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Further Notes on the Physiography of Portuguese East Africa, between the Zambezi River and the Sabi River

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journey across the Karakoram to Kashmir, and a host of other practical tasks, kept me hard at work all through June. In the meantime I had the great satisfaction of receiving through the kind offices of H.E. Sir George Buchanan, H.B.M.'s Ambassador at Petrograd, the final permission of the Russian Government for my long-planned journey across the Pamirs and through the mountain tracts north of the Oxus. In a few days I propose to set out on this journey, which is to serve mainly researches on the historical geography and archæology of those regions. In the autumn I hope to follow them up by similar work in easternmost Persia.

[The following is an extract from a letter dated "Camp Kara-Chem, Pamirs, August 8, 1915"] :—

I was able to start for the Pamirs by the first week of July. On my way I stopped for "daffar" work at Bostan-arche, a delightful spot below the Ulugh-art, with fir forest and quite alpine surroundings, which would make a splendid "hill station." I made my way north to the Alai, and am now proceeding from there along the grand snowy range which forms the western rim of the Pamirs towards the Great Pamir source of the Oxus. I propose to follow the latter down through Wakhan to Khorok, and thence to visit Roshan, Darwaz, Karategin before going to Bokhara and the railway. About the end of October I may hope to reach Meshed. The winter I propose to spend in Seistan, and by March I hope to return to India, if all goes well. I have asked for furlough to take me home in the spring and enable me to complete "Serindia," the final report on my second journey. I have met with nothing but kind help since I crossed the Russian border, and feel elated by the chance of seeing so much of new and fascinating ground. Some of it is decidedly rough to travel over, but my leg has so far stood the climbs and long marches quite well.

FURTHER NOTES ON THE PHYSIOGRAPHY OF PORTUGUESE EAST AFRICA, BETWEEN THE ZAMBEZI RIVER AND THE SABI RIVER.

By E. O. THIELE, M.Sc., F.G.S.

Introduction.

SOME of the major physical features of a portion of Portuguese East Africa south of the Zambezi River, and their probable relation to tectonic factors were described recently by Mr. R. C. Wilson and myself in this *Journal*.* The observations embodied in that account had then extended over three seasons of field work in connection with the mineral

* *Geogr. Journal*, January, 1915.

survey of the Companhia de Moçambique, and they led us to emphasize the view which had gradually matured in our minds that many of the

main surface features of that region were dominated by tectonic movement and fracture. In other words, while realizing the important part

played by ordinary erosion acting on rocks of various hardness and structure, we felt convinced that some of the important plateaus, scarps, and depressions were largely controlled by tectonic factors. Thus the frontier scarps of the Rhodesian plateau were described as mainly of fault origin and the lower Zambezi valley as a sunk land. The evidence in favour of tectonic control was in most cases based on physiographical features in conjunction with geological structure, but in several instances physiographical evidence was all that was available. Thus the ascribing of the features of Urema sunkland and the Sheringoma scarp to tectonic origin was based mainly on physiographical considerations.

During the recent field season of 1914 we were able to visit a portion of this region again, and devoted some time to the examination of the Sheringoma scarp, where we were fortunate in finding conclusive geological evidence of faulting. Further support was thus obtained in favour of the view advanced that the Urema depression was probably a southern continuation of the great African rift zone.

The same field season embraced another large tract of the coastal lowlands south from the Beira-Mashonaland railway line as far as the Sabi River, and included also a considerable strip of the hill country along the western boundary of the plains. Many additional physiographical studies were therefore provided. As the work of the mineral survey has been suspended on account of the war, and Mr. R. C. Wilson has volunteered for active service, there does not seem to be any immediate prospect of pursuing these physiographical studies. The following observations are therefore recorded to supplement those previously given, and accordingly bear mainly on the relation of the tectonic and physiographical features.

It is frequently very difficult in physiographical problems to ascribe the correct share due to tectonic and structural factors respectively. As structural features are more generally recognizable and capable of proof they are perhaps more frequently emphasized in the study of surface features; but it appears to be beyond question, that in certain regions tectonic movement is sufficiently rapid and powerful to dominate ordinary erosional factors. In this discussion, therefore, though the importance of structure has not been lost sight of that of tectonic control has received some emphasis.

The region embraced in this description forms part of the great coastal lowlands which consist mainly of featureless, bush-covered plains. There are, however, some extensive treeless areas also, notably along the Urema valley. That part most worthy of mention is the Sungwe region in Gorongosa where countless mobs of game are still to be seen and lions are extremely numerous.

Perhaps the most striking physiographical feature of the coastal lowlands is the wide shallow depression which takes the form of a trough in the north and in the south. Its western boundary is from 60 to over

BUZI VALLEY, LOOKING NORTH-WEST, SHOWING LIMESTONE SCARPS WHERE THE RIVER LEAVES THE PLAINS TO THE WEST AND INTERSECTS THE SOFALA-BUZI PLATEAU.

CLIFFS OF TERTIARY LIMESTONE, KUNDWI RIVER, SHERINGOMA,
SHOWING ALSO SURFACE OF THE PLATEAU NEAR THE
WESTERN SCARP.

UNDERGROUND PASSAGE LEADING OUT ON TO CLIFF, KUNDWI
VALLEY, SHOWING ALSO SINK HOLE IN THE ROOF.

80 miles from the coast, and consists of a clearly defined scarp rising suddenly from about 200 to over 1000 feet above sea-level. This is the eastern edge of the 1000-2000 feet shelf of crystalline rock previously described. Its southern portion was examined last season south from the railway line for a distance of about 100 miles. Its features are similar to those noticed previously to the north. All the rivers issue on to the plains through entrenched gorges, with numerous rock bars and rapids. Their character suddenly changes from active steeply graded courses to sluggish meandering streams, wandering over plains of sand and clay. This scarp continues in a direction from north-east to north-north-east for a distance of nearly 200 miles, and the question of its origin calls for some consideration. Geologically it consists almost entirely of gneiss, but it is noteworthy that basic dykes conforming closely in direction to that of the scarp are of frequent occurrence in this zone, but are rare to the west over a distance of about 100 miles until the frontier region is reached, where they are more abundant again. As a rule there is no rock showing on the plains to the east, for a deposit of recent sand and clay of unknown depth covers everything. Along the northern margin, however, in Gorongosa, basaltic hills become frequent, associated also with a sedimentary series of undetermined age, but probably Upper Karoo. These sediments have only a narrow outcrop along the margin of crystalline rocks and soon disappear under the recent deposits of the plains. They consist of coarse reddish grits, shales, and conglomerates which have so far yielded no fossils, but are continuous with similar beds in the Zambezi basin which appear to form the uppermost portion of the Karoo series. The deposits are of a coarse littoral character and mark, therefore, proximity to an old shore-line. The above evidence thus indicates some important structural features which suggest also the probability of associated tectonic movement; but it is not conclusive and other interpretations of the evidence are possible.

In the discussion of the Urema trough, given later, alternative views are represented diagrammatically, both of which, however, include a certain amount of relatively recent faulting along the eastern side of the trough (Figs. 1-5). Though no actual fault sections have been noted in the western side it is difficult to account for the physiographical features by structural factors alone. The scarp may either be regarded as of recent development or of Cretaceous or Karoo age and due then in the two latter cases to the stripping off the softer littoral sediments by recent erosion. In any case it seems most probable that a certain amount of tectonic action must be attributed to its formation, and the view that appears to harmonize most with the requirements is that there has been recent dislocation along an old tectonic line.

The eastern boundary of the depression under discussion is well defined in the north over a distance of more than 60 miles by the straight scarp of the Sheringoma plateau, and a similar but lower scarp has been traced

in the southern region through Western Sofala across the lower Buzi for a distance of more than 50 miles. In the central portion, however, there is no eastern wall, its place being taken by the vast plains of the Pungwe,

1. Late Karoo shoreline. Lacustrine deposits,—red grits, sandstones, shales and conglomerates.

2. U. Cretaceous shoreline,—cut out of soft Karoo sediments.
Sandy marls and limestone followed by Tertiary limestone.
Post Karoo Volcanic activity indicated near the old Karoo shoreline.

3. U. Cretaceous and Tertiary coastline may have approached practically to the crystalline rocks, the limestones and marls passing gradually into coarse littoral deposits.

4. Post Tertiary uplift with faulting causing the western Sheringoma scarp and Urema depression,—sagging without faulting along the western side.

5. Post Tertiary uplift with faulting on both sides of the trough. That on the western side being assumed.

DEVELOPMENT of the UREMA TROUGH.

Representing the probable successive positions of old coast lines and corresponding extent of various strata. 2 and 3 are alternative views with regard to the Cretaceous shore, and 4 and 5 concerning the western side of the Urema trough.

Gn. Gneiss.	K 1. ? Late Karoo Conglomerate.	L 1. Miocene Limestone.
V. Volcanic.	K 2. ? Sandstone.	L 2. Eocene.
(Basaltic)	K 3. ? Shale.	C. Cretaceous.
	Al. Recent Alluvium.	

which extend continuously from the western margin of the lowlands to the sea, a distance of more than 60 miles in a straight line.

The Urema trough and its eastern wall formed by the scarp of the

Sheringoma plateau were briefly described in the previous article which appeared in this *Journal*, but some additional exploration in this region during the past season has provided some interesting and important

Block diagram showing low coastal plains, limestone plateaus, sunklands and inland depression, 1000-2000, ft., with revised river system. The frontier scarp of the Rhodesian Plateau is also shown.

Fig. 6.

evidence bearing on the physiography of the area. One noteworthy feature of the Urema depression is that it is annually flooded over wide areas forming a series of shallow temporary lakes, with continuous water

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Fig. 7.
Diagrammatic Sketch, Masikedzi R. Sheringoma with lateral hanging valley due partly to the development of travertine terraces at the junction which have retarded the corrosive action of the tributary.

communication between the Zambezi and the Pungwe, a distance of more than 100 miles. The water drains off rapidly as the dry season advances, and the tough black clay, which covers wide areas, soon becomes hard baked in the sun and intersected by wide gaping cracks.

The Sheringoma scarp is remarkably straight and free from outliers to the west, and the tributaries of the Urema draining from the plateau

Fig. 8.
Underground Hanging Valley, Kundwi R., Sheringoma.
A. Limestone. B. Sandy and calcareous clays.

have cut narrow steep-walled canyons of rapid grade through the Tertiary and Cretaceous limestones and marls. These valleys provide some striking scenic effects and reveal some fine geological sections. Only a few of these have yet been traversed. The Kundwi, however, shows some important sections, and just where it issues on the plains, close to the base of the scarp, there is a fine fault section (see Fig. 9). The Miocene

Fig. 9.
Fault Section, Kundwi R., Sheringoma.

foraminiferal limestone, which occurs on the plateau at least 500 feet above, is here seen to be dipping at angles from 30° to 50° to the north-west. The displacement is therefore at least 500 feet. The character of the fault suggests one of considerable extent, and though the other streams have not yet been explored in parts corresponding to this fault line, it is highly probable that many would yield similar evidence. The age of the fault is clearly post-Miocene, and the Sheringoma scarp is

almost certainly a true fault scarp. Its age based on physiographical evidence is probably of recent date. The existence of this fault was previously inferred on physiographical grounds; it was therefore gratifying to find subsequently such clear geological support. The Sheringoma region exhibits many of the interesting surface features that are common to limestone country, but two less usual forms are worthy of mention; these represent special cases of hanging valleys, one of which was noted in the valley of the Kundwi and the other in that of the Masikedzi. These streams, like most of those draining west into the Urema, follow shallow channels on the plateau for a few miles and then drop into deep narrow fissures in the limestone which soon widen out into deep gorges with vertical and overhanging cliffs.

The instance in the Masikedzi valley is at the junction of a tributary with the main stream. The over-deepening of the main channel is due in part to its greater volume, but the corrasion of the lateral stream at its junction has been retarded by a fine succession of travertine terraces, like so many swallows' nests one above another, illustrated diagrammatically in Fig. 7.

The other case in the Kundwi valley is caused by the junction of an underground channel with the main stream. The tributary in this instance is a small intermittent one, and the over-deepening of the main stream, therefore, is due almost entirely to its greater volume (see Fig. 8).

The Buzi Depression and Scarp of Western Sofala.

This region repeats in the main the features of the Urema and Sheringoma but with some differences. The plateau of Buzi and Western Sofala is not isolated like that of Sheringoma, as it sweeps round and continues uninterruptedly to the west-south-west into Rhodesia, merging into the sandy gravel-capped lowlands of the Sabi basin. It is, moreover, much lower, barely reaching 500 feet above sea-level and is also crossed by a steep walled gorge, for the Buzi, after flowing parallel with the scarp for some distance, suddenly turns and crosses it.

The straightness of the western scarp and the general north-north-easterly direction are features resembling closely those of Sheringoma; the western streams, however, are not so numerous nor so well developed, and no fault sections have yet been noted. Both plateaus shade off gradually into the great central plains of the Pungwe. The general features of the whole area are represented in Fig. 6. The sudden change in character and in direction of the lower Buzi valley is of interest. It suddenly leaves the wide shallow trough it occupies to the west of the limestone scarp and follows a relatively narrow channel bounded by limestone cliffs about 200 feet high for 8 to 10 miles. These features are illustrated diagrammatically in Fig. 6, and are capable of being interpreted in different ways.

1. Differential erosion due to a stream crossing country composed of

MIOCENE LIMESTONE, KUNDWI RIVER, AT THE BASE OF THE SHERINGOMA SCARP:
TILTING OF THE STRATA DUE TO FAULTING.

SHALLOW VALLEY, SHERINGOMA PLATEAU, IN MIOCENE LIMESTONE, DROPPING INTO
DEEP FISSURE WHICH SOON WIDENS INTO A NARROW CANYON.

alternating strips of hard and soft rocks generally results in a succession of features similar to those represented here. In other words, the origin may be purely structural. Unfortunately the depression to the west shows few sections of any importance, for its surface is covered with recent drift and alluvium.

2. River capture caused by the headward erosion of one stream into the basin of a less active one will frequently result in the development of features similar to those under discussion.

3. Differential uplift or warping, with or without faulting, will also produce similar results provided the movement is not sufficiently rapid to divert the course of the stream.

The detailed structure of the area is not sufficiently well known to afford conclusive evidence on this question, but the close resemblance of the features with those of Sheringoma where faulting has been observed, together with the fact the two scarps are on the same line, strongly suggests a similar origin for both. The Buzi-Sofala scarp is therefore tentatively regarded as of fault origin.

The absence of any scarp features in the lower Pungwe region may be accounted for in several ways: either the uplift which raised the areas to the north and south did not affect the central zone, or if so, the erosion of the Pungwe has been many times more rapid and extensive than elsewhere, for the character of its wide swampy plains is in striking contrast to the youthful features of the Buzi Gorge.

It seems probable then that the orogenic movements affecting the coastal lowlands were of an undulatory character, the central or Pungwe portion partaking of a downward warping, and this may be causally connected with the heavy sedimentation of the Pungwe estuary.

The features of the broad coastal lowlands under consideration correspond approximately with what Prof. W. M. Davis * has described as a belted coastal plain; that is, it is divided into three longitudinal belts, the innermost consisting of a lowland depression of soft strata, the middle an upland of harder rocks, and the outer belt a smooth lowland. In the case of the lowlands of Portuguese East Africa, however, the uplift has been accompanied by differential movement and faulting which has accentuated the zonal distribution of the rocks, thus assisting the development of features which in some cases may be the result of erosion alone.

Many interesting physiographical problems still remain to be solved in this region, but much more detailed exploration is necessary before they can be satisfactorily considered. One of these may be briefly referred to in concluding.

The impression gained by rapid traverses over the vast plains of the

* 'Physical Geography,' p. 132, Fig. 82. Ginn & Co., Boston, U.S.A., and London.

Urema was that they may represent the site of a filled-up lake or series of lakes. It must be admitted, however, that at present there is not much field evidence in support of this view. No lake terraces have been observed, and nothing is known concerning the nature of the deposits underlying the superficial cover of sand and clay.

Summary of Conclusions.

The coastal lowlands form an imperfectly belted coastal plain 80 to 100 miles in width. Its innermost longitudinal lowland has no eastern wall in the central portion, for the middle upland belt of limestone rocks, which is well developed in Sheringoma and Western Sofala, is replaced by the low plains of the Pungwe in the central portion.

Downwarping of this region may be the explanation of this feature, probably causally connected with the heavy sedimentation in the vicinity of the Pungwe estuary. Though the belted structure of the lowlands may account largely for the features developed, it is certain that in the Urema region, and probably in the Buzi depression to the south, it has been assisted by tolerably recent faulting.

The line of this depression being a direct continuation of the Nyasa-Shire tectonic line suggests the probability of a synchronous control. The surface features here, however, are affected to a much less extent, indicating probably that the strength of the tectonic dislocation was dying out to the south.

TWO IMPORTANT MAPS FROM THE SURVEY OF INDIA.

TIBET AND ADJACENT COUNTRIES, 1 : 2,500,000.

CARTE INTERNATIONALE DU MONDE AU 1,000,000°. North E. 43, BOMBAY.

A GOOD map of Tibet and the adjacent countries has long been needed. Since the last edition of the Society's map of Tibet was published in 1906 much fresh information has been obtained which could scarcely have been shown upon the relatively small scale of that map. Moreover, it would hardly have been possible to undertake successful revision, inasmuch as the officers of the Survey of India have done far more than any others in the exploration of Tibet, and an important part of the new information remained inaccessible in the Survey Office at Dehra Dun. There alone was it possible to undertake the task of compiling a map such as that now under review.

The new map, on the scale of 1 : 2,500,000, is bounded by parallels 44° N. and 26° N. and by meridians 72° E. and 102° E., and is printed