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PLEISTOCENE MOVEMENTS IN THE GREGORY RIFT VALLEY

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With one figure

Summary

The Tertiary and post-Tertiary chronology of faulting in the Gregory Rift Valley is discussed with particular reference to areas where Middle Pleistocene deposits have been mapped. It is concluded that while strong faulting occurred at the end of the Middle Pleistocene period, the main faulting was earlier. At least three pre-Middle Pleistocene phases of faulting are recognised; the maximum movements probably occurred in late Pliocene or earliest Pleistocene times.

The Gregory Rift Valley, which extends from Lake Manyara and Lake Eyasi in Tanganyika to Lake Rudolf in northern Kenya (WILLIS, 1936) displays forms and structures which have developed since early Miocene times. Owing largely to the discoveries of Leakey (1931, 1936) it is now recognised that a considerable part of the rift faulting and associated deformation here took place during the Pleistocene period. It is not yet possible to estimate the variations in the rate of the deformation through the period of about 25 million years since early Miocene times, because in the central part of the Gregory Rift Valley between Lakes Magadi and Baringo, where the greatest deformation took place, there is no reliable dating between Lower Miocene and Middle Pleistocene. Thus a time scale is only available for about the last 1/4 million years, a mere 1% of the time since the early Miocene period. One of the objects of an expedition in 1946 was to determine how much of the total rift movements occurred within this last short period. For this purpose work was concentrated on three areas, Olorgesailie, Kariandusi and the Kinangop escarpment (fig. 1), where Middle Pleistocene deposits were known to be well displayed. Evidence from these localities and another which was only hastily examined, is summarised below.

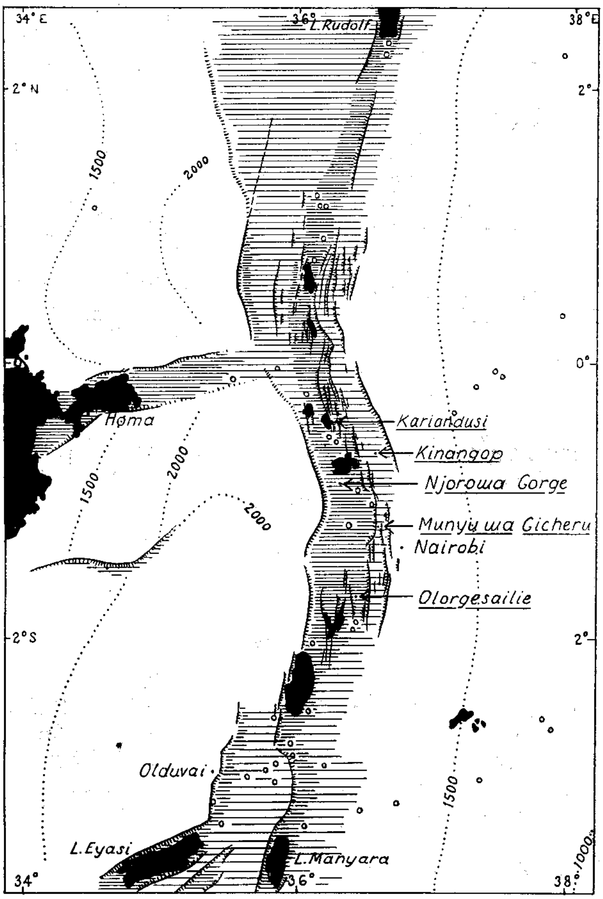

Fig. 1. The Gregory Rift Valley, East Africa, showing localities discussed. Existing lakes black; down-faulted areas lined; faults shown by lines with teeth on downthrown side; volcanoes ringed; contours (diagrammatic) on sub-Miocene surface

1. Olorgesailie (36° 28′ E., 1° 35′ S.).

On the floor of the graben, 50 Km. SW. of Nairobi at an elevation of about 1000 m. there are extensive exposures of lacustrine diatomites, marls and tuffs which contain, at a number of horizons, Acheulean type artifacts and mammalian bones. The deposits are dated as Middle Pleistocene and are attributed to the Kanjeran pluvial (LEAKEY, 1952, 209). They are about 50 m. thick and rest on lavas. Exposures extend over an area about 100 Km^2.

These Olorgesailie deposits are dislocated by many of the faults which traverse this part of the Rift Valley floor. The overlying deposits of Upper Pleistocene age (Gamblian pluvial) are not faulted. Many of the faults are well exposed and can be seen to be normal dip-slip faults. Their dips vary from nearly vertical to about 55°. The throws, in the lake beds, range up to about 50 m. It is however clear that more powerful faulting had taken place previously. At least three phases of faulting and erosion punctuate the long and varied sequence of volcanic rocks displayed in this district.

The earliest lavas, mainly phonolitic and basaltic, are probably Miocene (SHACKLETON, 1945), and are well exposed on the eastern flank of the Rift Valley around Nairobi (SIKES, 1939). Within the Rift Valley they are generally covered by younger lavas, but the mountains of Olgasalik (36° 26′ E., 1° 40′ S.) and Ol Esayeti (36° 33′ E., 1° 30′ S.), rising from the floor of the Rift Valley, are the denuded and faulted remnants of volcanoes from which some of the early lavas were erupted. A phase of strong faulting followed these eruptions; the present plan of the graben, with its grid of meridional faults, was by this time developed. Further copious eruptions, again from centres within the graben, built a series of alkali quartz-trachyte lavas and tuffs known as the Limuru trachytes (SIKES, op. cit.). These overflowed the eastern lip of the graben, spilled across the flanking plateau as far as the site of Nairobi and are the youngest lavas thereabouts. Strong faulting, apparently the main phase, followed these eruptions. The grid of fault ridges and troughs was heightened in relief and then strongly eroded. Subsequent lava floods did not keep pace with the subsidences and the younger lavas of this district, mainly basalts and alkali trachytes, are restricted to the graben itself. These lava sheets were dislocated by renewed faulting along the previous lines. It was on the eroded and fault-ridged surface of these lavas, within the graben, that the Olorgesailie lake beds were deposited. Thus although many faults cut the Middle Pleistocene beds they probably effected only a small part of the total displacement.

2. Munyu wa Gicheru (36° 32½′ E., 1° 11′ S.).

Lake deposits, probably of Middle Pleistocene (Kanjeran) age, occur at Munyu wa Gicheru, towards the foot of the Kedong escarpment which here forms the eastern wall of the graben. At least 25 m. of the deposits are exposed, at an elevation of about 1675 m. and nearly 200 m. above the adjacent part of the floor of the graben. These seem to be the lake beds discovered by Gregory in 1893. He supposed that they marked the shore line of a Pliocene Lake (Lake Suess) which extended across the Kedong Valley and the Suswa plains to the west (GREGORY, 1896). Later he classified the deposits as Lower Pleistocene (GREGORY, 1921, p. 199).

The beds, which consist of impure diatomites, overlain by tuffs, dip at about $4^1/_2$° westwards towards the graben and appear to rest unconformably against the eastern face of a fault block formed of steeper-dipping quartz-trachytes overlain by spherulitic rhyolite (Limuru trachytes and Kedong rhyolite of Sikes, op. cit.). About 2 m. from the top of the diatomites is a breccia band with obsidian fragments, similar to a bed in the Kariandusi deposit mentioned below. A few Acheulean hand-axes found in the vicinity probably came from the deposits.

As the dip of the deposits is so low, while the volcanic rocks generally dip at about 25° in the vicinity, it is evident that the lake originated after the main dislocations. The dip of $4^1/_2$° in the diatomites, though possibly depositional, more probably indicates a slight subsequent tilt. The lake might conceivably have been restricted to a narrow fault trough, as Sikes (op. cit.) assumed for other lacustrine deposits further south. If so, the breached fault-scarp which now forms the western limit of the deposits was the original dam of this lake. If however GREGORY's Lake Suess is accepted, there is no barrier to the south which could contain this lake within the Gregory Rift Valley in its present form. The same applies to lake beds, regarded as Pleistocene by Leakey, exposed at about 1800 m. in Njorowa Gorge (36° 19′ E., 0° 54′ S.) (GREGORY, 1921; LEAKEY, 1931; NILSSON, 1940).

3. Kariandusi (36° 17′ E., 0° 27′ N.).

A lacustrine series, mainly of diatomites and tuffs, is exposed at about 2,000 m. near the Kariandusi River, 2—3 Km. E. of Lake Elmenteita. Acheulean artifacts, found at a horizon in the upper part of the series, indicate a Middle Pleistocene age (LEAKEY, 1936, p. 46). The deposits, which vary in thickness up to more than 50 m., rest unconformably on a rugged topography formed of eroded fault ridges of alkali quartz-trachyte, and are themselves dislocated by a series of normal faults with throws up to at least 50 m. The throw of the earlier faults must here too have been much more than those affecting the Middle Pleistocene beds.

4. Kinangop Escarpment (36° 27′ E., 0° 35′ N. to 36° 33′ E, 0° 55′ N.).

East and southeast of Kariandusi the ground rises, across a series of meridional ridges and steps, to the Kinangop plateau, which reaches about 3000 m. in elevation. A well characterised group of tuffs and lavas, with some lateritic beds near the top, can be traced across this district. Their disposition shows that the difference in elevation, about 1000 m., between Lake Elmenteita and the Kinangop platform is accounted for by the faults which cut these rocks. The same tuffs occur at a still greater elevation on the Aberdare Range, east of the Sattima fault (SHACKLETON, 1945). The present Rift Valley here is essentially due to these faults.

In a series of eroded areas along the western edge of the Kinangop platform there are exposures of lateritic and tuffaceous beds which yield artifacts of Pseudo-Stillbay, Fauresmith and other late Middle Pleistocene types (Leakey, 1936, 49). These beds have been regarded as constituting the youngest member of the series of trachytic lavas and tuffs which builds the Kinangop platform, and the main faulting in this part of the Rift Valley was accordingly thought to have occurred after these beds were deposited (Leakey, 1936, fig. 4; Nilsson, 1935, p. 14; Zeuner, 1950). The 1946 survey showed however that along the edge of the Kinangop escarpment the implementiferous lateritic beds lie unconformably on the trachytic tuffs which form the escarpment. The lateritic beds are only a few metres thick. At Wetherell's site (Leakey, 1936, Pl. 11) they lie on the slopes of a wide shallow valley cut back into the plateau. The layers dip towards this valley at about 3°. Subsequently the valley has been eroded more deeply. At Durie's site (36° 32′ E., 0° 47′ S.) on the very edge of the escarpment, the unconformity is more obvious. The laterites clearly pass smoothly, on a 5° slope, over the edge, overstepping successive beds of the trachytic tuff beneath. Some of the artifacts were made of a green pantelleritic lava which outcrops on the escarpment. Thus it seems clear that an escarpment already existed when the lateritic beds were forming. This is in agreement with the Kariandusi evidence: the faulted and eroded quartz-trachytes which at Kariandusi are overlain unconformably by Middle Pleistocene lake beds, apparently belong to the same series which on the Kinangop is unconformably overlain by the Middle Pleistocene laterites. The duration of the period implied by the unconformity is unknown. The lithological similarity between the lateritic beds at the top of the faulted series and those unconformably above them, suggests perhaps that the interval was short.

Discussion

At the present time the East African Rift system is the scene of only feeble tectonic activity. The seismicity is moderate even compared with the Atlantic and Indian Ocean belts (Gutenberg & Richter, 1949, 28). The recorded shocks are classified as shallow and mostly release little energy. The strongest recorded from the Gregory Rift Valley was the Subukia Valley earthquake (magnitude 7.0) of 6th January, 1928. This was due to movement on a fault at the foot of the Laikipia escarpment (Willis, 1936, 321—328); the epicentre was located at about 0° 20′ N., 36° 22′ E. (Tillotson, 1937). Nor was there much tectonic activity during most of the Upper Pleistocene, for the high beaches of the Gamblian pluvial, which span nearly the full width of the graben in the Nakuru-Naivasha basin (Nilsson, 1932, fig. 33) are not faulted, although they are slightly tilted; the maximum dip is about 0° 17′ (Nilsson, 1940, fig. 17). The last phase of major faulting was the one which dislocated the Middle Pleistocene (Kanjeran) lake deposits, as indicated above. It is difficult to estimate the regional effects of this post-Kanjeran phase. The Kanjeran diatomites at Kariandusi are now about 1000 m. higher than those 120 Km. to the south at Olorgesailie. If both were originally deposited in one lake, near the same level, and were then lifted unevenly, Kariandusi being near a plunge-culmination of the floor of the graben, the mean resultant southerly dip would only be about 0° 30′. At both Olorgesailie and Kariandusi the southerly component of dip is often more than this, but is so variable, and the sections are so limited that a regional plunge cannot be demonstrated. If the Kanjeran deposits represent a number of separate lakes such a late differential uplift perhaps need not be postulated. But undoubtedly along this part of the Rift Valley there is a general southward fall in level of the younger lava sheets. This is apparent for instance in the fault scarps of trachytes and basalts between Olorgesailie and Lake Magadi; therefore even if the 1000 m. difference in level between the Olorgesailie and Kariandusi lake beds is not due to subsequent movement, one would have to accept movements of this order only a little earlier. On balance the post-Kanjeran date seems more likely, though more evidence is needed.

Pre-Kanjeran phases of faulting are poorly dated in the Gregory Rift Valley. Towards the periphery, at Olduvai, near the Kavirondo Gulf and in the Omo Valley, where sequences extending down into the Lower Pleistocene are proved, there does not appear to be evidence of major faulting during Lower Pleistocene times. The main faulting had already occurred before the accumulation of the Lower Pleistocene deposits began. In the central areas of the Gregory Rift Valley, Lower Pleistocene deposits have not been identified. Even a well-established Pleistocene climatic sequence must fail as a basis for correlating a series of deposits which extends back to the Lower Miocene period. Petrographic similarities give only precarious correlations of volcanic sequences, none of which are adequately tied to a time scale. The most reliable though still precarious correlations depend upon the tracing of erosion surfaces. From the East African coastal belt a flight of surfaces rises towards the highlands, marking stages in the intermittent uplift of the swell which is transected by the Gregory and Kavirondo Rift Valleys. A mid-Tertiary ("sub-Miocene") surface has been generally recognised. In Kenya this rises to over 2000 m. near the Rift Valleys. An "End-Tertiary" (Mid-Pliocene) surface, less well-planed, rises to at least 1800 m. in places. The vertical interval between the two surfaces, near the Rift Valley margins, does not seem to vary very greatly, suggesting that the dislocations between their completion were weaker than those afterwards. The two surfaces have been similarly warped and dislocated; their deformation is clearly related to the Rift faulting. Thus one may tentatively conclude that the main faulting in the Gregory Rift Valley occurred after the completion of the End-Tertiary surface and before the Lower Pleistocene deposits began to accumulate. In the areas described above, the main faulting is later than the Limuru trachytes and the trachytic lavas and tuffs of the Kinangop scarps. These rocks may be Pliocene or Miocene. The younger trachytes and basalts of the Olorgesailie district might be late Pliocene or Lower Pleistocene.

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INDICATIONS OF RECENT TECTONIC ACTIVITY IN CANADA

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Geologically speaking Canada consists of 3 giant continental geomorphologic and geologic segments. These are from West to East, the Rocky Mountains from the Pacific coast to the Western rim of the prairies, the West Canadian sedimentary Basin (Alberta Basin) and the Canadian Shield, which terminates at the Atlantic ocean.

There seem to be scarcely any references to live tectonics in Canadian geologic literature and it appears that at least the Canadian shield as such has remained stable for many geologic periods. Nevertheless there are reports of some live tectonic activity along the borders of the Shield and also from the Rocky Mountains.

J. T. WILSON (Toronto) reports that there are active earthquake zones along the British Columbia Coast, some of the earthquakes have been correlated with known faults.

There are also earthquake lines in Eastern Central Canada suspected to be related to movements along the Ottawa Bonnechere graben.

The Canadian Shield has undoubtedly been remarkably stable for a long period of time. Several small remnants of Paleozoic rocks have now been found on it. Except for the Devonian in the Hudson's Bay Lowlands these outliers belong to only two formations. This limited range and their preservation suggest great stability.

H. H. BEACH (Calgary) in mapping areas in Central Quebec Province has found indications of some fairly recent or sub-recent faulting near the rim of the Canadian Shield.

J. C. SPROULE (Calgary) reports and has shown to the writer photo-geologic evidence of recent faulting in the Ghost river valley about in Township 27 Range. 9 West of 5th. Meridian, that is in the vicinity of Banff-Lake Minnewanka. In this vicinity the decapitated Ghost river is crossed by a fault, which may be termed the Front Range fault and which is not to be confused with one of the Rocky Mountain Front thrusts. This fault must have moved in historic times and may still be active and it has created a line of displacement (East, that is the plains side down) in the alluvial river gravels of the Ghost river. The line runs about parallel to the Front Range and can be traced across