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ORIGINAL ARTICLES.

I.—NOTES ON THE GEOLOGICAL HISTORY OF THE VICTORIA FALLS.¹

By G. W. LAMPLUGH, F.R.S.

IT is difficult for anyone standing on the brink of the Chasm, after having seen the placid flow of the Zambesi above the Falls, to believe that the fissure into which the river is so suddenly precipitated has been formed gradually by the action of the river itself, and not by some great convulsion during which the very crust of the earth was rent. The narrowness of the abyss, the strange zigzags along which the tumultuous waters rush after their first great plunge, the mystery which has long surrounded the further course of the river after it swings away out of sight among its forbidding precipices, and the knowledge that the rocks across which it plunges are of volcanic origin, are all factors that have aided the illusion. Hence it is not surprising to find that the explanation given by David Livingstone half a century ago, that the majestic Zambesi has here been intercepted by a rent due to some earth movement in the solid rocks, has been adopted without question in all the later descriptions of this wonderful spectacle.

Meanwhile, however, geologists have been able to prove that in other parts of the world, canyons of even more impressive dimensions than this canyon of the Zambesi have been carved out by the erosive agency of water acting through very long periods of time; and this view has very recently been convincingly advanced by Mr. A. J. C. Molyneux, F.G.S., F.R.G.S., of Bulawayo, to explain the Victoria Falls and Canyon. In Mr. Molyneux's able paper ("The Physical History of the Victoria Falls," *Geographical Journal* for January, 1905), it is shown that the prevalent idea of a sudden rent in the

¹ A paper read before the British Association for the Advancement of Science, meeting in South Africa, at Johannesburg, August 30th, 1905. Reprinted from "The Official Guide to the Victoria Falls," compiled by F. W. Sykes, Conservator. (Bulawayo, 1905.)

earth's crust is inadequate to explain the phenomena observed around the Falls, while all the features are compatible with the view that the river has slowly sunk its channel into the hard rocks which have barred its passage seaward; and that the great waterfall has been developed as an incident in its long-continued work of erosion. A recent geological investigation of the country on both sides of the Zambesi between the Falls and the Deka River, about 70 miles eastward, has yielded much evidence confirmatory of Mr. Molyneux's conclusions, of which we can here give only the barest outlines.

It will be remembered that the Upper Zambesi flows, with a comparatively gentle course, over a portion of the elevated plateau of South-Central Africa, and that when it reaches the vicinity of the Falls its bed is still about 3,000 feet above sea-level. But at this point it breaks sharply away from its earlier habit, to begin a rapid descent across the mountainous eastern margin of the continent, and in doing so its capacity for erosive work is, of course, enormously increased. From the Falls onward until it reaches the coastal plain about 260 miles from the sea, the river has sunk its channel deeply through every obstacle, carving out narrow defiles like the Lupata Gorge, the Khebrabasa Gorge, the Kariba Gorge, and the canyon below the Falls, to which the name Batoka Gorge may be applied, wherever the rocks in its course are hard and resistant; and excavating a wider and less precipitous valley where it crosses the outcrop of strata that perish more readily.

The whole of the country for many miles on both sides of the Zambesi between the mouth of the Deka and Victoria Falls, and also for a considerable distance farther westward is occupied by hard basaltic rocks, the 'Batoka Basalts' of Molyneux, which have been poured out over the land as flows of liquid lava at some remote period of which the exact position in the geological time-scale has not yet been definitely ascertained. Scarcely was one of these lava-flows consolidated before it was overwhelmed by another, and still another, until the whole area surrounding this part of the course of the present Zambesi was covered to a depth of many hundreds, in places perhaps many thousands, of feet of volcanic material. The slowly-cooled central portions of these separate lava-flows have consolidated into the dense dark-blue rocks weathering with a brown crust that are so well seen in the precipices of the existing Falls, while their more quickly cooled slaggy upper portions, once porous with empty steam-cavities, have formed the deep red or purple 'amygdaloidal' bands that are rendered conspicuous to the eye, and very interesting to the mineralogist, by the varied minerals deposited by percolating waters. By this agency the cavities have been gradually filled up with the beautiful agates, green-coated chalcedony, quartz-crystals, and zeolites that may now be picked up so abundantly at the surface along the outcrop of these amygdaloidal rocks. And it may here be mentioned as of some interest to the archæologist that the chalcedonic pebbles have been frequently chipped to form rude cutting tools by some ancient race inhabiting the Zambesi valley, these relics of ancient man being especially numerous on the

patches of old river-gravel that are exposed around the low rocky bosses of the low ground in the vicinity of the northern bank of the river, in the angle between the Zambesi and its tributary, the Maramba.

The Batoka lavas in consolidating to their present state have developed a system of joints or shrinkage cracks which, together with rarer but more strongly marked lines of fracture or 'faulting,' have constituted planes of weakness that have materially facilitated the erosive work of the river, just as they would be found to facilitate the operations of artificial quarrying. Both 'master-joints' and 'faults' for the most part run approximately west and east, and are mainly accountable for the apparent vagaries in the course of the river, which in its innumerable windings through the Batoka Gorge tends constantly to take this direction, but crosses by rectangular or oblique traverses from one group of joints to another whenever the opportunity occurs. The Chasm into which the river plunges at the Falls is due to one of these lines of weakness in the rock, probably a fault-plane, where a vertical belt of comparatively soft vein-stuff, including a seam of crystalline calcite, breaks the continuity of the harder basalt. This vein may be examined by an adventurous climber in the little kloof at the eastern extremity of the Chasm; and its presence is indicated also at the inaccessible western extremity by the existence of a small cave, hollowed out by the surges from the Leaping Water.

At the remote period when the river first began to break across the eastern edge of the upland plains of basalt, the more powerful action of its troubled stream in this quarter, as compared with its tranquil course over the surface of the plains, must soon have brought about the development of rapids, cascades, and finally of a great waterfall separating the two portions according to their very different working capacity. The gradual recession of this waterfall by the undermining of its base and the breaking away of its edges, steadily progressing throughout the long period that these conditions have ruled in the Zambesi basin, are the main factors required for the interpretation of all the apparently complex phenomena associated with the present Victoria Falls and the Batoka Gorge; indeed, it is only thus that they become explicable. Among the many separate chains of evidence that strengthen this conclusion none is more striking than the different manner in which the tributary streams make their confluence with the main river above and below the Falls. Above the Falls the tributaries have had time to grade down their beds almost to the level of the Zambesi itself, so that (as, for example, in the Maramba confluence) we find a back-water from the main stream running for some distance into the mouth of its feeder, which here occupies a scarcely perceptible valley. Below the Falls, on the other hand, every tributary seems to emulate on a miniature scale the example of its mighty ruler and has sunk a deep gulch into the edge of the plateau roughly proportionate in length to the distance of its confluence below the Falls; and into this gulch it tumbles headlong from its older open valley on the

plateau, each little waterfall illustrating in its own small way many of the characteristics so magnificently displayed by its gigantic forerunner and originator. Another equally impressive line of evidence is afforded by the gradual falling away of the angle of slope in the Batoka Gorge itself as it is followed down from its present termination at the Falls. Here, as everyone may see, its walls, carved out as it were but yesterday, are approximately perpendicular, but even here they are already beginning to crumble down under the influence of the weather; at the distance of a few miles below the Falls, where they have been longer exposed to this influence, the average inclination falls to not more than 60° , and still farther eastward to 45° or less; and finally, in the lower parts of the Gorge, instead of the familiar wall-like lines of crags, we find that the river is bounded only by rugged hillsides whose average slope from crest to base is often not more than 30° .

The processes that have operated during the immeasurable past must continue also into the immeasurable future, so long as the Zambesi continues to thunder seaward over the edge of its upland basin. Imperceptible though the rate may be when measured by the short span of our human life, yet surely is the river gnawing its path backward into the heart of the continent; and the geologist, noting how already at the rapids above the Leaping Water the trench is deepening that draws down more and more of the flood at the expense of the shallower portions of the Falls, may look forward with confidence to a future when either here or along some still lower trench at present undeveloped the main trough of the river will become fixed. The present lip of the Falls will then be left dry to form another 'Knife-edge' around which the torrent will swirl in turmoil as it passes away from its new place of descent at some line of crags at present submerged under the placid waters of the upper river.

II.—THE MOUNT TORLESSE ANNELID.

By F. A. BATHER, M.A., D.Sc., F.G.S., British Museum (Natural History).

AMONG the geological specimens obtained by Mr. H. T. Ferrar, while the "Discovery" was visiting New Zealand, are seven rock-fragments containing tubular shells, and an eighth with some obscure markings. They are labelled as follows:—

No. 17.	Annelid tubes?	Mt. Torlesse.	H. T. F.	Dec. 8th, 1901.
No. 18.	"	"	"	"
No. 19.	"	"	"	"
No. 20.	Scaly markings.	"	"	"
No. 21.	Annelid.	Mueller Glacier.	Presd. Capt. Hutton,	F.R.S.
No. 22.	Annelid tubes?	Kowai River.	"	"
No. 23.	"	Wilberforce River.	"	"
No. 24.	"	Gorge of the Ashley.	"	"

Specimen No. 20 may at once be dismissed with the remark that it is merely an irregular imprint, showing no structure; even the "scaly markings" of the label appear due to incipient cleavage of the