



COLONY AND PROTECTORATE OF KENYA

**MINISTRY OF COMMERCE AND INDUSTRY
GEOLOGICAL SURVEY OF KENYA**

**SHAPE OF THE
SUB-MIOCENE EROSION
BEVEL IN KENYA**

by

**WILLIAM PULFREY, D.Sc., Ph.D., M.Sc., F.G.S., M.I.M.M.,
Commissioner (Mines and Geology)**

1960

PRINTED BY THE GOVERNMENT PRINTER, NAIROBI

Price: Sh. 3/50

CONTENTS

	PAGE
Abstract	1
I—Introduction	1
II—Basis and construction of the map of the sub-Miocene bevel	4
III—Warping of the sub-Miocene bevel	8
IV—Conclusions drawn from the map of the sub-Miocene bevel—	
1. Nomenclature of erosion bevels	10
2. Rise of the bevel to the Rift	10
3. Extent of concealed Miocene beds	11
4. Isostatic uplift at the coast	12
5. Origin of the Gregory Rift Valley	12
6. Early Tertiary river system	13
7. Development of the River Tana	15
8. The high central volcanoes	15
V—Future work on the erosion bevels of Kenya.. .. .	15
VI—References—	
1. Reports by the Geological Survey of Kenya	16
2. Other references	18

ILLUSTRATIONS

Fig. 1—Sources used in the preparation of the map of the sub-Miocene bevel ..	3
Fig. 2—Possible early Tertiary drainage pattern in Kenya	14
Fig. 3—Map of the sub-Miocene bevel (Scale 1: 2,000,000)	at end.

SHAPE OF THE SUB-MIOCENE EROSION BEVEL IN KENYA

By William Pulfrey, D.Sc., Ph.D., M.Sc., F.G.S., M.I.M.M.

ABSTRACT

The bulletin presents a map of the sub-Miocene erosion bevel in Kenya. It shows a large uplifted bulge in the west-central part of the country, split by the Rift Valley and diversified by other graben and faults in the west. The northern border is on the flank of another dome centred on Abyssinia, while in the south-east there is a marked depression.

Conclusions drawn from the map include support for the hypothesis that the Rift Valley arose as a result of upward pressure on its flanks, the floor being less raised than the flanks or sucked down, and that it developed along a topographical low. As a whole the bevel rises to the Rift, but is in several places warped over into the Rift at its edge.

I—INTRODUCTION

During the last 15 years several accounts have been given and many references made in literature on the geology of Kenya to the mid-Tertiary or sub-Miocene bevel, as it was named by Shackleton (1/1946A)* to indicate the widespread erosion bevel that matured somewhat earlier than the lower Miocene and on which sediments and lavas of lower Miocene age were laid down in some localities. Dixey (2/1946A, 2/1946B, 1/1948) devoted considerable attention to the bevel and in the last of these papers diagrams were given in an attempt to indicate the extent of areas in which the bevel can be readily traced in two large sections of northern Kenya. King (2/1951, map)† gave his idea of its visible extent throughout Kenya, but no author essayed to construct the total shape of the surface as it once existed after warping and before it had been largely destroyed by erosion until Shackleton (2/1951) published a contoured map of the original warped bevel in south-western Kenya. This bulletin presents a continuation and extension of Shackleton's work to cover the whole of Kenya. It is hoped that the map will serve as a guide when areas are mapped in future, as it may prove possible, with an idea of the regional shape of the bevel in mind, to construct detailed and accurate contoured maps of the erosion surface in the areas concerned. The bevel is most important in the interpretation of the structural development of Kenya in late Mesozoic to Recent times for, as Bailey Willis has said (2/1933, p. 384): "It constitutes a datum plain by which to determine the degree of warping of the continental surface in post-Miocene times and with reference to which both older and younger surfaces may be compared."

More intensive geological mapping, with a quarter of a degree square as unit, was started by the Geological Survey of Kenya in 1948. The geologists, when preparing reports on areas, attempted to indicate by diagrams the extent of remnants of the sub-Miocene bevel, or to indicate by sections its extent and slope (*see* reports mentioned on pp. 16-17). After a few years, it appeared that sufficient evidence had been mapped to attempt a reconstruction of the warped bevel, and its altitude at various places in the areas mapped was recorded on a small-scale diagram. It soon became evident, however, that although over restricted areas series of contour-lines could be drawn to represent the surface as it once existed, there were large gaps over which the

* References are given on pp. 16-18. Reference indicators in the text prefixed by 1/ apply to titles quoted in part 1 of the References on pp. 16-17; those prefixed by 2/ indicate titles in part 2 of the References on p. 18.

† In the writer's opinion, King's map gives an erroneous idea of the easily visible extent of the bevel in Kenya. Over much of the area where he represents it there appears, also, to be confusion between the sub-Miocene bevel and the end-Tertiary bevel.

contour-lines could not be continued owing to contradictory information. In such cases the surface would have had to assume sharp warps in areas in which it is clear the surface is to all intents a plane. Obviously all the evidence presented in the diagrams was not of equal validity. It was consequently necessary to re-examine the maps of the areas concerned and in some cases to reinterpret the plotted field evidence. It was found that sometimes errors of identification of bevels had been made, errors for which the writer must assume some responsibility, as he had the duty of supervising the reports.

It is not necessary to detail the changes of interpretation that proved necessary, as they will be obvious from comparison of the present map (Fig. 3, at end) with diagrams given in reports of the Geological Survey. A few examples, however, may be useful to indicate some of the difficulties of bevel identification, especially where no datable deposits are available to act as pointers. A notable example occurs in connexion with the Takabba-Wergudud area (Saggerson and Miller, 1/1957), for which bevels were determined by means of sections drawn roughly down the slope of the surfaces. In passing from the central to the eastern part of the combined maps that illustrate the report the line that represents the sub-Miocene bevel was jumped up a few hundred feet to a higher surface. An "intermediate surface" was also claimed, lying between the sub-Miocene surface and the end-Tertiary surface, which forms most of the low-lying parts of the area. Geologists working in the Derkali-Melka Murri area to the north (Thomson and Dodson, 1/1958) accepted the higher bevel of the eastern map of the Takabba-Wergudud area as the sub-Miocene surface, and concluded that a surface they had between that bevel and the end-Tertiary bevel must be the intermediate surface. They accordingly described Tertiary sediments at Banissa as lying on the intermediate bevel, whereas it can be seen by comparison of the maps of the two areas that they lie on a bevel equivalent to the true sub-Miocene surface of the western part of the Takabba-Wergudud maps. The same error was extended to the Bur Mayo-Tarbaj area (Thomson and Dodson, 1/not yet published), where sediments at Erib on similar reasoning, were considered to lie on the intermediate surface, and in the Mandera-Damassa area (Joubert, 1/not yet published), where the high bevel of the Danissa hills was accepted as the sub-Miocene surface, and surfaces further east labelled accordingly. A corollary of the redetermination of the "intermediate surface" is that the sediments lying on it may be older than was thought when the areas were mapped.

Pediments between erosion bevels were neglected in preparing a diagram of surfaces of the Kitui area (Sanders, 1/1954). This led to the remnants of the sub-Miocene bevel being given a greater extension than they have, and to the implication that the bevel occurs at considerably greater altitudes than can be seen in the field.

A further type of error was made in the preparation of an erosion bevel diagram for the South Machakos area (Baker, 1/1954). In that area remnants of the sub-Miocene bevel can be clearly seen in the north-east corner, south of Masii. The western part of the area is blanketed by Kapiti Phonolite, of presumed Miocene age, and it was assumed that the level of the base of the phonolite must everywhere represent the sub-Miocene bevel. It can be seen on the map of the area, however, that the phonolite is in fact banked against a rather steep slope and it is only in the southern part of the outcrop that the phonolite is approaching the altitude of the pre-lava bevel. The local high base of the phonolite having been accepted as the sub-Miocene bevel, flat surfaces at corresponding levels in other parts of the area were ascribed to the bevel. In the writer's opinion it is only in the north-east corner of the South Machakos area, and along its southern edges, that the sub-Miocene bevel is represented, most of the area being land that stood above the bevel.

The relationship of the Tertiary lavas of Kenya to the landscape of that time has been graphically described by Dixey (2/1946B, p. 376): "... widespread volcanoes of the Kenya highlands almost completely buried the multicycle topography of high

relief; their lavas poured down the eroded escarpments and great mountain valleys on to successive erosion surfaces and surrounded residual uplands . . .". The statement is a warning when attempting to map erosion bevels in parts of Kenya where volcanic rocks are widespread.

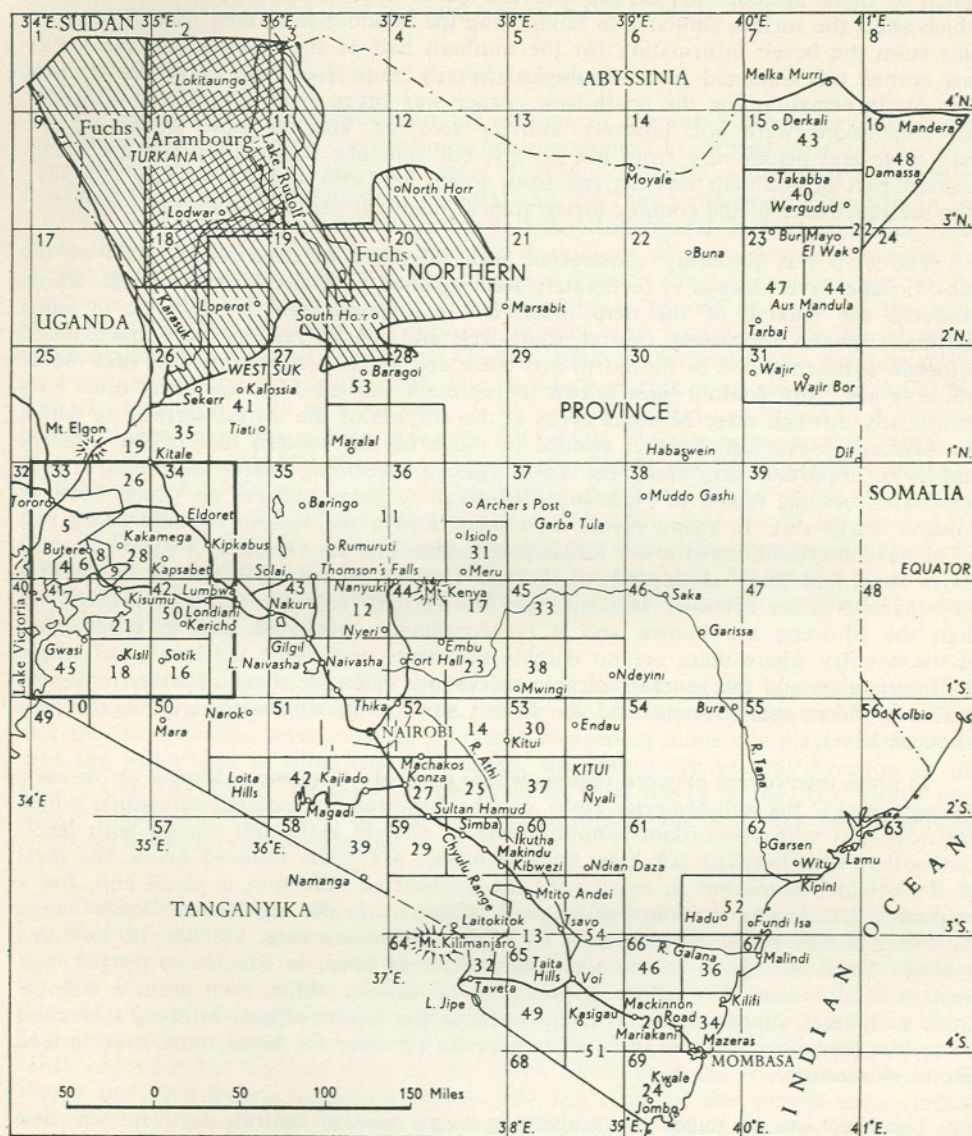


FIG. 1.—Sources used in the preparation of the map of the sub-Miocene bevel. Maps of the Geological Survey of Kenya that were available are outlined by heavy lines, but do not include the Mount Kenya area. The numbers in the top left corners of degree squares are the degree sheet numbers used by the Geological Survey. The numbers in the middles of map areas are report numbers. The extra thick outline in the south-west represents the area plotted by Shackleton (2/1951). Areas mapped by Fuchs (2/1939) and by Arambourg (2/1943) are indicated in the north-west.

II—BASIS AND CONSTRUCTION OF THE MAP OF THE SUB-MIOCENE BEVEL

A geological map of Kenya on the scale of 1:2,000,000 was used as a base on which to mark altitudes of the sub-Miocene bevel, faults (and in places monoclines, which affect the surface similarly to faults), and the boundaries of land that stood up as hills from the bevel. Information for the southern half of the country and the north-east corner was obtained from Geological Survey maps (*see* Fig. 1 and References, part 1). Information for the south-west corner was taken from Shackleton (2/1951). His conclusions were not, however, entirely accepted, and the lines shown on the map in several places vary from his. Scanty, but valuable, information for the north-western part of the map was derived from Fuchs (2/1939) and Arambourg (2/1943). For the remainder of the country topographical maps on various scales were used.

The map was primarily constructed with reference to determined levels of the sub-Miocene bevel. Kenya is fortunately well supplied with sub-Miocene levels, which rendered the making of the map much less hazardous than it might be in some territories. In the north-west, central, south-west and coastal regions there are exposed Miocene sediments, and in the north-east there are Tertiary sediments that may be of Miocene age. Any contour-lines drawn to represent the sub-Miocene bevel must pass realistically through these Miocene areas at the altitude of the lowest surface on which the Miocene rocks rest. Further control in much of the western half of the country and in an important strip along the Yatta Plateau, stretching nearly 200 miles toward the coast from the region of Nairobi, is afforded by plane surfaces on which Tertiary volcanic rocks rest. In many places in western Kenya the lowest volcanic rocks rest on or have intercalations of lower Miocene sediments and the evidence of the successions above them and their relationship to the end-Tertiary peneplain leaves no doubt that they themselves are often of Miocene age. No Tertiary volcanic rocks of earlier date than the Miocene are known and it is accordingly concluded that in other parts of the country where there are no datable sediments underlying the lavas, but where the lower lavas and the general volcanic successions resemble those of western Kenya, the lower lavas are Miocene, and the lowest surface on which they rest is the sub-Miocene bevel.

In areas intervening between regions where there are Miocene sediments or Miocene volcanic rocks, the sub-Miocene bevel can be followed by isolated remnants, which are now hills with concordant summit levels or shelves along hill masses with levels concordant with bevelled hill tops. Such remnants are often reduced below the level of the original bevel, but in most cases the amount of reduction is small and, for a map of the scale and contour-line interval presented, is not significant. Areas where the bevel is well preserved in almost its original form are rare, but can be seen for example north and south of the Kavirondo Gulf, at Masii in Machakos district, and west of Kitui, where the surface is preserved on divides. When seen from a suitable angle such areas appear almost as plane surfaces, the results of post-Miocene dissection being lost from view, and provide an impression of what the bevel must have looked like at its maturity.

The bevel can be traced by residuals in many parts of central, north-western and northern Kenya, where it was eroded on gneisses of the Basement System. In south-western Kenya it planed other Precambrian rocks, while in the north-east it can be traced across rocks of Jurassic and Cretaceous age, and near the coast in the south-east across rocks ranging in age from Permian to Jurassic.

The contour-lines on the map for the most part indicate the shape that the sub-Miocene bevel once had, or the shape that it is assumed to have under Tertiary volcanic rocks. In many parts of the country, even where there is no volcanic cover, the old surface cannot be divined by a cursory glance at the landscape and, in fact,

over wide areas the topography is dominated by the later end-Tertiary surface. The end-Tertiary bevel is prominent over much of eastern Kenya and can be traced continuously westward almost to the eastern edge of the Rift Valley, for example in the South Horr, Maralal and Namanga areas. West of the Rift Valley the end-Tertiary bevel is well developed in Turkana and around Lake Victoria.

SOME LIMITATIONS OF THE MAP OF THE SUB-MIOCENE BEVEL

For areas where information on the altitude of the sub-Miocene bevel is scanty or non-existent, presumed contour-lines are represented by dotted lines on the map. This applies particularly to the Rift Valley, Turkana, the north-central part of Northern Province, the Aberdare mountains, the coast and the Tana embayment. Throughout the Rift Valley, except at the northern end near Lake Rudolf and the Kalossia area, there is no direct evidence of the bevel, and the thicknesses of the volcanic sequences are as yet insufficiently known to allow of more than a rough approximation of the elevation of the sub-volcanic floor. The approximate throws of some of the main bounding Rift Valley faults are, however, known and give an indication of where the floor may lie. A recent borehole at Orgaria, south of Naivasha, also provides useful information for that part of the Rift. The bore-hole started at an altitude of 6,430 feet and was sunk to a depth of 3,096 feet, i.e. its bottom reached an altitude of 3,334 feet, where it apparently was not far down in the middle Pleistocene succession. Assuming that the remaining middle Pleistocene and lower Pleistocene rocks attain a thickness of the order of 2,500 feet, as seems likely from successions exposed within a few miles, the maximum elevation of the base of the volcanic sequence would be about 1,500 feet. If Miocene rocks are also present the elevation would be correspondingly diminished. For the purposes of the map 1,500 feet is assumed to be the elevation of the bevel at this locality, as it agrees reasonably well with altitudes in neighbouring areas determined on other grounds.

The contour-lines in the Rift Valley are, in addition to any uncertainty of their correct levels, essentially diagrammatic. There are numerous faults within the Rift, and the sub-Miocene bevel must be markedly stepped in numerous places, both down into the valley and in some cases, at horsts, up against the general direction of the fall of the Rift floor. The slope of the bevel at most places in the Rift Valley may well be little different from the degree of slope outside the Rift, but the generalized slope must be considerably greater.

The construction of the contour-lines in north-western Turkana was based on insufficient evidence, gained from Fuchs's 1939 map and by the projection of lines from the area further south-east, where Miocene sediments occur. No evidence is known for the contour-lines shown at the Lotagipi swamp, though it is evident that there must be a basin or trough in that region, as was pointed out by Fuchs (2/1939, p. 265). The contour-lines shown over much of northern Turkana are diagrammatic and do not fairly represent the detailed slope of the bevel. Much evidence has been adduced by Fuchs and Arambourg indicating that locally the slope of the sub-Miocene surface is to the west (as can be seen on the map at the Labur hills). Faults, however, step the surface, the blocks rising steadily to the west. The cumulative effect is that the sub-Miocene bevel declines towards Lake Rudolf, and it is this generalized slope that is shown on the map. Contour-lines at a much closer interval than 500 feet would be required to delineate the surface accurately, and the evidence at present available is insufficient for their construction. Using a suitably small interval the contour-lines would form a pattern of discontinuous ridges, the level of whose summits would decrease gradually to the east. Irregularities of the bevel have also been mapped by Joubert in the Loperot area, but again their amplitude is such that they cannot be shown on the scale of the present map nor using its contour-line interval.

There is no evidence for the contour-lines shown east of Lake Rudolf as far as Moyale, apart from the sub-lava surface north-west of Mount Kulal, a few bevelled hills in the Dukana-North Horr area, and the facts that the bevel must lie below 1,350 feet at Allia Bay and below the level of Lake Rudolf along most of its eastern shore. With the knowledge of levels in the Mandera district and in the Baragoi and South Horr areas this information is, however, sufficient to allow the tracing of tentative contour-lines. There is no evidence for the 1,000-foot contour-line drawn in Lake Rudolf. It is hypothetical and the reason for its insertion will be obvious from the map. There is similarly no evidence for the contour-lines drawn to indicate the Lake Stefanie trough, other than the fact that the altitudes of the lavas and the floor of the trough provide maximum levels below which the sub-Miocene bevel must lie. The thicknesses of the volcanic successions around Stefanie are not known, and the depth to the bevel below surface was estimated by projection of the apparent thickness of volcanic rocks north of Mount Kulal.

No direct evidence is available for the "peak" of the bevel shown by the contour-line at the Aberdare mountains. In view of the facts, however, that the main rift-fault has there a throw of about 2,500 to 3,000 feet and that no pre-Miocene rocks are exposed in the lower part of the Rift wall it seems unlikely that a topographic high above the level of the sub-Miocene surface exists beneath the Aberdares.

Evidence for the shape of the bevel and the area of residuals standing on it at the eastern end of the Kavirondo Gulf graben is scanty. As the Tambach Miocene, however, does not appear at the latitude of the graben it is concluded that the graben is separated from the Rift Valley by residual high land. It is also concluded that the altitude of the bevel at the east end of the graben is probably approximately the same as it is in the region of Tambach.

Much of the 500-foot and 1,000-foot contour-lines at the coast is based on the indirect evidence of the interval between the sub-Miocene bevel and the end-Tertiary surface further inland. There is some supporting evidence, however, in the presence of bevels at Mrima and Dakabuka, a bevel on the downthrow side of the fault bounding the coastal hills north of Mombasa, and the altitude at which Miocene sediments occur in the Malindi area.

There is at present no evidence for the 0, -1,000, -2,000 and -3,000-foot contour-lines in the Tana embayment, though a check for the southern part may be provided when the results of drilling by an oil company near Lamu are published. The lines were constructed on the evidence of general slopes in the exposed areas west and north of the embayment, and on the hypothesis that though a narrow depression must exist between the Kenya dome and the Abyssinian dome it must widen and flatten towards the sea, as there is no evidence of another dome in southern Somalia.

In addition to the areas just mentioned where information on the sub-Miocene bevel is scanty, there are other areas regarding which more profuse and more accurate information is desirable. The map, in fact, must be regarded rather as a large diagram, and the first stage of the production of a thoroughly reliable map of the bevel. In some parts there is at present scope for variation of interpretation of the evidence, and in some parts what evidence there is cannot be regarded as first class. The geological maps that form the basis of about half of the map are the result of rapid surveys, often in areas where no accurate contouring has been carried out. Much of the rest of the map is based on topographic maps that are often of doubtful validity, and which often have no contour-lines, or contour-lines that have been sketched in, not surveyed. The provision of more accurate and detailed topographic maps as time goes on, and the more detailed geological surveying of some areas, will enable the revision of the present map. The map, however, it is believed, does give a reasonably good general picture of the shape of the sub-Miocene bevel after warping and breaking.

THE RELATIONSHIP OF THE BEVEL TO MOUNT ELGON

The existence of the Kitale plain, a bevel somewhat earlier than the sub-Miocene bevel, as defined by Dixey (1/1948, p. 26) and re-affirmed by Gibson (1/1954, p. 9) is accepted, though it has been considered as the extension of the sub-Miocene bevel by Shackleton (2/1951, plate xxiv), by Bishop (2/1958, p. 1482), and following Shackleton by Trendall (2/1959). Bishop concluded from his work on the volcanoes of eastern Uganda that the Buganda surface, which he correlates with the sub-Miocene bevel, is considerably pre-Miocene, the Kyoga surface which appears to be the Uganda equivalent of the Kenya end-Tertiary surface, being slightly pre-Miocene. Such dating cannot agree with the facts east of the Uganda boundary, where none of the numerous lower Miocene deposits lie on the end-Tertiary bevel, but on the immediately preceding bevel, and in the case of Mount Elgon on a still higher bevel. It is suggested that Bishop has not recognized the true sub-Miocene bevel around Mount Elgon, and between Kadam and Elgon has transferred his attention from the sub-Miocene bevel to the Kitale plain.

Dixey considered that the Kitale plain forms part of the foundation of Mount Elgon, and with this conclusion the writer agrees except that he believes that on the southern side at least it underlies the mountain more completely than Dixey thought. The sub-volcanic sediments along the south edge of Mount Elgon clearly lie at greater altitudes than the sub-Miocene bevel as expressed in the country to the south by the highest concordant divides. The exact age of the Tertiary sediments underlying the volcanic rocks is immaterial in the argument (cf. Trendall, 2/1959, p. 5): they could be of any age from some time earlier than the sub-Miocene bevel to Pliocene though, in view of their nature, the probability is that they arose as a result of early Elgon volcanicity, and are nearer the higher than the lower age limit.

The Kitale plain slopes to the west at a generally similar angle to the sub-Miocene bevel. South of Kitale it is the surface on which the lavas of the Eldoret region were laid down.

Trendall (2/1959) gave a short account of the sub-Miocene bevel in the area around Mount Elgon, and as far north as Moroto, including Karasuk. He presented a contour-map of this area indicating a continuous rise from the region of Lake Kyoga in Uganda to an altitude of 6,500 feet at the Cherangani hills, with the 5,000-, 5,500- and 6,000-foot contour-lines passing north to the Turkana scarp, north-west of the Turkwell gorge. The contour-lines Trendall indicates cannot be reconciled with any possible lines based on evidence further east, and lead to insuperable difficulties if projected further north into Turkana. It is suggested that he has in fact transferred his contour-lines from the sub-Miocene bevel to a higher bevel as he has traced them northwards. The use of the contour-lines proposed by the writer resolves the apparent disparity of vertical interval between the sub-Miocene and end-Tertiary bevels at Kadam and Moroto mentioned by Trendall (2/1959, p. 7), and leads to the conclusion, contrary to Trendall's opinion, that the sub-Miocene surface hereabouts was not seriously warped until after the maturation of the end-Tertiary bevel.

Trendall (2/1959, p. 3) showed that the sub-Kadam floor was not warped after the deposition of the volcanic rocks that form Kadam. This provides evidence that the volcano is upper Tertiary or even Pleistocene in age.

Trendall also discussed the origin of the Suam and Kanyangereng rivers. He considered that the growth of the large volcanoes near the Kenya-Uganda boundary dammed waters against the tilted sub-Miocene bevel, forming a lake, which discharged to the east giving rise to the Turkwell gorge. Although a lake may have been impounded by the volcanic accumulations it seems unlikely that the overflow would in those circumstances be over the hard gneisses of the Turkwell gorge rather than through the incoherent volcanic rocks that impounded them on the west. Although the volcanoes

are high it is unlikely that the country between them was covered by sufficient volcanic debris to prevent streams flowing to the west. The writer thinks it more reasonable to consider the Suam, as can be seen on the map, as a consequent stream originally flowing from the high land underlying Mount Elgon, and subsequently reinforced with the growth of the volcanic mountain. With its increased powers of erosion derived by the faulting at the eastern end of the Turkwell gorge it is presumed that a north bank tributary cut back and beheaded streams flowing west off the Karasuk hills towards Lake Kyoga, giving rise to the modern Kanyangereng.

SLOPE OF THE SUB-MIOCENE BEVEL

At several places the general slope of the bevel has been indicated by arrows and figures representing the gradients in feet per mile. The gradients were determined by measurement on the map and are approximate only.

III—WARPING OF THE SUB-MIOCENE BEVEL

From evidence obtained throughout East and Central Africa it is clear that the sub-Miocene bevel, or "matureland", to use Bailey Willis' more appropriate term, was over large areas a well-developed plane surface, though in many other areas it bore many residuals. At the beginning of Miocene times it is to be presumed that some slight disturbance took place to allow the accumulation of Miocene sediments in lakes (cf. Shackleton, 2/1951, p. 385), though it is possible that some of the lakes may have developed by volcanic damming. Disturbance is, however, also indicated by some incision of the bevel before lower Miocene times, as is shown for example by the occurrence of an unusual thickness of phonolite discovered in a bore-hole east of Doi Ny Sapuk, where the base of the phonolite is possibly some 200 feet below the level of the sub-Miocene plain thereabouts.

The bevel stretched across Africa from the eastern to the western seaboard. As it is generally paralleled, with a vertical interval of a few hundred feet, by a lower erosion bevel dated approximately as end-Tertiary, and more precisely as mid-Pliocene, it is evident that after the maturation of the sub-Miocene bevel, there must have been general uplift of the whole of this part of Africa. At that time some gentle warping and breaking of the sub-Miocene surface took place, as can be seen in Turkana (Fuchs, 2/1939, p. 265; Arambourg, 2/1943, p. 212-213) and in parts of the Rift Valley, and as can be deduced for central east Kenya (*see* p. 13). In view of the constant general parallelism of the two bevels it can be concluded that any such warping and faulting was minor, and perhaps indeterminable except where Miocene sediments are well developed or where the bevels intersect, and that the end-Tertiary bevel, following the pattern set by its predecessor, swept across the whole of central Africa. Subsequent movements, in Pleistocene times (Bailey Willis, 2/1933, pp. 383-384; Shackleton, 2/1951, p. 386 and 2/1955, p. 262), had an irregular effect, the erosion surfaces being bent up into domes, and broken by strong fractures, notably in Kenya along the Rift Valley, the Kavirondo Gulf graben, and in several troughs in north-west Kenya. The pattern is part of the basin and swell structure of Africa. Bailey Willis (2/1936, p. 67) has pointed out that the dome was never continuous across the Rift Valley and that uplift and subsidence (or relative subsidence) were contemporaneous.

Using known altitudes of the sub-Miocene bevel it is possible to arrive at comparative ideas of how much it has been uplifted or sometimes depressed. It is necessary to make various assumptions to do this, the main assumptions here being that the seaward slope of the bevel was one foot per mile (cf. Willis, 2/1936, p. 71), and that the coastline lay parallel with and about 20 miles seaward from the southern half of the present coast, and passed northwards through Lamu. Figures of elevation and depression given below should be regarded as illustrating the orders of values.

Calculations were made for the following localities:—

				Elevation of bevel (feet)	Depression of bevel (feet)
1. <i>Eastern Flank of the Rift Valley</i>					
(a) Aberdare mountains	..	..		5,674	—
(b) Turoka	..	..	..	5,227	—
(c) Baragoi	..	..	..	3,846	—
2. <i>Within the Rift Valley</i>					
(a) Magadi	..	..	..	—	1,095
(b) Near Nakuru	..	..	..	2,410	—
(c) Lake Suguta	..	..	..	697	—
3. <i>Western Flank of the Rift Valley</i>					
(a) South-west of Narok	..	..		6,148	—
(b) South-west of Kitale	..	..		5,234	—
(c) Turkwell gorge	..	..	..	4,008	—
(d) Kaputir	..	..	..	2,512	—
4. <i>South-western Kenya</i>					
(a) Kisumu (Kavirondo Gulf graben)	..			3,056	—
(b) Mfanganu	..	..	..	3,467	—

The elevation is rarely of the order of isostatic recovery (1,200 feet) quoted by King (2/1956, pp. 357-358). It may be noted that had a slope of three feet per mile been assumed, a depression of bevel would have been registered for Suguta.

The elevation at Mfanganu has complex origin, owing to the movements that have taken place in that part of the country. It appears that here the bevel was first warped by doming at the Rangwa carbonatite centre, then generally raised as a result of the main doming of western Kenya. Finally the surface was lowered as a result of the warping and faulting that formed the Kavirondo Gulf graben.

The Lake Victoria basin is usually regarded as a depression caused by sag, but it is evident that it is as likely that it represents failure of part of the sub-Miocene land to be uplifted as much as it was further east. The western part of the basin must have been raised less than the eastern.

In a recent paper McConnell (2/1959, p. 250) has described the sub-Miocene bevel as occurring at altitudes of 14,000 to 15,000 feet at maximum elevation on the Ruwenzori mountains, and at 7,000 feet (at Msandama) at minimum elevation. Using the same constants as for the Kenya calculations, it is found that the surface would have to be uplifted some 14,000 feet to attain a present altitude of 15,000 feet and about 6,000 feet to attain the altitude of 7,000 feet. McConnell in the abstract to his paper states that the bevel has been raised by 10,000 feet at its highest part to 3,000 feet or less at the northern part of the range, with respect to the bevel as seen in the country surrounding the mountains.

The altitudes of the residual hill masses in central and western Kenya before warping of the bevel, would have varied from present altitudes slightly or considerably, according to the locality. For example, the "8,300-foot surface" of the Karissia hills (Dixey, 1/1948, p. 14) would at that time have stood at an altitude of about 4,000 feet, and the "10,000-foot surface" of the Cherangani hills (Dixey, 1/1948, p. 26) would have been at an altitude of only 6,000 feet.

MORVAN

Though the end-Tertiary bevel is approximately parallel to and a few hundred feet below the sub-Miocene bevel in most parts of the country, the two surfaces are in fact inclined to each other at a small angle, the older bevel having the greater gradient. The two plains intersect, i.e. there is a morvan, in the eastern part of the country, generally about the 500-foot contour of the sub-Miocene bevel. This indicates that before the time the end-Tertiary bevel matured, the Tana embayment had begun to warp, the effect being felt as far north as Habaswein.

The sequence of events pictured to allow the formation of the morvan is as follows:—

- (1) Maturation of the sub-Miocene bevel.
- (2) Flooding of the margin of the bevel by the sea.
- (3) Warping of the bevel leading to infilling by lower Pliocene sediments in the Tana embayment.
- (4) Regional uplift (or lowering of base-level) with some seaward tilting, enabling the formation of the end-Tertiary bevel. West of the margin of the depression the new planed surface was at a lower altitude than the sub-Miocene bevel, and east of it at a higher level, across the sediments deposited on the sub-Miocene bevel.
- (5) Deposition of upper Pliocene sediments on the end-Tertiary bevel.
- (6) Main warping of the bevels, renewed incision, and deposition of Pleistocene sediments.

The sequence can be compared with that established for south-western Kenya by Shackleton (2/1951, p. 385; cf. also Shackleton, 2/1955, p. 262).

IV—CONCLUSIONS DRAWN FROM THE MAP OF THE SUB-MIOCENE BEVEL

1. THE NOMENCLATURE OF EROSION BEVELS

It has been common for writers to refer to planed erosion surfaces by means of an altitude figure, as for example "the 4,000-foot surface" or "the 4,000-foot peneplain", with the implication that the bevel lies generally about that altitude, and that uplift that has closed a cycle of erosion has been more or less uniform throughout the extent of the bevel, rather than by extensive gentle warps as is revealed by the present map. It will be obvious from the map that it is only in small areas or along contours that the sub-Miocene bevel could be referred to as a surface with a certain altitude. The bevel extends over a large interval of altitude in Kenya, ranging from 6,500 feet above sea-level to more than 2,000 feet below sea-level. A considerable range of altitude was long ago recognized by Bailey Willis (2/1933) who stated, "It varies in elevation from 4,000 to 10,000 feet above sea, having been strongly warped during the later elevation of the continent. It is also faulted, being displaced vertically by the Rift faults. We may thus step it down from the Iringa highlands to the coastal region, where it is obviously to be correlated with the post-Cretaceous peneplain of von Staff."*

It is suggested that the naming of erosion bevels by altitudes may be misleading, and should be avoided (cf. Shackleton, 2/1956, p. 385).

2. RISE OF THE BEVEL TO THE RIFT

It has been remarked by several authors that the bevel rises to the Rift, though the conclusion was denied by Dixey (2/1946, p. 351) who at that time considered that "almost all recorded tilts (of the bevel) are illusory" and explained the apparent slopes

* It is perhaps worth noting that Bailey Willis in some cases confused the end-Tertiary and sub-Miocene bevels (see Willis, 2/1936, pp. 38-39).

by residuals on the bevel, by post-Miocene erosion on the seaward side, and by the fact that there has been maximum volcanic activity on the Rift shoulders. In a later paper (Dixey, 2/1956, p. 28), however, he recognized that there is an uninterrupted decline from the Rift shoulders to the coastal belt. In the earlier paper he believed that the altitude of the bevel at about 5,200 feet along the Rift "is no more than normal for this peneplain in the vicinity of original watersheds, and does not of itself necessarily indicate any considerable uplift along the Rifts themselves". The amount of uplift is considerable as has been shown on an earlier page, and though compared to the size of the earth the general slope up to the Rift on either side is negligible, as a local phenomenon it is of noteworthy magnitude.

The "rise to the Rift" is not, however, a slope that always continues unbroken to the Rift walls, as previous authors seem to have implied. In several places—between the Aberdare mountains and Lake Rudolf, in the Kalossia-Tiati area, in the region of the Elgeyo escarpment, and in the Narok-Loita Hills area—the bevel has a reverse slope and declines towards the Rift Valley. This indicates that the main walls of the Rift Valley are caused not only by faults but also by monoclinal warping of its shoulders. At certain places, indeed, there are no major faults at the walls, the main effect being produced by the warp into the Rift, as Shackleton (1/1946B, p. 46) recognized in the Maralal area and as Baker has since mapped in the Baragoi area (cf. also Willis, 2/1936, p. 63, though Willis exaggerated the extent of warping as compared with faulting). A similar feature is seen along the subsidiary rift, the Kavirondo Gulf graben, where north of Kericho and west of Kisumu the edges of the rift are formed by monoclinal warps.

3. EXTENT OF CONCEALED MIOCENE BEDS

A geological map of northern Kenya by Dixey (1/1948) showed the Tana embayment—roughly south of an east-west line through Tarbaj and east of a north-south line through the Merti plateau—and the Chelbi desert as occupied by Tertiary sediments ("probably Miocene in the N.F.D."*). This was repeated on the 1952 geological map of East Africa published by the Geological Surveys of East Africa in 1954. No evidence has yet been produced that the sediments exposed in these areas are Miocene, or even Tertiary. If, as the writer believes, the sub-Miocene bevel passes below sea-level at a longitude between Garissa and Bura and continues to decline to the east as shown on the map, it would be extremely unlikely that Miocene beds would be found at surface in the Tana embayment. This has, indeed, been proved at Dif, where Pleistocene beds have been found to a depth of 380 feet below the surface in a bore-hole, and at Gherille, where 450 feet of Pleistocene sediments are known (Joubert, 1 Wajir-Wajir Bor report). Concealed Miocene beds may, however, be expected at depth in the seaward part of the embayment. On the basis of the bevel-map their landward limit might be expected between Garsen and Kolbio, unless the sub-Miocene surface was warped down in the Tana basin before the onset of Miocene sedimentation. If this is the case, the determination of the northward extent of concealed Miocene beds is at present insoluble.

As the region of the Chelbi desert, probably lay near the divide between the main rivers that drained the sub-Miocene plain, it is considered unlikely that it would be a locality where Miocene sediments accumulated, though it is not impossible that early warping or damming by volcanic rocks could have given rise to a suitable environment. It appears more probable, however, that the development of the desert followed its almost complete encirclement by Pleistocene volcanic rocks, and that sediments deposited in it will prove to be of Pleistocene age.

* Northern Frontier District.

4. ISOSTATIC UPLIFT AT THE COAST

King (2/1956, p. 355; also cf. Pugh 2/1956) has indicated that in South Africa, after the completion of his post-Gondwana landscape, isostatic recovery led to the greatest uplift of the bevel in a zone from 100 to 150 miles inland from the coast. He continues, however, that the uplift that terminated the African cycle of landscape evolution (the cycle that led to the formation of the sub-Miocene bevel) was widespread and equable, and does not mention greater uplift in the coastal zone. The map of the sub-Miocene bevel in Kenya indicates that in a zone ending about 40 to 50 miles inland from the south-east part of the coast there is a considerable slackening of the slope of the bevel, and a slackening in the region south of the Taita Hills, some 90 miles inland, that may be related. There is at present, however, no evidence to indicate whether or not a similar slackening persists along the coast in the region of Lamu. It is possible that the coastal slackening may be the result of isostatic uplift but, if so, the order of uplift is evidently much less than imagined by King for the earlier post-Gondwana surface. It seems more likely that the slackening is the result of differential warping. The degree of warping would have been less near the continental margin, if the main warping took place in central Kenya. This is supported by the hypothesis that marked isostatic recovery near the coast would imply more or less uniform epeirogenic uplift of the whole of Kenya before the development of the sub-Miocene bevel which, judging from the shape revealed by the map, does not seem to have been the case. Down-warping into the Indian Ocean is indicated by the increase of slope of the bevel east of the coastal ranges, and by the repeated faulting that has taken place east of the coastal ranges.

5. ORIGIN OF THE GREGORY RIFT VALLEY

No evidence has yet been produced to show that the Rift Valley in Kenya had its origin before mid-Tertiary times. The shape of the sub-Miocene bevel is hence of importance in considering the origin of the Rift Valley. Pertinent facts are:—

- (1) The bevel turns over at several places, but not all, into the Rift.
- (2) The eastern slope of the bevel is gentler nearer the Rift Valley and the coast than in a steeper zone about half-way between the Rift and the coast.
- (3) The Rift is sited along a topographic low that existed in Miocene times.

These facts are incompatible with various theories that have been advanced to explain the origin of rift valleys. On a theory of origin by simple tangential thrusting from two directions towards the axis of the Rift, it would not be expected that the bevel would reverse its slope at the lip of the Rift. On a theory of origin of tangential warping of the bevel followed by thrusting from two directions, where the bevel does not warp over into the Rift it would be expected that the corresponding part of the bevel in the Rift would warp over into the walls of the Rift. This does not appear to be the case, and it is concluded that thrusting took no part in the origin of the Gregory Rift Valley.

It is equally evident that a hypothesis based on simple tangential tension of the unwarped bevel could not explain the slope as it now is: nor can Gregory's hypothesis of a great raised arch, in which tensional forces allowed the splitting off and sinking of a meridional "keystone". In such a case, though slackening its slope, the bevel would continue to rise to the Rift.

A theory of origin by tangential tearing alone is also incapable of explaining the shape of the bevel, nor can Shand's theory of a trench-like subsidence in a huge fissure volcano (Shand, 2/1936, p. 311). The writer concludes that the origin must be sought in vertical movements, which were usually positive, but in places negative. The vertical movements would, of course, lead to tangential tension effects. This is the hypothesis put forward by Bailey Willis (2/1936, p. 71). In view of the considerable depression of

the bevel in the southern part of the Rift Valley, it is clear that the foundation of the Rift is not simply an area that lagged behind the uplift of the bevel on either side, but an area that was in part dragged downwards. During such movements it is possible that some shearing might take place along the sides of the Rift, but the movements would not necessarily be in opposite senses on opposing sides of the Rift. Willis (2/1936, p. 261) suggested that there has been a north-westward shift of the block west of the Rift with respect to the block to the east, a suggestion that was repeated by McConnell (2/1951, p. 202). The bevel-map, if it suggests any shift at all, indicates the reverse, but the writer considers that no such conclusion can be drawn from present evidence. To accept such movement presupposes a regularity for the Kenya dome for which there is no proof.

The possible mechanics that could lead to the upward and downward movements have been discussed by Willis (2/1936, pp. 72-97), and apply equally to minor rifts, such as the Kavirondo Gulf graben, as they do to the Gregory Rift Valley. It should be noted that Willis points out that on his hypothesis the effects are not connected with isostatic adjustment, and that Dixey (2/1956, p. 50) has remarked that the "heaving of the swells" of Africa is to be regarded as a phenomenon separate from general uplift of the continent.

Willis's theory of the disturbance of the bevel by an expanding asthenolith at great depth, also gives a reason for the steepening of the bevel slopes on the eastern flank. Here one can imagine is the projection of the edge of a central Kenya asthenolith, with a gentler slope above the asthenolith and a steeper slope outside its margins. At such a slope, faults like those that form the east side of the Rift, but with throw in the opposite sense, could be expected. Such faults are known in the Kitui area. Willis (2/1936, p. 66) has offered an explanation of why faults are infrequent on the flank of the Kenya dome.

Consideration of the bevel-map leads inevitably to the conclusion that the main part of the Rift Valley formed along a lower Tertiary topographic low. This has already been postulated by Dixey for the African rift valleys in general (2/1946B, pp. 375-376), and for the Kavirondo Gulf rift (2/1946A, p. 245). In view of the apparent lack of topographic highs on the basement of the Rift, except locally and in narrow strips along its margins, and the marked alignment of topographic highs along the inner flanks, one can agree that the Rift Valley zone before the rift faulting and warping must have been the site of powerful rivers, flanked by high hills and mountains. Similar conditions may apply to the Kavirondo Gulf rift, though on a smaller scale. The arrangement of the large areas of high residuals on the sub-Miocene bevel provides a reason for the directions taken by the fracturing. The greatest effect would be expected on the west side of the Rift, where the residuals were and are highest, and is especially notable south-west of Narok, where the sub-Miocene bevel reaches its greatest altitude in Kenya. In flatter areas, as Fuchs (2/1939, p. 267) has pointed out for the Rudolf basin, the rifting is expressed rather by block-faulting and local folding.

Various authors have suggested that the Gregory Rift Valley was superposed on and guided by an older rift structure. There can be no doubt that in any particular section it was guided by structures in the basement. In the writer's opinion, however, its position was solely dictated by the position of the deep forces that caused it, and it would have lain elsewhere in Kenya if the position of those forces had been different, so that there would have been no sign of a rift at the site of the present Rift Valley. It is significant in this connexion that the main rift valley is meridional while the Kavirondo Gulf subsidiary rift is transverse.

6. EARLY TERTIARY RIVER SYSTEM

The map of the sub-Miocene bevel suggests that in the lower Tertiary one of the main rivers draining Kenya flowed generally south-eastwards from the region of Nairobi to the coast about Kilifi. An essay at depicting the course of this river and its

tributaries, and the course of an early Juba river system that probably flowed across north-eastern Kenya, is presented in Fig. 2. Many of the tributary courses would undoubtedly have been controlled by the generally meridional strike of the Basement System rocks that form much of the foundation of the country, and in south-western

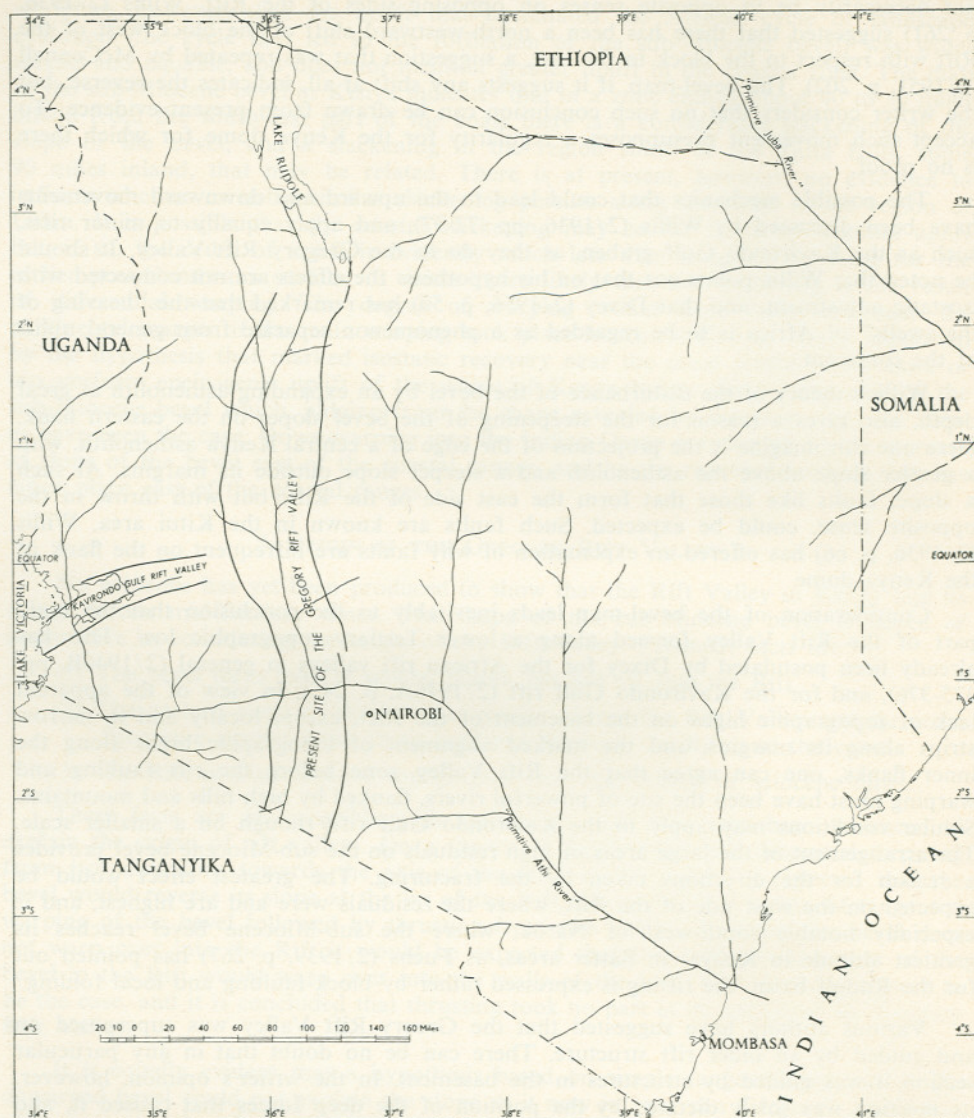


FIG. 2.—Possible early Tertiary drainage pattern in Kenya.

Kenya by the structures of the Nyanzian and Kavirondian Systems, which strike in directions between N.E.-S.W. in the north to N.W.-S.E. in the south. It is considered that at that time there was no primitive river Tana, except perhaps in the lower reaches of the modern river.

The diagram presented is tentative in the extreme, and will probably require much correction as more evidence becomes available.

It may be noted that B. C. King (2/1956, pp. 103, 106) has implied that the main watershed in lower Tertiary times ran almost along the western side of the Kenya Rift Valley. In view of the well developed sub-Miocene and end-Tertiary bevels of western Kenya the writer considers that supposition unlikely, and believes it more probable that the Atlantic-Indian Ocean divide lay near to the western Rift. Fuchs (2/1939, p. 264) has remarked that prior to the rifting movements the end-Tertiary bevel (which he calls the Central African peneplain, and apparently thought of as the sub-Miocene bevel) had extended over the site of the Rudolf basin. If the divide had been near the Kenya Rift the altitude of the sub-Miocene bevel in the region of Kisumu would have been of the order of 2,000 feet, as compared with the elevation of more than 5,500 feet on the same latitude at the Aberdares range. The formation of a rift valley with generally equally developed walls in such circumstances would be unlikely. The similarity of the altitude of the sub-Miocene bevel on either side of the Rift Valley in itself suggests that the main watershed lay well to the west of Kenya.

7. DEVELOPMENT OF THE RIVER TANA

The modern River Tana draws its supplies of water mainly from Mount Kenya, the Aberdare range, and the Nyambeni range. Although there was high land in the region of Mount Kenya and the Nyambeni range in Miocene times, it was low compared with the height of the subsequent volcanic piles. It is suggested in Fig. 2 that the streams draining the high land collected into a river flowing south to the primitive Athi river. It seems likely that the extensive outpourings of lavas in the lower Miocene in the Nairobi-Fort Hall area would have forced the main river further to the east and might even have diverted it around the northern end of Mumoni. With the warping in Pleistocene times the tilting of the surface would encourage the flow to the north past Mumoni, and thence eastward generally down the slope of the sub-Miocene bevel, until the Tana basin was reached. Here, it is presumed, the river would meet the course of a lower tributary of the primitive Athi and would take on a southerly course.

8. THE HIGH CENTRAL VOLCANOES

The two large central volcanoes in Kenya, Mt. Kenya and Elgon, and Kilimanjaro in Tanganyika, appear to have grown on high land or partly on high land that stood above the sub-Miocene bevel. The high land can be seen at places around the margins of the volcanic piles, though the representation on the map of the continuations of the high land under the volcanic rocks is at present largely conjectural. Geophysical depth-probing would reveal the value of such conjectures.

It is suggested that the great altitude of the volcanoes (and it must be remembered that, when youthful, their height was still greater) can be ascribed to the fact that they were built on generally high land. It is possible also that the attainment of great height has been assisted by doming of the sub-volcanic floor before extrusion began (cf. Willis, 2/1936, p. 66).

V—FUTURE WORK ON THE EROSION BEVELS OF KENYA

With the production of more geological maps of Kenya and the provision of accurate topographical maps of more remote areas, it will be possible to correct and refine the bevel-map. With the present map or its successors as guides it will perhaps also be possible to trace the shape of other bevelled surfaces, the end-Tertiary and the end-Cretaceous and other pre-Tertiary bevels. The construction of a map of the end-Tertiary surface would be relatively simple, as in many parts of the country it is a well-defined plain, and in some parts is marked by late Pliocene and Pleistocene sediments. Its usual approximate parallelism with the sub-Miocene bevel will also provide a useful guide.

The plotting of the older surfaces will, however, not be simple, as no dated sediments, except much more recent accumulations, rest on them. It is probable, too, that the vertical interval between the sub-Miocene bevel and any higher surface will vary in different parts of the country. The construction of maps of the higher bevels is, however, of considerable importance, as by their aid it will be possible to trace the movement of the surface of Kenya in Mesozoic times, and to discover whether it was epeirogenic or, as was the case in late Tertiary or Pleistocene times, movement that gave rise to warping.

VI—REFERENCES

Part 1

PUBLICATIONS OF THE GEOLOGICAL SURVEY OF KENYA

(Titles are abbreviated or summarized to the name of the areas described in reports.

As yet unpublished and often unnumbered reports are indicated by parentheses.)

- Ayers, F. M., 1952.—North-east Kenya. Report No. 22.
- Baker, B. H., 1954.—South Machakos. Report No. 27.
- 1958.—Magadi. Report No. 42.
- (——— — —Baragoi. Report No. 53.)
- (——— — —South of Magadi.)
- (——— — —Endau.)
- Baker, B. H., and Saggerson, E. P., 1959.—El Wak-Aus Mandula. Report No. 44.
- Bear, L. M., 1952.—South-east of Embu. Report No. 23.
- 1955.—Taveta. Report No. 32.
- (Binge, F. W.—Kericho. Report No. 50.)
- Caswell, P. V., 1953.—Mombasa-Kwale. Report No. 24.
- 1956.—Kilifi-Mazeras. Report No. 34.
- Crowther, A. F., 1957.—Mwingi. Report No. 38.
- Dixey, F., 1948.—Northern Kenya. Report No. 15.
- Dodson, R. G., 1953.—South-east Machakos. Report No. 25.
- 1955.—North Kitui. Report No. 33.
- (——— — —South Horr.)
- (Fairburn, W. A.—North Machakos-Thika.)
- (——— — —Fort Hall.)
- Gibson, A. B., 1954.—Broderick Falls. Report No. 26.
- Hitchen, C. S., 1936.—No. 2 Mining Area, Kavirondo, north-west quadrant. Report No. 4.
- 1937.—No. 2 Mining Area, Kavirondo, north-east quadrant. Report No. 6.
- Huddleston, A., 1951.—Kisii. Report No. 18.
- 1954.—Kakamega. Report No. 28.
- (Jennings, D. J.—Kapsabet.)
- Joubert, P., 1957.—Namanga-Bissel. Report No. 39.
- (——— — —Mandera-Damassa. Report No. 48.)
- (——— — —Wajir-Wajir Bor.)
- (——— — —Loperot.)
- Mason, P., 1955.—Meru-Isiolo. Report No. 31.

- Mason, P., and Gibson, A. B., 1957.—Kalossia-Tiati. Report No. 41.
(Matheson, F. J.—Kajiado.)
- McCall, G. J. H., 1959.—Gwasi. Report No. 45.
(——— — —Sekerr.)
- Miller, J. M., 1952.—Mariakani-Mackinnon Road. Report No. 20.
——— 1956.—Kitale-Cherangani Hills. Report No. 35.
- Parkinson, J., 1947.—Mtito Andei-Tsavo. Report No. 13.
- Pulfrey, W., 1936.—No. 1 Area, Kavirondo. Report No. 5.
——— 1937.—No. 2 Mining Area, South-west Quadrant. Report No. 7.
——— 1946.—Maramma, West Kakamega. Report No. 8.
——— 1946.—Maragoli. Report No. 9.
(Rix, P.—Nyali-Ndian Daza.)
- Saggerson, E. P., 1952.—Kisumu. Report No. 21.
——— 1957.—South Kitui. Report No. 37.
(——— — —Kasigau-Kurase. Report No. 51.)
(——— — —Simba-Kibwezi.)
(——— — —Loita Hills.)
- Saggerson, E. P., and Miller, J. M., 1957.—Takabba-Wergudud. Report No. 40.
- Sanders, L. D., 1954.—Kitui. Report No. 30.
(——— — —Mid-Galana. Report No. 46.)
(——— — —Voi-South Yatta. Report No. 54.)
(——— — —Eldoret.)
- Schoeman, J. J., 1948.—West of Kitui Township. Report No. 14.
——— 1949.—Sotik. Report No. 16.
——— 1951.—Embu-Meru. Report No. 17.
- Searle, D. L., 1952.—Kitale, Elgon and West Suk. Report No. 19.
——— 1954.—Sultan Hamud. Report No. 29.
- Shackleton, R. M., 1945.—Nyeri. Report No. 12.
——— 1946A.—Migori, South Kavirondo. Report No. 10.
——— 1946B.—Nanyuki-Maralal. Report No. 11.
- Sikes, H. L., 1939.—Nairobi. Unnumbered.
- Thompson, A. O., 1956.—Malindi. Report No. 36.
(——— — —Kijabe.)
- Thompson, A. O., and Dodson, R. G., 1958.—Derkali-Melka Murri. Report No. 43.
(——— — —Bur Mayo-Tarbaj. Report No. 47.)
(——— — —Naivasha.)
- Walsh, J.—South of Taita Hills. Report No. 49.)
(——— — —Ikutha.)
(——— — —Karasuk.)
- (Williams, L. A. J.—Hadu-Fundi Isa. Report No. 52.)
(——— — —Mara.)
- (Wright, J. B.—Ndeyini.)

Part 2

OTHER PUBLICATIONS

Arambourg, C., 1943.—"Contribution a l'étude géologique et paléontologique du bassin du Lac Rudolphe et de la basse vallée de l'Omo." Mission scientifique de l'Omo 1932-1933. Mus. Nat. Hist., Paris, vol. 1, fasc. 2, pp. 157-230.

Bishop, W. W., 1958.—"Miocene mammalia from the Napak volcanics, Karamoja, Uganda." *Nature*, vol. 182, pp. 1480-1482.

Dixey, F., 1946A.—"The relation of the main peneplain of Central Africa to sediments of lower Miocene age." *Quart. Jour. Geol. Soc.*, vol. 101 (for 1945), pp. 243-253.

——— 1946B.—"Erosion and tectonics in the East African Rift system." *Quart Jour. Geol. Soc.*, vol. 102, pp. 337-388.

——— 1956.—"The East African Rift system." *Col. Geol. and Min. Res.*, Bull. Suppl. No. 1.

Fuchs, V. E., 1939.—"The geological history of the Lake Rudolf basin, Kenya Colony." *Phil. Trans. Roy. Soc.*, series B, vol. 229, pp. 219-274.

King, B.C., 1958 - "The geomorphology of Africa, II - The geomorphic history of the Continent." *Science Progress*, No. 181, pp. 97 - 107

McConnell, R. B., 1951.—"Rift and shield structure in East Africa." Int. Geol. Congr., Report 18th session, Part 14, pp. 199-207.

——— 1959.—"Outline of the geology of the Ruwenzori Mountains." *Overseas Geol. and Min. Res.*, vol. 7, No. 3, pp. 245-268.

Pugh, J. C., 1956.—"Isostatic readjustment in the theory of pediplanation." *Quart. Jour. Geol. Soc.*, vol. 111 (for 1955), pp. 361-374.

Shackleton, R. M., 1951.—"A contribution to the geology of the Kavirondo Rift Valley." *Quart. Jour. Geol. Soc.*, vol. 106, pp. 345-392.

——— 1955.—"Pleistocene movements in the Gregory Rift Valley." *Geol. Rund.*, vol. 43, heft 1, pp. 257-263.

Shand, S. J., 1936.—"Rift Valley impressions." *Geol Mag.*, vol. 73, pp. 307-312.

Trendall, A. F., 1959.—"The topography under the northern part of the Kadam volcanics and its bearing on the correlation of the peneplains of south-east Uganda and the adjacent part of Kenya." Records, Geol. Surv. Uganda, 1955-1956, pp. 1-8.

Willis, Bailey, 1933.—"The peneplains of East Africa." *Geog. Jour.*, vol. 82, pp. 383-384 (correspondence).

——— 1936.—"East African plateaus and rift valleys." Studies in comparative seismology, Carnegie Inst., Washington.