THE GEOLOGICAL HISTORY OF THE RIFT VALLEY

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When in May, 1893, I camped on the unoccupied site of Nairobi, I little thought that, twenty-six years later, I should find it transformed into the capital of a vigorous and flourishing colony, and that I should have the honour of addressing here a Natural History Society which has already taken a good place among the scientific societies that have added so greatly to the knowledge of the Empire and its resources. Still less did I imagine when, a few weeks later, I decided to suggest 'Rift Valley' as the technical term for the type of valley between Naivasha and Baringo, that the name would be generally adopted for the district and used in the 'Rift Valley Hotel' and 'Rift Valley Club.'

The problem which mainly attracted me to British East Africa in 1892 was the nature of the valley which crosses the country from Lake Rudolf to Lake Magadi, and which I followed, in 1893, from the Kedong to Lake Baringo. It had long been recognised that a valley of an unusual type extends from the Jordan and the Dead Sea through the Gulf of Akaba into the Red Sea. The exploration of East Africa led to the discovery of a series of long fiord-like lakes and valleys, with many features similar to those of the basins of the Red Sea and Dead Sea. The conclusion that the Jordan-Red Sea valley was continuous with that of the fiord-like lakes of equatorial Africa was adopted by Professor Suess, after the discovery of Lakes Rudolf and Stephanie by Count Teleki and his gifted companion von Höhnel. Suess suggested that the basins of the Red Sea and the long lakes of East Africa were all parts of an almost continuous trench which extends from Galilee to the Zambesi.

Some doubt was expressed as to this conclusion: I was therefore glad in 1892 to accept an invitation to visit East Africa. When the collapse of the large expedition with which I came out left me to make fresh plans, I resolved to examine the country round Lake Naivasha at the highest part of this trench, and also around Baringo, its next fresh-water lake to the north.

The journey along the valley from the Kedong to Baringo, and examination of its walls convinced me that it had not been carved out by rivers and rain and wind, but was directly due to earth-movements—that is to say, it is a tectonic valley and not a valley of excavation.

The existence of tectonic valleys was distrusted by the then orthodox school of British geology, according to which, valleys are scooped out by the geographical agents that act on the earth's surface. The discussion of a recent paper by Mr. Parkinson on Lake Magadi shows that some authorities doubt whether earth-movements along faults and fractures ever give rise to cliffs and valleys. According to that view, the earth is an inert mass, on which the surface features are incised by such agents as rivers, glaciers, rain, wind, and the surf along the coasts, or are built up by piles of volcanic materials. The earth's crust is regarded as having no more share in producing the ups and downs on its surface—other than those produced by wave-like foldings of the crust—than a block of marble shares in the development of the features which are being carved on it by a sculptor.

According to the alternative view, the earth is not a mere impassive mass: its crust constantly pulsates under movements of its own; its surface heaves and falls in response to internal influences; and it is owing to these crustal movements that the earth remains suitable for the home of man.

The adoption of the latter view has been largely aided by the evidence of the Great Rift Valley, which is now generally accepted as due to a long strip of the earth's crust, extending from northern Palestine to southern Portuguese East Africa, having foundered between a series of parallel fractures.

The majority of valleys are no doubt valleys of excavation.

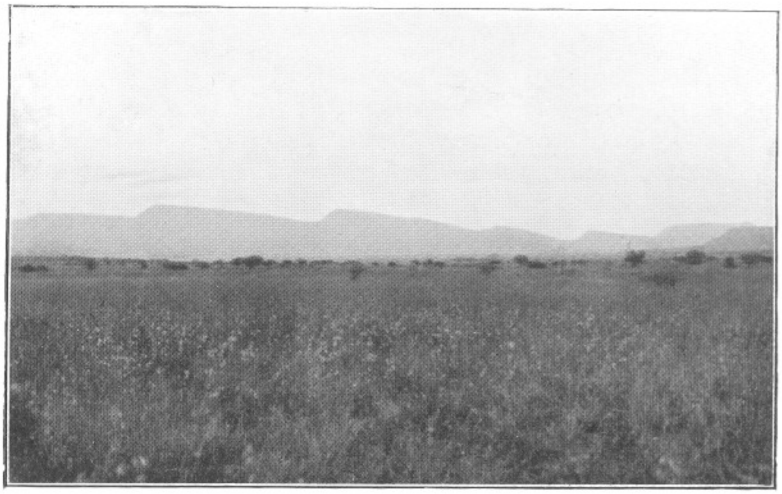

Fig. 1.—THE FAULT-BLOCKS EAST OF CATHEDRAL PEAK FROM THE KEDONG VALLEY.

Cathedral Peak is seen to the extreme right, over a fault-block, west of the Kedong; the hills to the south are composed of lava tilted down to the west (the right of the photograph) by six parallel faults. The hills consist of trachytic lavas and tuffs.

Photographed by Capt. H. L. Sikes.

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The rocks along them have been removed particle by particle by streams or rain or wind. The material that formerly filled the valley has been removed as a railway contractor removes the material from a railway cutting. In a rift valley, on the other hand, the material has not been removed piecemeal, but the block that filled the valley has sunk between two series of fractures known as faults; hence the floor consists of the material that originally stood at the level of the plateaus on either side of the valley.

River-worn valleys and rift valleys have distinctive features. River-cut valleys, owing to the eddying flow of water, are usually sinuous: their banks run in graceful curves; their sides project in spurs, and those of the opposite sides appear to overlap when looking up the valley. Moreover, masses of resistant materials remain as foothills in front of a river-cut bank or cliff. The views among the Kikuyu Hills, or from the summit of Mau westward down the valley toward Londiani and Lumbwa, are local examples of typical river-cut landscapes.

A rift valley, on the other hand, is essentially trough-shaped: its walls are predominantly straight and even, and they meet the valley floor like the banks of a railway cutting. The walls have no spurs except where they have been notched by gullies, and the original scarps have been replaced by stream-made ravines and spurs. The cliff-like bank of a rift valley may cut across the country quite regardless of the grain of the rocks, and in this respect resembles a sea cliff more than a river bank; but there is no possibility that the sea has eaten out the rift valley across British East Africa.

The only available explanation of the formation of this valley is that its floor has sunk between more or less parallel fractures.

The preparation of a section, in 1893, across the Rift Valley, near Lake Baringo, convinced me that only thus could its features and structure be explained. The parallel fractures as occurring south of the Kedong basin are illustrated by Mr. Sikes's photograph (Fig. 1).

The subsidence which made the Rift Valley was not a sudden complete collapse, like that to which tradition ascribes the origin of the Dead Sea and the destruction of Sodom and

Gomorrah. Sudden movements have no doubt taken place in East Africa—such as that which is reported to have made the Simbi Crater, to the south of Kavirondo Gulf, in a single night, and to have destroyed the inhabitants, with one righteous exception, in punishment for their inhospitality. There have probably been volcanic explosions in the Rift Valley of world-shaking violence. The formation of the Rift Valley itself was, however, not one swift catastrophe, but a long, slow process which lasted for millions of years and may not yet be complete. The process was probably not continuous: there were doubtless long breaks, during which the movements ceased; and we may now be in one of the quiet intervals.

The history of the Rift Valley may be compiled either with the interpretation that it has had a short history (all post-Miocene) or that its history is long and complex and extends to pre-Miocene times. The latter is the conclusion to which I was led, twenty-five years ago, and to which the evidence as a whole seems to point.

As in British East Africa the rocks along the Rift Valley are mainly volcanic, and there is a complete absence of rocks formed in the sea, its history depends on the history of volcanic action in the adjacent country. A volcano, it should be remembered, is not a burning mountain, but a vent through which subterranean plastic material can escape to the surface, when squeezed out by earth pressure. If you press in the sides of a kerosene-tin the oil escapes from any weak point along the seams. And if a block of the earth's crust sinks, the plastic rock below will tend to rise along the fractures around the sinking block and may be discharged at the surface in a volcanic eruption.

The first stage in the formation of the Rift Valley was the elevation of the country along it into a low, broad arch, which would have formed a belt of down-like highlands, ranging across British East Africa from north to south. In the second stage the lateral pressure was reduced, the sides of the arch cracked, and the blocks along the highest line sank as the key stone of a bridge sinks if the buttresses give way. The sinking of the great block which formed the keystone of the East African arch exercised heavy pressure on the underlying plastic material, which was forced up the weakest points along the adjacent cracks and produced a series of volcanic eruptions.

To determine the dates of these events it is necessary to consider the structure of East Africa in relation with that of the adjacent parts of the Indian Ocean. We must go back to the time when East Africa and India were both included in one great tropical continent, which extended from Brazil on the west to Australia on the east. This continent is known as Gondwanaland—a named based on that of the Gonds, a tribe who inhabited a part of India where the deposits of this land are well preserved. Gondwanaland existed through the Carboniferous Period, during which was formed all the world's chief coal-fields. The fresh-water shells which I collected on the Sabaki, in 1893, are the only Gondwana fossil animals yet found in British East Africa, and from their evidence it is probable that the sandstones of the Taru Desert were deposited on the ancient continent of Gondwanaland.

This continent continued through the two periods after the Carboniferous—the Permian and Trias; so that no marine beds belonging to them were deposited in tropical or southern Africa.

In the next period,[1] the Jurassic, Gondwanaland began to break up: the sea invaded the coastlands of India and of East Africa around Mombasa, Malindi, and the Juba.

The Mesozoic marine deposits are less varied in British than in German East Africa, where they are famous, as they have yielded the remains of *Gigantosaurus*—so far as is known, the biggest animal that has ever walked on land.

The marine fossils found on the mainland near Mombasa

[1] For convenience of reference, the names of the later geological periods and their English representatives may be summarised as follows:

Pleistocene.—The period from the present to the Great Ice Age.
Pliocene.—The period including the Crag beds of Suffolk.
Miocene.—The period of the main elevation of the Alps, and represented in East Africa by the *Dinotherium Hobleyi* beds of Kavirondo.
Oligocene.—The period including some beds along the Solent and the Amber forests of the Baltic and the Nari beds of India.
Eocene.—The period including the London Clay.
Cretaceous.—The period of the Chalk.
Jurassic.—The period of the Oolitic limestones.

belong to a Mediterranean fauna, and doubtless reached East Africa from the north. The fossils in the upper Cretaceous deposits of Mozambique, which were laid down at the same time as the English Chalk, are allied to those of southern India, and indicate that the sea in which they lived invaded East Africa from the south. These Mozambique fossils further show that a land connection still existed between India and East Africa—probably along the line of the Seychelles and Maldives.

The Jurassic rocks were laid down quietly on the bed of the sea, and their deposition was undisturbed by volcanic eruptions; but the more active earth movements in late Cretaceous times, and the foundering of the floor of the Indian Ocean between East Africa and India, led to volcanic outbreaks in western India on a colossal scale.

These eruptions discharged the lavas (basalts and trachytes) known as the 'Deccan Traps,' which cover over 200,000 square miles in western India, and perhaps an equal area now buried in the Indian Ocean. The age of the eruptions is fixed as Upper Cretaceous (Upper Senonian and Danian) by the fossil frogs found in the old lake beds, preserved among the lavas in Bombay, and by the shells of the Pab beds.

If the formation of the Arabian Sea led to such violent volcanic activity in India, it is natural to expect some corresponding events in East Africa, on the other side of the foundered land; and the beginning of the volcanic period in East Africa may prove to have been simultaneous with that of India.

The oldest modern lavas in eastern Africa appear to be those of the Athi and Kapiti Plains; they consist of a rock named phonolite, as thin slabs of it give a clear musical note, and are used for rock harmonicons. Its chemical characteristic is its richness in soda. Mount Jombo, south-west of Mombasa, consists of igneous rocks which are apparently intrusive in the Jurassic beds; and if so, they are not earlier than the Cretaceous. These Jombo rocks, I described, years ago, from specimens collected by Mr. Hobley, as nepheline-syenites, and they have strong chemical affinities to the phonolites.

The phonolite of the Kapiti Plains is clearly of considerable geological antiquity, for all the craters through which it was discharged have been swept away; but, here and there, on the plains, are low circular elevations gently sloping outwards in all directions. These rises are probably the vents through which the lava was discharged.

The phonolite of the Kapiti Plains may be regarded as material squeezed from below the crust by the sinking of the floor of the Indian Ocean.

The subsidence of the ocean was probably accompanied by the uplift of British East Africa into a vast low arch; and as the country settled after these two associated movements the centre of the arch was insufficiently supported and sank between a series of parallel fractures. This subsidence was the first of the movements which formed the Rift Valley.

That this movement may have begun as early as the Oligocene is indicated by a fossil sea-urchin (an *Echinolompas*) in the British Museum, which probably came from Lake Nyasa; and, if so, this fossil indicates that the sea occupied the southern end of the Rift Valley in Oligocene times. The evidence of this fossil is somewhat doubtful, since its exact locality and discoverer are not known. Moreover, Messrs. E. O. Teale and R. C. Wilson have shown that the Rift Valley faults which continue those of the Nyasa basin, south of the Zambesi, are there post-Eocene, and their collections give no evidence of any post-Eocene marine beds in the southern end of the Rift Valley.

That the volcanic history of British East Africa began before the Miocene is indicated by the evidence of the augite andesite of Kikongo to the east of the Victoria Nyanza. Some lake beds in the same province have yielded the bones of a primitive elephant—a species of *Dinotherium*, which has been appropriately named *D. Hobleyi*. Its age is Miocene, and Dr. Oswald has shown that the lake beds containing this fossil are earlier than the basalts and phonolites of Lumbwa, but younger than the augite andesite of Kikongo and the volcanic agglomerate of Metamala.

If this augite andesite is the same age as the augitic lavas of the Rift Valley, then they also are pre-Miocene; and the phonolites of the Kapiti Plains must be much older than the Miocene. Otherwise, if we accept the conclusions that the augite andesite of Kikongo is a very ancient lava, which has nothing to do with the modern volcanic series, and that the phonolites of Lumbwa are of the same age as those of the Kapiti and Athi Plains, all the phonolites in the country were discharged after the Miocene. The whole volcanic history of British East Africa would then be confined to the post-Miocene, and the oldest of the volcanoes would be Pliocene. It seems to me impossible that the whole volcanic history of British East Africa can be restricted within so short a time.

The evidence of Mount Kenya is illuminating in this respect: Kenya is an old volcano in a very advanced stage of decay. Its peak appears from a distance as a mere rock pinnacle on the summit of a vast mound. Teleki, impressed by the curved, smoothed form of the valley subsequently named after him, regarded that as the extinct crater. But the crater of Kenya was long since destroyed. The mountain was at least 3000 feet higher than it is now, and as it was worn down the crater was swept away.

The peak is the plug of lava which solidified below the floor of the crater and choked up the throat of the volcano.

The weathering of the volcanic rocks around the plug has produced two different types of rock scenery: there are rough crags and pinnacles due to ordinary subaerial denudation; there are smooth, rounded rock surfaces and blunted summits due to the abrading action of glaciers. The glaciers of Kenya were once more extensive, and flowed down the mountain for several thousand feet below their present level.

The contrast between the jagged rocks, due to ordinary denudation, and the smooth slopes worn by the glaciers, are well shown in the beautiful photographs of Kenya by the Hon. Wm. MacGregor Ross, Dr. J. W. Arthur, and Dr. J. D. Melhuish. (Photographs, Figs. 2 and 3.)

These glaciated surfaces show that the valleys had been cut down to their present depths at the time of the maximum extension of the glaciers. Not only had its eruptions ceased long before the formation of the volcanoes with well preserved craters—such as the Kibo summit of Mount Kilima Njaro, Longonot, Suswa or Meningai; but Kenya had been reduced

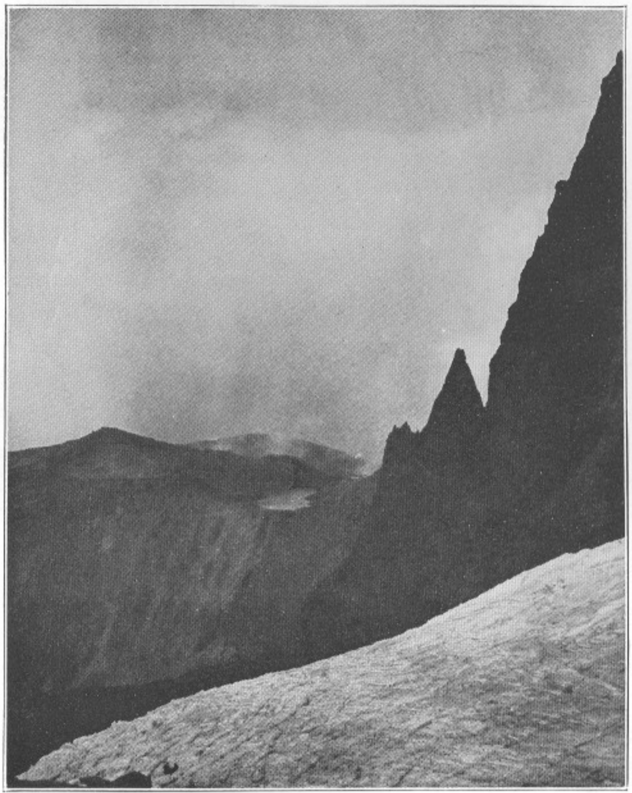

Fig. 2.—VIEW ACROSS THE LEWIS GLACIER, KENYA, OVER TWO TARN COL.

Showing the contrast between the jagged, serrate, unglaciated ridge (to the right) and the rounded, glaciated summits to the left.

Photographed by Dr. J. W. Arthur.

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practically to its present form by the time of the Great Ice Age and at the end of the Pliocene. And Kenya is not the earliest of the East African volcanoes. Hence the whole volcanic history of the country, from the beginning of the volcanic eruptions to the wearing down of Kenya into its present condition, cannot be compressed into only one geological period—the Pliocene.

The fact, then, that the crater of Kenya had been destroyed, and the plug of the old volcano worn down to essentially its present form and dimensions by glacial times, is evidence that Kenya is a very old volcano, and that the volcanic history of British East Africa must be carried back into pre-Pliocene times.

As the phonolites of Lumbwa are post-Miocene, and those of the Kapiti Plains not later than the Miocene, the simple classification which would attribute them both to the same volcanic period appears inadmissible, and we must be prepared for a longer and more complex classification of the volcanic rocks of British East Africa.

The main stages seem to be as follows: The oldest lavas are the phonolites of the Kapiti Plains, and the earth-movements which occasioned their widespread eruption were probably connected with the foundering of the Indian Ocean. The lavas may be co-related with the Deccan Traps and be of Upper Cretaceous age.

The eruptions of the soda-rich phonolites culminated in the eruption of the soda-rich kenyte of Kenya. Then followed a series of eruptions which produced the basaltic agglomerates of northern Kikuyu, vast basalt sheets around Lake Magadi, and the porphyritic basalts of Kijabe and the Aberdares.

These eruptions were probably accompanied by the first of the Rift Valley faults, and were followed by a long stage of denudation; and then renewed volcanic disturbances discharged the rhyolites and trachytes, which are especially well developed in the Kikuyu country. Then, after further faults, ensued a long, quiet period, during which the level of the Victoria Nyanza was higher than it is to-day, and the occurrence of *Dinotherium Hobleyi* in the lake deposits proves their Miocene age. Then followed the post-Miocene eruptions, including vast plateau eruptions, which gave rise to the Lumbwa phonolites and the later basalts. Fresh faults widened the Rift Valley, and these movements led to the building up of great trachyte mountains in the floor of the Rift Valley, including Lorgasailik, Suswa, Longonot, and Meningai. Some of these latest eruptions must have been quite modern. It is difficult to regard, for example, the north-eastern lava flow of Meningai as having been discharged more than a couple of centuries ago. Mr. Hobley regards the bare volcano that he discovered to the west of the Njorowa Gorge as not more than a century old. There are traditions among the natives of eruptions in modern times ; thus the formation of the Simbi Crater is said to have happened eighty years ago. Mrs. Ulyett, of Makalia, tells me that, according to a native once employed there, the mountains discharged fire a few generations back. The Masai appear to have no traditions of eruptions ; but they are nomads and pastoralists, and would have had no *shambas* devastated and homes destroyed, so negative evidence in their case is of little weight.

The conclusion that Kenya was dead and dissected before the beginning of the Pleistocene, is based on the natural assumption that the former greater size of the Kenyan glaciers was during ' the Great Ice Age ' in Europe ; for at that period the rain-carrying cyclones, which normally cross southern Europe and the Mediterranean, would have been deflected to a more southerly route by the anticyclonic conditions then dominant over north-western Europe.

Kenya, probably, then had a heavier snowfall as its share of the increased precipitation over northern Africa ; and after the disappearance of the glaciers from north-western Europe they dwindled on Kenya as part of that widespread desiccation of northern Africa, which led to the gradual reduction in the size of the lakes and the disappearance of Lake Suess from the basin south of Longonot.

The history of the East African lakes shows that the earlier stages of the volcanic activity in East Africa were passed through a long time ago. The surface of Lake Naivasha stood 150 feet above its present level when it overflowed southward down the Njorowa Gorge. The entrance of the gorge (Fig. 4)

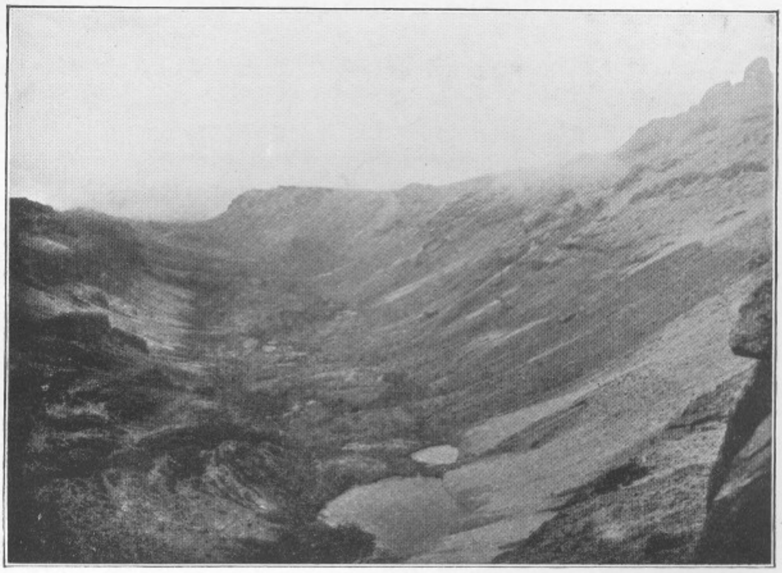

Fig. 3.—A GLACIATED VALLEY ON KENYA.

Photographed by Dr. J. D. Melhuish.

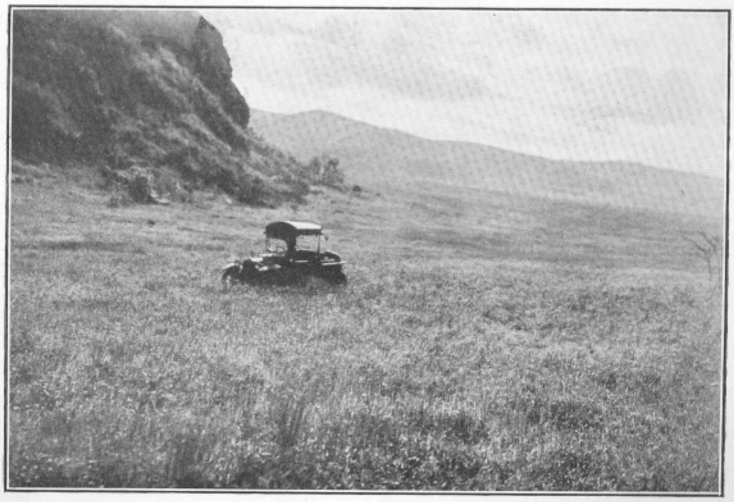

Fig. 4.—THE WESTERN ENTRANCE TO THE NJOROWA GORGE.

The cliff on the left is a lava flow of columnar lava (riebeckite trachyte); its base is an old beach of Lake Naivasha, and the cliffs, cut when the lake was at the level of this exit, are shown as dark areas along the foot of the hills to the right.

Photographed by Hon. Wm. MacGregor Ross.

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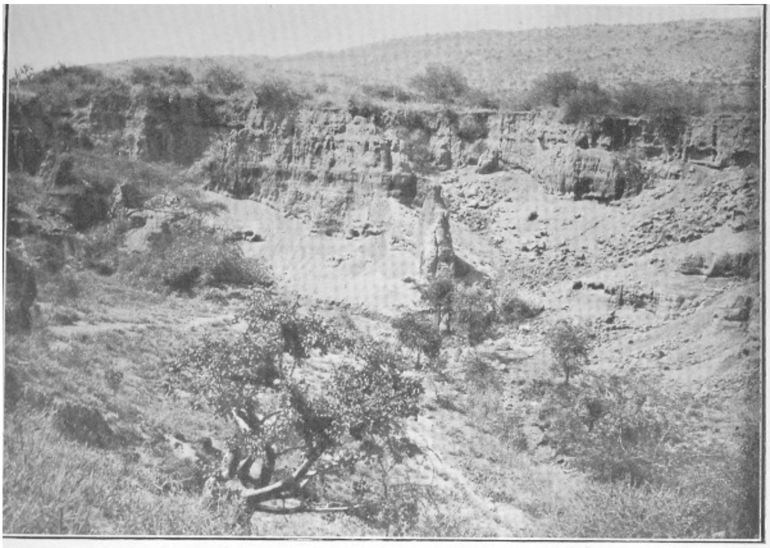

Fig. 5.—THE VALLEY OF THE ENDARIKI RIVER.

The photograph shows a ravine that has been excavated on the floor of the main valley and filled with loess which has accumulated during a drier period. The loess is now being excavated by the river, the discharge of which must have again increased.

Photographed by Hon. Wm. MacGregor Ross.

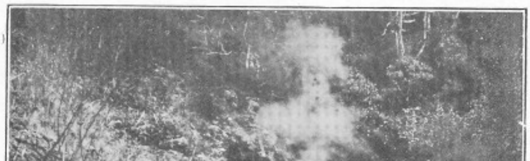

Fig. 6.—FUMAROLE DISCHARGING STEAM AND DEPOSITING SULPHUR, NJOROWA GORGE.

Photographed by Hon. Wm. MacGregor Ross.

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is cut through a lava flow, which is comparatively modern; yet it was much earlier than the time of the greater Naivasha, and must be at least Pliocene in date. The climatic variations indicated by the glacial history of Kenya, and the variations of the lakes, were probably not due to a progressive desiccation, but to alternations of drier and wetter periods. Thus on the floor of the Endariki Valley is a deep, young gorge, now being cut out by floods after storms (Fig. 5); but this gorge is being made by the re-excavation of an old gorge which has been filled by loess—a wind-carried deposit—during some recent period drier than the present or than during the formation of the original gorge.

With so many well-preserved craters along the Rift Valley, and such abundant evidence of recent volcanic activity, it is natural to inquire as to the chances of renewed eruptions. In some countries, where the craters are equally well preserved, the volcanoes may safely be certified as dead. Along the Rift Valley there are, however, symptoms that the volcanoes are only dormant; for steam vents and hot springs are abundant. Vents discharge carbonic dioxide; and, still more significant, some fumaroles still give forth sulphur, as in the Njorowa Gorge (Fig. 6). These may be the dying efforts of the volcanic forces; they indicate the possibility—not necessarily the probability—of renewed eruptions. Fresh outbreaks depend rather on whether the earth-movements along the Rift Valley faults have entirely ceased. The frequent earthquakes along the Rift Valley suggest that the movements are still in progress. I have been told of subsidences and changes of level since the railway survey in the neighbourhood of Naivasha and Kijabe; the evidence, so far as I know, is not conclusive, but is sufficient to call for careful investigation.

If the Rift Valley faulting is renewed, then fresh volcanic outbreaks are possible and on a much larger scale than the known eruptions of the Teleki Volcano, about 1888, or the recent outbreak on the northern peninsula projecting into Lake Rudolf, or the eruption of Doenyo Ngai in German East Africa, described by Mr. Hobley in the Society's JOURNAL.[1]

[1] Vol. VI., No. 13, pp. 339–43.

That there have been important earth-movements in the country in recent geological times is clear from the general topographic evidence. The narrowness of the valleys, the abundance of waterfalls and rapids, and the direct leap of tributaries from hanging valleys into the main river are all indications that the country has a young topography and that the rivers have not had time to cut down their beds since the last uplift.

That the modern earth-movements extend to the coast is shown by the raised coral reefs which have been uplifted in recent geological times, and, as shown by Mr. Hobley, by successive steps. Hence the crustal disturbances of British East Africa still affect the coastlands, the foundering of whose former eastward extension to India initiated the eruptions and earth-movements to which the country owes its chief features of geological interest.

DISCURSIVE NOTES ON THE FOSSORIAL HYMENOPTERA

By G. D. Hale Carpenter, M.B.E., D.M., F.E.S., F.Z.S., *Uganda Medical Service*

Fossorial, because they dig! *Hymenoptera*, because they belong to the great group of insects characterised by the firm linking together of the anterior and posterior wings on each side.

Popularly, 'sand-wasps'—this is not a bad name, more especially if applied to the *Bembecidæ*, which do look something like an ordinary wasp and do burrow in sand rather than other kinds of earth. Properly speaking, however, the Fossors are not true wasps, in the sense that our black and yellow common or garden wasp is. Anatomically, they are distinguished by the forewing not being folded. In a true wasp, when it alights, the forewing is folded on a longitudinal crease, so that the wings appear only of half their true width :