44. *The Rise and Fall of Lake Tanganyika.* By Dr. ROBERT SIEGER. (Communicated by the President. Read June 21st, 1893.)

PERHAPS I may be permitted to offer a few remarks concerning Mr. A. Carson's interesting paper, published in vol. xlviii. of this Journal, p. 401. That author regards the rise and fall of Lake Tanganyika as a purely local phenomenon, due to alterations of its outlet, the Lukuga, which was blocked up a long time ago, but reopened between the years 1874 and 1879; and he discusses in a very careful manner the geological conditions necessary for the damming-up and the outburst of the lake. Another opinion, now very common among German geographers and maintained by myself, treats these great oscillations of the level of Lake Tanganyika as analogous to the variations reported of other African lakes and resulting simply from climatic changes. I believe that there is no absolute contradiction between these two opinions, and that it is possible to arrive at a satisfactory explanation of the phenomena in question by combining the influences of climate with those of mechanical agencies.

The meteorological explanation of lake- and river-variations has been given already in a very important paper by Prof. H. Fritz, of Zürich, published in 'Petermann's Mittheilungen,' vol. xxvi. (1880), pp. 245 *et seqq.* I regret that I was not aware of the existence of that memoir at the time of my own first essays on the variations of level in African and other lakes. Prof. Fritz held it impossible that the amount of rainfall should vary and the temperature oscillate in the same manner over the whole surface of a continent or of the globe, but he held that there is a sort of compensation between the different areas. Subsequently, Prof. Brückner, now of Bern (chiefly in his valuable work on 'Klima-Schwankungen,' Vienna, 1890), and myself, succeeded in demonstrating a surprising coincidence of the epochs of oscillation in a great many lakes, rivers, and glaciers. This can hardly be explained otherwise than by *general* oscillations of climate, indicated by meteorological observations, and proved beyond doubt by Prof. Brückner's laborious researches.

In the course of my study of the secular oscillations of lakes, I published two short papers on the lakes of the Dark Continent, copies of which I have now sent to the Geological Society's library.¹

I have found that the culminating points of cold-and-moist periods stated by Prof. Brückner to approximately coincide with the years 1850 and 1880, and even the warm-and-dry period culminating in 1860, also coincide with the dates of the maxima and minima of level of the Central African lakes. The reader's attention is directed in this connexion to the great floods on Lake Tsad at the

¹ Jahresbericht des Vereines der Geographen an der Universität Wien vol. xiii. (1887), and 'Globus,' vol. lxii. no. 21, Brunswick, 1892.

time of Barth and Vogel's, and again of Rohlfs and Nachtigal's visit; to the variations of humidity in Southern Africa mentioned by Prof. Fritz; to the high level of Lake Nyassa about 1875, and the subsidence which followed; to the sinking of the Victoria Nyanza, inferred from Capt. Speke's narrative; to the rise of the same lake reported by Mr. Wilson in 1877 and 1878; and to the considerable decrease of all the lakes of the Upper Nile region observed from about 1880 until 1892. Moreover, I would remind the Society of the observations on the Lower Nile, dealt with by Profs. Fritz and Brückner in their respective papers. Finally, I would especially refer to so careful an observer as Dr. Franz Stuhlmann, who explains the observations and traditions concerning changes of level in the Victoria Nyanza by a "secular variation of rainfall."

The time when Lake Tanganyika was at its highest, and the Lukuga reopened its channel, being nearly coincident with the maximum level in Lakes Tsad, Nyassa, Albert and Victoria Nyanza, etc., and also with the high waters so frequent between 1870 and 1880 in European lakes and rivers, even in the Baltic Sea, I have had no hesitation in regarding the oscillations of Lake Tanganyika as also resulting chiefly from the climatic changes enumerated by Prof. Brückner.

This rise and fall of the lakes, due to meteorological influences, is, I believe, the main cause of the changes in the Lukuga; these, however, in their turn must influence and modify the amplitude and the particular mode of oscillation of level.

If the climatic conditions and the lake-level be constant or 'normal,' I am unable to account for agencies sufficient for damming up the whole efflux of the lake. The stopping-up has, indeed, been referred to a periodic upheaval of the land, to the action of earthquakes and volcanic forces (as visible in Lakes Rudolf and Stefanie), to the famous grass-bars or *sindi* and the formation of a bar at the river-entrance. These points, except the last two, being discussed in my papers, and Mr. Carson insisting especially on the blocking-up of the river by vegetation and its silting-up by sedimentation, I do not propose to speak here of the movements of the earth's crust, of Mr. Stanley's 'cataclysmal' theories, of Capt. Storms's hypothesis attributing the rise of Lake Tanganyika to an outburst of Lake Likwa, etc., but only of the two points referred to. Mr. Carson has himself seen the effects of the *sindi* on the River Shiré, and he regards them as inadequate to produce, without the help of other agencies, a rise of the lake to a height of 30 feet. I would add that at the very time when these masses of floating vegetation blocked the Shiré, Lake Nyassa continued to sink. Even the 'setts' of the Upper Nile (in connexion with which the reader will doubtless remember the disaster that overtook Gessi Pasha and his companions) had not force enough to dam up the Lakes. The observations show that the maxima of level on the Victoria and Albert Nyanzas were nearly simultaneous with the maxima on the Lower Nile.¹ Now, if the lake was rising, the water, by its pressure, would

¹ See also Lugard, Proc. Roy. Geogr. Soc. 1892, p. 827.

have very soon cleared the entrance of the Lukuga of those bars, or at least flowed beside and over the masses of vegetation which blocked its course. If, on the contrary, the lake was sinking, the diminishing current is more likely to have been too feeble to remove such a hindrance. Therefore the accumulation of *sindi* may have been a consequence of the subsidence of the lake, which prevented any considerable action being accomplished by the dwindling Lukuga.

Perhaps also the formation of a bar or bank at the entrance of the river, described by the explorers Cameron and Thomson, is a mere consequence of sinking water-level. The old embankment of 20 feet in height, described and sketched by Mr. Carson, was no doubt formed while the lake was high. But we must suppose that here there were not the same conditions for sedimentation as at the bar of the Lukuga. The sediments in question are deposited on the point where a flat valley or former bay debouches into the lake; they could be carried there by rain and small streams, and accumulated by wind, wave-action, etc., the more easily if the lake was rising, because there was no current strong enough to prevent their deposition. But how could the outlet of the lake be closed so long by such a bar, considering that it is undiminished in breadth and in volume and swiftness of current? In the struggle between sedimentation and river-erosion by a stream enlarging and deepening its bed, victory is clearly on the side of the latter. If the level of the lake rises, its outlet must all the more easily overcome the obstacle existing from former times. The formation of a new bar, however, is probable only in so far as the river-current becomes more and more enfeebled: that is, if the level of the lake be sinking. Only in this case the annual variation of rainfall and water-level may produce the effects described by Mr. Carson as a continuous struggle between the choked bed and the flood, while the filling-up of the separated mud-pool, the accumulation of *sindi*, the growth of aquatic vegetation, etc., accelerate the closure of the lake's outlet.

But it is at least an equally probable hypothesis that the formation of the bar commenced while the lake had no outlet and a comparatively small river, also called the Lukuga, discharged into the lake at the same locality (*cf.* Stanley, Storms, and others). In this case the deposition of sediments might take place just in the same way as in the locality mentioned above, and it might go on until the rising lake regained at least a temporary outlet. The small channel mentioned by Commander Cameron may be considered as the work of the current in its initial period, eroding perhaps only during the wet season. It would be very interesting to study the present condition of the bar, its increase or decrease, and its relation to the rise or fall of the lake. At all events, I believe that the dwindling of the lake, due to climatic oscillation, is the real cause of all the alterations of its outlet.

The above hypothesis agrees with the views of Herr Carl Ochsenius,¹ of Dr. Paul Reichard,² and others, who likewise regard

¹ *Zeitschr. d. Deutsch. geol. Gesellsch.* vol. xliv. (1892) p. 89.

² *Deutsch. Ostafrika*, 1892, pp. 387 *et seqq.*

the oscillations of the lake as the effect of climatic variations and of the resulting changes in the current, the depth, and the volume of the Lukuga. As the climatic causes act periodically, it is probable that the blocking-up and reopening of the Lukuga are similarly periodical (although the periodicity is not that of 15 to 20 years, advocated by Ochsénus, whose suggestion hardly accords with the observed facts).

It will be a highly interesting study to watch the future fate of the Lukuga, its increase or decrease in volume, and the action of erosion on the river-bed. It would, moreover, be a work of really considerable importance to connect a system of regular observations of water-marks or level-gauges with meteorological observations, not only along the shores of Lake Tanganyika, but also along those of other African lakes, and so to eliminate the influences of seismic and other tectonic agencies, and to determine with some certainty the periodicity of meteorological epochs. Perhaps the period of subsiding level is already nearing its end in the African lakes—and in that case we may expect a simultaneous rise of Tanganyika and the Lukuga, which would furnish a striking proof of the correctness of my opinion that the change of level in Lake Tanganyika is rather a meteorological than a geological phenomenon.

The subsidence of Lake Tanganyika was still going on in September 1892, as reported by Dr. Baumann.¹ A recent decrease of its tributaries has been observed by Mr. Shaw during a residence of ten years at Urambo, but is regarded by Dr. Baumann as a mere consequence of the sinking of the lake itself, because there are no proofs of any remarkable diminution of rainfall in Urambo. Capt. Lugard² reports that the year 1891–92 was a wet one on the shores of the Victoria Nyanza, and the lake-level had risen 6 feet above the normal. Dr. Merensky³ expresses some doubts concerning the diminution of Lake Nyassa reported by so many British travellers. These reports point perhaps to the first traces of a rise of level beginning in the African lakes, and so it appears the more highly desirable to continue regularly and patiently all such observations as may serve to elucidate the phenomena in question.

¹ Peterm. Mittheil. vol. xxxix. (1893) pp. 47 *et seqq.*

² Proc. Roy. Geogr. Soc. 1892, p. 827.

³ Peterm. Mittheil. vol. xxxviii. (1892) p. 250.