small and barely recognizable and are accompanied by occasional tiny feldspar crystals.

The thin section of a pale grey tuff (42/1088), from the Amala river a mile above its confluence with the Olpusimoru, shows very small crystals of sanidine, green pleochroic aegirine, reddish-brown biotite, kataphorite (X = pale yellow, Y = purple-brown, Z = greenish-yellow, $Y > Z > X$), and ore grains. Small devitrified pumice fragments and a few lithic clasts are set in a fine ash groundmass. The lithic clasts consist of sanidine, green aegirine ($X \wedge c$ small), kataphorite and cossyrite.

The groundmass of a mauvish-grey welded tuff (42/1110), from the north of Olenguruone contains numerous minute grains of strongly-pleochroic reddish-brown to opaque cossyrite, which undoubtedly accounts for the colour of the rock. An amphibole, occurring both as crystals and in lithic clasts, has the following optical properties: -2V moderate, $Z \wedge c = 12°$, X = pale yellow-green, Y = pale purple-brown, Z = yellow-brown, $Y > Z > X$. It probably corresponds closely to an amphibole of the barkevikite-kataphorite series described from the basal eutaxitic tuffs.

These welded tuffs are quarried for use as building stone west of Olenguruone village; close to the Amala river, east of Olenguruone; and near the Amala north-north-east of Olenguruone. Most exposures of the rocks are characterized by markings on weathered surfaces that give the tuffs a shattered appearance; the patterns are composed of polygonal units about 25 mm across that become slightly etched out, but they are not clearly related to any joint system visible in fresh rock and do not apparently affect the quality of the stone for building purposes.

The devitrified tuffs in the north-western parts of the area attain a maximum thickness of 80-100 feet.

Glassy welded tuffs - Most of the welded tuffs described above have suffered extensive devitrification, of both pumice lapilli and groundmass shards. A thin bed, about 60 cm thick, of black glassy tuff occurs, however, in the succession exposed in the Olombori stream two miles above its confluence with the Seyabei river. The glassy bed is underlain by rather friable buff tuffs and grades upwards through fine-grained, purplish rocks into typical devitrified tuffs.

The black tuffs at this locality have a glassy to resinous lustre and contain small feldspars s and flakes of biotite. In thin section, specimen 42/1035 shows crystals of sanidine and brown biotite together with completely collapsed pumice fragments that display no recrystallization. The crystals and lapilli are accompanied by clasts of porphyritic phonolite or soda-trachyte, composed of sanidine, aegirine and pale greenish-brown to purple-brown kataphorite. In essential composition, this glassy tuff thus corresponds closely to devitrified varieties already described.

(3) Eutaxitic Tuffs (Tvf3)

At a few localities eutaxitic tuffs were seen immediately overlying purplish devitrified varieties, or are inferred to occupy this stratigraphic position. Near the Enambadad stream west of Olombori trigonometrical beacon, grey porous tuffs containing flattened glassy fragments overlie hard, purplish-grey, devitrified tuffs that crop out in the river. Devitrified tuffs are not exposed in the succession seen in the Olombori stream east of Songorra beacon but they are exposed farther downstream and are likely to occur beneath a bed of brown, eutaxitic tuff. The latter contains dark grey, disc-like, aligned lapilli, about 25-35 mm long, 2.0 to 5.0 mm thick and having a waxy lustre. These are accompanied by small crystals and biotite flakes. The thin section of specimen 42/1028 from the Olombori stream shows crystals of sanidine ($-2V = c.20^{\circ}$) and rather common shreds of biotite, pleochroic from pale or medium brown to dark red-brown. The pumice lapilli are completely flattened with no pore-space remaining but there is no evidence of devitrification in the pumice or groundmass. Lithic clasts, 0.5 to 4.0 mm in diameter, consist of sanidine (in both small phenocrysts and laths), aegirine-augite and cossyrite in an analcime base, and were probably derived from phonolite.

In the Olchoro Lekilessi, a mile and a half upstream from its confluence with the Kerrerie, and also in the stream lying between these two rivers, a thin bed of eutaxitic tuff separates devitrified varieties from overlying coarse buff or yellowish tuffs characterized by little or no pumice collapse.

(4) Dark Friable Tuffs (Tvf3')

In the Tukeni stream at Chapaltarakwa dark, porous, friable tuffs underlie yellow lapilli-tuffs (Tvf_4), which in turn are overlain by eutaxitic varieties (Tvf_5) of the Upper Welded Tuffs. A similar succession is convincingly displayed near Olkiuliamon (Olokurto) where the friable grey to dark grey tuffs have been used as a building stone. The rocks contain occasional angular pumice lapilli less than 10 mm across together with small crystals, pellets of included lava and small brown plant fragments. Dark friable tuffs exposed in the Olpusimoru stream and the lower reaches of its two head-streams at Chapaltarakwa, overlie mauvish-grey devitrified tuffs (Tvf_2) and are overlain by yellow-brown lapilli-tuffs containing angular pumice fragments (the Chapaltarakwa Lapilli-Tuffs, Tvf_4). Dark porous tuffs are also exposed in the head-streams of the Uaso Ngiro at Kilaba; the rocks are correlated with those encountered at Chapaltarakwa.

Associated with the friable tuffs at many of these localities are more compact, eutaxitic varieties containing flattened lapilli seldom more than 10-15 mm long, suggesting that all these rocks are ash-flow tuffs and supporting the correlation with the eutaxitic tuffs near Olombori.

The dark friable tuffs and associated rocks are probably nowhere more than 50 feet thick.

(b) Ndorroboni Agglomerates and Chapaltarakwa Lapilli-Tuffs (Tvf_4)

Characteristic features distinguishing these rocks from underlying and overlying harder tuffs are their common coarse-grained and porous nature and the rare incidence of collapsed pumice blocks and lapilli. Colours are also frequently distinctive, many of the agglomeratic rocks being marked by yellowish tints. The agglomerates and the lapilli-tuffs are described together because a correlation is indicated by the present work.

The rocks show greater lateral variation than the eutaxitic and devitrified tuffs described above, but since they are often too coarse or too friable to study effectively under the microscope, the following discussion is devoted mainly to changes in general appearance and to local successions established in various parts of the area.

South-eastern Mau - Porous tuffs and lapilli-tuffs are exposed in the lower slopes of most of the valleys in this part of the area, the streams generally having downcut sufficiently to expose rocks of the Lower Welded Tuff succession. Most commonly the porous tuffs rest directly on purplish, devitrified varieties (middle member of the Lower Welded Tuffs), though in the vicinity of the Olombori stream porous tuffs and lapilli-tuffs are separated from the devitrified type by a lenticular bed of eutaxitic tuff (Tvf_3). Only in the Seyabei and Sigindirr rivers near Rotian do porous tuffs directly overlie eutaxitic rocks representing the basal member of the Lower Welded Tuffs. Throughout the south-eastern Mau, the Upper Welded Tuffs are absent and porous tuffs are overlain by Pleistocene ashes.

The commonest rocks overlying the eutaxitic and devitrified welded tuffs are porous, grey or grey-brown lapilli-tuffs containing angular to rounded pumice fragments generally around 15 mm across but ranging up to 50 mm in length, so that locally the rocks approach agglomeratic grade. The pumice is sometimes slightly flattened but always retains its original vesicularity. Small crystals are visible in most of the rocks.

The thin section of a grey, porous lapilli-tuff (42/1031) from the Enambadad stream south-west of Songorra beacon contains phenocrysts of sanidine and biotite. The crystals range up to 1.5 mm in length, have $-2V = 10°-20°$ and the optic plane perpendicular to (010), possibly indicating a type transitional to the high sanidine series (Tuttle, 1952; Mackenzie and Smith, 1956). Biotite flakes, 0.25-0.5 mm long, are pleochroic from pale or medium reddish-brown to dark reddish-brown. Uncollapsed pumice fragments all show evidence of devitrification, recrystallization giving rise to typical spherulitic structures. The groundmass comprises welded shards of ash grade, and rock inclusions in the tuff are composed of alkali , soda-pyroxene, kataphorite, cossyrite, biotite and ore. No feldspathoid was detected in the lava clasts in this rock but sub-rounded fragments in a similar tuff (42/1037), from the Olchoro Lekilessi at the southern boundary of the Mau area, contain nepheline together with sanidine, aegirine-augite, kataphorite, cossyrite and ore and were undoubtedly derived from phonolitic lava. The uncollapsed and locally-devitrified pumice lapilli in this tuff are marked by linings of analcime or tridymite/cristobalite in the vesicles, perhaps representing vapour-phase crystallization.

Friable, brown, yellow-brown, yellowish and buff-coloured lapilli-tuffs were encountered at numerous localities in the south-eastern Mau, notably in the Lekilessi stream, the upper reaches of the Enambadad stream and near the Seyabei and Sigindirr rivers at Orengitok and Rotian. Only rarely do these tuffs grade into rocks of agglomerate grade. Many of the lapilli-tuffs evidently represent the weathered equivalents of the porous grey rocks described above, brownish varieties replacing grey types in the higher parts of the successions, as for instance in the Seyabei section at Orengitok; at other localities grey and yellow-brown lapilli-tuffs occur in alternating beds, brown varieties sometimes immediately overlying eutaxitic and devitrified tuffs as in the Seyabei valley near the southern boundary of the area. In some rocks, for example specimen 42/1023 from the Olchoro Lekilessi east of Olombori trigonometrical beacon, slightly flattened but highly vesicular pumice lapilli over 25 mm long are accompanied by smaller, angular fragments composed of black glass. Distinctive friable yellow lapilli-tuffs are particularly prominent in the Sigindirr section at Orengitok and near the Olchoro Lekilessi and its tributaries about two miles from the southern boundary of the area.

A pale grey, compact tuff, bearing only occasional 10-mm-long pumice lapilli and small crystals, crops out in the upper part of the Enambadad stream about a mile south-west of Olchoro trading centre. A thin section of the rock (42/1022) shows sanidine crystals and rare devitrified but uncollapsed pumice in a devitrified matrix.

South-western Mau - Many of the rocks immediately overlying purplish devitrified tuffs in south-western parts of the area are agglomerates containing angular pumice blocks up to 200 mm long. Porous tuffs and lapilli-tuffs, similar to those described above, are associated with the agglomerates and the entire succession is provisionally correlated with the generally finer-grained rocks overlying representatives of the Lower Welded Tuffs in the south-eastern and northern parts of the Mau.

Agglomeratic rocks are well exposed in the Ndorroboni valley north-east of Ololonga. At Osongoroi, friable grey agglomerates, commonly containing 150-mm-long pumice blocks and angular fragments of obsidian 12-25 mm across, overlie devitrified welded tuffs that crop out in the stream. The grey agglomerates grade upwards into yellowish varieties, the change in colour possibly being attributable to weathering and decomposition. In this section, the agglomerates attain a total thickness of about 150 feet and they are overlain by some 40 feet of porous grey, grey-brown and khaki-coloured lapilli-tuffs bearing angular pumice fragments 6.0-18 mm across. These tuffs are in turn overlain by Pleistocene ashes. Farther north near the Ndorroboni-Ol Eshepani confluence, about 100 feet of porous grey tuffs separate grey and yellowish agglomerates from underlying purple-grey devitrified welded tuffs. Two and a half miles north of this confluence the Ndorroboni flows in alluvial deposits but a section in the western side of the valley shows coarse, grey, friable agglomerates overlain by yellowish varieties which are capped by grey lapilli-tuffs containing pale, 12-mm-long pumice fragments. The grey agglomerates bear 200-mm-long pumice blocks, angular obsidian fragments and occasional angular pieces of green to blue-black phonolite. The Ndorroboni section near the southern boundary of the area is of particular interest because a succession of grey and yellow agglomerates, more than 90 feet thick, is capped by a 30-foot-thick bed of hard, eutaxitic welded tuff, the only representative of the Upper Welded Tuffs in the southern half of the Mau area.

Along the lower part of its course in the Mau area the Uaso Ngiro flows in thick alluvial deposits, but agglomerates and lapilli-tuffs crop out near the river at Eoutoud. West of the Uaso Ngiro, coarse yellow and grey friable agglomerates form low topographic features; east of the river, similar rocks are accompanied by lapilli-tuffs containing abundant obsidian.

Grey and yellow agglomerates, bearing sub-angular to rounded pumice lapilli and blocks up to 100 mm across, overlie some 200 feet of eutaxitic welded tuffs that crop out in the Amala river four and a half miles downstream from its confluence with the Cheptuich. Agglomerates are probably more extensively developed than the meagre exposure suggests, being concealed elsewhere by overlying Pleistocene ashes.

North-eastern Mau - In the north-eastern quarter of the area, friable pyroclastic rocks that are tentatively correlated with those described above seldom attain a genuine agglomeratic grade, and the commonest types are yellow to yellow-brown lapilli-tuffs containing sub-angular pumice fragments 6.0-25 mm long, small angular pieces of obsidian and lithic clasts. These lapilli-tuffs are widely preserved by a capping of harder eutaxitic welded tuffs (Upper Welded Tuffs of the present report). A somewhat haphazard outcrop distribution of these two contrasting rock types is attributable to the south-westerly dip of both beds at an angle approximately corresponding to the stream gradients. As a result, many of the streams show repeated contacts between welded tuffs and friable lapilli-tuffs. Where the streams are flowing from harder to underlying softer rocks the true stratigraphic relationship between the beds is commonly displayed in attractive waterfalls, 20-60 feet high; on the other hand, a return to the overlying welded tuff is often accompanied by swampy areas in the stream course and the actual contact is seldom exposed.

Friable, yellow-brown lapilli-tuffs with angular, 12 mm-long pumice fragments are well exposed in the Olpusimoru river and its tributaries at Chapaltarakwa. South-east of the Purko Timber Co-operative Society sawmill these rocks are about 80 feet thick and overlie members of the Lower Welded Tuffs. Farther upstream, the river cascades through 40 to 50-foot-deep gorges cut in the friable tuffs, dropping rapidly over a series of waterfalls. The head-streams to the river often flow over eutaxitic rocks assigned to the Upper Welded Tuffs. Three and a half miles north-west of Olokurto, a tributary known as the Tukeni falls from the eutaxitic rocks into softer, yellowish lapilli-tuffs in a series of rapids; below the rapids the stream runs for several hundred metres in dark grey, friable, gritty tuffs that here underlie yellowish varieties.

The head-streams of the Uaso Ngiro flow in yellow-brown and grey lapilli-tuffs south of Kamarar and Makutano. These rocks are very similar to those exposed in the Olpusimoru, yellow, powdery pumice fragments only rarely attaining lengths of 25 mm; much of the material is now unrecognizable as pumice, but locally less-advanced stages in an alteration process are visible, grey pumiceous lapilli being streaked with yellow, clay-like material. In many of the tuffs the altered pumice is accompanied by small angular fragments of obsidian.

Yellowish lapilli-tuffs grading locally into agglomerates are exposed at numerous localities in all the major head-streams of the Ngare Narok, the Sigindirr and the Seyabei rivers, generally in a broad belt of country between Olokurto and Mbatebat. The rocks, which closely resemble those described above, are overlain by harder, eutaxitic varieties constituting the Upper Welded Tuffs. Waterfalls exposing the contact between lapilli-tuffs and eutaxitic welded tuffs were encountered in all the streams, fine examples occurring in the Ngare Narok tributaries. Half a mile upstream from Ol Razella Sawmills, Olokurto, an excellent section is visible at a 50-foot-high waterfall; and three miles north-east of Olokurto trading centre, the Mutengwarr stream plunges some 60 feet over a ledge of eutaxitic welded tuffs into yellowish lapilli-tuffs. Waterfalls in the Sigindirr course, one of them three and a quarter miles east-north-east of Olokurto and the other on Sessions' farm, show similar contacts. Smaller waterfalls and rapids were found in the Seyabei head-streams.

North-western Mau - Lapilli-tuffs and agglomerates containing angular fragments are only rarely encountered in the north-western quarter of the area. In the Ambosket stream, four miles south-west of Olenguruone village, tuffs bearing angular yellowish pumice fragments 12-25 mm long in a brown matrix overlie members of the Lower Welded Tuffs. At the road bridge crossing the Cheptuich stream, friable brown, yellowish and grey agglomerates with pumice blocks up to 80 mm long overlie eutaxitic rocks of the Lower Welded Tuffs. In the Amogong stream at the northern boundary of the Olenguruone Settlement Area, grey and yellowish lapilli-tuffs contain angular fragments of pumice 12 mm across.

Origin of the Ndorroboni Agglomerates and Chapaltarakwa Lapilli-Tuffs - Agglomerates and lapilli-tuffs with uncollapsed pumice fragments are not necessary ash-fall deposits. Smith (1960B) draws attention to zonal variations in welded ash flows, pointing out that deposits with uncollapsed pumice frequently occur between basal and upper zones showing strong eutaxitic textures. The agglomerates and lapilli-tuffs described here separate beds of eutaxitic tuffs (the Lower and the Upper Welded Tuffs) so the deposits with angular fragments are provisionally regarded as rocks in a zone of little or no collapse in the core of a single ash flow unit.

Though it was beyond the scope of the present work to measure the flattening ratios of pumice fragments in the Mau Tuffs, a detailed investigation of this sort, along the lines described by

Peterson (1961), might assist considerably in correlation of ash-flow tuffs. The method is likely to be particularly useful in an area like the Mau, where a correct interpretation depends to large extent on a comparison of successions established in separated valley sections.

(c) Upper Welded Tuffs (Tvf5 and Tvf5')

(1) Eutaxitic tuffs (Tvf5)

Eutaxitic welded tuffs some 50-100 feet thick crop out extensively in the north-eastern quarter of the Mau area; they have been separated on the geological map from very similar rock types already described because they appear to occupy a higher stratigraphical position in the pyroclastic succession. Between Chapaltarakwa and Mau Narok, many excellent stream exposures show eutaxitic tuffs overlying yellow and yellow-brown lapilli-tuffs (the Chapaltarakwa Lapilli-Tuffs) that are characterized by small, sub-angular pumice fragments. Repetitions of these two distinctive rock types in individual stream sections is attributed to a south-westerly dip of the beds at about the average stream gradient; the alternative explanation involves postulating several alternating beds of eutaxitic tuff and yellowish lapilli-tuff, but this has been rejected in view of the approximately co-planar nature of the contact between the two rock types over an appreciable area. Some lapilli-tuffs do overlie the eutaxitic bed, but at several localities it can be demonstrated that these rocks grade upwards into friable ashes, and they are to be regarded as a basal bed of the Pleistocene ash succession and hence probably of ash-fall origin.

The correct stratigraphic position of some eutaxitic tuffs that crop out between Olenguruone and Keringet Estate is not easily determined, but for the purposes of this report all the eutaxitic rocks west of the Olpusimoru stream (a tributary of the Amala river) are referred to the Lower Welded Tuffs, because they are widely overlain by pale grey or mauvish-grey devitrified welded tuffs, and because no underlying yellowish lapilli-tuffs were encountered.

On the other hand, a 30-foot-thick bed of eutaxitic tuff, forming a small scarp overlooking the Ndorroboni stream near the southern boundary of the area, is tentatively referred to the Upper Welded Tuffs since it overlies the friable Ndorroboni Agglomerates (which may represent an extension of the Chapaltarakwa Lapilli-tuffs of the north-eastern Mau), and these in turn rest on purplish, devitrified welded tuffs.

The rocks constituting the Upper Welded Tuffs are grey to grey-brown eutaxitic ash-flow tuffs; in general appearance, they have much in common with eutaxitic varieties of the Lower Welded Tuffs which have been described in some detail in previous pages. The flattened and aligned pumice lapilli are generally dull, dark grey to black and most commonly 6,0-18 mm long, seldom attaining a thickness of more than 2.5 mm. Larger lapilli, ranging up to 60 mm in length, were seen at a few localities, notably near the Ndorroboni stream close to the southern boundary of the area, and in isolated outcrops of eutaxitic tuffs on the Mau watershed north of the Mau Narok farms. Rocks containing only black, glassy lapilli are rare. Tiny feldspar crystals are visible in most of the tuffs and small rounded or sub-rounded fragments of lava are always present. These lava clasts are generally pale or dark brown and only exceptionally attain a diameter greater than 5.0 mm. The largest lithic clasts were found in the eutaxitic tuffs near the Ndorroboni stream where the rocks bear occasional sub-angular fragments over 25 mm across. Though superficially resembling fine-grained quartzofeldspathic rocks of 'Basement System' origin, the clasts were found to be fragments of a quartz-bearing lava (cf. pantellerite).

Thin sections of the Upper Welded Tuffs show collapsed pumice lapilli, sub-rounded lava clasts and small crystals of pyroxene and amphiboles set in a matrix of ash grade. Some of the pumice lapilli retain evidence of original vesicularity, either in the form of rare circular cavities or, more commonly, as elongate holes in the brown glass. Devitrification of pumice or groundmass is never a prominent feature and is often absent; where it is recognizable, it is represented by brown spherulitic patches in the glass. The commonest crystals are composed of sanidine, though grains of aegirine, kataphorite and cossyrite are present in most of the rocks examined. The majority of the lithic clasts are evidently of phonolitic composition, comprising sanidine laths and micro-phenocrysts together with grains of green soda-pyroxene, cossyrite and kataphorite and sometimes a little unconfirmed interstitial nepheline. The lithic clasts in the tuffs (42/1063) near the Ndorroboni stream are of particular interest since they are of pantelleritic composition. A fragment examined contains euhedral phenocrysts of sanidine and quartz and microphenocrysts of cossyrite in a groundmass of sanidine, quartz, arfvedsonite, aegirine-augite and cossyrite. Jennings (1970) has described quartz-trachytes from the Molo area farther north, but they are evidently younger than the Mau Tuffs so a source for the pantelleritic clasts must lie elsewhere.

(2) Dark porous tuffs (Tvf5')

Poorly-consolidated, dark, porous tuffs, containing numerous tiny feldspars and occasional small pumice lapilli which are never appreciably flattened, are found in stream sections in the extreme north-eastern parts of the area. When damp the rocks are nearly black, but they dry out to shades of dark grey or mauvish-grey; they correspond to the 'porous black ash' described by Jennings (1970) from the south-eastern parts of the Molo area. Jennings regards these deposits as older than the black ashes derived from Menengai (see McCall, 1957, p. 16).

In the Naishi stream, near Likia Forest Station, the porous tuffs immediately underlie eutaxitic rocks (Tvf5), which are in turn overlain by (?)Pleistocene yellow agglomerates and lapilli-tuffs (Plt) described later. Porous tuffs are also overlain by eutaxitic varieties in the Ngare Njoro at the northern boundary of the area, but in the upper reaches of the Makalia Kiboso stream the porous rocks are both underlain and overlain by eutaxitic tuffs. The dark porous tuffs are therefore regarded as intercalations in the Upper Welded Tuffs.

(d) Source and mode of formation of the Mau Tuffs

The Mau area lacks deep gorge or cliff sections which are desirable for a clear understanding of the eruptive mechanisms which produced very extensive sheets of fragmental rocks, many of which are characterized by streaky, eutaxitic textures. Stream dissection on the flanks of the Mau Range proceeded rapidly through a thick cover of poorly-consolidated Pleistocene volcanic ashes, but downcutting was checked by underlying beds of relatively tough eutaxitic rocks (the Mau Tuffs) which are exposed therefore only in the lower parts of valleys. Studies of vertical variations in the tuffs depend to some extent on correlations between one stream section and another, and any horizontal gradations can only be investigated by traverses along the bottoms of the valleys which are frequently choked by dense vegetation. Despite the drawbacks presented by discontinuous exposure of this sort, it is nevertheless possible to offer some comments on the probable mode of formation of the Mau Tuffs.

Various criteria have been described (e.g. Ross and Smith, 1961) to assist in the identification of ash-flow tuffs, and many of these features are recognizable in the Mau area. The pyroclastic character of nearly all the deposits jointly described here as the Mau Tuffs is readily apparent in the field and very few of the rocks are likely to be interpreted as lava flows. Pumice fragments show

all stages of flattening and welding, and range from angular and sub-rounded blocks and lapilli (brown, grey or yellowish) to disc-shaped, black glassy lenticles (fiamme). Gradations also exist between glassy discs and fragments which have undergone devitrification; the latter have a stony appearance and tend to merge with the groundmass. The rocks differ from ash-fall tuffs in being non-sorted and non-bedded.

The great areal extent of comparatively thin units of similar lithology supports the concept of an ash-flow origin for the Mau Tuffs. In total thickness, the deposits probably do not exceed 800 feet even in the eastern parts of the area. To the west and south-west they wedge out completely and Pleistocene ashes rest directly on Miocene phonolite. The tuffs clearly covered more than 2,600 km^2 of the Mau area and they are known to extend northwards across a further 2,600-3,400 km^2 in the Molo and Eldama Ravine areas. Outcrops of the Mau Tuffs are largely concealed by ashes in the Rift scarps immediately east of the present area, and their extent in the floor of the Rift Valley is unknown. Deep boreholes near Lake Naivasha (Thompson and Dodson, 1963, pp. 63-64) penetrated rhyolites, trachytes and pyroclastics to a depth of 944 m beneath the Rift floor. Welded tuffs were not distinguished but compact bands reported for instance between about 530-660 m below the surface could well indicate their existence. Flows of fragmental rocks (the Bahati tuffs) of about the same age as those in the Mau area are exposed in the Bahati platform east of Nakuru and they are said to attain a total thickness of at least 300 m (McCall 1967, p. 46). These rocks are regarded by McCall (1965, 1967) as products of froth flows. McCall (1967, pp. 49-59) suggested that both trachytes and associated fragmental rocks may have been derived from a central volcano near Gilgil which was subsequently obscured by later formations. Somewhat similar flows (the Kinangop tuffs) which underlie poorly-consolidated pyroclastics across the Kinangop platform may be rather younger than the Bahati tuffs, but in estimating areas and volumes of possible ash-flow material within the Rift and on its western flanks the Kinangop and Bahati rocks are conveniently included with the tuffs of the Mau, Molo and Eldama Ravine areas. On the other hand, widespread ignimbritic flows east of the Rift Valley are excluded from the present calculations which are not intended to be comprehensive.

Estimates of the areal extent and approximate volumes of ash flows/froth flows in the Mau and surrounding areas are presented in Table 4. The figures are considered to be reasonably accurate for those areas west of the Rift Valley (i.e. Mau, Molo, Eldama Ravine and Narok) where there is generally sufficient exposure to enable the limits of the sheets to be traced with some confidence. Products of ash flows/froth flows are again well exposed across the Bahati and Kinangop platforms which separate the inner graben from the main eastern Rift boundary faults in the Nakuru and Naivasha areas. Similar rocks undoubtedly occur along the greater part of the Rift floor between Suswa and Menengai calderas but are largely obscured there by younger volcanics and sediments of the inner graben. This lack of exposure is reflected in correspondingly greater discrepancies between maximum and minimum values in Table 4 for areas in the Rift floor compared to figures quoted for regions west of the Rift. Throughout the table, the larger values for areal extent and volume are probably more correct.

The Mau Tuffs and their equivalents in the surrounding areas covered some 8,000-15,000 km2 and have a total volume in the range 1,300-2,800 km^3. Pyroclastic flows of about the same age crop out over more than 5,000 km^2 east of the Rift Valley. With an areal extent of perhaps 20,000 km^2 this ash-flow field in Kenya ranks as one of the largest in the world. It should be noted however that greater volumes of pyroclastic flow deposits have been reported elsewhere, e.g. nearly 10,000 km^3 in the San Juan Mountains of Colorado and northern New Mexico (Larsen and Cross, 1952).

Smith (1960A, pp. 817-819) drew attention to a connection between the order of magnitude in

volumes of ash-flow tuffs and the nature of the vents and source areas. In examples that have been well studied, deposits exceeding about 10 km^3 are related to calderas or other major volcano-tectonic depressions, whereas some of the smaller occurrences are associated with domes and open craters. Clearly, subsidence structures are to be expected in the source areas of the Mau Tuffs and equivalent formations.

The general distribution of ash-flow deposits in southern Kenya strongly suggests that the source areas are located in what is now the Rift floor between Suswa and Menengai caldera volcanoes, and in a region around Londiani and Kilombe volcanoes close to the intersection of the east-west Kavirondo trough and the main meridional Rift.

3 Mau Ashes (?Middle Pleistocene)

The Mau Ashes are dominantly unconsolidated, non-eutaxitic, ash-fall types which differ markedly from the ash-flow types of the Mau Tuffs statigraphically below. Although there is no conclusive evidence, they are taken to be Pleistocene solely from their stratigraphic position above the Mau Tuffs. Their high degree of erosion and deep weathering make a Recent age unlikely.

A two-fold lithological and stratigraphical subdivision is proposed:

2 Ashes

1 Basal Lapilli-Tuffs and Agglomerates

(a) Basal Lapilli-Tuffs and Agglomerates (Plt)

At a few isolated localities in the north-eastern parts of the Mau lapilli-tuffs were encountered visibly overlying eutaxitic rocks of the Upper Welded Tuffs. One of the best examples was seen beside the Tukeni stream four miles north of Olokurto, where the lapilli-tuffs rest on pavements of polygonally-jointed eutaxitic welded tuffs which are exposed down into the stream. The lapilli-tuffs at this locality contain powdery, yellowish pumice fragments 6.0-18 mm long set in a brownish-grey ash base; the fragments are somewhat flattened and poorly aligned. In a section exposed in a head-stream of the Seyabei which passes through Granger's farm, Mau Narok, eutaxitic welded tuffs overlie lapilli-tuffs containing small angular pumice fragments. At a locality about three-quarters of a mile south of the bridge carrying the main road, however, yellowish lapilli-tuffs of very similar appearance also overlie the eutaxitic bed. Two miles farther south, near the confluence of the stream mentioned above with the Lolgabunyo river, lapilli-tuffs (containing well-spaced, yellowish pumice fragments, about 6.0 mm across, in a khaki base) are separated from similar rocks exposed in the stream bed by a thin development of eutaxitic rock. The upper lapilli-tuffs evidently grade upwards into ashes. The exposure here indicates a thickness of some 45 feet for the tuffs overlying the eutaxitic bed.

Yellowish lapilli-tuffs exposed in the headwaters of the Naishi stream south of Likia Forest Station contain sub-angular altered pumice fragments up to 25 mm across, and here the rocks overlie eutaxitic members of the Upper Welded Tuffs. In the Makalia Kiboso stream friable, grey and yellow agglomerates bear pumice blocks up to 80 mm across, angular obsidian fragments 6.0-25 mm long, and somewhat angular rock fragments commonly 50 mm across. The rock fragments weathered out from the agglomerates at this locality are mainly of lava (?phonolite), though pieces of eutaxitic tuff were also recognized.

Table 4 Aerial extent and estimated volumes of ash-flow tuffs/froth flows in the Mau and surrounding areas

Region	Minimum area underlain by ash flows/froth flows (km^2)	Maximum area underlain by ash flows /froth flows (km^2)	Estimated average thickness (m)	Approximate volume of ash-flow tuffs/ froth flows (km^3)
Mau area	2,000	2,600	120	250-300
Momo and Eldama Ravine areas	2,600	3,400	150	400-500
Naivasha area	400	3,100	300	100-900
Nakuru area	1,800	2,900	300	500-900
Narok area	650	1,500	60	50-100
Suswa area	250	1,500	50	20-100
TOTAL	7,700	15,000		1,320-2,800

(b) Ashes (Plt)

In the account that follows, fine, friable pyroclastic material is referred to as ash, despite the fact that the deposits frequently display some degree of consolidation or cementation; more correctly, many of these rocks should be described as tuffs, but the writer is of the opinion that less confusion will be experienced if the distinctive term ash is reserved for the friable deposits, to distinguish them from hard welded tuffs and from coarser agglomerates and lapilli-tuffs. Most of the pyroclastic fall material examined in the Mau area is of fine ash grade. The symbol Plt is used to stress a correlation with ashes in the Molo area (Jennings, 1970).

Recognizable volcanic ash is largely confined to the more arid, southern parts of the Mau, where it rests unconformably on a somewhat irregular surface of harder pyroclastic rocks, lavas, and 'Basement System' rocks. In the north-western parts of the area, characterized by very heavy rainfall, the ashes have undergone complete alteration to clays and clayey soils, so that the continuation of the ash cover in that direction can only be inferred from the lack of exposure of phonolites and welded tuffs on interfluves and from various physiographic observations described earlier. Recognizable ashes are seldom encountered in the north-eastern Mau, despite the fact that the annual rainfall figures correspond closely with those recorded in the southern parts of the area. Perhaps the explanation lies in the more even distribution of the rainfall throughout the year in the north-east, a feature that might accelerate alteration processes.

In the south-eastern parts of the area, friable ashes are best exposed in erosion gullies near the crests of the interfluves and in some of the cattle-tracks leading down to the streams. Erosional features such as ledges, caves, spurs and earth-pillars are frequently developed on a small scale in

exposures that are nearly devoid of vegetation. On the steep slopes, over-grazing by cattle and the too-frequent use of tracks, coupled with destruction of the natural vegetation, has led to serious soil erosion problems. The true soil is often only about 30-60 cm thick, capping the pyroclastic deposits. The earthy, poorly-consolidated ashes are commonly reddish-brown or yellow-brown, though grey, off-white and greenish varieties are found at many localities. The better exposures show the bedded nature of the deposits, with fine colour-banding and cross-bedding on all scales often being visible.

Angular obsidian clasts 25-50 mm across are extremely common and artefacts of this material are sometimes found lying loose on the surface or incorporated in the soils; no artefacts were found embedded in the ashes so they can provide only a minimum age for the pyroclastic rocks. Several were collected from the thin soils overlying the ash surface at a locality nearly three miles east-south-east of Rotian trigonometrical beacon. The site lies on a spur defined by the confluence of the Olombori and Enambadad streams. Dr. G. Isaac, formerly of the Centre for Prehistory and Palaeontology, National Museum, Nairobi, kindly examined four artefacts and reported that two are sub-triangular rough bifacial points of generalized Stillbay type; one is a small unifacial point comparable to Magosian types; the remaining one is a broken, rough unifacial point. Dr. Isaac concluded that, though small assemblages of this kind are inadequate for definite determination of cultural status, the material submitted is tentatively assigned to the late Stillbay or Magosian,* and therefore provisionally dated as late Upper Pleistocene. The artefacts were not embedded in the ashes (though they could, of course, have been weathered out from ashes forming the spur), so it can be inferred that the bulk of the ash is older than the late Upper Pleistocene.

Many of the bedding planes are marked by mats of fine feldspar crystals. At some localities, rounded calcareous concretions 50-75 mm in diameter are embedded in the ashes. The significance of rounded pebbles and boulders of welded tuffs that were occasionally encountered high in the ash sequence is not fully understood. They have clearly been transported great distances and perhaps represent accumulations in early abandoned stream courses that became dammed during continued ash falls. A source for the boulders is likely to lie far to the north, in the outcrops of the Upper Welded Tuffs.

The evidence examined suggests that a great deal of the ash was deposited subaerially but detailed work would be required to distinguish waterlain deposits and to determine their importance in the ash sequence as a whole. In the Narok area to the south, Wright (1967) recognized two main groups of ashes; the older ashes are dominantly waterlain deposits which evidently accumulated before the extrusion of alkali basalts of the Seyabei section (and therefore before the formation of the Mau ash-flow tuffs of Pliocene age). The younger ashes in the Narok area (indicated by Wright on his map as 'soils derived from volcanic ashes') are regarded as subaerial deposits and they can confidently be correlated with the ashes on the Mau.

The Mau Ashes attain a maximum thickness of over 750 feet in the Sogo district of the south-western part of the area. They are evidently about 500-600 feet thick in the central parts of the Mau, but they thin to less than 150 feet at the northern boundary. Throughout the greater part of the Mau area, the ashes rest on various members of the Mau Tuffs, though in the north-west they overstep the welded tuffs to lie directly on Mau Phonolite. In the south-western corner of the area, ashes are banked against 'Basement' rocks. Occurrences of eutaxitic tuffs (which are referred to the Upper Welded Tuffs) near the Ndorroboni stream at the southern boundary of the area suggest that the Upper Welded Tuffs once extended over most of the eastern half of the Mau, and that they

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* These names refer to industries which are now either defunct or have undergone reassessment, but the age assigned to artefacts of this type probably remains broadly acceptable (Eds).

were subsequently removed by erosion before deposition of the ashes.

Attention has already been drawn to evidence indicating the flat nature of the original ash surface, and to the asymmetrical form of valleys dissecting the ash cover, their eastern sides being steeper than the western. It is concluded that a gentle eastward tilt of the entire area occurred, probably during Late Pleistocene times.

Extent of the Mau Ashes beyond the present area - Soft volcanic ashes and tuffs of Middle Pleistocene age are described by Thompson and Dodson (1963, p. 11) from the Mau Escarpment, immediately east of the present area. Wright (1967) mapped 'soils derived from volcanic ashes' across a large part of the Narok area south of the Mau, and Jennings (1970) shows Pleistocene bedded ashes with basal tuffs in the Molo area to the north. The main problem, therefore, lies in determining the extent of the Mau Ashes to the west of the Molo, Mau and Narok areas.

Schoeman (1949, p. 27), in a report describing the geology of the Sotik district west of the Mau, referred local developments of ashes and tuffs to the Tertiary, claiming that the pyroclastic rocks are interbedded with phonolites; the ashes and tuffs were not differentiated on the map. The present writer encountered ashes, partly altered to clays, forming interfluves at several localities in the south-eastern parts of the Sotik area. Near the Chepkositoni stream (35°28' E, 0°45' S), for example, phonolite is overlain by several hundred feet of friable ashes. Furthermore, typical Mau ashes overlie phonolite in the Nyangoris river at Bomet (35°21' E, 0°47' S) and weathered material, probably derived from volcanic ash, was seen at the roadside about six miles east-north-east of the Sotik township.

Volcanic ashes overlie phonolite near the eastern boundary of the Mara river area (Williams, 1964b), and it is likely that the dark soils mapped in the north-eastern quarter of the same area are derived from an extension of the Mau Ashes.

In a description of the soils in the Kericho area (north of the Sotik area), Binge (1962, p. 40) notes that 'a particularly deep soil-cover is characteristic of the interfluves of Kericho phonolites'. He draws attention to a driller's log recording 175 feet of soils and clay overlying lava, and concludes that the so-called clay represents weathered phonolite. The writer considers it more likely that the clays encountered in the borehole under discussion are altered volcanic ashes. Binge (1962, p. 42) also describes a number of caves in the south-western parts of the Kericho area, 'hewn artificially in what appears to be a grey powdery ash or light volcanic tuff'. Though Binge doubts the existence of a widespread ash horizon (evidently considering only the possibility of pyroclastic material intercalated in phonolites) it is perhaps possible that some of these caves occur in an extension of the Mau Ashes.

A detailed investigation would be required to define precisely the westward continuation of the Mau Ashes, but it seems likely that a thinning cover can be expected as far west as the meridian 35°10' E.

4 Ages and Correlation of the Mau Pyroclastic Rocks

No direct and conclusive evidence of the ages of any of the pyroclastic rocks is forthcoming from the Mau area, and those suggested depend not only on tentative correlations with neighbouring areas, but also to some extent on the reassessment of evidence in the Narok area described by Wright (1967).

The Lower Welded Tuffs (basal members of the Mau Tuffs) of the Seyabei section extend a few

miles southwards into the Narok area to overlie alkali basalts near Seyabei Mission. Wright (1967, p. 8) referred these alkali basalts to the Lower or Middle Pleistocene, and noted that the basaltic flow is overlain by tuffs and ashes which are in turn capped by orthophyre-trachytes near Angata Naado. Attention was drawn to the similarity between the Angata Naado trachytes and Lower Pleistocene orthophyre-trachytes forming the Rift floor farther east (see Baker, 1958, p. 21); but, despite this similarity, a Middle Pleistocene age was preferred for the Angata Naado lavas. On the evidence described by Wright, the writer (Williams, 1964a, p. 46) favours a correlation of the Angata Naado and Rift floor orthophyre-trachytes, thereby placing both the alkali basalts and the intervening pyroclastic rocks (the Mau Tuffs) in the Pliocene. From the results of recent mapping along the Rift scarps south-east of Narok, Randel (in press) supports the correlation suggested above.

Further support for assigning the Mau Tuffs to the Pliocene comes from a consideration of likely correlations with areas farther north, and a comparison with successions established on the eastern side of the Rift Valley. Jennings (1970) correlates the Tinderet, Elburgon, Londiani and Mau Tuffs and, together with the Kedowa Tuffs, refers all these rocks to the Pliocene, regarding them as younger than the Miocene Kericho Phonolite but older than the Tinderet Phonolite and the Londiani and Kilombe trachyte and quartz-trachyte (?Plio-Pleistocene).

McCall (1957, p. 5 and Map 1) correlated the Bahati tuffs (welded trachytic tuffs with intercalated yellow pumice tuffs) of the Nakuru area with similar pyroclastic rocks seen in the Mau Escarpment; a Miocene age was tentatively suggested for all these rocks, since the welded tuffs overlie the Solai Phonolite north of Mbaruk and at Solai.

Petrological similarities in the Mau and Nairobi areas are of interest in attempting a correlation with successions established east of the Rift Valley. In petrography and general appearance, the purple and grey, devitrified welded tuffs (the middle members of the Lower Welded Tuffs) closely resemble the well-known Nairobi Stone (a building stone from the Kerichwa Valley Tuffs of Pliocene age). Eutaxitic tuffs and yellowish lapilli-tuffs also occur within the Kerichwa Valley Tuffs, enhancing the similarity between the pyroclastic rocks of the Nairobi and Mau areas.

In the Naivasha area, Thompson and Dodson (1963, p. 11) found the Mau Escarpment to be composed predominantly of soft volcanic ashes and tuffs, which were assigned to the Middle Pleistocene. They (pp. 36-37) reported compact grey agglomerate forming a prominent bluff at one locality, and also described a bed of welded tuff which occurs in the lower slopes of the escarpment east of Mau Narok. The welded tuffs were evidently regarded as an intercalation in the deposits forming the bulk of the escarpment and were also referred to the Middle Pleistocene. The volcanic ashes and tuffs are clearly to be correlated with the Mau Ashes of the present area, but the possibility that the agglomerates and welded tuffs represent older rocks mantled by ashes should be considered. From observations in the present area, representatives of the Mau Tuffs are likely to crop out in the fault scarps to the east, but evidence from the Mau Narok district suggests that a great deal of volcanic ash was deposited during or after the faulting and that stratigraphic relationships between ashes and welded tuffs are not always clear because ashes tend to form a veneer over pre-existing scarps.

VII ALLUVIAL AND SUPERFICIAL DEPOSITS

1 Alluvial Deposits of the Uaso Ngiro

Brown clayey or sandy alluvial deposits occupy the lower Uaso Ngiro valley and the upper and lower parts of the Ndorroboni course. The Uaso Ngiro has now cut steeply down some 40 feet into the alluvium without exposing solid rock. Deposits of this sort were not encountered in any quantity elsewhere in the area and the developments in the Uaso Ngiro drainage system are attributed to temporary damming of the river, probably near the Rift scarps south-east of Narok, in Late Pleistocene times. The deposits are often bedded, and small rapids have developed locally over lateritic beds up to 150 cm thick. Boulders and pebbles in the alluvium near Ololonga are dominantly of phonolite, but boulders of lapilli-tuffs occur in the deposits near Eoutoud. Away from river sections, the boundary between alluvium and volcanic ashes cannot be located with any accuracy, and the line shown on the map is based mainly on the change in slope from the old alluvial flats.

2 Superficial Deposits

Extensive tracts in the more open parts of the southern half of the area are covered by brown and greyish-brown loams derived from volcanic ashes, though black clayey soils are well represented. Pale grey calcareous beds in the extreme south-west, between Kuto and Ngorengore, may have been derived from calcareous beds in the ash sequence, suggesting that deposition there perhaps took place in lakes and that the deposits might be better classified as sediments; exposures, however, are too poor to provide the critical evidence.

In the more densely forested parts of the Mau, the soils are dominantly reddish varieties. Complete decomposition of the Mau Ashes in the regions of heaviest rainfall is indicated by a thick cover of red clays in the northern parts of the area. This contrasts strongly with the situation along the southern fringes of the forest belt, where soils are sometimes little more than 30 cm thick and recognizable ashes are exposed in cattle-tracks.

Reddish-brown soils overlie 'Basement System' rocks near the Amala river. More sandy varieties are found across the quartzite hills farther south.

The various soils have not been indicated on the geological map, for there is sufficient evidence to show that most of the superficial deposits in the area were derived from the Mau Ashes or from 'Basement System' rocks, so the solid geology can be presented with a fair degree of accuracy.

IX STRUCTURE

1 Structures in 'Basement System' Rocks

Complex 'Basement System' structures have been described from areas south and south-west of the Mau (e.g. Williams, 1964b), where early NE-SW folds are affected by later NW-SE structures. Furthermore Schoeman (1949, p. 34) found that although fold axes in the Sotik area trend dominantly NE-SW, local changes to an E-W direction occur, and these were attributed to refolding.

Very little additional information on Precambrian structures was expected or obtained from the Mau area, where 'Basement System' rocks crop out only in the extreme south-west. The strike of foliation in both quartzites and biotite gneisses is generally NE-SW and of the few lineations and minor folds encountered, most plunge to the NE or ENE. A single lineation in quartzite at Kuto plunges steeply to the ESE and may be related to a later period of folding.

A change in the direction of dip of foliation between the Amala river and Olmirani indicates the continuation of an anticline shown by Schoeman (1949). There is no evidence to determine whether the quartzites at Olmirani and Kuto belong to a single band repeated by folding.

2 Structures in Tertiary Volcanic Rocks

Perhaps the most striking feature of the Tertiary geology of the Mau area is the extensive outcrop in valleys, of a few comparatively thin beds of welded tuff. The distribution of the various beds would undoubtedly be even more spectacular were it not for the thick mantle of Pleistocene ashes (the Mau Ashes) which largely conceal the Tertiary outcrop pattern. The overall impression gained from traverses of stream sections is that the Tertiary pyroclastic rocks (the Mau Tuffs) dip to the SSW at approximately the average stream gradient, with the inevitable result that streams frequently flow in individual members of the sequence for considerable distance.

Table 5 gives an indication of the SSW gradients of the Mau Tuffs in various parts of the Mau area. The figures are necessarily tentative. In the first place, they often depend entirely on the accuracy of correlation between sections recorded in separated valleys. Secondly, the possibility of faulting has been ignored. Thirdly, it has not been possible to provide sufficient altitude measurements on the base of the bed or formation concerned to allow accurate drawing of strike lines. Nevertheless, the figures probably give a reasonable indication of the gradients involved.

It is perhaps significant that the lowest figure refers to the oldest tuffs, and the highest to the youngest Tertiary tuffs in the area. This might be attributed to an expected north-easterly thickening of the Mau Tuffs, or alternatively it might indicate a steepening of the dip in the north-eastern parts of the area, i.e. towards the main faults mapped.

The Mau Tuffs rest on Miocene phonolite, and locally on Precambrian 'Basement System' rocks, in the western parts of the Mau. The thickness of the phonolite sheet is unknown but the lava clearly flowed across a tilted sub-Miocene erosion bevel in areas south-west of the Mau, so that a projection of this surface (it slopes at about 35 feet per mile in the Mara river area) into the present area is likely to provide an approximate elevation for the base of the phonolite, at least in the south-western corner of the Mau. The phonolite gives every indication of having been derived from

the Mau area and is likely to thicken to the north-east, so that the top of the lava sheet (i.e. the surface across which the Mau Tuffs flowed) can be expected to have a gradient of 45 feet per mile quoted above for basal beds of the Mau Tuffs in the south-western parts of the area. The Mau Tuffs thin and eventually wedge out when traced to the west and south-west, so they are believed to have originated in or near the north-eastern corner of the Mau area.

The main structural problem, therefore, lies in deciding whether the south-westerly inclination of the welded tuffs is a depositional or a tectonic feature, or a combination of both. Evidence from other parts of south-western Kenya shows that marked anticlinal warping of the sub-Miocene surface occurred before extrusion of late-Tertiary lavas (i.e. probably during Miocene times), though additional tilting of the bevel and overlying volcanic rocks may have taken place much later.

Table 5 SSW gradients of the Mau Tuffs

Stratigraphic unit	Area	Gradient (ft/mile)
Purplish devitrified tuffs (Tvf_2)	South east quarter	90-120
Devitrified tuffs (Tvf_2)	North west quarter	85
Eutaxitic welded tuffs (Tvf_1)	South west quarter	45
Upper Welded Tuffs (Tvf_5)	North east quarter	150
Upper Welded Tuffs (Tvf_5)	Mid north east quarter to southern boundary near the Ndorroboni river	90

3 Pleistocene Movements

Attention has already been drawn to a suspected gentle eastward tilt of the entire area. This evidently occurred after the development of an early drainage pattern on the surface of an extensive ash cover tentatively dated as Middle Pleistocene. The tilting must have taken place at an early stage in stream incision to have produced the present valley forms, which indicate a steady eastward or south-eastward migration of the streams as they cut down rapidly through the ashes.

4 Faults

Several NNW-trending faults in the Mau Narok district are inferred from topographic and meagre stratigraphic evidence.

The most easterly of the three faults shown on the geological map marks the foot of a prominent scarp some 500 feet high; it clearly represents a continuation of the system of Rift boundary faults mapped in the Naivasha area (Thompson and Dodson, 1963, p. 50). Few reliable exposures of Tertiary rocks were found in the fault scarp, which is mantled by a thick cover of Pleistocene ashes. Eutaxitic tuffs that were encountered at several localities are tentatively assigned to the Upper Welded Tuffs (the upper division of the Mau Tuffs), while lapilli-tuffs and agglomerates which visibly overlie the welded rocks are probably basal beds in the Pleistocene sequence.

The second fault evidently downthrows the Upper Welded Tuffs about 500 feet to the east. It is marked by a scarp west of Likia Forest Station but probably dies out farther south. The third fault,

the Ngare Njoro fault, flanks the ridge which forms the highest part of the Mau, and may have an eastward downthrow of over 1,000 feet (see section C, attached to the geological map). There is no topographic expression of this fault at Enteani, but an inferred fault (Fig. 2) at Mbatebat, south of Mau Narok, may be a continuation of the Ngare Njoro fracture. The northward extension of the fault is to be found between Mariashoni and Nessuit Forest Stations in the Molo area (Jennings,1970).

Though the age of faulting cannot be precisely determined from evidence displayed in the Mau area, the main movements evidently occurred after the formation of the Mau Tuffs (Pliocene) and before, or during, deposition of the Mau Ashes (?Middle Pleistocene).

Thompson and Dodson (1963, p. 51) concluded that the bulk of the faulting in the Naivasha area took place in late Middle Pleistocene times. Jennings (1970), on the other hand, suggests that porous black ash (undoubtedly to be correlated with the dark porous tuffs Tvf5' of the present survey) was derived from fault fissures or vents aligned along them, the inference being that some faulting occurred in late Tertiary times. The suggested correlation of trachytes at Angata Naado, in the Narok area, with Lower Pleistocene orthophyre-trachytes forming the Rift floor farther east presupposes major fault movements in post-Lower Pleistocene times. Lack of agreement over the age of faulting in this region is perhaps to be expected, for rejuvenation of faults is a feature of the Mau and Ngurman escarpments and movements are likely to have occurred from mid-Tertiary times onwards.

X ECONOMIC DEPOSITS

The Mau cannot be expected to rank high among areas likely to yield minerals or rocks of economic value. The present survey not only confirmed the dominantly volcanic nature of the rocks exposed, but in addition it proved the existence of a thick ash cover; this, unfortunately, must be regarded as a feature which further reduces the likelihood of locating or exploiting economic deposits. Other factors that hamper prospecting are the densely forested nature of the Mau, the lack of communications over much of the area, and to some extent the high rainfall.

1 Building Stone

Though not greatly in demand at present, the most promising material of economic importance in the Mau area is bulding stone; it occurs exclusively in the Mau Tuffs.

Various tuffs have been quarried at scattered localities for building purposes. In the Mau Narok district only members of the Upper Welded Tuffs are available, but good use has been made of eutaxitic tuffs in the construction of farm buildings. The intercalated dark porous tuffs (Tvf_5') are generally unsuitable as building stone owing to their poorly-consolidated nature and their tendency to become quickly saturated under damp conditions.

At Olkiuliamon, dark friable tuffs (Tvf_3') were selected to build the Administration rest house. The stone was probably chosen because of the ease with which it can be dressed, and the house will provide a useful indication of the wearing properties of this type of material.

Building stone comparable in appearance and quality to the much-used Nairobi Stone (devitrified welded tuffs of the Nairobi area) are abundantly available in the north-central and south-eastern parts of the area, and similar good quality stone also occurs in the Ndorroboni stream. All the purple and grey devitrified tuffs (Tvf_2) are likely to be highly suitable for building purposes. In the Olenguruone Settlement Area, the rocks are quarried near the Ambosket stream west of Olenguruone village; near the Amala river east of Olenguruone; and also farther upstream at its confluence with the Absege. At Enabilibil, midway between Narok and Mau Narok, pale purplish devitrified tuffs are quarried on the western side of the Seyabei valley for local buildings.

Until there is a greatly increased demand for building stone, quarrying problems are unlikely to arise, and shallow excavations along valley outcrops will yield sufficient material. The thickness of overburden varies considerably from one part of the area to another. It depends not only on the thickness of the Mau Ashes but also on whether middle and upper members of the Mau Tuffs are represented, where a marked asymmetric valley cross-section is apparent, quarrying is best carried out on the gentler western slopes.

2 Volcanic Ashes

Large quantities of volcanic ash are available in and around the Mau area. It is possible that careful prospecting and testing of the deposits might lead to the discovery of material with marked pozzolanic properties, but the demand for such material is likely to be small. In any investigation of the Mau Ashes, it should be remembered that advanced stages in decomposition to clays will mark deposits in areas of high rainfall.

3 Roadstone

The construction of all-weather roads through the Mau area would entail the use of large quantities of stone. Lavas, such as trachytes and phonolites, have been utilized successfully as roadstone in many volcanic areas in the country, but lava outcrops in the Mau area occur mainly in western districts and are generally inaccessible. Some use could be made of phonolite in the western part of the Olenguruone Settlement Area, and the phonolite inlier in the Sigindirr (Ngusur) river at Rotian might yield a limited supply of material for surfacing the Narok-Mau Narok road. Further sources of phonolite could be found not far beyond the southern boundary of the present area. Though the phonolites are likely to be superior to most of the pyroclastic rocks for road works, the stone suffers from an objectionable splintery fracture owing to its fine-grained nature.

Should supplies of roadstone be required for improvements to the Ololonga-Ol Eshepani track, the ankaratrite at Ndunyagerro would supply extremely durable stone, and is easily approached by vehicle. An alternative source of material could probably be found in phonolite outcrops near Ololonga, beyond the southern boundary of the Mau area.

Since it is unlikely that lavas will prove to be adequate or convenient sources of stone for extensive road works, the various pyroclastic rocks in the area will probably have to be utilized. In general, the eutaxitic tuffs and less friable types of purple and grey devitrified tuffs will clearly be superior to other members of the Mau Tuffs and to the Pleistocene rocks. Some difficulty can be anticipated in providing vehicle tracks to quarries opened in the lower parts of valleys, particularly in the deeply-dissected portions of the area.

4 Water

The Mau area is well supplied by permanent rivers and streams and the only problem likely to be encountered will be the pumping of water to higher ground if large volumes are ever required.

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