12. *The* Geology *of the* Zambezi Basin *around the* Batoka Gorge (Rhodesia). By George William Lamplugh, F.R.S., F.G.S. *With* Petrographical Notes *by* Herbert Henry Thomas, M.A., B.Sc., F.G.S. (Read January 23rd, 1907.)

[Plates X–XVII.]

Contents.

I. Introduction.

At the request of the Council of the British Association, I undertook to examine the country in the neighbourhood of the Victoria Falls of the Zambezi[1] River before the meeting of the Association in South Africa in the summer of 1905. Through the helpful co-operation of the British South Africa Company and the aid afforded to me by its officers in Rhodesia, I was enabled to make good use of the short time available to me for the task; and by rapid traverses of the wild country eastward of the Falls I gleaned much information regarding the geology and physiography of this little-known region. A preliminary account of the exploration was presented at the meeting of the British Association in Johannesburg, and has since been published in the 'Report' of that body.[2] In this account the objects of the exploration and the circumstances of the journey are stated, and therefore need not be repeated here; but of the geological results it was only possible at that time to give a bare outline, pending the further examination of the material collected. My present object is to deal more adequately with the geological evidence.

The traverses occupied seven weeks in July and August, 1905, during which time a distance of over 600 miles was covered, partly on the northern and partly on the southern side of the Zambezi, as shown on the sketch-map (Pl. XVII), the area embraced within

[1] This spelling is adopted to conform with the usage of the Royal Geographical Society, although personally I think that Livingstone's spelling Zambesi should have been retained.

[2] Rep. Brit. Assoc. 1905 (South Africa) [London, 1906] pp. 292–301.

these traverses being over 2000 square miles. In exploration of this kind, through difficult country, where the exigencies of the daily march are ever insistent, it is of course rarely practicable to follow up the evidence that presents itself. One must usually be content to snatch just so much as lies in one's path; therefore it is inevitable that the facts which come under observation will frequently be of less consequence than those which remain undiscovered. In my attempt in the following pages to give coherence to the collected data, I am aware that some of the conclusions rest upon an imperfect basis; but it may be long before fuller knowledge is accumulated, and meanwhile it seems desirable that what we already possess be used so far as may be in temporarily bridging the gaps.

The most serious difficulty in work of this kind arises from the absence of a topographical map upon which to record the geological observations. In the present case, some parts of our route appear not to have been previously traversed by the white man, while for the other parts the existing maps are too inaccurate to be of much service; and I unfortunately found it impossible, under the conditions of our journey, to construct a map adequate to supply the deficiency. In plotting the imperfect sketch-map that accompanies this paper, I have had to rely largely upon compass-bearings and dead reckoning, taking as a basis the plan of the railway.

The country which I personally examined, and shall now more particularly describe, extends from near the Victoria Falls eastward for about 75 miles to the confluence of the Zambezi with its tributary the Deka, and from the plateau north of the Zambezi southward for about 70 miles to the head-waters of the Deka.

II. Previous Literature.

Until recently our knowledge of the geology of this part of Rhodesia depended upon the casual notes of a few travellers, of whom David Livingstone was first and foremost. In his eastward march from the Victoria Falls in 1855, and in his later journeys of 1860, Livingstone went to the northward of the country now to be described; but at one place he turned southward to visit the great Moamba [Mamba] cataracts of the Zambezi within its gorge; and at this spot only did our expedition touch the track of the great explorer. His record of these journeys includes some notes on the rocks of the Batoka Highlands,[1] which are still, so far as I am aware, the only published information on the geology of that district (see p. 171).

The best account, even to the present day, of the more frequently traversed country south of the Zambezi is that given by James Chapman in 1868. Though not pretending to technical knowledge, Chapman had an observant eye for the rocks; and much geological

[1] 'Missionary Travels & Researches in South Africa' (London, 1857) chap. xxvi, p. 534 & chap. xxvii, pp. 542–43; and 'Narrative of an Expedition to the Zambesi & its Tributaries' (London, 1865) chap. xi, pp. 222–23.

information may be gleaned from his descriptions.[1] The writings of the numerous later travellers who have recorded their journeyings through this part of the country contain no material addition to our knowledge of its structure.[2]

With the beginning of a technical literature within the last few years, the geology of the whole region has been placed on a firmer basis. In a paper contributed to this Society in 1903,[3] Mr. A. J. C. Molyneux, F.G.S., described the sedimentary rocks of a broad strip of country south of the Zambezi, nearly conterminous with the eastern margin of the tract with which I have to deal, and evidently related to it in structure. In a later paper[4] Mr. Molyneux discussed the geological and physiographical features of the Victoria Falls, and showed that the singular chasm into which the Zambezi plunges at this spot has been developed by normal erosion, and not, as popularly supposed, by a sudden rending of the earth's crust.[5] In this paper the term 'Batoka Basalt' is introduced for the basic lavas that form the country-rock around the Falls.

[1] 'Travels in the Interior of South Africa' vol. ii (London, 1868) chaps. iv–xi, pp. 83–278.

[2] Some scraps may be gleaned from the following:—'Explorations in South-West Africa' by Thomas Baines (London, 1864); 'To the Victoria Falls of the Zambesi' by Eduard Mohr (Engl. transl. by N. D'Anvers, London, 1876); 'Seven Years in South Africa: Travels, Researches, & Hunting Adventures etc.' by Emil Holub (Engl. transl. by E. E. Frewer, London, 1881, two vols.); 'How I crossed Africa' by Major Serpa Pinto (Engl. transl. by A. Elwes, London, 1881, two vols.); 'A Hunter's Wanderings in Africa' by F. C. Selous (London, 1890); 'The New Africa' by Aurel Schulz & August Hammar (London, 1897); and later works by Major A. St. H. Gibbons and by Col. C. Harding, to which reference will be made in the context.

[3] 'The Sedimentary Deposits of Southern Rhodesia' Quart. Journ. Geol. Soc. vol. lix (1903) pp. 266–90.

[4] 'The Physical History of the Victoria Falls' Geogr. Journ. vol. xxv (1905) pp. 40–55.

[5] Although this idea of Livingstone's was repeated by all later travellers and had obtained general currency, it must be remembered that so long ago as 1865, Sir Archibald Geikie, now our President, had already recognized the real character of the Batoka Gorge. In the first edition of his 'Scenery of Scotland' (Macmillan, 1865), after pointing out that in countries where the rainfall is small and frosts trifling or unknown, the rivers will cut perpendicular chasms of great depth, he remarks:—'Thus the Zambesi in plunging over the precipice at the Victoria Falls enters a gorge 100 feet deep [the depth originally assigned to it by Livingstone] and only 80 feet broad, which runs in a zigzag course for many miles. The river seems to have cut its way backward through this winding ravine until, owing to some subterranean movement, effecting a change of level, or to some other cause which would probably be detected by a geologist on the spot, the body of water in place of entering at the top of the ravine has been emptied over one of its sides' (p. 33). And in a footnote on the same page, referring to his examination of the model of the Victoria Falls (now in the possession of the Royal Geographical Society) which had been prepared from Livingstone's description, our President adds '. . . . . In looking at it I was much struck with the resemblance of the so-called "gigantic fissure" to a ravine cut by the action of a stream where springs, rains, and frosts have played only a subordinate part.' The foregoing passages were written when Livingstone's great discovery of the Falls was still novel; they were not reprinted in the later editions of the book, probably because, after the first flush of interest in the Falls had passed, it was felt that this reference to them was not well placed in a description of Scotland.

An excellent report on the geology of Southern Rhodesia[1] by Mr. F. P. Mennell, F.G.S., published in 1904, deals more especially with the country around Bulawayo, which is illustrated by a geological map; but it also contains a general sketch of a much wider region, and includes some references to the rocks in the area now under description. In this report, and in an earlier paper,[2] Mr. Mennell records the petrographical characters of the Batoka Basalts and of other Rhodesian rocks.

The 'Proceedings of the Rhodesian Scientific Association' (Bulawayo: vols. i–v, 1899–1905) contain some further information respecting Rhodesian rocks, though not directly referring to the tract within my traverses.

In 1904 was published the important work of Dr. S. Passarge, entitled 'Die Kalahari,'[3] in which all the available data regarding the great interior basin of Central South Africa are summarized and discussed. In the light of his extensive personal researches in the Kalahari desert between the years 1896 and 1898 while acting as mining expert to the British West Charterland Company, Dr. Passarge skilfully brings together the scanty material contained in the records of previous travellers, and evolves an admirable interpretation of the geological structure and physiographical development of the whole basin. Although his bold generalizations frequently rest upon slender evidence, and are likely to require much modification, this remarkable work enables us to grasp the essential elements and probable significance of the structure of this vast territory. Disregarding the usual geographical limitations of the term, he includes within 'the Kalahari' the whole region wherein 'half-steppe' or 'semi-arid' conditions prevail. Thus, Barotseland and a wide contiguous tract north of the Zambezi are entitled by him the 'Northern Kalahari'; and his 'Middle Kalahari' embraces a great belt of country south of the Zambezi, extending from the inner margin of Matabeleland to the western watershed of the continent. The country which I traversed falls therefore within this latter division; and its geological structure is described, and in part represented on a geological map, based mainly on the accounts given by Chapman and Livingstone. I shall have occasion frequently to revert to Dr. Passarge's work in the context.

III. Physical Features.

Though complex in detail, the broader features of the region under examination are simple. Above the Victoria Falls, the Zambezi is a wide placid river flowing at an elevation of about

[1] 'The Geology of Southern Rhodesia' Special Report No. 2, Rhodesia Museum (Bulawayo, 1904) pp. 42, with geological map.

[2] 'Contributions to South African Petrography' Geol. Mag. dec. 4, vol. ix (1902) pp. 356–66 (description of basalt from Victoria Falls and Deka, with figure, p. 358).

[3] 'Die Kalahari, Versuch einer physisch-geographischen Darstellung der Sandfelder des südafrikanischen Beckens' Berlin, 1904, pp. 822 & Kartenband.

3000 feet above sea-level in a shallow valley through a country of low relief. This country forms part of the great interior basin of South Africa, whose featureless plains extend far to the northward, westward, and southward; ranging through some 20 degrees of latitude, from beyond the watershed of the Congo nearly to the Orange River; and through 8 or 10 degrees of longitude, from the rim of the west-coast slope to the valley of the Limpopo. Except around a few clustered 'island-hills' (Insel-bergen) the drainage-gradients throughout this great basin are peculiarly low, and the river-channels are only very slightly incised and present many abnormalities. Dr. Passarge gives strong reason for believing that the development of this plain has been due to prolonged and recurrent desert-conditions. That there have been important changes of condition as regards rainfall and surface-drainage during and since the development of the plain is evident, as Livingstone and later travellers have recognized, from the character of the superficial deposits; the latest change in this, as in many other parts of the world, having been one of progressive desiccation. From his investigation of these deposits Dr. Passarge considers that at some time previous to the setting-in of the recent desiccation, there was a period of exceptional humidity in the region, probably contemporaneous with the Glacial Epoch of higher latitudes, during which the plain was watered by many rivers and lakes that have now disappeared. But before this humid period there was, he believes, a time of arid conditions; and he interprets the evidence as indicating also earlier cycles of alternation.

Whatever its origin, this high-lying basin-plain, for the most part deeply sand-covered, with its anomalous drainage-system, constitutes the most striking feature in the physiographic structure of Southern Africa.

At the Victoria Falls, however, the broad Zambezi drops in a single plunge from this region of low relief; and narrowing into a deep and powerful torrent, hurries impetuously towards the Indian Ocean. That a large volume of the drainage from the interior must long have held this course is proved, as Mr. Molyneux has pointed out, by the length and character of the trough which has been excavated; the distance from the Falls to the lowermost of the great gorges which these inland waters have carved out in crossing the high eastern rim of the continent being nearly 600 miles, besides the further 350 miles of low country that is traversed by the river before it reaches the ocean. The antiquity of the interior plateau denoted by this great drainage-channel is indeed significant.

The country with which I have now to deal lies around the highest of the gorges—the Batoka Gorge, as I have proposed to name it. The strange zigzagging chasm just below the Victoria Falls, into whose astonishingly narrow gullet the waters of the Zambezi are gathered after their shattering plunge, has been frequently described. In tracing the river eastward we found that the gorge maintained its trench-like character for about 60 miles, and then rather suddenly expanded into a more open valley. The geological structure of the country remained unchanged, however, up to Makwa [1] or Wankie's Drift, the eastward limit of our journey along the Zambezi, several miles below the termination of the gorge; where we were still on the same plateau-basalts which we had traced uninterruptedly from the Falls. Through its great trench the river pours tumultuously, like an overgrown mountain-torrent, fretted at short intervals into foaming rapids, and at the season of low water in places confined within rock-bound gullies sometimes not more than 20 or 30 yards in width; but in such places bordered by wide platforms of bare rock, deeply indented with 'pot-holes,' over which the enormously augmented stream is poured in flood-time. The difference between the volume of the river during low water and during the floods must indeed be great; since we saw indications, where the bottom of the gorge was narrow, that the river rises at least 50 feet above its dry-season level. It is to the effect of this extreme seasonal variation upon certain structural peculiarities of the basalts, presently to be described, that the characteristically acute swerves of the river within its gorge are to be attributed.

The Zambezi at the Victoria Falls loses at once 360 feet of altitude, but this is only the first great step in its rapid descent; for, by the time that it reaches Makwa, after its emergence from the Batoka Gorge, it appears to have lost at least a further 800 or 900 feet.[2] And although the basaltic plateau itself declines eastward, the river falls more rapidly in this direction; so that the depth of the cañon is increased from about 400 feet near its beginning to about 800 feet (by aneroid measurement) at the spot where I descended into it a few miles above its termination. As I have elsewhere discussed the indubitable evidence for the gradual development of the Gorge by erosion, it is needless for me to recapitulate the points. The photographs reproduced in Plates X–XIV, selected to show the features of the cañon at different parts of its course, will also suffice to illustrate one of these points, to wit, the progressive reduction eastward in the steepness of its sides, from verticality in the newly-cut portion at the Falls to slopes of 30° or under in the older portion which has suffered prolonged weathering.

[1] I have found that so much confusion arises from the repetition of Wankie or Wankies as a place-name in the district formerly ruled by the chief, Wankie or Tzwanki, that I propose hereafter to restrict the use of the name to the place where the coal-mine, railway-station and post-office are established, and to adopt Major A. St. H. Gibbons's term, Makwa, for Wankie's Drift or Ferry across the Zambezi. The old chief was much harried by the Matabeli, and had several times to shift the site of his settlement, so that there are still three or four places bearing his name. The nomenclature of the country, however, at present stands in need of revision in many particulars.

[2] This estimate is based on my aneroid observations; it is borne out by the figures given by Mohr ('To the Victoria Falls of the Zambesi' 1876, p. 329) for the height above sea-level of Wankie's village [Makwa]—1680 feet; and by Baines for the level of his camp at Logier Hill—1550 feet ('The Gold Regions of South-Eastern Africa' London, 1877, p. 187).

Another result of the slow recession of the gorge is evident in the relation of the tributaries to the main river. On the north, these feeders radiate from the Batoka Upland, while on the south they mostly hold a north-easterly course at a low angle to that of the Zambezi. Above the Falls, the tributaries flow to the Zambezi in channels sunk very slightly below the general level of the plateau and make their confluence in open estuary-like inlets; but below the Falls they are precipitated, before reaching the main river, into gloomy chasms that lead into the Batoka Gorge; and these become longer in proportion to their increasing distance from the Falls. Thus the country bordering the main gorge is slashed by precipitous ravines that stretch back farther and farther into the plateau as we go eastward, so that a great wedge of exceedingly broken country, very difficult to traverse, has been produced, expanding eastward on both sides of the river from its apex at the Falls. Where the influence of the rejuvenated drainage has been longest established, certain of the larger tributary rivers, as for example the Matetsi and the Deka, have likewise had time to widen out the lower reaches of their valleys, but all sooner or later entrench themselves within precipitous cañons when traced back towards the plateau. The same rule appears to apply also far to the eastward of the country examined. Thus the Kafue River, a great tributary which joins the Zambezi from the north some 220 miles below the mouth of the Deka, is described as having a comparatively sluggish and navigable course for 20 miles back from its confluence; but at the head of this low-level stretch the river tumbles in a succession of foaming cataracts for 2 miles through a rugged gorge which leads up to the high plateau; and before reaching this sharp descent, in which it loses over 1000 feet of altitude,[1] the stream has flowed placidly in a broad shallow channel over the undulating plateau for several hundred miles.

This tearing-down of the high plains at their edges and the gradual lengthening of the low-level channels is the ruling factor in the physiographical development of the Zambezi basin everywhere below the Victoria Falls. Therefore this region may be separated naturally into two sharply-marked divisions:—(1) The unbroken plateau with mature drainage-features; and (2) the region of rejuvenated drainage. In ground-plan the boundary between these divisions forms a succession of gradually deepening loops around the tributary streams, and, as already mentioned, steadily recedes from the main river on both sides as it goes eastward.

Between the network of gorges that characterizes the second division there are irregular patches of flat ground, representing fragments of the old plateau; but this country is almost everywhere rugged and stony from the ready transport of the surface-products of weathering into the gulches by the torrential rains. Where

[1] A. St. H. Gibbons, 'Africa from South to North through Marotseland' (London, 1904) vol. i. pp. 65–66; and C. Harding, 'In Remotest Barotseland' (London, 1905) pp. 319–20.

not too steep, the ground is covered more or less thickly by scrub and low trees, interspersed with a scanty growth of tall harsh grasses. At the time of our traverse, in the long drought, the streams were dry or merely trickling, the trees mostly leafless, and everything was parched and still; but during the rains (November to March), when floods are roaring through all its ravines, this must indeed be a turbulent region.

On the outer fringe of this broken country the strips of original plateau between the ravines become broader, and frequently include truncated segments of shallow valleys, showing where the youthful drainage is destroying the older system. The present streams possess similar shallow troughs farther back, where the plateau is as yet intact; and most of these break off suddenly at a deep waterfall or a series of cascades, below which the stream is at once engorged, like the Zambezi itself at the great Falls. Thus the valleys of the upland stand in the relation of 'hanging-valleys' to the low-level drainage.

These shallow troughs of the plateau-streams are generally bordered by low slopes of greatly decomposed basalt, and their broad floors are covered with dark stiff loam or earthy clay, not often exceeding 3 or 4 feet in thickness, apparently derived partly from the rotting rock upon which it rests and partly from the dense growth of tall rushy grasses which it nourishes. The stream-channels along these flats are somewhat canal-like, showing an alternation of long narrow pools where the basalt is most readily decomposed, with low bars of bare rock where weathering is less effective. During the season of drought, water is retained in the pools long after the stream has ceased to flow; and further aid is thus lent to the decomposition of the rock beneath them, which leads to the rapid excavation of deep crevice-like gorges (Pls. X & XV & fig. 8, p. 191), often curiously angular, along the rotted belts as the rejuvenated drainage breaks back into the plateau.

The grassy flats are generally bordered by a fringe of well-grown trees, while the low stony slopes of the valleys are covered with the bushy growth and scanty grasses that overspread the neighbouring plateau. But, towards the head of most of the streams, the grassy flats of dark earth expand into shallow basins ranging up to a mile or two in width and several miles in length. These sometimes become confluent and lose altogether their relation to any definite valley, the loam then thickening and spreading over gentle slopes in a manner somewhat similar to the peat of humid climates. The dark soil of such tracts is indeed called 'torf' by the Boer farmers, but in composition it is quite different from peat. In the wet season it is a very tenacious clay, which retains the moisture and works up into a pasty mud; and during the drought it contracts so greatly in drying that the surface is reticulated by gaping cracks which are very troublesome to the traveller. Of such tracts I saw the most striking examples in the upper basins of the Lukunguli, the Matetsi, and the Deka, but they are prevalent throughout the district, especially south of the Zambezi, and appear to be still more extensive in the shallow basins of the Kalahari.

Much of the plateau between these grassy depressions is covered deeply by rusty-red sand, occurring usually in broad gentle swells or 'bults,' which may be a mile or more in width and many miles long. These sand-bults occur on both sides of the Zambezi, but their proportionate area increases southward as the plateau merges gradually into the true Kalahari. From their capacity for retaining moisture these sands nourish taller trees and more vigorous vegetation generally than the rocky portions of the plateau. They are equivalent to the 'Kalahari Sand' of Dr. Passarge, and must have been accumulated under climatal conditions very different from the present (see p. 201).

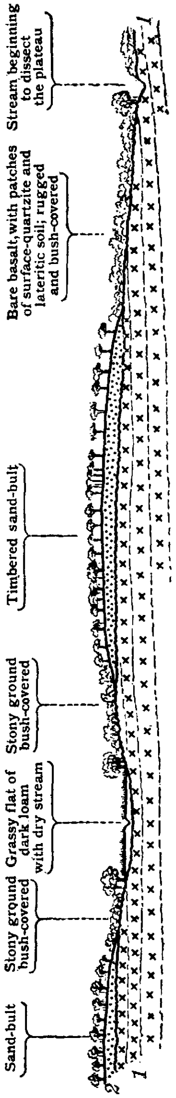


Fig. 1.—*Diagrammatic section illustrating the general features of the plateau.* (*Length = about 4 miles; vertical scale much exaggerated.*)

[1 = Batoka Basalts; 2 = Kalahari Sand.]

On flat ground where the sand is absent the surface is for the most part thinly covered with a firm, rusty, lateritic soil derived from the basalt, through which protrude many blocks of partly weathered rock. In some places this soil, like the well-known laterites of India, is full of small hard pellets or ferruginous concretions, about the size of peas.

The appended diagram (fig. 1) will serve to illustrate the physical features which we found to be constantly repeated in traversing the plateau along the margin of the newly-dissected country.

There is a decided fall of the surface of the plateau towards the Zambezi both from the north and from the south, which appears to reflect its original structure; and the gradual sinking of the country eastward until the Deka is reached is probably also structural. Hence the course of the Zambezi may roughly coincide with an original depression in the plateau, which has, of course, been greatly accentuated by long-continued erosion.

IV. Geological Structure.

The main features in the geology of the region, so far as these are known to me, are broadly outlined, without pretence to accuracy in detail, in the accompanying sketch-map and sections (Pl. XVII). On this map the following rock-systems are represented:—

(5) Kalahari Sand, with Chalcedonic Quartzite, etc.
(4) Flaggy Sandstone of Boomka=? Forest Sandstones (Molyneux).
(3) Batoka Basalts.
(2) Wankie Sandstones and Coal-measures=Matobola Beds and (?) Escarpment-Grits of Molyneux.
(1) Fundamental Complex (granite, schist, etc.).

From the map and sections it will be seen that the great floor of ancient metamorphic and intrusive rocks, presumably pre-Palæozoic, which underlies the whole region and emerges around the rim of the interior basin of Central South Africa, is deeply buried under newer rocks in the portion of the Zambezi basin included within my traverses. Except at one point, 3 or 4 miles south of the Wankie coal-mine, at the extreme south-eastern limit of my journey, I gained no opportunity for examining these oldest rocks *in situ*. The overlying Matobola Beds or Rhodesian coal-measures I examined in some detail, in their outcrop between the Wankie mine and the Deka River; but elsewhere my routes lay almost entirely over the basic lava-flows which constitute the Batoka Basalts, or over the superficial detritus by which these basalts are partly covered.

(1) The Fundamental Complex.

From Livingstone's mention [1] of the presence of granite in the upper part of the Kalomo river-basin, and of gneiss and mica-schist dipping away respectively westward and eastward from this granite-mass, we could surmise with some confidence that the Tijarida Hills, which rose within easy sight to the north-east of us after we crossed the Kalomo on our route north of the Zambezi, are composed of the ancient rocks; and I was disappointed not to find the southward prolongation of this mass within our traverse. The shape of the ground indicated that the basalts did not extend to these hills (which for a time were not more than 10 or 15 miles distant from us), but that at least in one place the volcanic rocks ended off in a low escarpment fronting the hills. The only positive evidence, however, that I obtained in this quarter respecting the rocks to the northward of the basalts was from the detritus brought down by the Kalomo and two other south-flowing streams farther eastward, the Namaruba and the Gwemanzi. West of the Kalomo River I had found no trace of any rocks other than basalt and the later chalcedonic quartzite in the stream-beds; and it was therefore

[1] 'Missionary Travels & Researches in South Africa' 1857, chap. xxvii, pp. 542, 543, & 548.

pleasing to find a pebble or two of grey granite in the stony flood-bars of this river, along with much mica, felspar, and pink quartz in its sand-banks. I may here mention also that among the larger blocks strewing the same river-bed were some masses of red basaltic breccia full of scoriaceous and bomb-like inclusions, more like a true eruptive breccia than any portion of the basaltic series *in situ* that came under my notice.

In the next stream, the Namaruba, a few miles farther east, extraneous pebbles became very numerous, varied, and of large size, nearly one half of the stones being other than basalt; and not only was there a varied assortment of igneous rocks among these, including pink and grey granites, pegmatite, syenite, gneissose schist, etc., but also many fragments of coarse reddish and grey sandstones and pebbly grit. This gravel was not confined to the stream-bed (a shallow trough on the plateau), but was also scattered plentifully over the slopes and eastward over a low watershed into the deeper valley of the Gwemanzi, 2 or 3 miles farther east. It is, therefore, a little uncertain whether the streams derived the material directly from outcrops of rock in their higher reaches, or at second hand from an ancient river-gravel; but in either case the source must have lain to the northward, and at no great distance.

The sandstone-fragments must, I think, imply the presence of a belt of sedimentary rocks to the northward, between the Batoka Basalts and the ancient massif; and this inference receives support from other scraps of evidence, notably from the reported discovery of coal-bearing deposits in the country between the Victoria Falls and Kalomo. Judging from the conditions observed in the Wankie coalfield (see Section 2 of Pl. XVII) and from the resemblance of the sandstone-fragments to the sandstones and grits associated with the Wankie coal-measures, it is probable that these sedimentary deposits north of the Zambezi rest directly upon the ancient complex, and are themselves overlain by the basalts; but the junctions may, of course, be affected by faults of which I have no knowledge. As the railway has, since my visit, been carried northward past Kalomo to the Kafue River and beyond, we may expect ere long to obtain more definite information regarding the geology of this region; and meanwhile I have ventured to draw the hypothetical boundaries shown on the map, interpolating the Wankie Series between the Batoka Basalts and the Fundamental Complex, as an indication of the present state of our knowledge, and as an incentive to anyone who may find opportunity of proving its inaccuracy.

If we turn now to the country south of the Zambezi, we shall find that, on the strength of a statement by Chapman,[1] Dr. Passarge has inserted on his map [2] an inlier of the ancient rocks, surrounded by the basalts, near the head of the Deka river-basin. With the hope of learning in this quarter something of the rocks underlying

[1] 'Travels in the Interior of South Africa' vol. ii (1868) p. 212.
[2] 'Die Kalahari' 1904, Kartenband, Blatt ii.

the Batoka Basalts, I made a long journey to the place indicated, at the site of the old hunter's camp known as Deka; but with disappointing results. The basalts were still the lowest rocks visible there; nor could I detect in the surrounding featureless country any indication that promised change, or any trace of rocks other than basalt and chalcedonic quartzite in the scanty detritus of the stream-beds. To the southward of this place the shallow depression which constitutes the head of the Deka basin appeared to merge almost imperceptibly into the great wilderness of the Kalahari; and although, in such a country, it is easily possible for one to miss a vaguely-defined locality, the impression was strongly borne in upon me that the search was hopeless, and that in this quarter the Batoka Basalts are prolonged without interruption south-westward under the superficial desert-formations of the Kalahari. It may be that Chapman's observation 'near the source of the Luluesie (Daka)' of 'a vertical stratum of sandy schist' (*op. cit.* pp. 212–13) refers to some place farther eastward, where a prolongation of the boundary-fault of the basalts is likely to occur; or it may refer only to the thin sandy flags, presently to be described, that were seen to overlie the basalts in a limited tract north-west of Deka (p. 196).

At the one locality, some 3 miles south of the Wankie coal-mine, where, as previously mentioned, I gained a glimpse of the old rocks, they emerged from beneath the Wankie Series in the manner shown in Pl. XVII, Section 2. The exposure occurred in a rugged gully eroded through the sandstones, at the foot of a high steep ridge which my friend and guide, Mr. J. M. Kearney, Manager of the Wankie Mines, has since ascertained to be also composed of sandstone.

In this gully, the rocks which came within reach of my hasty examination (with night approaching, and no chance to revisit the spot) were a schistose quartzite and a highly sheared coarse-textured rock resembling a conglomerate with crushed pebbles of felspar, but possibly a much-deformed pegmatite. Judging from a rough sketch-map accompanying an engineer's description of the Wankie coalfield published in 1902,[1] this exposure probably forms the western end of a long spur jutting out from the main mass of the ancient igneous and metamorphic series lying to the south-east in the region described by Mr. F. P. Mennell.[2]

(2) The Wankie Sandstones and Coal-measures.

During a stay of four days at the Wankie coal-mine, I was enabled, through the facilities afforded to me by the kindness of Mr. J. M. Kearney and his staff, to make three traverses of the sandstone-country between the railway-line and the Deka River,

[1] Anon. 'Colliery Guardian' vol. lxxxiii (Feb. 21st, 1902) pp. 390–92.

[2] 'The Geology of Southern Rhodesia' Special Report No. 2, Rhodesia Museum, Bulawayo, 1904.

up to the margin of the Batoka Basalts. My foremost object was to determine the character of the junction between the basalt and the sandstone-series; but in doing this I obtained some knowledge of the structure of this coalfield.

The engineer's report above cited contains a rough diagrammatic section across the field, and some details respecting the succession of the coal-measures. The Wankie coalfield is referred to, but not described, by Mr. Molyneux in his paper on 'The Sedimentary Deposits of Southern Rhodesia'[1]; and he classes these deposits, along with those of other Rhodesian coalfields, under the term Matobola Beds. Mr. Molyneux seems, however, to have had in mind the probability that the next higher division of his scheme of classification—the 'Escarpment Grits'—was likewise represented in the district[2]; and I think that this is indeed the case.

Athough no fossils had been found in this field, Mr. Molyneux obtained some palæontological evidence from other areas in favour of the 'Permo-Carboniferous' age of the Matobola Beds, which thus fall into line with the coal-bearing deposits of the Transvaal and Natal. Some ill-preserved plant-remains which I collected near Wankie lend support to this conclusion.

The series developed around Wankie consists mainly of massive irregularly-bedded sandstones, generally coarse in grain and sometimes rough and pebbly, with subordinate beds of micaceous sandy shale, clay-shale with ironstone-nodules, carbonaceous shale, and coal. The fine-textured deposits are subject to rapid changes laterally, but on the whole tend to occur as a middle division between the massive and more persistent sandstones.[3] These softer middle beds are well exposed in the hollow in which the coal-mine is situated, while the rugged kopjes to the north and south of it reveal underlying and overlying sandstones. The beds frequently swing into broad dome-shaped undulations, but dip as a whole northward.

The succession across the hollow about a mile south-east of the mine is shown in Section 2 (Pl. XVII); and $4\frac{1}{2}$ miles farther west, near the old Falls road, the sequence is as in Section 3 (Pl. XVII). On traversing the intervening ground, my impression was that these two sections were complementary, the base of the second (No. 3) being stratigraphically a little above the top of the first (No. 2); but my examination was not sufficiently close to eliminate the possibility of duplication by cross-faulting, which is suggested by the points of resemblance in the sections.

The curious ferruginous crust on the upper surface of some of the massive grits where these are overlain by shale, and the local induration of the top of the grit beneath this crust into quartzite, is noteworthy, as alteration of similar type appears to be still in

[1] Quart. Journ. Geol. Soc. vol. lix (1903) p. 281.

[2] *Ibid.* table on p. 278.

[3] In the general section given in the report published in the 'Colliery Guardian' vol. lxxxiii (1902) p. 392, three main sandstones are recognized, and are respectively named 'Upper, Middle, and Lower Grits.'

progress among the superficial formations of the plateau. The thin band of peculiarly indurated shale, apparently silicified, upon the lower sandstone in the second section (Bed 4, Section 3) is probably a further result of the same process. Another rock of unusual aspect associated with this sandstone is the ferruginous claystone, which is sprinkled with concretionary spherules of deep-red hæmatite, about the size of large oolite-grains and having a radial structure internally.

In colour, the sandstones vary from dull-red to pale yellowish-grey, the paler tints predominating. While some beds are marked by distinctive tints, there is also in places a mingling of the red and grey tints in the same bed. Both in colour and texture, these sandstones recall the characters of the familiar English Bunter Sandstones; and the likeness becomes accentuated in the pebbly beds occurring in the higher part of the series, the pebbles having the same thoroughly rounded outlines and the same scattered distribution as in the pebbly sandstones of the Bunter. This similarity I noticed especially in the steep kopje at 'Mtoro's Kraal.

The thicker sandstones are strongly jointed, one set of joints striking east-and-west like those of the basalt-country, with other cross-joints striking approximately north-and-south. In the stream-beds, the rock is sometimes eroded along these joints into deep crevices; as, for example, in a dry stream-bed 3 or 4 miles west of Wankie, where one crevice of this kind, which crosses the stream-bed at right angles, is 8 or 10 feet deep and not more than 2 feet wide. On the top of the kopjes, these jointed sandstones often weather into huge blocks of fantastic outline; and in the precipitous krantzes the scaling away of the rock along the joints gives a botryoidal aspect to the exposures.

From the remarkable scantiness of superficial covering, which characterizes the whole region except in the sand-bults and loam-flats, the sandstones crop out in many places in absolutely bare platforms of wide extent, but with numerous bushes and trees rooted in the crannies; and in this manner the weathering and subsequent erosion along the crevices is evidently facilitated. One of these bare platforms, about a mile east of Wankie, was curiously pitted with hollows, and also contained, embedded in its surface, a few small lumps of silicified wood, not rooted like trees but looking as if derived in their present condition from some older deposit. The pittings appeared to be the casts of similar lumps which had been removed.

Some blocks of silicified wood of the same character were found lying loose, along with a sprinkling of quartz-pebbles, on the surface of the basalt adjacent to a bold ridge of sandstone, in the Deka basin, 6 miles east-north-east of our Bumbusi camp, one being a segment of a stem 15 inches in diameter, showing a well-marked core; and these blocks, like the accompanying pebbly detritus, have no doubt been derived from the sandstone.

Near the place where the lowermost sandstones abut upon the previously described spur of ancient schistose rocks south of

Wankie, I noticed a few rounded boulders of schistose quartzite, up to 8 or 10 inches in diameter, embedded in the sandstone; but I did not, at the time, appreciate the suggestiveness of the fact as a possible indication of the horizon of the Dwyka Conglomerate. I must be content, therefore, to throw out the hint, in the hope that it will attract the attention of some future worker to this place.

In the carbonaceous sandy shale (Bed 3 of Section 2) exposed at the Wankie railway-station and in a bank near the entrance to the mine, obscure fragments of plants are abundant; while in the shale forming the roof of the mine, Mr. Kearney pointed out to me some crushed reed-like stems measuring several feet in length, and 3 or 4 inches in breadth; but all were too imperfectly preserved for determination.

I obtained rather better specimens, however, from a brown silty shale in the section $4\frac{1}{2}$ miles west of Wankie (Bed 5 of Section 3) exposed in a little gully between the old wagon-road and the railway, here running within 100 yards or so of each other. Among these specimens, Prof. A. C. Seward has recognized fragmental *Vertebraria*; and if this fossil is, as supposed, the stem of *Glossopteris*, it confirms Mr. Molyneux's correlation of these measures.

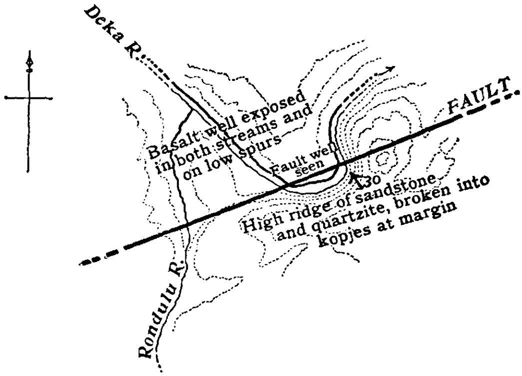
In the character and predominance of the sandstones; in the prevalent sandiness of the shales; and in many other features, these deposits differ greatly from our British Coal-Measures, and indicate very different conditions of accumulation.

The grounds on which a belt of the Wankie Series is inserted on the map (Pl. XVII) to the northward of the basalts have already been stated (p. 172) and require no further discussion.

The Deka Fault.

On finding that the monotonous basalt-country, after sinking steadily eastward, came at last to an abrupt termination at the foot of the steep hill-range of sandstone and quartzite bordering the southern side of the Deka Valley, my first impression was that the Batoka Basalts had shelved underneath the sandstones; and, although there were difficulties in the interpretation, it was with this idea in mind that I reached the Wankie coalfield. But the idea became untenable when I ascertained that metamorphic rocks, and not the basalts, emerged on the south from beneath the coal-series. Returning to the Deka, therefore, to make further examination, I soon obtained clear evidence that the junction was in truth a line of faulting, the actual fault being well exposed in the river-bed near the Deka railway-bridge, within a mile below the place where I had first crossed the junction. By another journey northward from Wankie to the Deka, at the confluence of its tributary the Rondulu, some 7 or 8 miles lower down the valley, I was enabled again to intercept the fault, which was here even more strikingly displayed. It then became evident that a faulted junction of the

Fig. 2.—*Sketch-plan showing the loop of the Deka River at the great fault, near the confluence of the Rondulu River.*

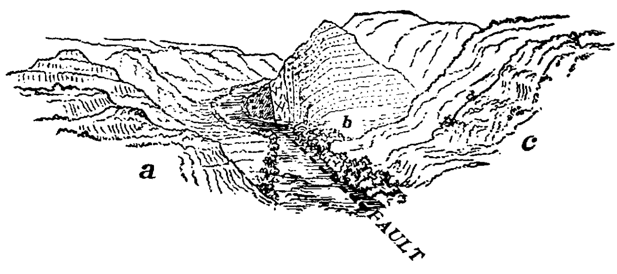


[Scale: 1 inch = 1 mile.]

The ridge of pebbly sandstone rises 500 feet above the river, and forms high cliffs at the bend. The rock, altered to quartzite and much shattered and veined, plunges steeply as it approaches the fault, which is well exposed in the bed of the river, and also in the Rondulu stream-bed.

Fig. 3.—*Sketch-diagram of the fault along the Deka River, about a mile below the railway-bridge, looking north-eastward.*

N.W. S.E.



a = Rugged kopjes of coarsely porphyritic basalt, breaking into a cliff above the river in the foreground.

b = Conical kopje, about 200 feet high, in the middle distance, exhibiting the fault in a river-cliff at the bend. Vertical bands of quartzite, much veined and shattered, occur on the right side of the fault.

c = High bluffs of pebbly sandstone, extending in terraces which reach the right bank of the river.

sandstone and basalts which I had previously noticed at 'Mtoro's Kraal, 8 or 10 miles west-south-west from the Deka railway-crossing, lay approximately upon the opposite continuation of the same fault-line, although I had at the time thought it of slight consequence.

My personal knowledge of the faulted belt thus embraces a distance along its direction of 16 or 18 miles; but there is evidence that it is much farther prolonged in both directions, and is a structural feature of prime importance in the geology of the region.[1] The phenomena associated with it are also of sufficient interest to deserve particular description.

In the segment that came under my observation, the strike of the fault is from west-south-west to east-north-east. For a long distance its course coincides very closely with that of the Deka valley: not, however, that the valley is a fault-trough, but because of a secondary effect presently to be discussed. It was long ago observed by Chapman, whose testimony should in itself have led one to suspect the faulting, that—

'The Luluesie or Daka River is the limit of the basaltic rocks, presenting formidable cliffs of red sandstone, while the western banks have at intervals mural cliffs of basalt, and thus throughout the whole distance which I traversed (upward of 80 miles), I have seen no red sandstone west of the Luluesie, nor basalt east of it, excepting only in the banks where the river, by an abrupt bend, has encroached on either side a little.'[2]

Some details of the fault at the places where I had the best opportunity for examining it, north and west of Wankie, are shown in the plan (fig. 2, p. 177) and diagrammatic sketch (fig. 3), and in Section 3 of Pl. XVII. Its course and probable prolongation are represented on the map; but in this I have been greatly hampered by the uncertainty of the topography, especially with respect to the position of the localities in the upper part of the Deka basin, between Deka and 'Ngoni's Kraal, which may be several miles from their true bearings on the fixed position of Wankie.

The fault affects in a striking manner the sandstones which abut upon it. In all the places that I examined, except in the transverse valley of the Rondulu River, these sandstones are of the red coarse-grained or pebbly type, and appear to belong to the 'Upper Grits' of the Wankie Measures, as indicated in Section 3 (Pl. XVII). In some places (fig. 3, p. 177) these sandstones plunge steeply as they approach the fault, and are not only greatly crushed and contorted, but are also converted into quartzite and much veined with quartz and hæmatite, thus producing a highly indurated belt bordering the dislocation.

The basalts are also affected, but in an opposite manner, the altered rock along the fault yielding more readily to the weather

[1] Since the above was written I have received a letter from my friend Mr. Kearney, in which he informs me that he has recently traced the fault south-westward for 30 miles, from Wankie to Bumbusi, and finds its course to be parallel with the road that I followed and sometimes within a few hundred yards of it, as I had suspected (see p. 181).

[2] 'Travels in the Interior of South Africa' vol. ii (1868) p. 213.

than does the unaltered basalt. Thus there has sprung into existence a range of high kopjes marking the course of the indurated sandstone, with lower ground on the one side due to the more rapid disintegration of the unaltered sandstone, and on the other side due to the decomposition of the basalts. At the same time, as a whole, the basalts are less enduring under the African climate than even the unaltered sandstones, so that there has been relatively a general lowering of the country on the basalt side of the fault. The presence of a few high flat-topped kopjes of approximately equal elevation on the opposite sides seems, however, to indicate the former existence of a plateau, before the initiation of the present drainage-system, on which there was no conspicuous feature to mark the fault; and this condition should be borne in mind in any attempt to trace the fault south-westward into the unbroken plateau beyond the head of the Deka basin.

The effect of the fault upon the course of the Deka River now requires notice. As previously mentioned (p. 173), the upper portion of this river, so far as it came under my observation, lies wholly within the basalt-country, the two main branches of its head-waters, which unite a short distance below Mr. Geise's ranch at Deka, having shallow channels on the surface of the plateau, while below their confluence the valley is still sunk but little below the general level of the hummocky plain of basalt. This open valley is continued for many miles; but afterwards gives place to a steep-sided gorge, the change setting in somewhere between 25 and 35 miles east-north-east of Deka, in a portion of the river-course which I was not able to examine. This steep trench where we struck into it near 'Ngoni's Kraal was still entirely within the basalts, though the high kopjes of sandstone marking the great fault ran almost parallel with the cañon within 2 or 3 miles to the south. About a mile above the place where the railway crosses the Deka, the river swings up to the foot of the sandstone-kopjes, but rebounds from them in a sharp curve; and in this neighbourhood the valley has lost for a time its cañon-shape, through the disappearance of its north-western or basaltic wall. Immediately below the railway-bridge, the river runs for nearly a mile almost exactly along the junction between the two rocks, as shown in fig. 3 (p. 177), once or twice impinging upon the hardened sandstone, but swinging off sharply again as if rebounding from the impact, and finally sweeping away northward into the basalt-country in a bold curve.

These phenomena are repeated almost exactly near the Rondulu confluence, 7 or 8 miles farther down stream, where the river returns with a south-easterly course from its incursion among the basalts, and again impinges upon the fault, managing to carry one sharp loop of its bed just within the sandstone-boundary before being driven off again into the basalts (see fig. 2, p. 177).

The presence of several low streamless 'poorts' or cols gapping the high ridge on the sandstone side of the fault suggests that the river may at some past time have broken through the belt; but whatever its original course may have been, its present direction is clearly determined by this hard barrier.

Nor is the influence of the fault likely to be confined to the Deka valley, for it is highly suggestive that the great northerly bend of the Zambezi itself east of the Deka confluence should coincide very closely with the position and direction which this fault will have if prolonged north-eastward. That it is indeed thus prolonged is supported by travellers' records regarding the Gwai River near its confluence with the Zambezi: from the descriptions of Chapman[1] and Mohr[2] we gather that the sombre gorge of the Gwai at some little distance above the confluence is eroded through massive sandstone, while the great trough of the Zambezi between the mouths of the Gwai and the Deka appears, from the accounts given by Chapman[3] and Major A. St. H. Gibbons,[4] to lie within the basalts; and the following sentence seems to show that Chapman struck the actual fault-line at a short distance south of the Zambezi:—

'A little valley coming into the Gwai, half a mile north of this [referring to the place where he reached the Gwai], seems to be the dividing point of the large square blocks, layer on layer, of hard red sandstone.' (*Op. cit.* p. 193.)

Furthermore, I am inclined to think that we have some evidence suggesting the continuation of the fault to the north-eastward far beyond the Gwai. In his account of the sedimentary rocks of Southern Rhodesia, Mr. Molyneux describes, under the term of 'Sijarira Series,' a great series of quartzites, indurated shales and current-bedded sandstones which form a bold hill-range (the Sijarira Range) overlooking the Zambezi flats some 70 or 80 miles east of the Gwai.[5] These deposits he believes to occur beneath the Matobola Beds (coal-measures), which are supposed to rest upon them in strong unconformability. Mr. Molyneux several times makes particular reference to the evidence for crushing, faulting, and induration in the 'Sijarira Series'; for example, he remarks:—

'Where the quartzites or indurated rocks occur, it may often be noticed that there is a fault-fissure or displacement, and the axes of these movements take a north-easterly direction, or at right angles to the dip. Thus at Chongolo the rocks are indurated on either side of a dyke of shale-and-sandstone crush-breccia. At the Lubu are parallel dykes of crush-breccia, made up of angular blocks of red sandstone, cemented by secondary white silica; and at many other localities it is noticeable that movements have taken place along lines following a north-easterly direction, and have crushed the rocks into angular fragments, now cemented together. . . .

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[1] 'Travels in the Interior of South Africa' vol. ii (1868) pp. 193 & 212.

[2] 'To the Victoria Falls of the Zambesi' 1876, pp. 297 & 302.

[3] 'Travels in the Interior of South Africa' vol. ii (1868) p. 191. The rocks 'of a stratified or laminated appearance,' externally very black, and internally yellowish-brown, are probably the curious platy basalts presently to be described (see p. 193). The rocks containing agates, and those of 'a scaly appearance, like the scales of a bulb or onion,' are evidently basalts.

[4] 'Africa from South to North through Marotseland' vol. i (1904) p. 93.

[5] Quart. Journ. Geol. Soc. vol. lix (1903) pp. 269-79, & sections, pl. xix.

'The regional alteration extends for some distance on either side of these lines of breccia, and the indurated rocks, resisting erosion better than the unaltered loose-grained sandstones, consequently form the core of the ridges, hills, and mountains of this part of the country.'[1]

Now, when the Deka Fault is plotted on the map, its prolongation, so far as the present indefiniteness of the topography enables one to judge, will be found to fall very nearly along the escarpment of these Sijarira Quartzites as mapped by Mr. Molyneux; and I strongly suspect that the lines of disturbance described in the foregoing extracts represent the north-eastward continuation of the fault.

Moreover, the phenomena are so closely analogous to those which I observed in the Deka Valley, that I shall venture to suggest that the 'Sijarira Series' may be only the 'Matobola Beds' contorted and altered along this great belt of disturbance.[2] In the present state of our knowledge, this suggestion must of course be merely conjectural; but it appears to fit most of the facts contained in Mr. Molyneux's description of the 'Sijarira Series' and of the relations of this series to the underlying gneissose rocks and to the Matobola Beds.

If the Sijarira disturbance proves to be no other than the Deka Fault, the sandstones, etc. of the Zambezi Flats on its north-western or downthrow side will represent some portion of the Matobola Beds of the plateau; and the steep northern face of the Sijarira Range will approximately mark the fault-scarp. This reading is, I think, in accordance with our present knowledge—scanty, it is true—respecting the geology of the middle reaches of the Zambezi.

Even if the Sijarira disturbance be not the direct prolongation of the Deka Fault, it must certainly belong to the same fault-system; and we may recall, too, that the strike of this fault-system is approximately parallel to the major axis of elevation in the ancient complex farther eastward pointed out by Mr. F. P. Mennell.[3]

As regards the prolongation of the Deka Fault in the opposite direction, up the Deka Valley, there is no doubt that its course was marked by the range of craggy sandstone-kopjes on the southern margin of the Deka basin, which we gradually approached after leaving Bumbusi on our march to 'Mtoro's.[4] Farther south-west this feature evidently dies away into the plain of the Kalahari, where it is perhaps hopeless to expect that the fault will be traceable.

From my examination of the fault itself at the places accessible to me I could gain no evidence as to the amount—or even as to the direction[5]—of downthrow, owing to its effective severance of the

[1] Quart. Journ. Geol. Soc. vol. lix (1903) pp. 279-80.

[2] On suggesting this possibility to Mr. Molyneux in the course of our correspondence during the preparation of this paper, I am pleased to find that he regards it as quite worthy of consideration.

[3] 'The Geology of Southern Rhodesia' Special Report No. 2, Rhodesia Museum, Bulawayo, 1904, pp. 8-9 & fig. 1.

[4] See footnote on p. 178.

[5] The breadth of the crushed belt obscured the hade of the fault in the sections that I examined; but in two places—at the bend of the Deka east of the Rondulu confluence (fig. 2, p. 177) and in the kopje a mile below the railway-

country into basalts on the one side and sandstones on the other, leaving no link between them. One is hampered also in attempting an estimate by the uncertainty as to the thickness of the basalts, regarding which we know only that it must exceed 1000 feet; but by how much, it is impossible at present to conjecture (p. 195). Considering their total disappearance from the high ground on the opposite side of the fault together with the probable depth to which their base is sunk on their own side, it is not likely that their downthrow at the fault is less than 2000 feet; and it may be very much more. The fact that all the basalts should have perished from the upthrow side and that the country should have been planed down to its present condition on both sides, denotes considerable antiquity for the fault.

It will be noted that this great dislocation throws inward towards the centre of the continent, and may therefore have lent aid in the construction of the interior basin of the South African plateau.

(3) The Batoka Basalts.

Under any conditions, large areas of plateau-basalt are somewhat monotonous deserts to the stratigraphical geologist, and such to me the Batoka Basalts proved. During our long treks over their surface, I gleaned but scanty information on many essential points; for which, perhaps, the necessity of following a definite route through the wild country may be partly responsible. Thus I nowhere saw their true base, nor did I find any recognizable vent from which these old lavas were poured; and, what is still more regrettable, I did not light upon any intercalated sediments such as the previous descriptions had led me to expect.

The Batoka Basalts present the usual characteristic of basic lavas, in maintaining great uniformity of composition over wide areas. All the varieties that were found may be included under the term olivine-dolerite, used in its wider sense. When massive, they form dark-blue heavy rocks, varying somewhat in the size and relative abundance of their crystalline constituents, and still more in the degree of development of a vesicular or amygdaloidal structure and in the composition of the amygdules. Stratigraphically these basalts present the usual trap or step-like features, due to the intercalation of thick bands of the more massive rock with thinner bands of less durable vesicular breccias which mark the under and upper surfaces of individual lava-flows. This structure is often excellently brought out by weathering in the walls of the cañons and along the broken edges of the plateau, the hard bands protruding in bold scarps or 'krantzes,' and the slaggy breccias breaking down into inclines.

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bridge (fig. 3, p. 177)—the shattered sandstones seemed slightly to overhang the basalt, though with very little departure from verticality. I saw no indication of overthrusting, however, and do not think that the dislocation is actually a 'reversed fault,' though the basalts may perhaps in places have sunk slightly under the edge of the sandstones.

At the Victoria Falls, the section in The Chasm reveals at least four massive beds, in thickness ranging from 40 feet to 80 or 100 feet, with intercalated breccias which show lateral variation in thickness from a few feet to 30 feet. It was observed, in excavating one of these breccias for the foundation of the railway-bridge on the western side of the gorge, that the rock though hard at the surface was comparatively soft within, the surface-induration being no doubt caused by mineral deposition from evaporating moisture—a condition of common occurrence throughout the region, especially in the more porous rocks.

The Breccias.

The breccias, which are usually red or pale ashy-green, vary greatly in texture as well as in thickness, swelling out occasionally into huge bosses of coarse agglomerate, in which some of the masses are vesicular and 'bomb'-like. I kept in mind the possibility that some of these might indicate the position of eruptive vents or 'necks,' but failed to detect any instance where this origin could be proved. In the bottom of the gorge at the confluence of the Songwi, 6 or 7 miles below the Victoria Falls, a thick mass of breccia, composed in part of huge angular blocks, was well exposed on the flood-platform of the river, and rose up at one place in crags over 30 feet high. This, at first sight, suggested a small vent; but the mass could be traced as a definite band in the adjacent cliff, and was there underlain by the sheet of dense basalt which extended across the floor of the gorge; and there was no sign that this basalt was anywhere pierced by the breccia. The absence of any other than basaltic fragments from all the breccias that I examined also tells against the probability of any of the breccias being truly eruptive.

At two or three places while traversing the plateau, especially in the broken country immediately east of our route after crossing the Kalomo River, we passed over areas in which the basalts lost for a space their usual tier-like aspect and became tilted, confused, and irregular, leading me temporarily to anticipate that we were approaching an eruptive focus; and it is, of course, possible that in these places we may have traversed the outskirts of a volcanic centre without making a near approach to it.

From previous information I had expected to find red sandstone interbedded with the basalts in the gorge below the Falls; but all the red beds that I could reach proved to be stained breccias and not sandstones. As already mentioned, my search for interbedded sediments was fruitless throughout the district; but this does not preclude the possibility of their occurrence beyond the area examined. Indeed, I saw from the train, in the Katuna valley (between Deka Bridge and Matetsi), some greenish-grey and reddish beds of shaly aspect among the basalts, unlike any rocks that I had the opportunity of examining at close quarters. As the massive rocks also show much irregularity and variability in this neighbourhood, its investigation may yield more notable results than I found myself able to attain.

Some of the finer breccias present tuff-like characters; and though it was my impression in the field that all the fragmental rocks that came under my notice were 'flow-breccias' derived from the surface-shattering of the lava-streams, the petrographical examination of my specimens has shown that in at least one case, the composition of the rock cannot be entirely thus explained. A finely-fragmental rock collected from a thin band among hard platy basalts at the Mavangu creek, about 17 miles east of the Victoria Falls, has been found by Mr. Thomas to contain much clastic quartz; which denotes either that the bed is a true tuff, or that it represents an admixture of land-waste with the basaltic detritus (see Appendix I [F 1018], p. 210).

It is to be remembered that Mr. Molyneux[1] and Mr. Mennell[2] have described the intercalation of basaltic lavas with the 'Forest Sandstones' of the country to the eastward, between Bulawayo and the Zambezi; and that these lavas are assigned to the same period of volcanic activity as the Batoka Basalts—with which indeed they may at one time have been directly connected, though now severed by the Deka Fault. If this correlation be established, it will imply that sandy deposits of wide extent were accumulating contemporaneously around the outer margin of the Batoka lava-field and were occasionally interbedded with the fringe of the flows; and the sand-grains in the Mavangu breccia may be due to wind-drift from some such marginal area.

The Amygdaloids.

The basalts are prevalently amygdaloidal, sometimes only slightly and sometimes highly so, the cavities being filled sometimes with green-coated chalcedony or crystalline quartz or a combination of both, and sometimes with zeolites. The amygdules vary in size from a mere speck to 8 or 10 inches in diameter; and I noticed a few isolated instances in which they assumed a pipe- or tube-like form. Around the Falls and in the higher part of the Batoka Gorge, zeolite-cavities predominate; while in the country farther eastward, and especially in the floor of the cañon in its lower reaches, quartz and chalcedony prevail as the infilling material. I sought to use this difference as an indication of the position of the basalts in the series, my impression being that the rarity or absence of zeolites marked the lower beds; but, on descending the plateau as we approached Makwa, and also in the Deka valley, zeolites again became plentiful, although I judged that we there reached the lowest part of the series that came under observation. It is, however,

[1] 'The Sedimentary Deposits of Southern Rhodesia' Quart. Journ. Geol. Soc. vol. lix (1903) pp. 267–70.

[2] 'The Geology of Southern Rhodesia' Special Report No. 2, Rhodesia Museum, Bulawayo, 1904, pp. 15–18.

possible that in this quarter the higher basalts are brought in again by disturbances due to the proximity of the Deka Fault.

Among the zeolites in my collection Mr. Thomas has recognized stilbite, mesolite, and laumontite (?). Mr. F. P. Mennell also mentions scolecite as occurring abundantly in the basalt at the Falls.[1]

The chalcedonic amygdules often possess a curiously minute botryoidal structure, their outer portion being made up of small globules showing concentric laminæ, which give the material a pisolitic aspect. These and the many handsome varieties of agate would make pretty ornaments if polished: and sooner or later the tourist will no doubt be able to purchase 'Zambezi Pebble' trinkets at the Falls.

Structural Features of the Basalts.

The apparent absence of dykes and sills in the areas which I examined is noteworthy. In spite of the numerous deep sections that came under scrutiny in the walls of the great gorge and its branches, I saw no case where the nearly horizontal banding of the series was definitely interrupted. In some places, as for example at the sharp bends just below the Songwi confluence (Pl. XVI), the weathered precipices of the Batoka Gorge are rendered jagged by the protuberance of sharp narrow spurs that at first sight suggest the presence of vertical bars of harder rock; but, after as careful scrutiny as I could make by the aid of field-glasses, I came to the conclusion that in this and other similar cases the outstanding ridges and buttresses were simply the weathered remnants of peninsulas and 'knife-edges' like those which divide the great zigzags of the river just below the Falls, and were of similar origin (see p. 187).

Small dyke-like strings, showing a vertical arrangement, were occasionally visible on broad bare surfaces of basalt; but when seen in cross-section these could not be traced downward below the lava-sheet on which they were displayed. They probably represent merely the infilling of cracks in the consolidated crust of the flow, from the yet fluid interior. On account of their differential weathering, these dyke-like veins sometimes have considerable influence in diverting the channels of the smaller streams; as may be well seen on a bare platform overlooking The Chasm 50 yards beyond the western end of the Victoria Falls, which being occasionally covered by flood-waters is sharply trenched along the course of one of these veins.

I suspected the presence of a discontinuous dyke at the truncated margin of the basalts along the Deka Fault; and this suspicion is partly sustained by the result of Mr. Thomas's petrographical examination (see Appendix I [F 1032 & 1035], p. 207), though the coarsely-crystalline rock near the Deka railway-bridge [F 1034], p. 210, on which my opinion was mainly based, proves to be less

[1] Fourth Ann. Rep. Rhodesia Museum, Bulawayo, 1905, p. 21.

dyke-like than I anticipated. As trap-like characters reappear in the basalts within a few yards of the fault in several places, the dyke, if it exists, can be of no great breadth. The so-called 'Mavinga Dyke' shown on an engineer's sketch-map of the Wankie coalfield (see *ante*, p. 173 & footnote), though it happens to fall in the same position as this supposed intrusion, represents a misapprehension of the faulted junction of the basalts and sandstones, as it was evidently intended to include all the basalts seen beyond the fault.

Dips.

In a series of lava-flows the true stratigraphy is necessarily difficult to decipher, as the structural dip may be completely masked by their original inclination. Hence it is doubtful how far the dips that were observed in the Batoka Basalts are original, and how far superinduced. One thing is certain, that the surface of the plateau does not stand in simple relation with the original surface of the lava-field, but has been developed by erosion across the edges of the flows.

The dips observed along our route are recorded, with other local information regarding the basalts, in tabular form in Appendix II (p. 212), which contains the details condensed from my note-book. From this it will be noticed that gentle south-easterly dips prevail for a few miles eastward from the Falls; and that this direction is reversed for a space in the middle portion of the district, but reappears occasionally towards the eastern limit of the route. The dips, however, are usually so low, that it would be unsafe to assign much significance to them; and in the few restricted areas where comparatively steep dips were observed, they might well be due to original irregularities. Nevertheless, it is almost certain that structural tilting of some degree would result from a dislocation of the magnitude of the Deka Fault; and the evidence as a whole suggests that the dominant dip of the basalts is southward or south-eastward from the core of ancient rocks forming the Batoka upland, until they are intercepted by the great fault. On a broad scale, therefore, the basalts may be regarded as occupying a faulted syncline.

Joints and other Fractures.

The basalts are everywhere strongly and closely jointed, and the joint-system possesses a remarkable uniformity of direction over very wide areas. The prevalent direction of the governing set is approximately east and west, usually a few degrees—say 10° to 20°—north of east and south of west.[1] There is also a tendency for other joints to be developed more or less at right angles to this set, which are however much less regular and in every way less conspicuous (see Appendix II, p. 212).

As one might expect, the joints, especially the governing set,

[1] From travellers' descriptions of the country north and north-west of the district here described, it may be gathered that east-to-west jointing and faulting is extensively developed in this part also.

are much more strongly and closely developed in the massive basalts than in the breccias and slaggy amygbaloids. The columnar appearance which is often conspicuous in the walls of the gorge is usually due to the emergence of close-set parallel joints on the vertical faces of the more massive beds. The only place at which I saw really well-formed columnar structure was in a low cliff overlooking the 'Nongu, an eastern tributary of the Kalomo River; although in a few other places, as, for example, in the main gorge at the confluence of the Karamba, the basalt showed a tendency towards wide-spaced polygonal jointing, without system or regularity.

Besides possessing this joint-system, the basalts are also sliced at intervals in the same approximately east-to-west direction by pronounced fractures, along which there are sometimes signs of actual displacement; the opposing rock-faces showing slickensides and brecciation, with the occasional intercalation of vein-stuff, principally calcite and chalcedony. That vertical movement has occurred along these fractures is certain, but the monotonous character of the basalts generally renders its estimation impracticable. In one case, however, just above Kalonga's Cleft on the Karamba (see fig. 8, p. 191, and Pl. XV) where the throw of a very conspicuous fracture of this kind could be measured, it was only 3 or 4 feet.

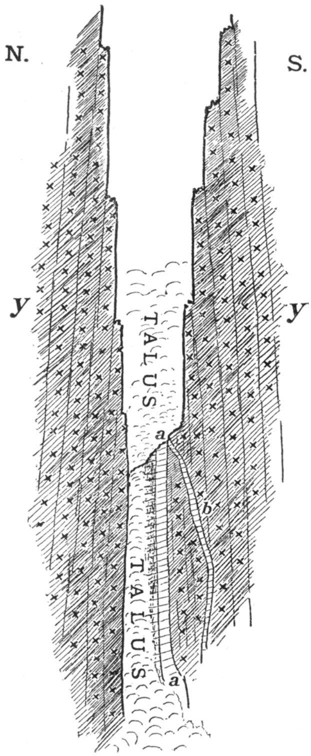
These fractures tend to run in belts, within which they recur at short intervals, forming veritable 'shatter-belts.' They probably represent the minor re-adjustments of the great subsidence that finds its main expression in the Deka Fault.[1] As we approached this fault in descending the Deka valley, veins of calcite were particularly conspicuous in the basalts, all striking approximately parallel to the fault.

Effect of the Joints and Fractures on the Drainage-Channels.

Both joints and 'shatter-belts,' but especially the latter, form vertical planes of rapid erosion, which, though invisible on the surface of the plateau where the stream-gradients are low, are picked out very rapidly into deep troughs by the forceful torrents rejuvenated by the recession of the main gorge (see p. 168). And as these structural planes frequently lie athwart the water-courses of the plateau, they constantly give rise to sharply-angular diversions from the previous direction where the streams plunge suddenly downward on leaving the upland. This effect is produced the more readily owing to the enormous seasonal variation in the volume of drainage. Except the Zambezi, almost all the stream-beds of the country traversed are mere flood-channels, filled to the brim for short periods during the rains, but during much of the year either quite

[1] One of these veins, over 2 feet wide, which we crossed when about 12 miles south-west of Bumbusi, was entirely filled with calcite in very large crystals, and was seen to the east and west of our track for at least 40 or 50 yards. In a country where limestone is scarce, it is possible that this material may eventually become of some economic value.

Fig. 4.—*Section about half-way down in the cleft at the eastern end of the Chasm at the Victoria Falls, showing the vein to which the chasm is due.*



[The vein, as a whole, has a decided hade to the south. The unshaded spaces are hidden by talus.]

a=Vein-stuff, partly vertical ribs of crystalline calcite, and partly red and purple decomposed rock and earthy material; 4 feet seen, but probably 4 feet more in places, hidden under débris.

b=A small 'stringer' of crystalline calcite, 1 to 3 inches in width, cutting off a 'horse' or wedge of basalt.

yy=Massive basalt, amygdaloidal in places, with strong east-and-west jointing which is cut at a low angle by the vein.

dry or maintaining a very feeble flow. Hence, when a gully is formed in the stream-bed it soon serves to trap the whole flow except during temporary floods; the erosive activity of the stream is thus concentrated along the trench; and it is steadily enlarged until even the flood-waters cannot escape from it, so that the rest of the bed is abandoned.

The grandest illustration of this method of erosion is afforded by the weird zigzags of the great gorge immediately below the Victoria Falls; but these have been so frequently described that it is unnecessary for me here to enter into details regarding them.

I have elsewhere shown [1] that the mile-long transverse Chasm into which the waters of the Falls descend has been scooped out along one of the vertical fractures, as I found on scrambling down its eastward termination, where the section illustrated in fig. 4 was revealed.

The deep cleft which notches the lip of the Falls on Cataract Island, illustrated in Pl. X, is due, as Mr. Molyneux has pointed out,[2] to the erosion of an oblique fracture by a small overflow-channel from the upper river. It exemplifies the development of a trench along a weak plane, which, if it should happen to strike diagonally up-stream above the present Chasm, may eventually capture the whole river and lay dry the broad lip from which the water now plunges.

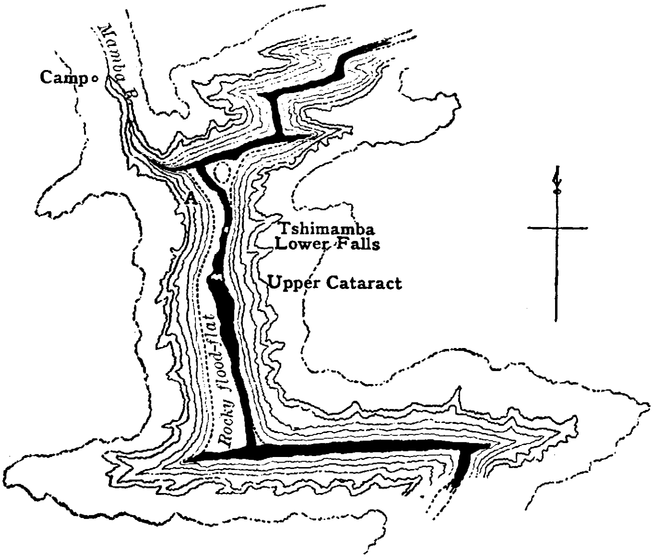
At many spots within the great gorge high above the present river I saw traces of abandoned channels

[1] 'Notes on the Geological History of the Victoria Falls,' in the 'Official Guide to the Victoria Falls' compiled by F. W. Sykes, Conservator (Bulawayo 1905); reprinted in Geol. Mag. dec. v, vol. ii (1905) pp. 529–32.

[2] 'The Physical History of the Victoria Falls' Geogr. Journ. vol. xxv (1905) p. 51.

overhung by picturesque buttresses and isolated pinnacles, carved by the Zambezi in its search for the easiest passage when entrapped among the transverse trenches. Generally, where the river breaks away from these trenches, they are continued as deep rain-gullies into both walls of the cañon; or they form the subsidiary cañons of tributary streams, into the waters of which the Zambezi itself may penetrate for some distance at times of high flood.[1] These features are admirably illustrated in the broad floor of the gorge at the Tshimamba Cataracts, shown in the sketch-plan below (fig. 5) and

Fig. 5.—*Sketch-plan of the Batoka Gorge at the Tshimamba Cataracts, showing water-filled inlets and steep gullies prolonging the east-and-west reaches of the Zambezi beyond its angular bends. (Approximate scale: 2 inches = 1 mile.)*



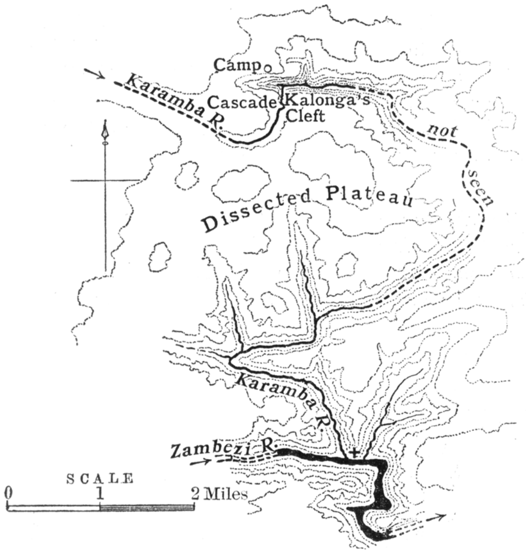
The water-area at the dry season is shown in black, and the dotted line marks the space covered at floods.

in Pl. XIII, where the river, at low water, twice forms a ⊥ in breaking away from its east-to-west trenches. At this place I found it not easy to determine whether the placid water of the straight reach on the south came into it from the east or from the west, even when I had traversed the flood-flat and stood at its rectangular termination.

As a typical example of the effect of these structures on the

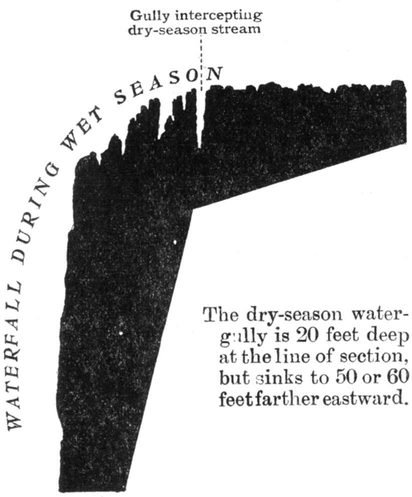
[1] From Chapman's description it would appear that the gorge of the Gwai must also be of this character at its mouth.

Fig. 6.—*Sketch-plan of the gorge of the Karamba River, from above Kalonga's Cleft to its confluence with the Zambezi.*



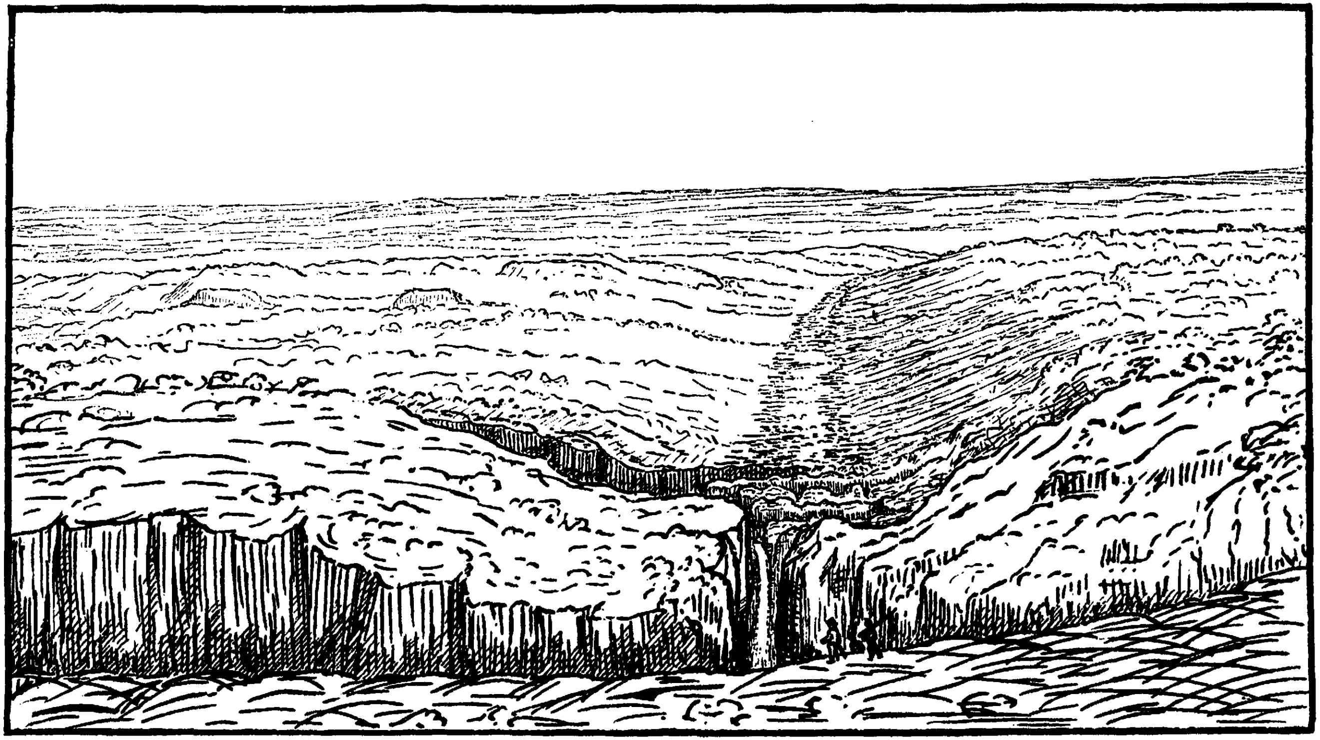
[+ = View-point of Pl. XIV.]

Fig. 7.—*Profile of the river-bed at the waterfall above Kalonga's Cleft.*



smaller streams, we may take the case of the Karamba River, which joins the Zambezi on its northern bank, 35 miles east of the Falls, and reproduces neatly in miniature some of the principal characteristics of the great cañon. This stream has carved out a wild gorge some 5 miles in length, into which it drops from an open valley on the plateau (see plan, fig. 6). The sides of this gorge at the mouth of the river, where they are 500 to 600 feet high, form bold rocky slopes rising at an angle of 30° to 40° from the stream-bed; then they become gradually more precipitous as we proceed up into the sharp loops above the first straight reach; their crests approach nearer and nearer to

Fig. 8.—*Bird's-eye view looking up the Karamba valley, from near Kalonga's Cleft.*



The fissure in the foreground is Kalonga's Cleft (see Pl. XV for a view along the Cleft, from right to left). The dry-season stream is intercepted by a transverse gully (partly visible in the middle distance), in which it turns at a sharp angle and emerges to fall into a deep pool (hidden by the buttresses of the short ravine in the line of sight). The profile of the dry river-bed above the cascade is shown in fig. 7, p. 190. The valley becomes shallow and open above the distant bend.

each other, until the walls are almost vertical; and finally the gorge is narrowed to a profound cleft, 300 feet deep and only 15 to 20 feet wide at the bottom and about as many yards wide at the top (see Pl. XV). At this gloomy spot, which we have named 'Kalonga's Cleft,'[1] the gorge turns at right angles and holds a sombre, cliff-bound water-pool. Into this pool the Karamba, when shrunken with the drought, makes a sideway leap from the plateau; but when flooded it must pour over the terminal wall in a terrific cascade occupying the whole breadth of the chasm. Between the water-pool and the lip of the shallow upper valley, the basalts and amygdaloidal breccias which form the precipice are sliced transversely to the valley by several vertical planes of fracture and crushing, with anastomosing branches, which have been gouged out by the stream into a series of deep riffles, as shown in the section, fig. 7 (p. 190) and bird's-eye view, fig. 8 (p. 191). At the time of our visit all the water was intercepted by the first of these riffles, and conveyed sideways to a lateral recess, from which it recoils at a sharp angle and leaps into the pool.

Both as a spectacle, and as a most instructive lesson in the erosion of the basalts, I commend Kalonga's Cleft to the notice of any traveller who may find himself within reach of its flood-rent portals.

Other Noteworthy Structures.

At the surface, the basalt usually exhibits the familiar spheroidal habit of weathering; but while in some places the rock is deeply rotted to a rusty earth or loam, in others it remains perfectly hard and fresh immediately beneath a thin scaly crust which is shed off almost as rapidly as it is formed. Yet there did not seem to be any difference in composition accompanying this difference in weathering. The same anomaly is, of course, sometimes noticeable in the basalts of temperate climates, but I have never seen the distinction so sharply marked as in the Batoka Basalts.

The vesicular basalts occasionally show a kind of 'pillow-structure,' in the concentric arrangement of the amygdaloidal vesicles, due to the rolling-over of masses of half-cooled lava during the flow. This structure, so far as I saw, was not developed at the surface of the flows, but in their interior. The best example that came under observation was on the smoothly-worn rock-floor of the Mamba River, 200 yards below our camp, where the concentric outcrop of coarsely amygdaloidal bands divided up the rock into irregular oval masses, measuring from 2 to 6 feet in diameter.

The more massive basalts, when fresh, occasionally show a curiously knotted aspect on stream-worn surfaces, somewhat resembling a spherulitic structure. This appears to be due to the segregation of the porphyritic constituents, especially the plagioclase-

[1] Named after a native guide.

felspars, into small round clusters (see Appendix I [F 1030] p. 208). This structure was especially well seen in the bed of the Matetsi River, about a mile above the railway-bridge.

Besides the flaggy or thick-platy arrangement such as is common in basalts, which was a constantly recurring character in every part of the series, I noticed in a few places an unusual fissile or shaly structure for which I could find no explanation. So strongly marked was this structure in the bed of the Bwani River, 6 miles north of Makwa, where I first saw it, that I supposed the rock to be an indurated shale or schist, until closer examination showed it to possess the composition and crystalline character of the basalts. This shaly-looking material was, at one spot in the Bwani, curiously entangled among massive amygdaloidal basalt, with a sharp and irregular junction resembling an intrusive contact. Neither in the field nor under the microscope does the rock show any indication of shearing, so that the structure can hardly be a superinduced schistosity. Its petrographical characters are described in Appendix I [F 1024, 1025, & 1026] p. 209.

This shaly structure was also conspicuous on the southern shore of the Zambezi near Makwa, and was prolonged up the dry bed of the Gongobujo or Logier River; and in a less striking form it was visible at a few other places, notably at the head of the Lukunguli River, south-west of Dambi's. From the description given by Chapman, we may gather that the basalts display a similar character in the Zambezi valley for some distance below Makwa.[1]

Extent of the Basalts.

The eastern boundary of the Batoka Basalts at the Deka Fault has already been described; and I have also referred to the possibility that the basic lava-flows interbedded with the 'Forest Sandstones' (Molyneux) of the country farther eastward may belong to this series (p. 184). The scanty evidence respecting the northern boundary as far west as the longitude of the Victoria Falls has also been stated (p. 172). As to their further westward prolongation, I have received information from my friend, Lieut. T. A. G. Budgen, who accompanied us during part of our journey north of the Zambezi, that he has recognized the basalts at a locality some 30 miles north-west of the Falls, in the bed of the Umgwezi or Marimba River, a west-flowing tributary of the Zambezi. There is, so far as I am aware, no further evidence until we reach the confluence of the Chobe

[1] Chapman and Baines were evidently puzzled—and not without reason—by this rock. Chapman remarks:—'Baines thinks that the rock in the bed of the Zambesi, at Wankie's, is what is called altered sandstone; it is a fissile or laminated brittle rock, with a glossy coating where influenced by water, but of a yellowish-brown colour inside (perhaps shale) .... The other grey scaly rocks seam [? seem] in it near to Wankie's. The outer scale of this rock is easily peeled off, and is brittle, but becomes harder towards the centre' ('Travels in the Interior of South Africa' vol. ii, 1868, p. 213; see also p. 191).

or Linyanti River with the Zambezi, 50 miles west of the Victoria Falls, where Livingstone records the occurrence of amygdaloidal trap[1]; while Aurel Schultz notes the presence of 'volcanic rocks' along the Chobe above the junction.[2] Above the Linyanti flats the Zambezi in its long and tortuous south-easterly course, for a distance of 75 miles, flows in many places over a rocky bed and is broken by numerous rapids; and, according to Livingstone,

'the rapids are caused by rocks of dark-brown trap, or of hardened sandstone, stretching across the stream.'[3]

The river is then confined within a shallow rocky gorge for several miles, at the head of which are the Gonye Falls, 20 to 50 feet high, according to the season. Livingstone's account of the geology of this place is as follows:—

'The rocks of Gonye are reddish grey sandstone, nearly horizontal, and perforated by madrepores, the holes showing the course of the insect in different directions. The rock itself has been impregnated with iron, and that hardened, forms a glaze on the surface—an appearance common to many of the rocks of this country.'[4]

Serpa Pinto, however, describes the rocks of this locality (near Sioma) as 'basaltic strata .... forming natural ramparts, ever running east and west'; and he found similar rocks above the Gonye up to the edge of the Lialui flats[5]; beyond which, for an interminable distance, the solid rocks are entirely concealed beneath the sands and loams of the plateau. The apparent discrepancy between the two accounts may, I think, be that Livingstone's description refers to a capping of the 'surface-quartzite' (see p. 198), beneath which the rock is probably basalt. At any rate, there can be no doubt that the Batoka Basalts extend westward across the Zambezi in some portion, if not in the whole, of its course between the Lialui Flats and the Linyanti Flats. Beyond the river, there is no hope of tracing the basalts, as the whole country for some hundreds of miles—right up to the western edge of the plateau—is a sandy plain over which several travellers have passed without seeing a single stone.

Southward, as I have previously shown, the basalts may be followed along the outer margin of the Zambezi basin until they disappear under the sands of the Kalahari Desert, where the conditions are analogous to those on the western plains. Somewhere in the northern part of the desert, Chapman, during his earlier hunting trips reached two solitary conical hills of 'ironstone,'—the

[1] 'Missionary Travels & Researches in South Africa' 1857, chap. xiii, p. 233.
[2] 'The New Africa' 1897, map.
[3] 'Missionary Travels & Researches in South Africa' 1857, chap. xiii, p. 238.
[4] *Ibid.* chap. xxv, p. 498.
[5] 'How I crossed Africa' English transl. vol. ii (1881) p. 83. Serpa Pinto's descriptions of the trench of the main river below the Gonye Falls, and of the minor trenches of its rejuvenated tributaries, are interesting, as showing a repetition of some of the characteristics of the Batoka Gorge on a small scale. The physiographical problems raised by the presence of this gorge so far within the plateau-country are too wide to be discussed in this paper.

'Chenamba Hills'[1]—which Dr. Passarge considers to be probably indicative of the re-emergence of the basalts; but the position as well as the geology of these hills is uncertain. At the farther side of the desert south-westward, Dr. Passarge found the ancient gneissose and schistose rocks exposed in the neighbourhood of Lake Ngami; but if he is right in correlating the amygdaloids ('Loalemandelstein') which emerge at the eastern fringe of the desert in the Palapye district with the Batoka Basalts, it seems possible that a considerable portion of the Kalahari between the Zambezi, the Chobe, and the Makarikari Saltpans may be underlain by these rocks. The basis for this speculation is however so slender, that it is not worth further discussion.

Without extending the hypothetical boundaries far into either the western or the southern desert, we obtain an area of over 20,000 square miles as the approximate extent of the Batoka Basalts on a conservative estimate, and it may be very much more. But in any case the area of these old lava-fields cannot nearly attain the magnitude of the Deccan Traps of India or of the Snake-River Basalts of Western America.

Thickness of the Basalts.

As will be understood from the foregoing description, I found no means of ascertaining the thickness of the Batoka Basalts. It must in places exceed 1000 feet, as I saw nearly this thickness in a single section, in descending from the plateau south of the Zambezi to the bottom of the gorge approximately opposite the confluence of the Namaruba River; and at this spot presumably a very considerable mass had been removed from the top in the development of the plateau, and the base was still not exposed. What the thickness of the lava-fields in their deepest part may originally have been, must, I think, from the nature of the country, always remain a matter of conjecture.

Age of the Basalts.

Two views have been expressed respecting the geological age of the Batoka Basalts, but the evidence for either is at present slender. Mr. A. J. C. Molyneux,[2] whose opinion is endorsed by Mr. F. P. Mennell, considers them, as already mentioned (p. 184), to be probably contemporaneous with the similar basalts interstratified with the 'Forest Sandstones' of the country which he examined, farther eastward. In the absence of palæontological evidence, the age of the 'Forest Sandstones' is left uncertain by Mr. Molyneux; but Mr. Mennell considers them to be probably Tertiary, basing his argument chiefly upon the supposed recency of volcanic activity in

[1] 'Travels in the Interior of South Africa' vol. i (1868) pp. 150, 161, & 277–78.

[2] 'The Sedimentary Deposits of Southern Rhodesia' Quart. Journ. Geol. Soc. vol. lix (1903) *passim*.

the district,[1] and this view of the age of the Batoka Basalts is accepted by Mr. Molyneux in his later description of the Victoria Falls.[2]

The second view is that implied in Dr. Passarge's above-mentioned correlation of the Batoka Basalts with the Loale Amygdaloid and Diabase ('Loalemandelstein'). Here again the age of the rocks with which the comparison is made remains itself uncertain; but Dr. Passarge suggests that the 'Loalemandelstein' may fall within the Jurassic Period, pertaining possibly to some stage of the great epoch of volcanic activity represented by the Stormberg Series of the southern colonies.[3]

Further exploration will doubtless in time bring to light more direct evidence on the point; but my own endeavour to obtain such evidence having been unsuccessful, I can only state my impression, based mainly upon the relation of the basalts to the physical structure of the country, that they are likely to prove older than Tertiary. That they are older than the planation of the great plateau of which they form part is evident from the structure of the country around the Deka Fault; and if we dare follow Dr. Passarge in considering that this planation was largely accomplished during a Mesozoic desert-period, the early Mesozoic age of the basalts might be taken as established. But this hypothesis of Dr. Passarge rests upon a highly speculative basis, and his evidence that the superficial deposits laid down upon the plateau carry back its history into Eocene times is by no means convincing.

(4) The Flaggy Sandstone of Boomka, etc.

Along my route, the surface-sands and surface-quartzite presently to be described were usually seen to rest directly upon the Batoka Basalts of the plateau. At a few spots, notably along the northern edge of the sand-bult between Matetsi and the head of the Lukunguli basin,[4] the sands were indurated towards their base into the condition of soft sandstone or 'sand-rock,' but the direct relationship between this semi-indurated material and the incoherent sand was clear.

In going southward from Matheison's to Deka, however, I found traces of a flaggy, dull-red or green, siliceous rock overlying the basalt, differing in character from any material that I had hitherto seen and apparently representing the relics of a stratified deposit. It

[1] 'The Geology of Southern Rhodesia' Special Report No. 2, Rhodesia Museum, Bulawayo, 1904, p. 17.

[2] 'The Physical History of the Victoria Falls' Geogr. Journ. vol. xxv (1905) p. 46.

[3] 'Die Kalahari' 1904, pp. 71, 82, 540–42 & Kartenband, Blatt ii.

[4] The Lukunguli River is known to the natives by this name in its lower reaches only, toward its junction with the Matetsi; its head-waters are known to them as the Jambezi. It is probably the same stream as the 'Myatambesi' of Chapman's map, which has disappeared from the later maps. I intend further to discuss some of these geographical matters in the notes which I am preparing for publication in a geographical journal.

occurred along the northern slope of the sandy plateau between the head-waters of the Matetsi and the Deka Rivers—an upland known to Chapman as 'Boomka,' although this name appears to be no longer current. Here, though poorly exposed, the flaggy rock seemed to underlie a loamy flat of considerable extent, and was visible along our route at intervals for 3 miles or more, the surface of several shallow depressions or dry vleys being littered with its débris. I thought at first that it might be only an abnormal silicified surface-bed of recent origin, pertaining to these vleys; but on crossing for 4 or 5 miles the intervening sand-plain, I found similar rock cropping out along the edge of a shallow valley on the Deka side of the bult, under conditions implying that it might be the relics of a formation distinct from and older than the other surface-deposits. It differs from any of the surface-quartzites that I examined in its closely-knit fine-grained texture, flaggy bedding, colour, and general aspect; and I saw nothing like it in any other part of our traverses. The surface of the slabs occasionally showed flattened cylindrical markings recalling the 'worm-tracks' of some of our ancient greywackes. Microscropically, it is described by Mr. Thomas as

'a fine-grained quartzose sediment, iron-stained, and made up of very angular grains .... certainly not wind-blown' (see Appendix I, F 1038, p. 211).

Unfortunately, I saw no clear section in this deposit; but I think that its thickness where I crossed it can only have been slight—probably not more than 10 or 15 feet—as the basalts emerged in several places in the immediate neighbourhood. In the above-mentioned exposure at the margin of the little valley, the flaggy fragments frequently protruded edgewise at the surface, as if the beds possessed a steep dip; but this tilting appeared to be merely a superficial condition, confined to the loose slabs. I mention this, because it is just possible that an exposure of similar character may have supplied the basis of Chapman's description of 'vertical strata of sandy schist (?)'[1] in and around the head of the Deka Valley, which was my main incentive in making this particular journey.

These flaggy Boomka strata may conceivably be a feeble equivalent of some portion of the similarly fine-grained 'Forest Sandstones' of the Bulawayo country; or they may belong to the earlier of the superficial formations, like the 'Pfannensandstein' of Dr. Passarge; but, without further knowledge, it is useless to attempt their correlation. Once more the absence of fossils—that perpetual hindrance to conclusions in South African geology—brings to mind Livingstone's striking apophthegm, 'In Africa; the very rocks are illiterate.'[2]

Another exposure deserves notice here, as possibly indicating the presence of beds of a different character overlying the basalts. On the march from Deka to Wankie, about a mile before reaching 'Mtoro's Kraal, at the south-eastern side of the Deka basin some 15 miles distant from Wankie Station, a small steep hillock or

[1] 'Travels in the Interior of South Africa' vol. ii (1868) pp. 111 & 158.
[2] 'Missionary Travels & Researches in South Africa' 1857, chap. xii, p. 214.

kopje, isolated and of conical shape, lay close alongside our road on the left (north). This hillock was composed of shale with a capping of thin sandstone, apparently resting upon basalt. I made a hasty examination (near the end of a long trek), and the rough sketch in my note-book shows the following section:—

Top of kopje (slopes clad with *Euphorbia*).

	Thickness in feet.
Flaggy greenish sandstone	$0\frac{1}{2}$
Green marly shale	3
Purple shale	6 ±

on decomposed basalt? with platy structure, much hidden by talus.

Hard amygdaloidal basalt-débris at foot of kopje.

Note: Bedding of the shales nearly flat: looked rather promising for fossils, but none found.

At the time when I saw this section I was of opinion that the basalts were shelving underneath the high ridges of sandstone that lay immediately to the right of our track, not having yet discovered the faulted character of the junction. Consequently, I did not pay such close attention to the evidence for superposition as I should afterwards have done; but I distinctly remember that bare surfaces of basalt were exposed in close proximity to the kopje; and this being on the downthrow side of the great fault, it seems impossible that the sediments can have been brought up by the faulting. The spot certainly deserves further investigation, which I hope that it will receive from the next geologist who may pass that way.

(5) The Chalcedonic Quartzite, Kalahari Sand, and other Surface-Deposits.

The Chalcedonic Quartzite.[1]

In many places the basalts of the plateau are overlain by a curious siliceous rock that has figured largely in all travellers' descriptions of the country; for, although of insignificant thickness, it renders the ground which it occupies exceedingly uncomfortable to traverse. Frequently it occurs only as a chaos of loose blocks thickly strewn over the flats; but occasionally it attains a thickness of several feet, and from its resistant nature gives rise to conspicuous table-topped kopjes.

The rock is a hard sandstone or quartzite, sometimes of a greenish tint, though more often reddish-grey or yellow. It is knit

[1] For locally indurated patches in the superficial deposits of our own country, I have proposed the short terms, 'calcrete' (when the cement is calcareous), 'silcrete' (when siliceous), and 'ferricrete' (when ferruginous): see Geol. Mag. dec. iv, vol. ix (1902) p. 575; and despite the etymological faultiness of the first and second, I think that these terms might be very usefully applied to the indurated surface-beds of Africa. This particular rock I should describe, using the above nomenclature, as a 'silcreted' sand. There are strong objections to the application of the term 'quartzite' to this material.

together by a chalcedonic cement, but is full of irregular cavities from which some soluble or incoherent material has seemingly been removed. Consequently, while the rock is of flinty hardness, its surface is excessively rough and irregular, and therefore very damaging to foot-gear of any description.

I found this quartzite or 'silcrete' to be very generally, though sporadically, distributed throughout the country along the margins of the sand-bults, often forming a broad ragged fringe between the sands and the bare basalt. It does not, however, form a continuous layer beneath the sand, as it was not encountered in a well sunk by Mr. F. W. Sykes near the residency at Livingstone through the sand to the basalt; and is similarly wanting in some of the sand-cuttings on the railway between Deka Bridge and the Victoria Falls.

I saw some good sections of the 'silcrete' along the eastern margin of the shallow valley of the Maramba River, 2 miles above Livingstone, where it occupies the surface of a little plateau 30 to 40 feet above the river-flat, apparently an old terrace of the Maramba, and is cut through in several little kloofs. It is here from 3 to 10 feet thick, resting on decomposed basalt; and has a brecciated aspect, rounded lumps of the chalcedonic quartzite being enclosed in a gritty siliceous matrix honeycombed with the usual irregular cavities.

It is also well-displayed, as a rugged bouldery capping to small table-like kopjes, in the much-dissected country bordering the gorge of the Zambezi on the west in the basin of the Masui River, 4 to 5 miles south of the Falls; and in this neighbourhood it is also seen along the eroded margin of the sand-bult, being there generally associated with hard ferruginous sand-rock.

The greatest thickness of this surface-rock that came under my observation was in the sharp south-eastern rim of the Matetsi Valley, some 500 feet above the alluvial flat at Tsheza's, 5 miles from the mouth of the Matetsi. Here the beds cropped out at the margin of a high sand-covered upland in a bold krantz, which showed 8 to 10 feet of chalcedonic quartzite with 10 to 15 feet of partly siliceous, partly calcareous, brecciated or conglomeratic material below, resting on much-weathered spheroidal basalt. The position of this bed in relation to the valley appeared to denote its considerable antiquity. Thinner patches of similar chalcedonic rock occurred, however, on the stepped slopes along the opposite side of the valley at all elevations. Nor could I find in any part of the region that the formation was restricted to any definite position in respect to the present surface; for although, as in the above-described instance, it frequently caps the highest ground, it occurs in abundance also on the lower terraces and even in the bottoms of valleys.

The general impression that I gained was, that in most cases the 'silcrete' represents a progressive induration of the exposed base of the sands, due to the deposition of silica on the evaporation of ground-water which has slowly percolated through the sands. The solution and redeposition of silica, as Dr. Passarge has admirably shown, has been throughout their history one of the most characteristic geological processes within the great sand-velds of south-central Africa. The 'silcretes' of the region which I traversed appear in all respects to resemble the surface-quartzites of Cape Colony described by Mr. A. W. Rogers[1] and his colleagues; and, as with these, the conditions for their production still prevail. Therefore, while the induration of some may be of considerable antiquity, that of others is certainly very recent.

From his study of similar deposits in the Kalahari Desert, where they attain their widest development, Dr. Passarge believes that a definite sequence of events may be traced in them, involving many changes of climatic conditions and dating back from Eocene times. Hence he divides these deposits into several stages, which are grouped together as a system under the term Botletle-Schichten. From the descriptions of travellers he has concluded that these 'Botletle-Schichten' are exposed with considerable regularity along the dissected edges of the plateau in the Zambezi basin below the Falls; and he has therefore indicated their presence in this region on his map.[2]

However, as will be gathered from the foregoing account, I do not think that the surface-deposits of the Batoka country afford support to the complicated hypothetical deductions which Dr. Passarge has drawn from the 'Botletle-Schichten' of the Kalahari.[3]

In the country between Bulawayo and the Zambezi, Mr. Molyneux describes the occurrence of 'innumerable heaps of travertine,' composed of 'rounded quartz-grains cemented together by silica, often assuming the shapes of roots,' which form 'the capping of small rises.'[4] These he considers to have been deposited by hot springs now extinct; but I venture to suggest that in most cases they are surface-quartzites similar to those described above.

The petrographical characters of two of the surface-quartzites are described by Mr. Thomas in Appendix I [F 1045 & 1046] p. 211.

Blocks of the chalcedonic quartzite are among the commonest pebbles of all the streams that trench the ground which it occupies. The stone has been used in ancient times by the natives for manufacture into cutting implements. These implements lie scattered in large numbers on the rocky flats bordering the upper part of the Batoka Gorge: and, as I have elsewhere shown,[5] some may be of considerable antiquity.

[1] 'An Introduction to the Geology of Cape Colony' London, 1905, pp. 357-61.

[2] 'Die Kalahari' 1904, pp. 540-42, & Kartenband, Blatt ii.

[3] *Ibid.* p. 648.

[4] 'The Sedimentary Deposits of Southern Rhodesia' Quart. Journ. Geol. Soc. vol. lix (1903) p. 282.

[5] 'Notes on the Occurrence of Stone Implements in the Valley of the Zambesi around Victoria Falls' Journ. Anthrop. Instit. vol. xxxvi (1906) pp. 159-69.

The Kalahari Sand.

The mode of occurrence and the distribution of the surface-sands have been indicated in the first part of this paper, and are further illustrated by the section, fig. 1 (p. 170), and by the map (Pl. XVII).

These red sands must attain a great depth in the broad smooth bults of the plateau, but are rarely exposed in section. In the well-sinking near Livingstone previously mentioned (p. 199) they were 20 feet thick; in railway-cuttings south of the Victoria Falls they are exposed up to a depth of 15 feet: and these are the principal sections that came under my observation.

Where untrodden, these sands are firm and compact at the surface, but they rapidly disintegrate and become quite friable under traffic. So far as I could find, they show no sign of bedding or other evidence of sedimentation; and their position with regard to the present surface debars the possibility that they can have been accumulated as aqueous sediments where they now occur. For example, besides occupying the higher parts of the plateau, they enwrap the slopes of the shallow outer valley of the Zambezi in several places, and reach close up to the river on both sides above the Falls; and I noticed similar conditions in several of the smaller open valleys. This gives some clue to the period of their accumulation, since it is evident that they have attained such positions at some time subsequent to the erosion of these particular valleys. But it is noteworthy that the sands on the opposite sides of the Zambezi are identical in appearance; and it appears, therefore, that the river, if still existing at the time, did not form a barrier to their accumulation.

Although the sands are at present always heavily bush-clad and firmly fixed in position, the hypothesis that they have been wind-borne under conditions different from those which now prevail agrees best with their general characters. I did not anywhere, however, see any dune-shaped masses—always the sand lay in broad smooth swells or bults, with gentle slopes leading to an even summit; and the flatness of the sandy surface over wide tracts was very striking.

The identity of these sands with the 'Kalahari Sand' of Dr. Passarge has already been mentioned, and was indeed first recognized by that observer himself.[1] His explanation of their origin is that they have been, in the first place, brought down by large rivers into the interior basin during a period of heavy rainfall; and then partly redistributed by wind and other local agencies during a subsequent epoch of drought: and this idea finds no contradiction in any evidence that came under my own observation. Very little of the sand can have been derived from the basalts, in which the quartz-filled amygdules alone could supply this material; so that, unless indeed the sand represents the destruction of supra-basaltic arenaceous deposits of wide extent, for which there is little evidence,

[1] 'Die Kalahari' 1904, pp. 541 & 561.

it must have been transported into this region from without. Curiously enough, I saw comparatively little surface-sand in the sandstone-country around Wankie, where there is an immediate source for the material; but this district is so much dissected that loose detritus is likely to find its way rapidly into the stream-beds, whence it will be transported out of the sandstone-country to the Deka, and thence to the Zambezi.

Dr. Passarge considers that the river-transport of the sands was mainly effected during a 'Pluvialzeit' which was contemporaneous with the Glacial Period of our latitudes, and that their rearrangement took place during an 'Interpluvialzeit.'[1] Into these speculations I shall not venture to enter further than to state my impression that, whatever their earlier history may have been, the sands bordering the Batoka Gorge have reached their present position during a period of greater aridity and stronger winds[2] than now obtain in this region; and that there has since been a time (? the Glacial Period) of much greater rainfall than the present, during which the sands became fixed, clad with vegetation, and in places deeply eroded by streams which have now disappeared.

The reader who desires fuller information should peruse Dr. Passarge's great work, in which the Kalahari Sands, together with the other superficial deposits, are fully discussed in all their aspects.

Surface-Limestone and Tufa.

In the region traversed, calcareous deposits due to the evaporation of lime-charged waters are of common occurrence, but are usually of very limited extent and of recent origin. Owing to the interest excited in all the superficial deposits by Dr. Passarge's work, a short description of those which I observed seems, however, desirable.

Surface-incrustations of this character border many of the dry stream-courses and shallow vleys, reminding me of a similar crust or 'caliche' which I have seen under like conditions in Arizona.

In the Batoka Gorge the great cliffs of basalt are frequently streaked vertically with greyish-white incrustations, due to lime and other minerals deposited by water oozing from small springs and evaporating in the torrid air of the chasm (see, for example, Pl. XI). These markings are frequently strung along a definite bedding-plane, but at the time of our visit all these places appeared to be absolutely dry. Indeed, I was everywhere impressed with the rarity or absence of true rock-springs, seeing that the strongly-jointed structure of the basalt and the deep trenching of the country by the gorges appeared to afford most favourable conditions for them. The springs that I saw were all due to the slow oozing of water from the loamy flats, except a single one which I

[1] 'Die Kalahari' 1904, chap. xxxvii.

[2] I am informed by Mr. R. T. Coryndon that, in Northern Rhodesia, the winds at the present day are never strong enough to drift these sands, even if they were not sheltered by vegetation. I take this opportunity of also acknowledging my indebtedness to Mr. Coryndon for many useful items of information regarding the structure of the country beyond my traverse north of the Zambezi.

found issuing from the fault-rock low down in the eastern recess of The Chasm at the Victoria Falls. The temperature of this anomalous little fountain indicated that it was fed from the river above; and although within the perpetually spray-drenched atmosphere of The Chasm, it had deposited a thick cushion of tufa, charmingly overgrown with moss and fern.

Traces of a calcareous layer underlying the alluvial loam were noticed, in places, on the flats bordering both sides of the Zambezi above the Falls. It will be remembered that Livingstone found thick calcareous deposits in a higher part of the valley, and believed them to be the relics of a lake which was drained by the opening of the rift at the Falls.[1]

Besides the 'valley-calcretes,' I saw in a few places somewhat similar deposits of greater antiquity, that could not have been formed under existing conditions. These were generally associated with chalcedonic quartzite and with hard ferruginous material ('ferricrete'), which appeared in part to replace them and to represent a gradual alteration that is probably still in progress. Dr. Passarge has dealt very fully with the alteration (verkieselung) of lime-rocks into quartzites in the Kalahari; and I think that this process must have taken place in the cases to which I refer.

My best opportunity for examining material of this kind was near our camp at Makwa, just after we had crossed the Zambezi. Here the river, having emerged from the Batoka Gorge, has again expanded into a wide shallow stream, bordered by an irregular flat diversified with steep-sided basaltic kopjes of varying height. Two of these kopjes that I examined are capped by the deposits in question; and I should probably have found the same conditions on other hills in the neighbourhood, if I had been able to reach them. The first kopje overlooks the right bank of the river close to our landing-place, and is the 'Logier Hill' of Chapman and Baines, described by the former as being composed of 'tufa, dipping eastward.'[2] On this hill I estimated the thickness of the superficial rock at about 20 feet, the material being partly siliceous and partly calcareous, but showing the same rugged cellular structure throughout the mass. A similar but thinner capping was observed on the second kopje, near our camp $1\frac{1}{2}$ miles west-north-west of Logier Hill, which rose to about the same elevation and stood in like position with regard to the river. These hills are both much below the general level of the plateau, and must have received

[1] 'Missionary Travels & Researches in South Africa' 1857, chap. xxvi, p. 527.

[2] 'Travels in the Interior of South Africa' vol. ii (1868) p. 213. I was anxious to determine this site, so famous in the annals of African travel, where Baines and Chapman in 1862 made their unsuccessful attempt to build a boat in which to pass down the Zambezi. My ever-helpful pilot for the southern traverses, the late H. F. Greer, the Assistant Native Commissioner for the district, therefore called in some of the oldest natives to guide us to the place; and there, on the very spot, two of them told us how, as boys, they had come across the river to see the first white men in their country,—Gabimani (as they called Chapman) and his comrades—giving us a faithful narrative of the doings of these impressive strangers.

their capping after erosion had already greatly lowered this par of the country. They are some 400 feet lower than the place already described (p. 199) on the rim of the Matetsi valley, 7 or 8 miles to the north-westward, where very similar surface-rocks were observed; and we cannot therefore regard these surface-beds as forming part of a once-continuous sheet of 'Botletle-Schichten.' Moreover, I found the same kind of material to be plentiful at still lower levels, in the banks and dry bed of the Gongobujo River which drains eastward to the Zambezi on the northern side of Logier Hill.

The sections in the banks of this stream, 2 to 3 miles above its mouth, showed much white 'calcrete' and 'silcrete'—sometimes in soft sintery banks of 15 to 20 feet—along with masses of a hard splintery green rock, partly silicified (see Appendix I [F 1046, p. 211]), and some red jaspery streaks; and material of this kind was found to characterize the places where the gradient of the stream was low, being generally absent where the stream flowed steeply over the basalts.

These deposits therefore sustain the conclusion previously stated, that the surface-rocks have been formed on the flats at different stages in the lowering of the valleys, and that in this part of the country they do not mark any definite period.

Some further details with regard to the surface-accumulations of the region will be found in Appendix III (p. 213).

Lateritic Material.

In places where the basalt is bare, or nearly so, the surface is sometimes littered with rough irregular lumps of ferruginous grit ('ferricrete'), due to the segregation of iron from the decomposing rock; but I did not light upon any place where this material formed masses comparable to those of siliceous and calcareous composition described above. The same segregative process is probably indicated by the occasional presence of thin cakes and narrow strings of iron-ore on the rock-surface and in joints and crevices of the basalt. I noticed these small iron-filled crevices in several places, particularly in a dry kloof on the ridge 5 or 6 miles north-east of Matetsi, where the ore had been dug by the natives and smelted in the adjacent forest, the relics of their old bloomeries still remaining.

The pellety lateritic soil of the plateau has been previously described (p. 170).

Fluviatile Deposits.

The paucity of pebble-gravel along the bed of the Zambezi and its tributaries is remarkable. On the unbroken plateau this may be explained by the very low gradient of the streams; and in the rejuvenated valleys the force of the water is, perhaps, too great to allow such material to lodge. But it seems rather as if the basalt-blocks, when once broken into fragments, are soon completely disintegrated. Thus, within the Batoka Gorge, the river at low water is generally fringed on both sides by a forbidding border of great boulders only partly waterworn, interrupted here and there by miniature beaches of glaring-white quartz-sand, loudly 'musical' when trodden on; but the very scanty material intermediate in size between the boulders and the sand consists almost entirely of agate and chalcedonic pebbles derived from the amygdules.

The same peculiarity is observable in the case of the smaller streams draining the basalt-country; so that neither in their present beds nor on the higher ledges which they have once occupied is there any noticeable accumulation of fluviatile detritus; and even their flood-bars, like those of the Zambezi itself on its emergence from the great gorge, are built up of partly-worn basalt-blocks, occasionally faced with patches of white sand.

In the north-eastern district, however, where the streams have derived part of their detritus from the older rocks (p. 172), medium-sized pebbles of these rocks and nut-like pebbles of pink quartz are abundant, not only in the present river-beds but also on low flats away from the streams, indicating a former drainage-system differing in detail from that of to-day. But even here the pebbles, where thickest, seem only to form a surface-layer, and I saw no instance of a gravel-terrace of construction such as one is accustomed to find in the home-country.

I could not detect any of these extraneous pebbles on the flats of the Zambezi at Makwa, below the confluence of the above-mentioned streams; but the abundant flakes of white mica contained in the river-sands at this place, and absent in the higher reaches, have no doubt been carried by these streams. I can therefore confirm Chapman's shrewd guess[1] that this mica was brought down to the river from the north.

The smoothly-worn basalt along the stream-beds, especially on the flood-platforms and other places slightly above ordinary water-level, is generally glazed with a thin black surface-film bearing a high polish, which gives no foothold and renders passage along the floors of the gorges very difficult. Glazing of this kind appears to be of very common occurrence on similarly-situated hard rocks in hot climates, and its origin has been frequently discussed. In Egypt, Mr. A. Lucas, who has carefully studied its occurrence at the Nile Cataracts, leans to the opinion that the film is deposited by water evaporating from the rock[2]; and my experience of the phenomenon in the Zambezi valley led me to the same opinion.

I have elsewhere[3] remarked on the singular absence of recent animal-remains in the region, but the point will bear repetition. From the hunters' records we know how abundant formerly were the bigger mammals, including the elephant, rhinoceros, hippopotamus, buffalo, zebra, lion, etc., and indeed, though sadly diminished, they still inhabit the country. In the district south of the Batoka Gorge they were killed in great numbers during the last century; yet I failed to find anywhere either bone or tooth to

[1] 'Travels in the Interior of South Africa' vol. ii (1868) p. 213.

[2] 'The Blackened Rocks of the Nile Cataracts & of the Egyptian Deserts Govt. Rep.: Ministry of Finance, Cairo, 1905.

[3] Rep. Brit. Assoc. 1905 (South Africa) p. 299.

indicate the fact, despite my searches in the apparently favourable stream-beds and trenched loam-flats of the plateau. The African climate, aided perhaps by insect- and other low forms of life, appears to bring about the rapid disintegration of animal-remains, even of the hardest teeth.[1] Supposing similar conditions to have prevailed in the past, it is easy to understand the deplorable lack of fossils in most of the African sedimentary rocks.

V. Summary and Conclusion.

1. The predominant feature in the geology of the Zambezi basin around the Batoka Gorge is the wide development of the Batoka Basalts, a great series of lava-flows of undetermined age, but probably Mesozoic. These basalts stretch southward into the Kalahari Desert, and westward beyond the great bend of the Zambezi above the Linyanti Flats; but their extreme limits in these directions is not yet known. They are terminated northward by the emergence of the older rocks which form the Batoka upland.

2. The basalts are cut off on the east by the Deka Fault, which brings in the sandstones and shales ('Wankie Series') of the Wankie coalfield (= Matobola Beds, probably Permo-Carboniferous). This great dislocation, striking east-north-east where seen, is probably continued far to the north-eastward of the country examined, and constitutes a governing feature in the structure of the district.

3. The Wankie coal-measures rest directly upon the ancient schistose, metamorphic, and igneous rocks of Rhodesia; and an equivalent series of sandstones, etc., probably occupies a similar position along the northern margin of the basalts.

4. Superficial material, principally unconsolidated red sand ('Kalahari Sand') and chalcedonic 'surface-quartzite,' overspreads large areas of the basaltic plateau, and denotes great changes of conditions in the central basin in late Tertiary and in Quaternary times.

5. The main element in the physiography of the country is the rejuvenation of the sluggish plateau-drainage, consequent upon the erosion of the Batoka Gorge by the Zambezi. The singularly zigzagging courses followed by the rejuvenated streams are due to certain structural characters of the basalts.

It remains for me to render sincere acknowledgments for assistance rendered to me by many friends.

To the Council of the British Association I am initially indebted for the opportunity of undertaking this pleasurable investigation in a new field.

[1] That mammalian remains may, however, be preserved, under exceptional circumstances, is proved by the occurrence of calcareous bone-breccia in the 'Rhodesia Broken-Hill' mining district in the 'hook' of the Kafue River (N.W. Rhodesia). The country-rock of this district, in places, is limestone. Specimens of this bone-breccia were obtained by Mr. A. Bromwich, of the British South Africa Company, during a recent visit to the locality, who kindly brought it to my notice. The much-desired recovery of specimens indicating the South African fauna antecedent to that of recent times is therefore not quite hopeless.

To Sir Lewis Michell and to the officers of the British South Africa Company, both in Rhodesia and in London, my thanks are due for the liberal co-operation by which alone it was made possible for me to carry out the field-work in this wild region.

To Mr. F. W. Sykes, until recently the District Commissioner and Conservator at the Victoria Falls, who organized and led our expedition on the northern side of the Gorge, I owe more than can be expressed in this simple acknowledgment.

It is impossible within the allotted limits of space to particularize at length the assistance that I received on all sides in Rhodesia; to some of which I have, however, been able to make reference in the text of this paper. But my appreciation of the kindness shown to me is none the less keen if unexpressed.

I have to thank Mr. F. W. Sykes, and Miss Louisa Rhodes (acting as the representative of her brother, the late Col. F. W. Rhodes, who accompanied us on our journey north of the Gorge), for the photographs with which this paper is illustrated.

The collection of rock-specimens made during the investigation has been handed over to the Petrographical Department of the Geological Survey of Great Britain, for preservation at the office in Jermyn Street, London.

Appendix I.

Petrographical Notes, by H. H. Thomas.

The Dolerites.

Intrusive ophitic olivine-dolerites.

F 1032 & 1035. Localities: 10 yards from fault at Jack's (Mtoro's) Kraal, Deka Valley; and 30 yards from fault, Rondulu, Wankie.

Of the specimens examined, two rocks seem to possess undoubted intrusive characters; in the hand-specimen they present a fairly compact appearance, without any conspicuous porphyritic mineral.

The fresh rock is greenish-brown in colour, with small dark-green patches; and F 1032 showed a few minute amygdaloidal cavities, filled with zeolites, chlorite, and secondary quartz.

Under the microscope these rocks prove to be almost holocrystalline ophitic olivine-dolerites, of somewhat unusual type. They consist of magnetite, plagioclase with a little orthoclase, and augite. The magnetite is for the most part the earliest product of consolidation and builds well-formed octahedra, but also occurs in strings and patches. The olivine exists as small idiomorphic crystals, slightly elongated, parallel to the edge (100) (010), and as rounded grains. No fresh olivine now remains, but that it was a variety fairly rich in iron is indicated by the border of iron-ores fringing the pseudomorph. The pseudomorphs are composed of a fibrous highly-refracting mineral, with straight extinction and a yellow to yellow-brown colour, recalling the 'Potluck' pseudomorphs of the Derbyshire 'toadstones' or those of some of the Tertiary dolerite-sills of Skye.

The felspars, which are practically all of one generation, build lath-shaped crystals ranging up to 1·2 mm. in length. Generally they are twinned according to the Carlsbad law alone, but a few show albite-lamellation. The low and sometimes almost straight extinction of these crystals indicates an acid plagioclase, approximating to if not actually reaching oligoclase. The augite, which is a pale variety, but not quite colourless in section, forms plates ophitically enclosing the plagioclase-laths. The orthoclase occurs as small untwinned patches, filling the spaces between the earlier-formed crystals, and was evidently the last product of consolidation. A few small needles of apatite may be seen, but the mineral is rare; and chlorite occurs as a decomposition-product of the ferromagnesian minerals. Small chloritic patches might possibly represent residual glass, but proof is wanting. Both these rocks were completely devoid of flow-structure.

In the apparent high percentage of alkalies these dolerites approximate in composition to the mugearites of Harker, but differ strongly from them in a greater percentage of the bisilicates and in the paucity of apatite.

The Flows.

These rocks may be divided into two types:—

(*a*) Those in which the augite is mostly granulitic, but which also contains larger subophitic plates.
(*b*) Those in which all the augite is granulitic in character.

(*a*) The Subophitic Dolerites.

F 1019. Locality: Creek at Mamba Camp, north of the Zambezi.
1028. Locality: Bed of Lukunguli (Jambezi), near Dambi's; (bedded).
1029. Locality: First crossing of the Lukunguli from Tsheza's.
1030. Locality: Matetsi River, south of Matetsi Station.

In the hand-specimen the above rocks are of a dark-grey colour, one alone (1028) having a dull-red tinge. They are heavy and compact, and show bright felspar-crystals. They are typically non-amygdaloidal. Specimens 1019 & 1029 show a platy structure, apparently parallel to the surface of the mass; while 1030, on a weathered surface, shows light-coloured circular patches about a quarter to three-eighths of an inch in diameter, the origin of which is obscure unless it be a greater percentage of felspar in that area.

The rocks consist of magnetite, augite, and plagioclase-felspar, with olivine and apatite as accessories. The texture is fine-grained and there is no flow-structure.

The magnetite builds octahedra, but occurs also in irregular patches and strings. The augite, which is pale in colour, occurs in two forms, either as plates wrapping round but seldom enclosing the felspar, or as knots or small crystals without good outline in the groundmass.

These rocks may be said to be rich in augite, but this is compensated in a measure by the almost complete absence of olivine; only in two specimens (1028 & 1030) were doubtful pseudomorphs after this mineral detected. The granules of augite are often twinned, and elongated parallel to the twin-plane.

The felspars occur in two generations, but are seemingly very similar in composition, both being just on the acid side of typical labradorite. The earlier generation builds porphyritic slightly-zoned crystals, usually twinned according to the Carlsbad and albite-laws, but occasionally showing pericline-lamellæ. The symmetrical extinctions on the twin-plane range up to 36°. The microliths are extremely slender, usually twinned on the Carlsbad plan only. Apatite occurs sparingly, and there seems to have been a small residue of interstitial glassy material.

It is quite probable that some of these rocks may be sills; but, apart from field-evidence, there is no reason for removing them from those considered as true flows.

(*b*) The Granulitic Dolerites.

F 1016. Locality: Railway-cutting at west side of bridge, Victoria Falls.
1017. Locality: Bottom of the Zambezi Gorge at the entrance to the Songwi.
1020. Locality: Lower cataract at the Tshimamba.
1021. Locality: Upper cataract at the Tshimamba.
1022. Locality: South side of the Zambezi, floor of the gorge near the Namaruba confluence.
1024. Locality: Bwani River, north of the Zambezi.
1025. Locality: Bwani River, north of Makwa (platy beds).
1026. Locality: Bwani River, north of the Zambezi (platy beds).
1033. Locality: Kopje near the railway-bridge, 6 miles west of Wankie.
1037. Locality: Rock in the fault, Deka River, kopje near the railway-bridge.

The fresh rocks, such as 1016, 1020, 1031, 1033, are compact, and dark-grey to grey-brown in colour, weathering brownish or greenish according to the extent to which oxidation or chloritization has proceeded. They are feebly vesicular: in F 1024 cavities reach half an inch in diameter; in other specimens they are smaller, while in some they are absent. Mineralogically they are identical with the rocks containing subophitic augite, and the two groups undoubtedly pass one into the other. F 1017 represents an intermediate stage, in which there are occasional bigger crystals or knots of augite.

The felspars occur in two generations, as before; but the microliths often tend to take up a parallel arrangement indicative of flow, although flow-structures are generally ill-defined or absent. In composition and dimensions the felspars agree with those described above.

Magnetite is comparatively abundant in octahedra, but by no means constant in its percentage.

In texture these rocks are all fine-grained, some more so than others. Olivine is rare and in many cases absent, while the augite, where it exists as large crystals, has undergone partial re-absorption.

The vesicles are usually filled by zeolites, but sometimes by secondary quartz and also chlorite.

Some of the flows are much decomposed, and occasional specimens, such as F 1037, show a mass of felted felspar-microliths silicified and highly iron-stained.

Unusual Types.

F 1034. Locality: Near the fault, Deka River, near the railway-bridge.

This rock in the hand-specimen shows large porphyritic felspars set in a red, highly ferruginous ground-mass, which is apparently wholly crystalline. Under the microscope the porphyritic felspars are seen to be twinned according to the Carlsbad and albite-laws, and to belong to a species of labradorite. The groundmass contains olivine now converted into yellow pseudomorphs, sometimes showing the original crystal-outline. Augite occurs in small, mostly idiomorphic crystals, and also plentifully in the groundmass. The felspar-microliths are labradorite: they are much twinned (Carlsbad and albite-laws) and lack any definite arrangement. There is a good deal of interstitial material which was originally glass, now rendered absolutely opaque by limonitic iron-ores.

The rock, as a whole, is slightly vesicular; the vesicles, which range up to half an inch in diameter, are filled with stilbite and lined with chlorite. Locally it shows signs of brecciation, and from this and other properties it is suggested that it is the margin of an intrusion or flow.

F 1031. Locality: 2 miles south of 'Klaas's, near the head of the Matetsi.

A remarkably fresh-looking, dark greyish-brown rock, in which light amber-coloured grains and crystals are very noticeable. Under the microscope it is seen to ally itself to the subophitic or glomeroporphyritic examples described above, but to differ in the occurrence of an abundance of a bright-yellow mineral of secondary origin. This mineral, which is fibrous and strongly refracting, both replaces small crystals and grains of olivine and fills minute cavities.

In all other respects this rock may be grouped with the subophitic varieties already described.

Fragmental Rocks, etc.

F 1018. Locality: Eastern bank of Mavangu Creek, near Camp.
1023. Locality: South side of the Zambezi, floor of the gorge near the Namaruba confluence.
1027. Locality: Bwani River, north of the Zambezi.

Among the fragmental rocks one true tuff was noticed, namely F 1018. It consisted of broken felspars, almost opaque reddish tachylytic glass, angular and vesicular masses of fine-grained dolerite, set in a matrix of fine broken felspar-microliths and clastic quartz. The other specimens are apparently flow-breccias: they are largely made up of fragments of tachylytic glass as before, but these are cemented by doleritic material which is of the nature of a flow and not fragmental.

Zeolites.

The zeolites collected separately include stilbite, mesolite, and laumontite (?). Stilbite and laumontite (?) are associated in the same mass, the stilbite being pinkish and the supposed laumontite opaque-white. The mesolite occurs in colourless, translucent, radiating masses.

The Sediments, etc.

Boomka Flags.

F 1038. Locality: Sandstone, 6 miles north of Geise's, Deka valley.

A fine-grained quartzose sediment, iron-stained, and made up of very angular grains measuring not more than 0·15 millimetre in greatest dimension; certainly not wind-blown.

Surface-Deposits.

F 1044. Locality: Limestone, 10 miles north of Deka valley at Geise's.

This rock is yellowish-grey, compact, and fine-grained, with white patches and streaks. Under the microscope the main mass of the rock is seen to be composed of a calcareous paste which has undergone little or no silicification, and a few small patches of recrystallized calcite. The white patches are seen to consist of well-rounded quartz-grains, with some equally well-rounded limestone-grains set in a fine detrital calcareous cement. The limestone is probably of organic origin, and contains many sections of organic remains which may be referred to Cyprids.

It is suggested that the streaks and patches are solution-tubes and cavities filled with blown sand.

F 1045. Locality: East of Mavangu Camp, north of the Zambezi.

A pink quartzite, made up of millet-seed grains of quartz and microcline, with a little finer material of subangular character. The matrix is chalcedonic. The large proportion of microcline would seem to indicate derivation from an area of crystalline schists and gneisses. Probably this is a desert-sand solidified by secondary silicification.

F 1046. Locality: Bed of the Gongobujo River, Makwa.

Greenish-grey siliceous rock, with white calcareous patches. It is similar to the above, with the exception that it is not red-stained and contains a less quantity of microcline. The matrix between the grains is chalcedonic, but in this case evidently replaces an original calcareous cement. In the white patches the replacement of the calcareous material has gone on to a very small extent. The white patches seem, therefore, to represent more or less the original character of the rock.

Pebbles from the Gwemanzi River, north of the Zambezi, include several schists and gneisses, among which may be mentioned a quartz-biotite-gneiss and a garnetiferous pegmatite-gneiss.

Appendix II.—Local Notes on the Batoka Basalts.

Locality.	*Predominant Characters.*	*Dip, when seen.*	*Joints, etc.*
Northern Side of the Zambezi, and Batoka Gorge.			
Victoria Falls	Three slightly amygdaloidal massive beds, with two amygdaloidal breccias at ry.-bridge.	(Slight) S.E. or S.S.E.	E. 10° S., cut at low angle by Chasm-fracture (see p. 188).
Gorge at Songwi	Massive amygdaloid, with several bands of breccia, some thick.	S. 20° E. at 3° to 5°.	E.; to E. 20° N.
Moravu, 6 miles east of Songwi.	Dense, slightly amygdaloidal; platy structure.	E. to S.E.	E. 25° N.
Mavangu, between Camp and Gorge.	Dense platy basalt, with thin tuff-like breccia (see p. 184).	Variable; N.E., W., & W. 20° S.	Obscure & irregular: S. & S. 10° E.
Gorge south-east of Mavangu Camp.	Several thick massive bands, with soft greenish-grey intercalations.	Apparently W. at 2°.	Strong.
Mamba Creek, near Camp.	Amygdaloidal basalt, with 'pillow'-structure, and in places platy; with red spongy breccia below.	Rolling, but mainly S.E.	Irregular, chiefly E. 10° S.
Gorge at the Tshimamba Cataracts.	Dense platy basalt; with intervening breccia in lenticular masses.	S. at 5° to 15°.	Mainly E.
Kalonga's Cleft, Karamba River.	Amygdaloidal basalt, hard and splintery; with a band of red breccia about 60 feet thick.	W. at 3° to 5°.	E. & a few S.; also many 'shatter-planes' with veining.
Lower (south-eastern) reach of the Karamba River.	Basalt and breccias.	Apparently S.	Strong S.E.
Kalomo River, near Camp.	Dense.	Indefinite.	Irregular; some S. 20° E.
Gorge near the Namaruba confluence.	Massive basalt, with amygdaloidal bands and breccia.	S. at 8°.	E. 10° N., & others S. 10° E.
Gwemanzi River, near Camp.	Dense, platy.	N.E.	Master-joints E.; others S.E.
Bwani River	Purple amygdaloidal basalt, and greenish basalt with shaly structure.	Rolling, mainly S.E., up to 15°.	Some E.; others S. 30° E.
Southern Side of the Zambezi.			
Zambezi shore at Makwa.	Platy amygdaloidal basalt and spongy breccias.	Apparently flat.	Irregular; E. 35° N. & S. 30° W.
Matetsi River, near the Zambezi confluence.	Dense basalt and slaggy amygdaloid, confusedly mingled.	?	E., with calcite-veins.
Lukunguli River, first crossing.	Dense greyish basalt.	?	Dominant, E. 20° S.
Lukunguli River, above Dambi's Kraal.	Purple porphyritic rock, with regular platy structure resembling bedding.	S.W. at 10°.	E. 20° N.
Matetsi River, 1 mile above the railway-bridge.	Dense greyish basalt with spherules (glomeroporphyritic); and purple basalt with chalcedonic & zeolitic amygdules.	Not seen (but 2 miles higher up-stream, rolling & mainly E.)	Dominant, E., but rather confused.
Matetsi River, near head, 8 miles from Pandamatenka.	Dense, slightly amygdaloidal.	Ground flat: dip not seen.	Obscure; some S. 30° W.
2 miles W. of Matheison's.	Dense, platy.	S.S.E.	
Stream south of Deka ...	Amygdaloidal basalt, with spheruloid structure.	Not observable.	
Deka River, 2 miles below Deka.	Platy, with spheruloid structure, and amygdaloidal.	S.W. or W., but rolling.	
Deka valley, 10 miles below Deka.	Do. Do.	......	E., with calcite- and hæmatite-veins.
Same General Features Continue to 'Mtoro's.			
Deka valley, between 'Mtoro's and 'Ngoni's.	Dense, amygdaloidal.	......	E., with veins.

Appendix III.

Notes on the Superficial Deposits along the Routes marked on the Map (Pl. XVII).

Locality.	*Character of the Surface traversed.*
Northern Side of the Zambezi.	
Victoria Falls to the Songwi River.	Stony flat, a former bed of the Zambezi, cut by gullies; with sprinkling of gravelly chalcedonic detritus.
Songwi River to Mavangu	First, alternations of stony lateritic ground with grassy flats of thin loam: then, a sand-bult at the head of small streams draining to the Zambezi.
Mavangu to Tshimamba	Continuation of the sand-bult, with loose blocks of 'silcrete' (surface-quartzite) in patches along the edge; then broken basaltic country, with lateritic soil.
Tshimamba to Kalonga's Cleft.	Rugged dissected basalt-country, with some heavily grassed stretches of loam along dry stream-beds on the plateau.
Kalonga's to the Kalomo River.	Very rugged basalt-country: huge bars, up to 12 feet high, of basalt-boulders, in the bed of the Kalomo, with a sprinkling of pebbles and mica-flakes from the Fundamental Complex.
Kalomo River to the Gwemanzi River.	Smoother and less broken plateau beyond the Kalomo basin, with shallow valleys containing much detritus of the ancient rocks, etc. (see p. 172). A patch of 'silcrete' on the flat east of the Namaruba River, and traces of high-level gravel.
Gwemanzi to 'Ntoro	Slightly-broken basalt-plateau, with scattered blocks of 'silcrete' and some pinkish quartz-pebbles, but little or no detritus of ancient rocks in the streams.
'Ntoro to Makwa	Descent from the plateau over basalt, with sprinkling of granitic, etc. gravel in places, and patches of 'calcrete' on the lower ground: tract of red sand on the slope leading to the Zambezi.
Southern Side of the Zambezi.	
Makwa to the Matetsi River ...	Sloping bult of red sand, covering a ridge, with 'silcrete,' 'calcrete,' etc. at the edge (see p. 199).
Matetsi valley, from Tsheza's to the confluence with the Zambezi.	Broad valley with steep sides; several terraces of dark alluvial loam in the bottom, the lowest containing many freshwater shells [1]; broad delta of basalt-boulders at the confluence.
Matetsi River (Tsheza's) to the Lukunguli River (Sianteti's).	Blocks of 'silici-calcrete' abundant on the basalt-spurs of the Matetsi valley, and a patch about 15 feet thick on the crest, at the margin of the plateau. Upland flats of thin loam thickly grassed, breaking away into stony basaltic valleys. Some mottled red sandstone and 'silcrete' at the margin of a thinly sand-covered tract.
Sianteti's to the Batoka Gorge.	Basaltic upland, with lateritic soil and gravelly 'ferricrete,' 'silcrete,' and loam in places, becoming very rugged towards the Batoka Gorge.
Sianteti's to Dambi's (Lukunguli valley).	Ferruginous and chalcedonic gravel on a high terrace in the valley: stony slopes on the south, leading to a plateau of the usual type—alternately stony and loamy—; but westward, grassy loam-flats expand into a wide basin, edged on the north and south by sand-bults.
Dambi's, to the head of the Lukunguli valley, and across the water-parting tò Matetsi Station.	Loamy flats, edged by rocky ground and partly surrounded by sand-bults; some 'ferricrete' and 'silcrete' along the edge of the sands: also cakes and veins of iron-ore at the top of the basalt in places.

[1] See list in Rep. Brit. Assoc. 1905 (South Africa) p. 301.

Locality.	*Character of the Surface traversed.*
Matetsi Station to Lukubiro's (Matetsi and Tshitshigumba valleys).	Narrow sand-bult in the angle between the rivers, indurated to a soft red rock at the base; but chiefly loam-flats, with stony lateritic tracts in the valleys.
Lukubiro's to Matheison's (head of the Matetsi basin).	Succession of broad grassy flats of black loam, up to 9 feet deep, interspersed with low rises of basalt with thin lateritic soil: a thin patch of 'calcrete' on the north side of the Matetsi River where crossed.
Matheison's to Deka (head of the Deka basin)	Broad sand-bult, rising 200 to 300 feet (Boomka of Chapman), between the basins of the Matetsi and Deka, with some patches of flaggy sandstone at the edge (see p. 196); but country otherwise as last.
Deka to 'Ngoni's (southern edge of the Deka valley).	Grassy loam-flats and stony basalt-country interspersed, the latter thickly sprinkled in places with small pebbles and rough lumps of quartz, quartzite, chalcedony, and sandstone: also some sand-veld in approaching 'Mtoro's.

EXPLANATION OF PLATES X–XVII.

Plate X.

Rift, about 80 feet deep, in Cataract Island, Victoria Falls, excavated along a vertical joint or small fault in the Batoka Basalts by an overflow streamlet. The 'Leaping Water' is seen in the distance.

Plate XI.

The Batoka Gorge, looking up from the confluence of the Songwi River, about 6 miles below the Victoria Falls. A sand-bult forms the sky-line on the left.

Plate XII.

The Batoka Gorge at Syakowi, near the confluence of the Mavangu stream, looking down, about 17 miles E.S.E. of the Victoria Falls.

Plate XIII.

The Batoka Gorge, about 25 miles E.S.E. of the Victoria Falls, immediately below the Tshimamba Cataracts looking N.E., down stream (see plan, fig. 5, p. 189); showing the flood-platform with islands, and the development of zigzags along joints in the low-water channel.

Plate XIV.

The Batoka Gorge at the confluence of the Karamba River (see fig 6, p. 190) about 35 miles east of the Victoria Falls, looking west, up-stream; depth of gorge = about 750 feet.

Plate XV.

Kalonga's Cleft, nearly 300 feet deep, at the head of the gorge of the Karamba River, a tributary of the Zambezi (see figs. 6, 7, & 8, pp. 190–191).

Plate XVI.

The Batoka Gorge at the sharp bends just below the confluence of the Songwi River; showing promontories ('knife-edges') partly destroyed by weathering, and a lower pinnacle (in the middle of the picture) cut off by an ancient channel of the river.

Plate XVII.

Geological sketch-map of the country around the Batoka Gorge of the Zambezi, on the scale of 10 miles to the inch; and three diagrammatic sections: (1) across the Zambezi basin; (2) across the lower portion of the Wankie Series at Wankie; and (3) in the Wankie Series adjacent to the Deka Fault.

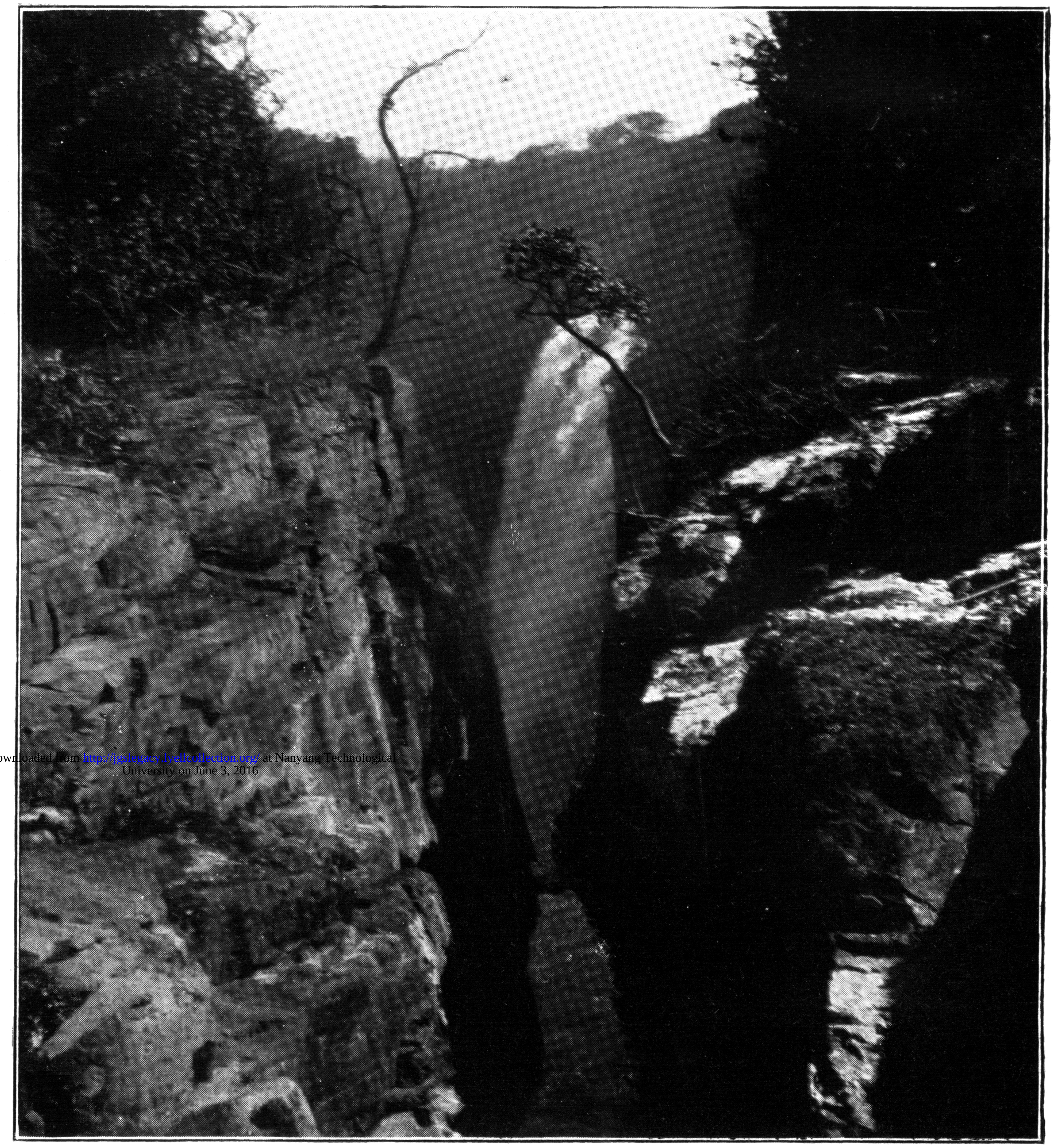


Photo by the late Col. F. W. Rhodes.

Rift, about 80 feet deep, in Cataract Island, Victoria Falls, excavated along a vertical joint or small fault in the Batoka Basalts by an overflow streamlet. The 'Leaping Water,' in the distance.

The joint-plane showed traces of slickensides.

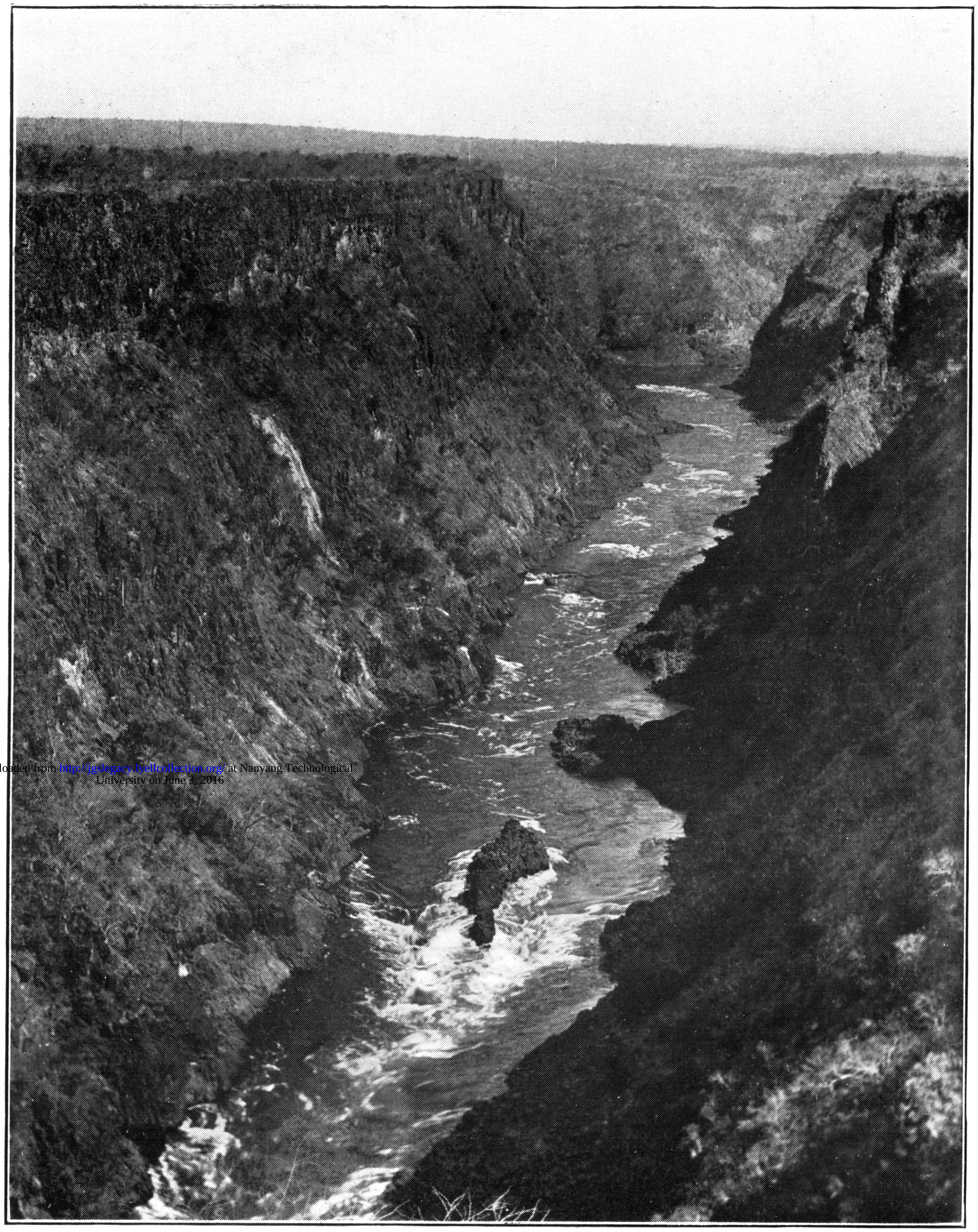


Photo. by F. W. Sykes.

The Batoka Gorge, looking up from the confluence of the Songwi River, about 6 miles below the Victoria Falls. A sand-bult forms the sky-line on the left.

Note the sharp trenching of the plateau; and compare the angle of slope of the walls, here nearly 500 feet high, with that shown in the next three Plates.

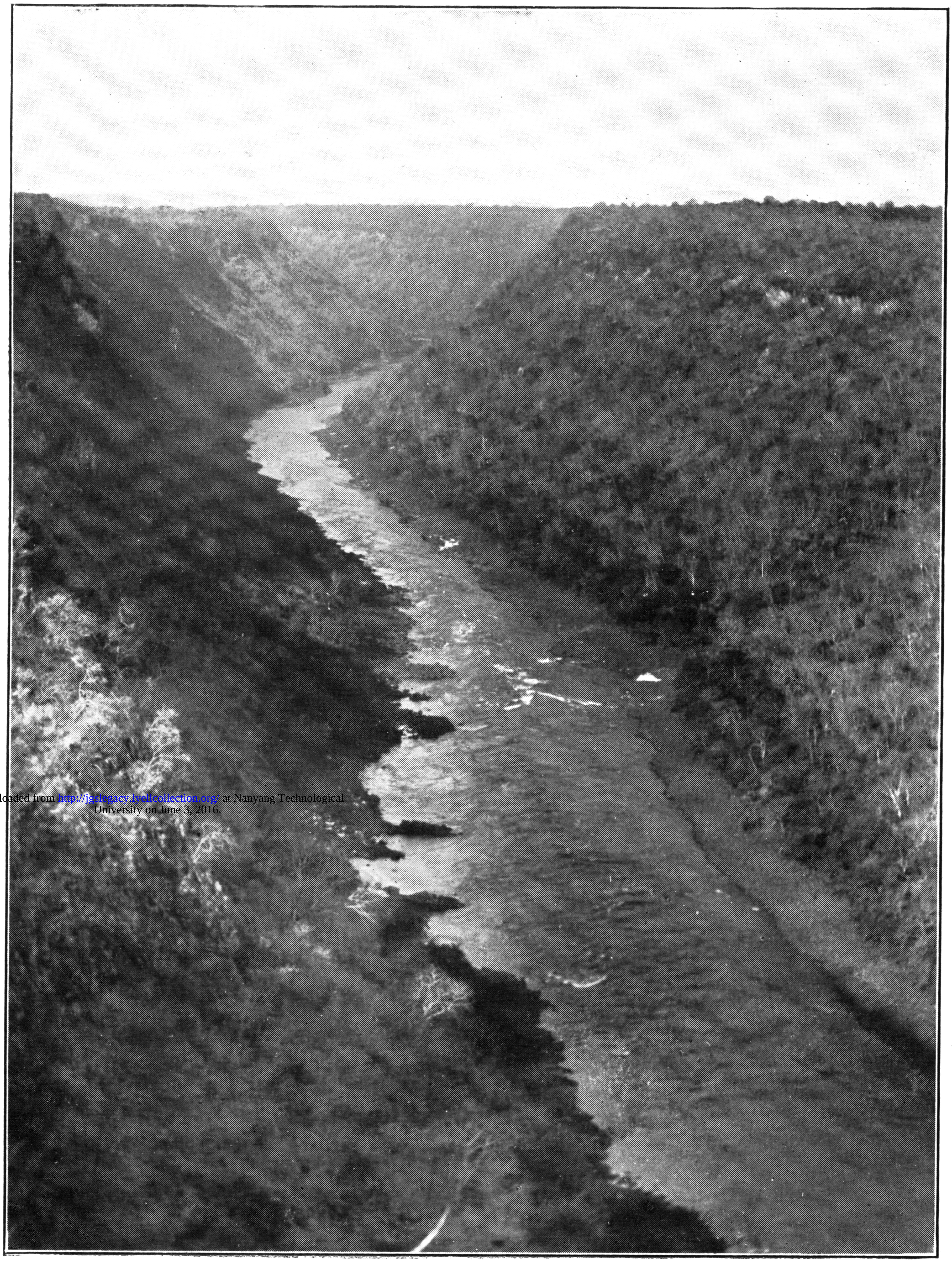


Photo. by F. W. Sykes.

The Batoka Gorge at Syakowi, near the confluence of the Mavangu stream, looking down, about 17 miles E.S.E. of Victoria Falls.

Note the dip of the basalts in the distant cliff; also, the diminished angle of slope compared with that shown in Pl. XI.

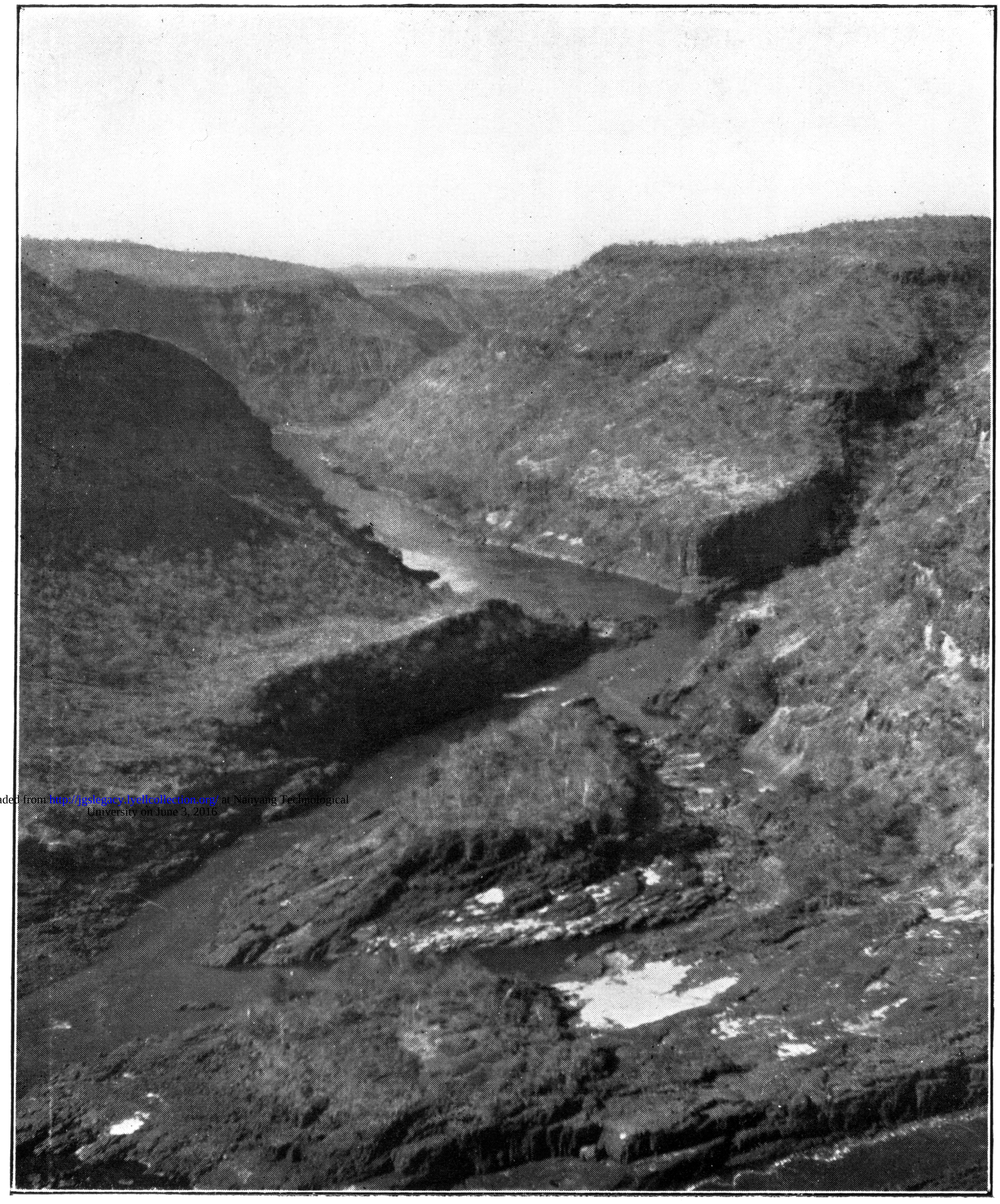


Photo. by F. W. Sykes.

The Batoka Gorge, about 25 miles E.S.E. of Victoria Falls, immediately below the Tshimamba Cataracts, looking N.E., down-stream (*see plan, Fig.* 5); showing the flood-platform with islands, and the development of zigzags along joints in the low-water channel.

Note the prolongation of the middle reach into an inlet on the right bank, and the escape of the river from it at right angles. The white patch in the foreground is a little beach of quartz-sand. The depth of the gorge here is about 600 feet.

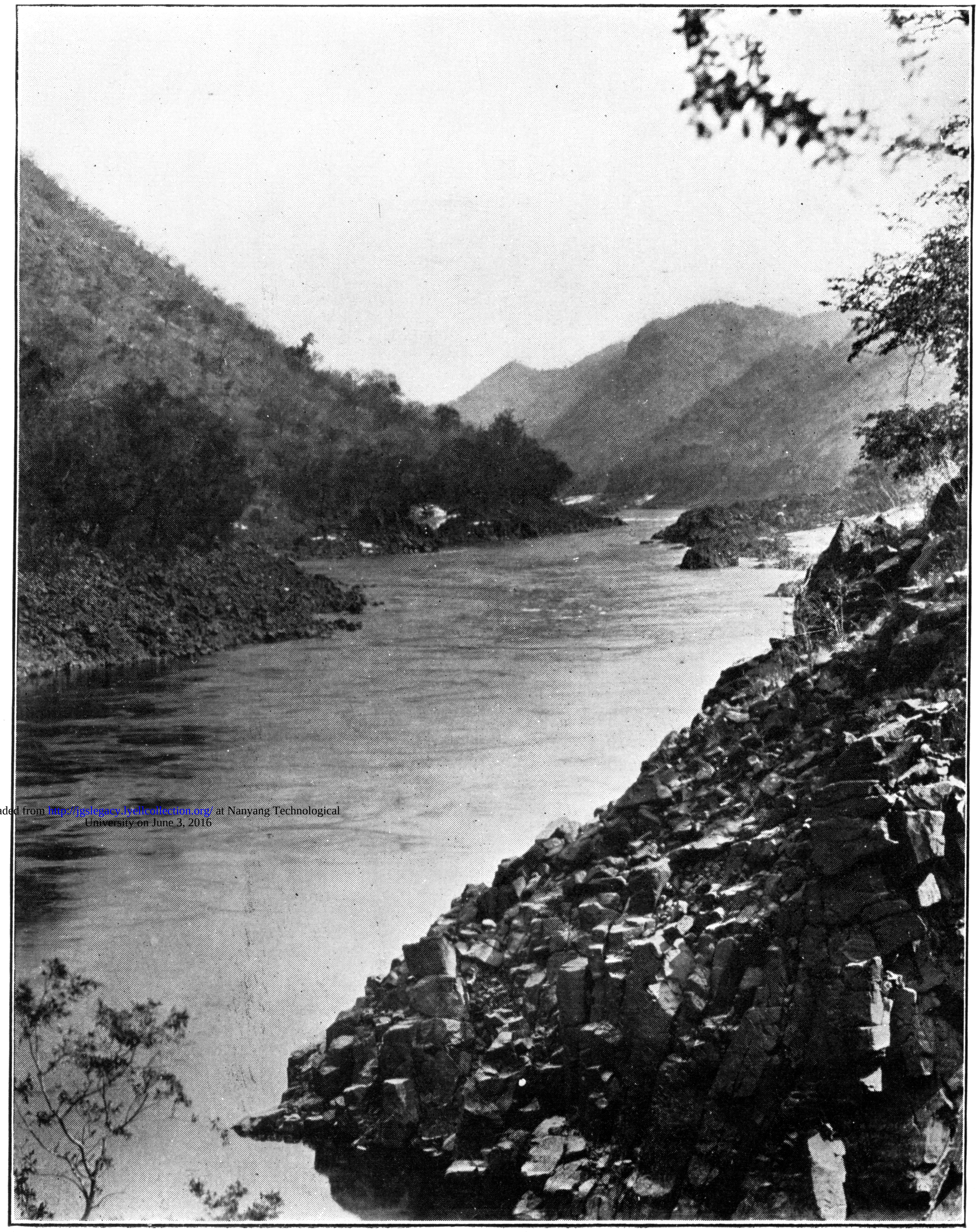


Photo. by F. W. Sykes.

The Batoka Gorge at the confluence of the Karamba River (*see Fig.* 6) **about 35 miles east of Victoria Falls, looking west, up-stream; depth of gorge, about 750 feet.**

Compare the angle of slope with that in the preceding Plates; and note the close-set joints of the basalt in the foreground.

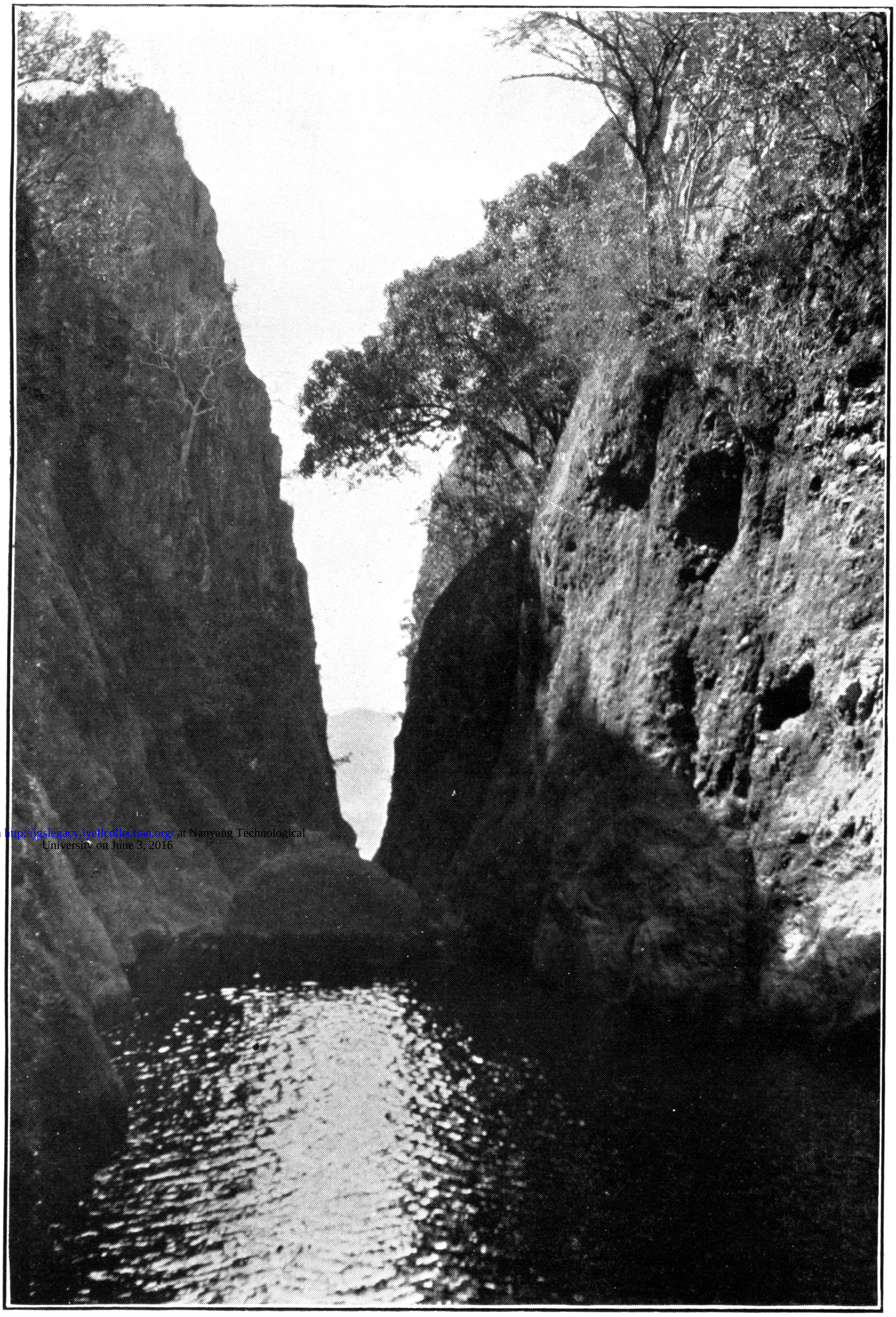


Photo. by F. W. Sykes.

Kalonga's Cleft, nearly 300 feet deep, at the head of the gorge of the Karamba River, a tributary of the Zambezi (*see Figs.* 6, 7, *and* 8).

The stream enters the Cleft on the right, after dropping from the plateau into a shorter chasm branching off from this at right angles.

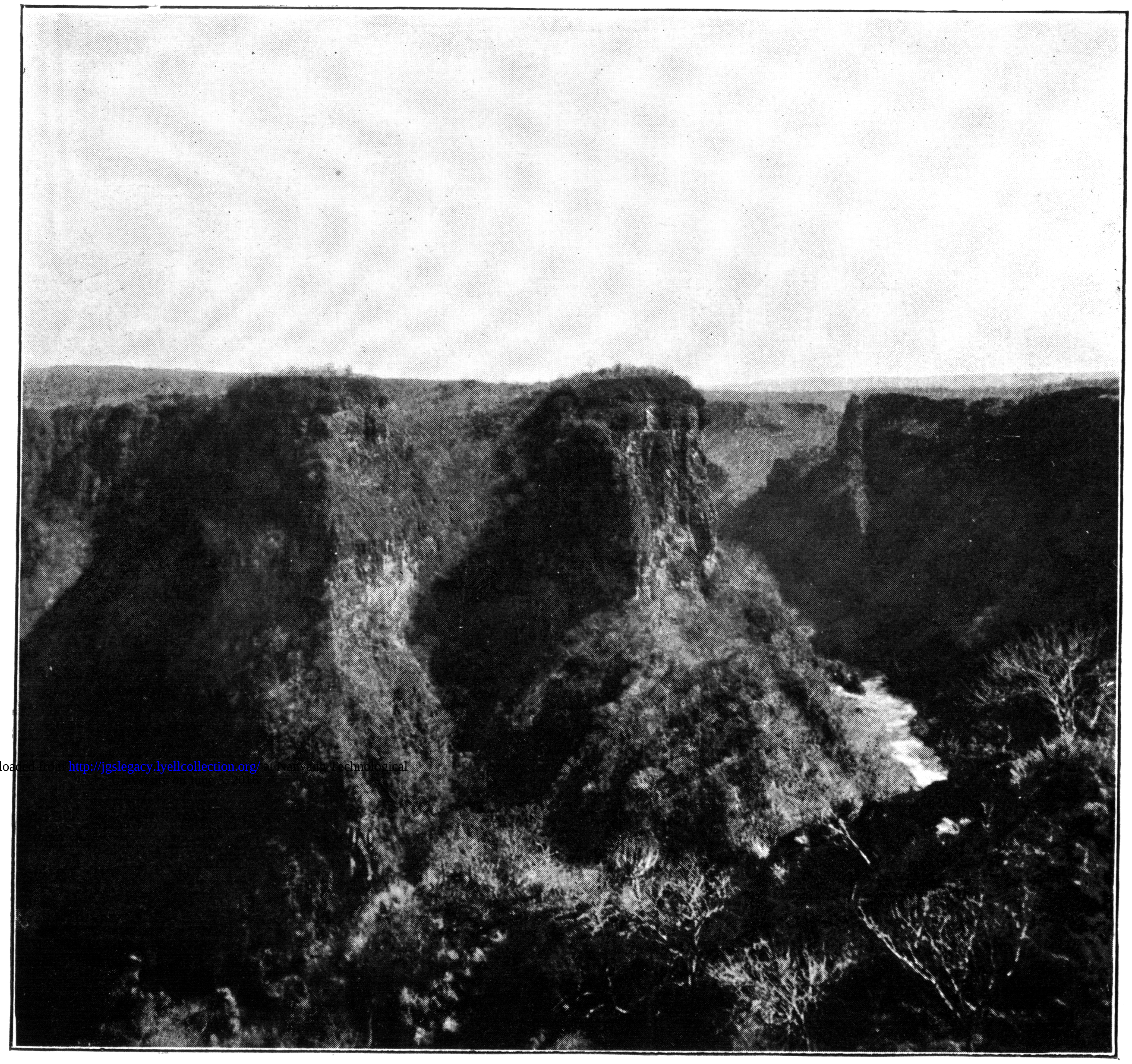
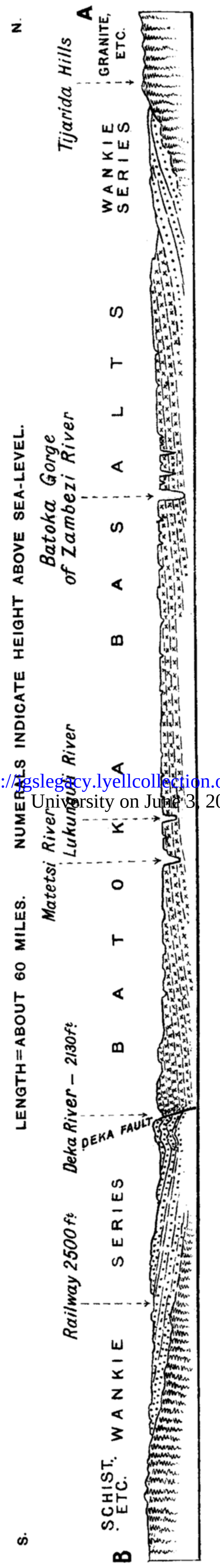


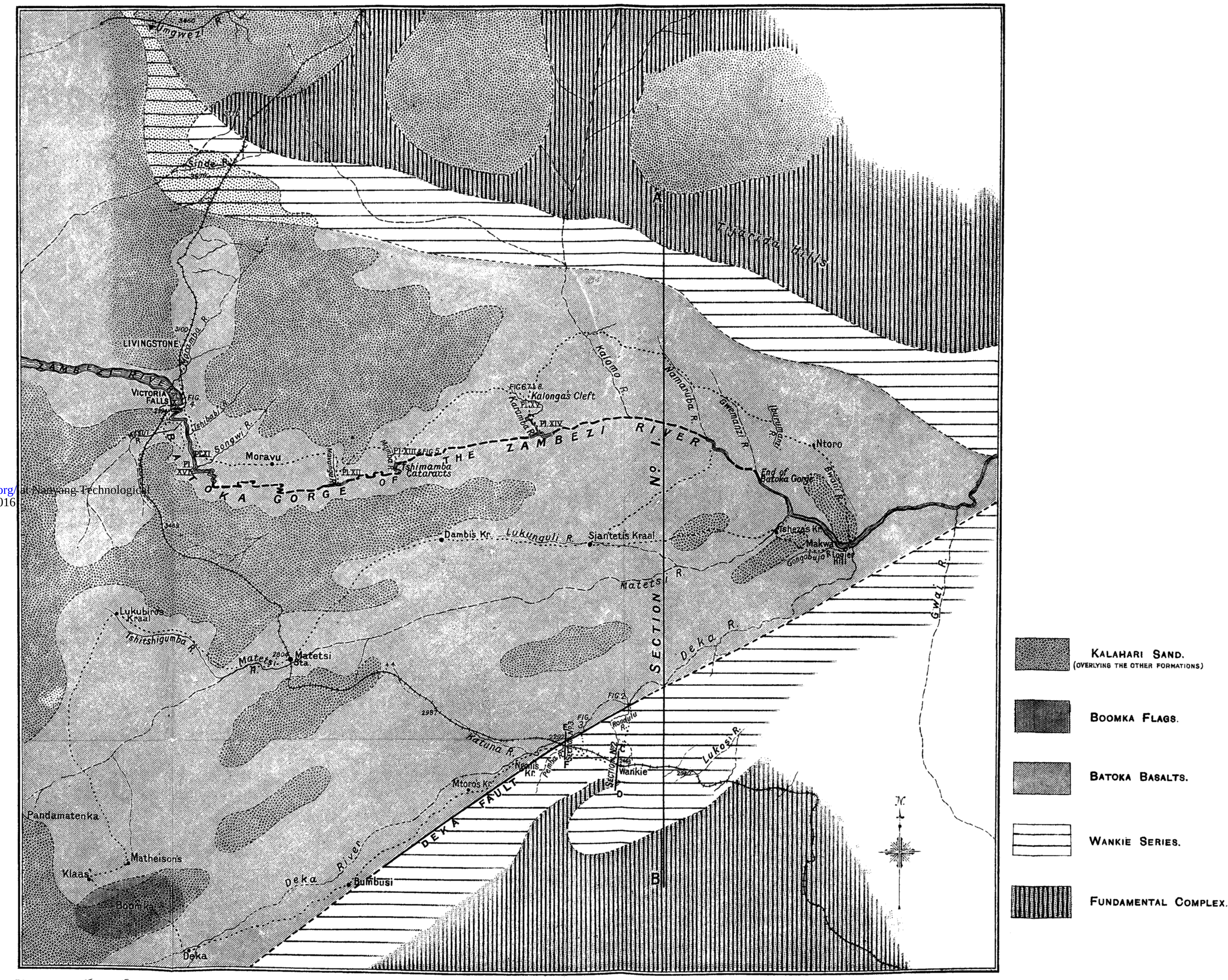
Photo. by the late Col. F. W. Rhodes.

The Batoka Gorge at the sharp bends just below the confluence of the Songwi River; showing promontories ('knife-edges') partly destroyed by weathering, and a lower pinnacle (in the middle of the picture) cut off by an ancient channel of the river.

GEOLOGICAL SKETCH-MAP OF THE COUNTRY AROUND THE BATOKA GORGE OF THE ZAMBEZI.

No. 1.—DIAGRAMMATIC SECTION ACROSS THE ZAMBEZI BASIN, FROM THE WANKIE DISTRICT TO THE BATOKA UPLAND. ALONG THE LINE B---A ON THE MAP. LENGTH = ABOUT 60 MILES. NUMERALS INDICATE HEIGHT ABOVE SEA-LEVEL.



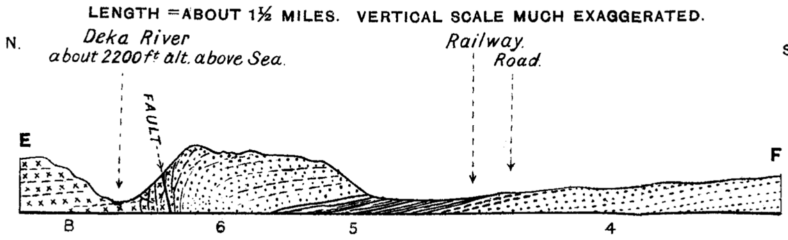


Rivers ——— Railway, +++++++ Routes traversed .... Heights above Sea-Level, in feet ...... 2987 SCALE 1 INCH = 10 MILES.

No. 3.—DIAGRAMMATIC SECTION IN THE WANKIE SERIES ADJACENT TO THE DEKA FAULT,

4½ MILES WEST OF WANKIE STATION (E---F ON MAP).

LENGTH = ABOUT 1½ MILES. VERTICAL SCALE MUCH EXAGGERATED.

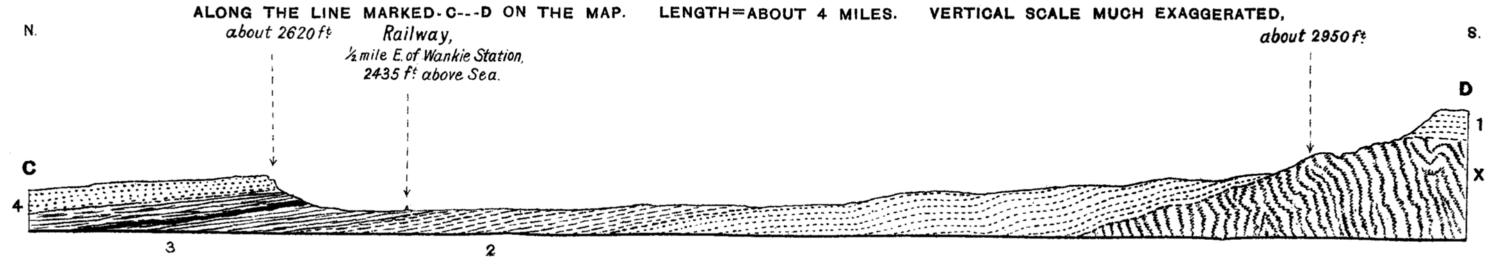


B. Batoka Basalts (see description of fig. 3).
6. Coarse red pebbly Sandstone, converted to quartzite along the Fault.
5. Blue-black Shales, with a pale-brown band, 2 feet thick, near the base, containing plant-fragments (*Vertebraria*, etc.).
4. Flaggy, pale-grey and reddish Sandstone, strongly current-bedded, with a thin band of hard (? silicified) claystone and tabular lenticles of concretionary iron-rock at the top.

The general dip is northerly at 3°–5°.

No. 2.—DIAGRAMMATIC SECTION ACROSS THE LOWER PORTION OF THE WANKIE SERIES AT WANKIE,

ALONG THE LINE MARKED C---D ON THE MAP. LENGTH = ABOUT 4 MILES. VERTICAL SCALE MUCH EXAGGERATED.



4. Coarse Sandstone, with small quartz-pebbles.
3. Dark Shales, with Coal-seam and ironstone-nodules. 80—100 feet thick.
2. Dark-blue micaceous Sandy Shales (dipping N. 10° E. at 8°).
1. Coarse grey Sandstone, with ferruginous top, curiously piped and containing blocks of silicified wood. Occasional boulders or large pebbles near the base.
X. Schistose Quartzite, etc. = Fundamental Complex.

Discussion.

The President, in returning the thanks of the Society for the interesting and luminous contribution to our knowledge of African geology and physiography made by the Author of the paper, referred to the earliest information regarding the region which was obtained by Livingstone, and to the prevalent opinion at the time that the striking gorge of the Zambezi is due to a vast rent in the crust of the earth. It was satisfactory to him to find the suggestion confirmed which he then made, nearly half a century ago, that even the ravine of this African river is no exception to the rule that such topographical features are due to river-erosion. The details furnished by the Author from his own personal survey of the ground were of great value, in showing how rock-structures had modified the progress of the erosion and would give rise to future important changes in the course of the river and the excavation of its cañon. The similarity of geological conditions and of the resultant topography between the basalt-plateau and gorge of the Zambezi, and the lava-fields and cañons of the Snake River in Western America, was remarkable. If the Author had succeeded, during his short sojourn in the country, in gleaning such an amount of new and important facts, it was to be expected that a still ampler harvest awaited more prolonged and exhaustive investigation. As a piece of pioneer-work, his paper was an admirable example of how much could be achieved in a short time by a trained eye and an experienced judgment. It would form a memorable feature in the history of African geological exploration, and meantime was heartily appreciated by the Society.

Dr. Hatch said that, during his visit to Rhodesia in 1894, he did not get as far north as the Zambezi River, and therefore he could not speak from any personal knowledge of the district so admirably described by the Author; but he had made some study of the volcanic rocks of other parts of South Africa, and the Author's paper appeared to the speaker to have an important bearing upon these. His description of the Batoka Basalts, especially of the amygdaloidal bands that occur in the upper part of the flows, with their vesicular cavities infilled with agate, green-coated chalcedony, quartz, and zeolites, recalled exactly the character of the Bushveld Amygdaloid, which covers a large area of the Transvaal immediately north of Pretoria, namely, the well-known Springbok Flats. The work of the Transvaal Geological Survey had shown that these lavas overlie sandstones which are considered to be of Karroo age and younger than the Permo-Carboniferous coal-measures of the Transvaal. The Author stated that the Batoka Basalts are younger than the Wankie coal-measures or Matobola Beds, which Mr. Molyneux also considered to be of Permo-Carboniferous age. Again, there was a remarkable resemblance in petrographical habit between the Bushveld Amygdaloid and the lavas of the Volcanic Group of the Drakensberg and the Malutiberg, especially in the occurrence of the long drawn-out vesicles which had originated the name of 'pipe-amygdaloid.' It was interesting to note that the Author also referred to the occurrence of a 'pipe-amygdaloid' in the Batoka Basalts. The Volcanic Group of the Drakensberg was classified by South African geologists, following Dunn, as the uppermost division of the Stormberg Beds, and consequently as younger than the Permo-Carboniferous coal-beds of Cape Colony.

Considering the vast extent of the plateau-basalts of North America and of the Deccan in India, geologists would admit the possibility that in South Africa these great basaltic flows of Rhodesia, the Transvaal, and the Cape Colony may have had a common genetic origin, and were erupted towards the close of the Stormberg Period.

There appear to have been three chief epochs in the geological history of South Africa, when volcanic activity took the form of a vast extrusion of lava. The first followed the close of the Witwatersrand Period, producing the lavas, accompanied by breccias and tuffs, of the Ventersdorp Volcanic System. The second followed the deposition of the Pretoria Beds, producing the acid felsites of the so-called 'red granite'-formation of the Transvaal; while the third took place towards the close of the Karroo Period, producing the basic lavas of the Stormberg, the Springbok Flats, and (as it would appear) the Batoka Basalts.

The Author expressed, in reply, his thanks for the reception accorded to his paper.