The Longitudinal Section of the Nile

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of stone and gravel which rise on either side of the Su-lai-ho depression, suggests a likely explanation.

The wall shows everywhere a uniform thickness of 8 feet, and still rises in places to over 10 feet. But that its builders knew how to make greater efforts where needed in spite of all difficulties about labour, materials, etc., is proved by the watch-towers, which are ordinarily built of sun-dried bricks of considerable strength, rising in one solid square mass to heights of 30 feet or more. One small fort, marking probably the position of the gate station of Yü-mên, long vainly sought for by Chinese antiquaries, at a period when its original position at the westernmost extension of the wall had already been abandoned, about the commencement of our era, showed high and solid walls of stamped clay fully 15 feet thick. Still more imposing is a solid block of halls nearly 500 feet long and with walls of 6 feet thickness still rising to 25 feet or so, which at first puzzled me greatly by its palace like look and dimensions, until finds of dated records of the first century B.C. near by proved that it had been constructed as a great magazine for the troops garrisoning the line or passing along it (Fig. 11).

(To be continued.)

THE LONGITUDINAL SECTION OF THE NILE.*

By Captain H. G. LYONS, F.R.S., F.R.G.S.

THE reopening of the Sudan after the capture of Omdurman and the defeat of the Dervish army in 1899 enabled the detailed investigation of the Upper Nile and its tributaries to be commenced, and it has been diligently prosecuted for the last eight or nine years. Our knowledge of the geography of the Nile basin has been greatly increased thereby, and the regimen of the main stream and of each of its tributaries has now been elucidated, although there are many points of detail which will repay further study.

The yearly increasing demands of the cultivator in the Nile valley and the Delta have led to the preparation of several projects for increasing the available water-supply during the early summer months, when the cotton crop requires to be regularly watered. The first step in this direction was the completion of the Delta barrage, 12 miles north of Cairo, which enables the river to be maintained at such a level as will supply the main canals of the Delta; the second was the construction of the dam at Aswan (1898-1902), by which some 80 kilometres (50 miles) of the Nile valley in Lower Nubia were converted into a reservoir from January to June, in which the water of November and December, which is surplus to the needs of the country at that season, is stored to augment

* Map, p. 120.

the inadequate supply of the summer months from May to July. For the efficient distribution of this supply, "barrages" were also built at Assiut in Middle Egypt and in the Delta at Zifta, on the Damietta branch of the Nile. But even this increased supply did not suffice for the reclamation of a large area of land on the northern fringe of the Delta, which is still, to a large extent, salty and water-logged. No improvement in its condition was possible until the water needed for its improvement could be guaranteed with certainty each year. The Abyssinian tributaries of the Nile afford no assistance in this matter, for the rains on that tableland cease in October at the latest, and the levels of the rivers which drain it then fall rapidly. The White Nile, therefore, had to be thoroughly investigated, since it flows directly from the equatorial lakes, which might be expected to furnish the additional supply required. Also, the site where this additional supply of water was to be stored had to be decided upon. Was the dam at Aswan to be raised, with the consequent submersion of an additional portion of Lower Nubia, or was it possible to find another site which should possess equal or greater advantages?

The investigations which have been undertaken to solve these problems have led to the surveying and levelling of the upper reaches of the river, and it is with some of the results which have been obtained that the present paper deals.

The units of measurement have not been the same throughout, since feet have been employed in Uganda and metres in Egypt and the Sudan. In order, therefore, to avoid introducing errors by conversion from one system to another, all altitudes and distances will be given in both the British and metric measures, the one placed first being that in which the observations were originally made, while the equivalent in the other system will follow within brackets.

At the present time, the whole length of the main stream from the Mediterranean sea to Lake Victoria has been levelled except two lengths, one of 32 kilometres (20 miles) between Gondokoro and Rejaf, and the other of 212 kilometres (132 miles) between Dufle and Lake Albert; and, except for a distance of 178 kilometres (106 miles) between Dufle and Rejaf, which was levelled tachometrically in the course of a railway survey by the engineers of the Congo Free State, the whole has been done by spirit-levelling, either in duplicated lines or by repeating the work.

We have now, therefore, a line of reliable levels extending from the Mediterranean to Lake Victoria, a distance of 5600 kilometres (3480 miles), and thence the Uganda Railway Survey has furnished another levelled line to the shore of the Indian ocean at Mombasa, a distance of 584 miles (940 kilometres); and this newly acquired information enables us to discuss a matter of some geographical interest—the longitudinal section of this great river, which, in flowing from the equator

to the Mediterranean sea, passes through such various types of country, from the lake plateau where rainfall is almost continuous throughout the year to the rainless, arid region of Northern Africa.

I will first describe the material from which this longitudinal section has been compiled, and will then indicate briefly the points of interest which it has brought to light.

The altitude of Lake Victoria was determined by the staff of the Uganda Railway to be 3720 feet (1133·86 metres) above the sea-level at Mombasa, and this value was confirmed by the triangulation of the Anglo-German Boundary Commission, in so far as the mean lake-level thereby determined was 3729 feet (1136·60 metres) above sea-level; but unfortunately this verification depends only upon Genda-Genda, which is 1710 feet above sea-level at Zanzibar according to reciprocal barometric observations,* a result which has not yet been verified by spirit-levelling.

In 1906 the Survey Department of Uganda carried a single line of levels from Entebbe on Lake Victoria to Butiaba on the eastern shore of Lake Albert, and determined the lake surface to be 1692 feet (516 metres) below that of Lake Victoria at Entebbe.

During the summer of 1907 a party of the Egyptian Survey Department, under Mr. L. B. Weldon, levelled several lines between Lake Victoria and the head of the Bahr el Jebel in order to extend our knowledge of the upper reaches of the river, and it was intended to carry on this work northwards to Gondokoro, but this was not done during that season. The Sudan Irrigation Service are now completing this portion.

The lines levelled were—

Entebbe to Masindi;

Masindi to Butiaba, on Lake Albert;

Masindi to Hoima; and

Masindi to Fajao, at the foot of the Murchison falls.

Sixty-nine bench marks were fixed, of which twenty were metal bolts set in masonry or concrete.

The zero of the lake-gauge at Entebbe was taken as the starting-point; and its altitude above the mean sea-level of the Indian ocean at Mombasa was accepted as being 1132·469 metres (3667·5 feet). Each line was levelled twice; and if the difference was more than $2\sqrt{L}$ centimetres, where L is the length of the line in kilometres, the line was re-levelled; 0·4 of the permissible discrepancy was classed as "good" work, and 0·7 as "fair," but the discrepancy of a 10-kilometre section only fell once within this last category, all the rest being less than 0·4 of the limit, so that the accuracy of the work was quite satisfactory.

By means of these four lines of levelling the altitudes of the following

* Behrens, *Geogr. Journ.*, March, 1907, p. 307.

places, with reference to the zero of the lake-gauge at Entebbe on Lake Victoria, were determined : * —

Above mean sea-level.		
Metres.	Feet.	
1132·469	3657·5	Zero of lake-gauge, Entebbe, assumed correct.
1031·873	3385·5	Water-level Kafu river, July 15, 1907.
1147·595	3765·1	No. XI. bolt in concrete pillar, Masindi.
618·848	2029·8	Water-level of Albert lake at Butiaba, September 5, 1907.
617·350	2024·9	Zero of Butiaba lake-gauge.
1144·209	3754·0	No. XV. bolt in concrete pillar at Hoima.
625·767	2052·5	B.M. No. XVI. at Fajao.
622·000	2043·5	Water-level at foot of Murchison falls, September 5, 1907.
659·500	2163·2	Water-level above Murchison falls, September 5, 1907.
617·794	2026·4	Zero of river-gauge on Victoria Nile at Fajao.

North of Lake Albert there is a reach of about 432 kilometres (269 miles) between Fajao, or the north end of Lake Albert, and Gondokoro, which has not yet been levelled throughout, although it is now being done; 178 kilometres (110 miles) of it have, as already mentioned, been tachemetrically surveyed by the engineers of the Congo Free State between Rejaf and Dufile, that is, over the whole portion in which there is a rapid fall of the ground, so that when we interpolate their results between the levels carried from Lake Victoria and those from the Mediterranean sea, the total uncertainty is very small.

The levelling along the Nile in Egypt and the Sudan extends from the shore of the Mediterranean sea to Gondokoro, on the northern frontier of Uganda, and has been carried out in three sections; the first from the sea to Wady Halfa, the second from Wady Halfa to Khartum, and the third from Khartum to Gondokoro. The Egyptian portion has been levelled more than once, but the values now employed are those of the Irrigation Service, which gives the mean low-stage level of the river at Wady Halfa as 118·0 metres (387·2 feet) above sea-level. From this point parties of the Egyptian Survey Department carried a duplicate line of levels to Khartum during the winters of 1905–6 and 1906–7; the results of each day's work were checked, and if the difference exceeded that which was laid down as mentioned above the day's work was re-levelled. The results are reliable, and give 364·9 metres (1197 feet) as the altitude of the *zero* of the present river-gauge at Khartum above Mediterranean mean sea-level, depending on the zero of the Wadi Halfa river-gauge being 116·8 metres (383·2 feet) above it according to the levelling of the Irrigation Service.

This work was done in order to ascertain whether there was any reach of the Nile between Khartum and the First Cataract which provided a suitable site for a reservoir in which the additional water required for Egypt might be stored, and two reaches which seemed the

* For a complete list of the bench-marks, see 'Report of the Survey Department of Egypt for 1907' (Cairo: 1908), p. 57.

most suitable were also contoured throughout at 2-metre intervals, so in these portions there was an additional control of the original work, since the contouring was executed in the second season.

South of Khartum, the Sudan Irrigation Service has levelled up the Blue Nile to Fazogli, up the White Nile to Lake No, and from the mouth of the Sobat river to Bor, Mongalla and Gondokoro, with the result that the low-stage level of the Bahr el Jebel at the last-named place, 4809 kilometres (2993 miles) from the sea, is found to be only 446·2 metres (1464·0 feet) above the mean sea-level of the Mediterranean sea, corresponding to an average slope of 1 in 10·800, or nearly 6 inches per mile, so that from this point to the Mediterranean sea, there is now a continuous line of spirit-levelling, and we can determine with a fair accuracy the amount of uncertainty in the accepted levels of points between Gondokoro and Lake Albert.

The low-stage level at Mongalla, 41 kilometres (25 miles) downstream of Gondokoro, is 435·7 metres (1429·5 feet) above Mediterranean sea-level, while at Gondokoro it is 446·2 metres (1464·0 feet), so that the water-slope here is about 1 in 4000, and becomes steeper above Gondokoro as the rapids are approached. We may, therefore, assume it to be about 1 in 3000 from Gondokoro to Rejaf, a distance of 32 kilometres (20 miles). Thus the low-stage level there will be very nearly 457 metres above the Mediterranean sea-level.

The tacheometric railway survey between Rejaf and Dufle makes the difference of level between the bank-level at these places 138 metres (452·8 feet), so if we assume that the banks at each place are of equal height, and since the low-water level at Rejaf is 457 metres (1499·4 feet) above sea-level, as has just been deduced from the reliable altitude of Gondokoro, the low-stage level of the river at Dufle will be about 595 metres (1952·2 feet) above sea-level.

The level of Lake Albert, referred to that of Lake Victoria, has been found to be 618 metres (2027·7 feet) above the mean sea-level at Mombasa, so that if no error of importance exists in these two chains of levelling, and nearly all of it has been duplicated, the river falls 618 to 595 = 23 metres (75·5 feet) in the 212 kilometres between Lake Albert and Dufle. This corresponds to an average slope of 1 in 9200, or about 7 inches a mile. This part of the river is described as being rather shallow, flowing with a low velocity, and opening out at times into lagoon-like expanses as much as 3 miles in breadth; the slope must therefore be slight, but probably does not fall below 1 in 20,000. The closing error, therefore, of these two lines of levelling carried up respectively from the Indian ocean and the Mediterranean sea does not seem to exceed about 10 metres, or 33 feet, and may well be less.

While the paramount importance of finding a means by which the supply of water from Lake Albert in the spring months might be

utilized to increase the normal low-stage supply of the Nile in Egypt has led to the surveying and levelling of the course of the main stream, we have still to be content with aneroid and hypsometric determinations when we commence to study the various tributaries, and for many of these the result alone, and not the original observations, are accessible to us. Their economic importance is so much less that we shall probably wait for many years before accurately levelled sections of them are available, and must therefore confine our attention to the main stream.

Looking at the longitudinal section of the Nile, as it can be drawn to-day from the recent levelling, four portions of it stand out very clearly as differing greatly from one another. The first is the mountain tract exemplified by the equatorial plateau, and the Abyssinian tableland, from which the streams pour down their steep beds in the rainy season and carry vast quantities of material in suspension to be deposited in lakes or on the alluvial plains of the lower reaches; the second is a valley tract, in which erosion is in active progress, and which extends from Khartum to Aswan 1878 kilometres (1167 miles) long, in which the river flows through alternate reaches of low slope where sandstone occurs, and others of rapid current and steep slopes where crystalline rocks form the cataracts of the Nile. The third class or plain tract is extensively developed, and occupies, as might be expected, the valley of Egypt, where the fertile flood-plains, formed by the detritus brought down by the Blue Nile and Atbara from the Abyssinian plateau, have for centuries supported a dense population. But, besides this, there is another long plain tract extending from the foot of the equatorial plateau at Gondokoro to Khartum, a distance of 1723 kilometres (1071 miles), in which the slope is very low and the river banks are often lined with a marsh vegetation. In a part of this region, the lower half of the Bahr el Jebel, occur from time to time those blocks of drift vegetation known as "sadd," which impede navigation and may divert the course of the stream, whose former channels then remain as lagoons in the marshes of the valley.

With the assistance of the reliable data which are now available, and which have just been described, we can investigate certain characteristics of the main stream of the Nile more satisfactorily than has hitherto been possible.

The main stream of the Nile must undoubtedly be considered that which flows from the Victoria Nyanza to the Mediterranean, but the regimen which governs the rise and fall of the river for two-thirds of its length is that of its Abyssinian tributaries: the Sobat, the Blue Nile, and the Atbara; so that here, at the outset, we have a conflict of claims to consideration on the part of the two great catchment areas of the Nile basin, the equatorial plateau, and the Abyssinian tableland.

The first of these regions ranges in altitude from about 1200 to 2000

metres (3600 to 6000 feet), and, from its geographical position, receives a copious rainfall of about 1200 to 1580 millimetres (47 to 62 inches), which reaches its first maximum in March—April—May, and a second one in November—December, though some rain falls in almost every month except in the region to the south-east of Lake Victoria, where the climate is considerably drier.

The second region consists of a tableland rising to from 1800 to 3000 metres (5500 to 9000 feet) above sea-level, which drains almost wholly to the Nile basin, the exceptions being the streams of the southern and eastern margins which flow to the closed basins of the Omo and the Hawash, and the northern streams which flow to the country in the neighbourhood of Suakin. The rainfall here is that which is furnished by the monsoon of eastern Africa, and, if we omit the light rains of March and April, we may say that the whole falls within four months, for actually about 15 per cent. of the year's total falls in June, 30 per cent. in July, 30 per cent. in August, and 15 per cent. in September. It is this rainfall of from 1200 to 1400 millimetres (47 to 56 inches), and probably more in the southern part, falling on the high tableland of Abyssinia within four months that determines the rise and fall of the Nile level throughout the year for two-thirds of its length, that is, from the Sobat junction in lat. $9^{\circ} 29' N.$ to the Mediterranean. The rest of the basin to the northward being practically rainless,* these two regions of precipitation supply the Nile with the means of eroding its bed, or of raising it by deposit, and so modifying its slope in accordance with the usual laws of the development of rivers.

If we disregard the rivers which flow into the Victoria and the Albert Edward lakes, and consider the longitudinal section of the Nile from these two lakes as a starting-point, we find that the river's course in equatorial regions exhibits a succession of steep falls and level reaches. Recent geological investigation of this equatorial plateau has shown that the granite and gneiss of which it consists have been subject to considerable movement in comparatively recent times, and the blocks of country which the lines of fracture bound, have been but little modified as yet by weathering. Herrmann remarks on the sharpness of the fractured edges which have not yet been worn into the rounded outlines of an ancient landscape; drainage lines have not yet completed their development sufficiently to form a very efficient drainage system, and the depressions between the blocks are occupied by lakes, swamps, or by slowly flowing streams in which papyrus, reeds, and other water plants grow luxuriantly. In one area, at least, we have evidence of recent and rapid movements of such blocks, for at Entebbe the ground

* The basin of the Bahr el Jebel and Bahr el Ghazal, where 1000 to 800 millimetres of rain fall annually, may be excepted, but here the marshes prevent any considerable amount of the rainfall from reaching the main stream, and the region is one in which the river system loses rather than gains in its supply.

has sunk relatively to the lake level by about 0·2 metre in 1899, and again by about the same amount in 1901, as shown by the gauge readings at this station when they are compared with those taken at other stations on the lake; * and at the Ripon falls, too, movements have taken place in the early part of 1908. †

It seems highly probable that in this part of the Nile basin we have a series of crust-blocks which have been moved comparatively recently, and between and across which the drainage waters are finding their way without as yet having had time to grade their channels.

The first of the ledges of the plateau with which we have to do, is that which forms the basin of Lake Victoria, 1134 metres (3720 feet) above sea-level, and to the north of it the ground falls rapidly. The river, after pouring over the 5-metre drop of the Ripon falls, plunges down a series of rapids towards Kakoji, where a second ledge occurs, which is occupied by the marshes and lagoons of Lake Choga, the altitude of which we may take with considerable accuracy as being 1035 metres (3396 feet) above sea-level, since Mruli, at the junction of the Kafu river with the Victoria Nile, is 1032 metres (3386 feet), since the water surface of the former was 1031·873 metres (3385·5 feet) on July 15, 1907. From Mruli to Foweira, the river flows placidly, and is free from rapids for a distance of about 75 kilometres (47 miles), so that if we allow 10 metres for the fall in this distance, we are probably overstating it and understating the altitude of Foweira in fixing it at 1022 metres (3353 feet). Beyond this point another steep descent commences, and the river bed is little else than a continuous chain of rapids from Foweira to the base of the Murchison falls. The levelling carried out in 1907 has shown that the total height of these falls is 37 metres (120 feet), the altitude of the water-level above the falls on September 5, 1907, being 659·5 metres, and that at the foot of the falls 622 metres on the same date. The low-stage discharge in March, 1903, was 577 cubic metres per second, which must represent the supply coming from Lakes Victoria and Choga, for the tributaries below Foweira are then almost dry, and the amount contributed by the Kafu river cannot be great. On September 5, 1907, however, the discharge at the same spot, Fajao, below the falls, was found by Mr. L. B. Weldon and Mr. W. G. Maule, of the Survey Department of Egypt, to be 1600 cubic metres per second, or about 1000 more than at the low stage. Any increased discharge from Lake Victoria is taken up by the vast area of Lake Choga and its swamps, as is shown by the water-level at Mruli only rising 1 foot 6 inches in the middle of the rainy season, April, 1906,‡ so that this increase of 1000 cubic metres per second is mainly supplied by the streams and torrents which stream down the face of the plateau and pour their

* 'Physiography of the Nile,' p. 43 and plate iv. Cairo: 1906.

† *Cairo Science Journal*, November, 1908, p. 385.

‡ 'The Rains of the Nile Basin, 1906.' Cairo: 1907.

united volume over the Murchison falls. The effect of this erosive action is seen in the rapidly-forming delta of sand and mud which is being deposited where the Victoria Nile enters the Albert lake.

The other drainage line which reaches this lake exhibits very similar characteristics: the level basin of the Albert Edward lake, situated 2995·6 feet (913 metres) above sea-level, as determined by triangulation,* is drained by the Semliki or Ituri river, which flows with a moderate slope for about 75 kilometres (47 miles), as far as Fort Mbeni, and we may estimate the fall from the lake to this point as about 25 metres (82 feet). Again, it is navigable for boats for some distance before it reaches Lake Albert, and the commencement of this reach we may put provisionally at 50 kilometres (80 miles) up-stream of, and 5 metres above the Albert lake (618 metres). This leaves a middle reach, some 135 kilometres (84 miles) long, in which the river falls 265 metres (869 feet). Fed by numerous tributaries from the western slopes of the Ruwenzori range, and eroding its own bed as it descends, the Semliki must annually carry a vast quantity of sediment into the Albert lake, and the disappearance of the lake must eventually be the result of the continued deposition of the load brought down in suspension by the Victoria Nile and the Semliki.

The valley in which the Albert lake lies extends northwards as far as Dufile and Nimule, a distance of some 210 kilometres (130 miles), as a valley of which the slope must be low; no measurements exist, but the river is described as flowing with a gentle current, and being wide and full of papyrus islands. The water-level at Dufile has been shown to be most probably about 595 metres (1952·2 feet) above sea-level, so that the river has already descended more than one-half of the vertical distance between the Victoria lake and sea-level in traversing about one-eighth of its course. The river, as the Bahr el Jebel, now plunges down the last of its steps from the plateau of the crystalline rocks, in a series of rapids amongst which the principal are those of Fola, Muggi, and Beden, and by the time Rejaf is reached, the total fall from Dufile has amounted to 138 metres (430 feet). From here to Gondokoro (446·2 metres, or 1464 feet), the slope is more gradual and the river is navigable by boats.

At this point the country changes, and the granite, gneiss, and schist of the plateau are replaced by the alluvium which extends northwards from the foot of the equatorial plateau, and forms the plains of the southern Sudan. These great plains are a remarkable feature in the basin of the Nile, and date from a time when the drainage of the region must have been very different. To-day they occupy a vast area of some 100,000 square miles, which extends from the foothills of the Kaffa in the south-east to the valley of the Bahr el Arab, between Shakka and Deim Zobeir, 650 or 750 miles away to the west-north-west, while its breadth from Bor to a point north of Taufikia, on the White Nile, is 250 miles.

* Behrens, *Geographical Journal*, March, 1907.

This area is enclosed by the ridge which forms the Nile-Congo watershed on the south, the low watershed between it and Lake Tchad on the west, and the hills of Kordofan on the north. Here and there in it low hills of granite appear, as Jebel Zaraf near the river of that name, and others on the Sobat plains, near the upper reaches of the Pibor, showing that the alluvium fills a low depression, of which the granite and gneisses of the old land surface form the floor.

The origin of this alluvial deposit still remains a problem for solution, but it is difficult not to connect it with the erosion of the hill masses of Kordofan, of the Nile-Congo watershed, and those of the Eastern Sudan, before they had been reduced to the low isolated knolls that we see to-day. At least it is evident from the section that it could not have been produced by the river as it is to-day. The present conditions are depositing coarse sand and gravel in the reach between Gondokoro and Mongalla, and even as far as Bor, but the marshes in the valley intercept the flood waters, and the material in suspension is soon deposited, so that the building up of the flood plains has not advanced far, and is indicated in the increased slope between Gondokoro and Bor.

From	To	Distance.		Fall.		Slope, 1 in
		Kilom.	Miles.	Metres.	Feet.	
Gondokoro	Mongalla	40	25	10.5	34.4	4,000
Mongalla	Bor	135	84	19.7	64.6	7,000
Bor	Lake No	580	360	29.5	96.5	19,600

On the southern side this level alluvial region is well defined by the swamps and marshes in which the streams which rise on the Nile-Congo watershed lose themselves, and the posts of Chak-Chak, Wau, Rumbek, and Bor mark the boundary fairly well. To the east of this the last foothills of the equatorial plateau bound the plains to the south, and to the north of Lake No a narrow belt of plain divides the river from the rising ground of Kordofan. To-day the general slope is to the east-west line of the Bahr el Ghazal—White Nile—Sobat, and from Taufikia, where these join, the combined rivers flow northwards to Khartum, but everywhere the slope is extremely low.

Recent levelling by the Sudan Irrigation Service gives the following values for the slope of the White Nile at low water :—

From	To	Distance.		Fall.		Slope, 1 in
		Kilom.	Miles.	Metres.	Feet.	
Bor	Lake No	580	360	29.5	96.8	19,600
Lake No	Taufikia	140	87	3.8	12.5	37,000
Taufikia	Melut	160	99	1.3	4.3	123,000
Melut	Renk	180	118	1.4	4.6	128,000
Renk	Dueim	280	174	2.6	8.5	108,000
Dueim	Khartum	210	130	2.5	8.2	84,000

The result of so slight an inclination of the river-bed is that, when the Blue Nile rises 7 metres in flood, the lower portion of the White Nile valley is converted into a lake, and for 300 miles above Khartum the surface is horizontal, and the flow is hardly perceptible. From the time that the Blue Nile is discharging about 5000 or 6000 cubic metres per second, the rise of level in the lower reaches of the White Nile takes place simultaneously with that of the Blue Nile, and is wholly dominated by it.* The same effect is caused by the rise of the Sobat in flood, which raises the water-level of the Bahr el Jebel, north of Hellet el Nuer, and of the Bahr el Ghazal, and maintains it until December, when the Sobat falls. The water so pounded up in the White Nile flows off in November and December, thus delaying the rate of decrease in the levels in the lower reaches of the main river when the Abyssinian rains have ceased.

At Khartum the Blue Nile, which drains the plateau of Abyssinia, joins the main stream, and supplies almost the whole of the water of the annual flood. Accurate levelling has only been carried as far as Fazogli, beyond which aneroid or hypsometric determinations are alone available. These indicate that the river rises about 2300 metres above sea-level, and passes through Lake Tsana at 1755 metres, after which it falls rapidly to an altitude of about 900 metres, flowing then in a deep and steep-sided valley. The slope of the lower reaches in the plains of the Sudan, where the river is in its valley tract, is given in the following table: †—

Place.	Distance from Khartum.		H. W. L.		L. W. L.		Slope, 1 in
	Kilom.	Miles.	Miles.	Feet.	Miles.	Feet.	
Khartum	—	—	382·7	1256	374·7	1229	—
Kamlin	105	65	393·2	1290	383·7	1259	12,300
Wad Medani	206	128	402·7	1321	391·7	1285	12,800
Sennar	352	219	418·4	1373	409·7	1344	8,070
Singa	442	275	430·4	1411	418·0	1371	12,650
Roselres	642	399	454·7	1492	442·7	1452	7,760
Fazogli	742	461	—	—	477·4	1566	2,900

At Khartum a long tract is entered, in which the river falls from a low-stage level of 375 metres (1230·4 feet) above sea-level at Khartum to 118 metres (387·2 feet) at Wadi Halfa, in a distance of 1535 kilometres (954 miles). This is equivalent to an average slope of 24·4 centimetres per kilometre, or 16·6 inches per mile.

Considerable erosion is taking place in this reach, especially where the crystalline rocks form short reaches of comparatively steep slope,

* 'Physiography of the River Nile and its Basin,' p. 174. Cairo: 1906.

† From the levelling of the Sudan Irrigation Service.

and in which occur numerous bars and rocky islands, forming the cataracts of the Nile.

Immediately below Khartum is a reach some 78 kilometres (48 miles) long; the river flows through sandstone (Nubian) of Cretaceous age, between low banks, and has a wide and not very deep section. The width varies from about 750 metres (817 yards), where the river is in a single channel, to 1500 metres (1640 yards) in other places where islands occur. In the last few miles the channel gets narrower as the gneissose rocks are reached. At Jebel Royan, 78 kilometres (48 miles) from Khartum, the river turns abruptly to the east-north-east, and 3 kilometres later enters the Shabluka gorge, through which it flows for 12 kilometres (7·5 miles), changing its direction to north in the last four.

This is the so-called Sixth Cataract, but such a term is a misnomer, for recent levelling has shown that there is no steep slope here, but that the broken water is due to the river flowing through a narrow and deep gorge. This gorge cuts through a mass of columnar felsite, which stands up as an isolated mass in a plain of gneiss, and the reason for the Nile having selected such a course is not at first sight clear. Further examination is necessary before a reliable decision can be reached, but the position of Nubian sandstone at a low level close to the down-stream end of the gorge appears to indicate that the original erosion of the channel took place in very remote times, and that the Nubian sandstone was deposited in it, to be removed in recent times when the present drainage lines of the country were being developed. The remarkable character of the gorge may be seen from the dimensions given in the following table:—

From Khartum.		Width in		Depth, January, 1906, in		Low-water level (above sea-level).	
Miles.	Kilom.	Feet.	Metres.	Feet.	Metres.	Feet.	Metres.
50·3	81	1300	400	—	—	1200·5	365·9
51·0	82	1300	400	—	—	—	—
51·6	83	980	300	—	—	—	—
52·2	84	980	300	—	—	1198·6	365·3
52·8	85	980	300	—	—	—	—
53·4	86	900	275	—	—	—	—
54·1	87	980	300	—	—	—	—
54·7	88	1150	350	66·3	32·5	—	—
55·3	89	1150	350	—	—	—	—
55·9	90	900	275	—	—	1198·3	365·23
56·5	91	1150	350	—	—	—	—
57·2	92	670	200	—	—	—	—
57·8	93	1480	450	80·3	24·5	1198·2	365·21
Total fall						2·3	0·7

From this point the river flows through a level country mostly of Nubian sandstone, past the mouth of the Atbara, to a point 46

kilometres (29 miles) further down-stream than the town of Berber, where crystalline rocks again occur and form the Fifth Cataract. In this length of 314 kilometres (195 miles), the river at its low-stage falls from 365.21 metres (1197.8 feet) to 336.66 metres (1104.2 feet), or 28.55 metres (93.7 feet) in this distance, which is equivalent to 9 centimetres per kilometre, or 6 inches per mile.

The river now flows among a series of rocky islands with an increased slope for 21 kilometres (13 miles), in which distance it falls 7.9 metres (25.9 feet), or 38 centimetres per kilometre (23.9 inches per mile). This is the first stage of the Fifth Cataract, and other sets of islands and rapids occur 50 kilometres (31 miles), and again at 65 kilometres (40.4 miles) further on. In all, the total fall in this collection of rapids is 25 metres (82 feet) to a point about 170 kilometres (106 miles) down-stream of Berber, below which the slope is less.

At 578 kilometres (359 miles) from Khartum, the Nile reaches Abu Hamed and turns sharply westwards, entering the crystalline rocks and again plunging down 27 kilometres (17 miles) of rapids.

This cataract is not one of those especially numbered on maps, but it is of importance, for the river falls 18.1 metres (59.4 feet) in the 27 kilometres (17 miles), or 67 centimetres a kilometre (43.2 inches per mile).

From this point the river flows in a very irregular course through an area of crystalline rocks for 189 kilometres (117 miles), to a point where it divides in order to pass round Shirri island at the head of the Fourth Cataract; its fall in this distance is 12.28 metres (or 40.29 feet), equivalent to 6.5 centimetres per kilometre (or 4.1 inches per mile). This place, the head of Shirri island, was investigated as a possible site for a reservoir-dam; but the reach of the river between it and Abu Hamed proved, when contoured, to be able to contain too small a volume of water, and moreover the rock at Shirri is so much crushed and fractured as to furnish an unsatisfactory foundation for a large and important work.

Between Shirri island and Kareima, 708 to 805 kilometres (420 to 500 miles) from Khartum, the river passes the rapids of the Fourth Cataract; the whole fall amounts to 33.44 metres (109.72 feet), or an average slope of 34.5 centimetres per kilometre (21.9 inches per mile). The principal fall occurs between 751–759 kilometres (467–472 miles), where the river descends 14 metres (45.9 feet) in this short distance.

The Nile now enters on its long bend near Dongola, where in a distance of 331 kilometres (206 miles) it flows through a district where sandstone alone occurs; its fall is 26.7 metres (87.6 feet), or 8 centimetres per kilometre (5.2 inches per mile). At Abu Fatma, 1148 kilometres (713 miles) from Khartum, there begins a long series of rapids, with intervals of more level reaches, which continue until the Second Cataract has been passed, and Wadi Halfa is reached. These

Distance in kilometres.		Distance in miles.		Mean low-water level above mean sea-level.		Distance in kilometres.	Fall in metres.	Distance in kilometres.	Fall in metres.	Distance in miles.	Fall in feet.	Slope, inches per mile.	Cataracts.
From Khartum.	to Wadi Halfa.	From Khartum.	to Wadi Halfa.	In metres.	In feet.								
1148	387	713.4	240.5	216.49	710.30	—	—	—	—	—	—	—	Hannek or Third cataract
1153	382	716.5	237.4	213.15	699.35	5	3.34	3.1	3.34	3.1	10.95	43.6	
1157	378	719.0	234.9	211.28	693.21	4	1.87	2.5	1.87	2.5	6.14	29.5	
1159	376	720.2	233.7	209.36	686.91	2	1.92	1.2	1.92	1.2	6.30	63.0	
1167	368	725.2	228.7	206.69	678.15	8	2.67	5.0	2.67	5.0	8.76	21.0	
1172	363	728.3	225.6	205.20	673.26	5	1.49	3.1	1.49	3.1	4.89	18.9	Kaibar
1210	324	751.9	201.4	202.44	664.21	—	—	—	—	—	—	—	
1213	323	753.8	200.7	199.64	655.02	1	2.80	0.7	2.80	0.7	9.19	157.5	Amara rapids
1218	323	753.8	200.7	199.64	655.02	—	—	—	—	—	—	—	
1217	317	819.0	134.8	192.13	630.38	2	0.59	1.2	0.59	1.2	1.94	19.4	
1820	215	820.2	133.6	191.34	628.44	3	1.03	1.9	1.03	1.9	3.38	21.3	Dal cataract
1323	212	822.1	131.7	190.51	625.06	6	1.14	3.7	1.14	3.7	3.74	12.1	
1329	206	825.8	128.0	189.37	621.32	—	—	—	—	—	—	—	Dal cataract
1358	177	843.9	110.0	185.07	607.21	1	1.35	0.6	1.35	0.6	4.42	88.4	
1359	176	844.5	109.4	183.72	602.79	6	1.24	3.8	1.24	3.8	4.14	13.1	
1365	170	848.2	105.6	182.46	598.65	5	1.19	3.1	1.19	3.1	4.08	15.8	Dal cataract
1370	165	851.3	102.5	181.27	594.57	6	1.32	3.1	1.32	3.1	4.33	16.8	
1376	159	855.0	99.4	179.95	590.24	2	0.39	0.6	0.39	0.6	1.28	25.6	Dal cataract
1377	158	855.7	98.8	179.56	588.96	1	1.09	1.2	1.09	1.2	3.58	35.8	
1379	156	856.9	97.6	178.47	585.38	1	1.01	0.7	1.01	0.7	3.31	56.7	Dal cataract
1380	155	857.5	96.9	177.46	582.07	1	1.55	0.6	1.55	0.6	5.09	101.8	
1381	154	858.2	96.3	175.91	576.98	1	2.65	1.2	2.65	1.2	8.69	86.9	Tanjore
1382	153	858.8	95.1	173.26	568.29	1	1.47	0.6	1.47	0.6	4.82	96.4	
1383	152	859.4	94.5	171.79	563.47	6	2.51	3.7	2.51	3.7	8.23	26.7	Ambigol
1404	131	872.4	81.4	167.08	548.02	5	6.85	4.4	6.85	4.4	22.47	61.3	
1410	125	876.2	77.7	164.57	539.79	6	1.22	3.7	1.22	3.7	4.00	12.9	Semna cataract
1415	120	879.3	74.6	164.56	539.76	5	2.40	3.1	2.40	3.1	7.87	30.4	
1415	113	883.6	70.2	157.71	517.29	7	6.76	3.7	6.76	3.7	22.17	71.9	Kagingar rapids
1430	105	888.8	65.2	155.62	510.43	6	0.43	3.7	0.43	3.7	1.41	4.6	
1436	99	892.3	61.5	154.40	506.43	7	3.41	4.4	3.41	4.4	11.19	30.5	Second cataract
1441	94	895.4	58.4	152.00	498.56	35	1.05	3.8	1.05	3.8	15.71	75.4	
1447	88	899.2	54.7	145.24	476.39	6	4.79	2.5	4.79	2.5	15.71	75.4	Second cataract
1453	82	902.9	51.0	144.81	471.98	8	0.80	3.7	0.80	3.7	2.63	8.3	
1460	75	907.2	46.6	141.40	463.79	6	1.06	21.7	1.06	21.7	3.47	1.9	Second cataract
1467	68	911.6	42.3	140.35	460.35	6	7.54	5.0	7.54	5.0	24.74	57.9	
1471	64	914.1	39.8	135.56	444.64	9	0.83	5.6	0.83	5.6	2.72	5.8	Second cataract
1477	58	917.8	36.0	134.76	442.01	8	0.83	5.6	0.83	5.6	2.72	5.8	
1512	23	939.6	14.3	133.70	438.54	9	0.83	5.6	0.83	5.6	2.72	5.8	Second cataract
1518	17	943.3	10.6	126.16	413.80	9	0.83	5.6	0.83	5.6	2.72	5.8	
1526	9	948.3	5.6	118.80	389.66	9	0.83	5.6	0.83	5.6	2.72	5.8	Second cataract
1535	0	953.8	0.0	117.97	386.94	9	0.83	5.6	0.83	5.6	2.72	5.8	

alternations of steep slope and more level river may be conveniently shown in a tabular form. It is difficult to fix the exact point at which rapids should be considered as beginning, but during the levelling operations this was judged as nearly as possible, and in the more level reaches the water-level was measured at least once in every day's work.

The levels and slopes of the principal cataracts in this reach from Abu Fatma to the end of the Second Cataract are given in the following table, since they follow each other too closely to be satisfactorily indicated in a description.

Below Wadi Halfa there are only two reaches, one of 396 kilometres (246 miles) from Wadi Halfa to the top of the cataract at Aswan, in which the average slope is 1 in 10,000 (6·3 inches per mile), and the other from Aswan below the cataract to the sea, where the river falls 85 metres in 1208 kilometres (751 miles), which corresponds to a slope of 1 in 14,000 (4·5 inches per mile).

The conditions of erosion and deposition vary greatly in different parts of the system as the slopes and the volume of discharge alter. Erosion goes on actively from Ripon falls to Lake Choga, and from Foweira to the Albert lake, while the material carried in suspension is being deposited in these two lakes. From Nimule to Rejaf erosion is rapidly wearing away the rock and depositing the material in the Bahr el Jebel valley. The White Nile must receive the material brought down by the Sobat in suspension when the Blue Nile flood ponds back the waters of the main stream; but possibly this is scoured out to some extent when the discharge of the White Nile increases in the late autumn. From Khartum to Aswan erosion is in progress rapidly in the cataracts and rapids, and very slowly in the intermediate reaches where the valley lies in the sandstone areas. From Aswan to the sea is a region of steady deposition, and such data as the nilometers, quay walls, temples, and town sites of ancient Egypt furnish, indicate that an average rise of the river-bed due to deposition has been proceeding for some five thousand years at the average rate of 10 or 11 centimetres per century.*

A glance at the longitudinal section shows that we have not to do with the course of a normally developed river where the mountain tract of rapid erosion passes gradually into a valley tract of slight erosion, and this in turn into a plain tract where deposition is going on. The present Nile system must include portions of river systems of very different origin and date. While the drainage lines of the equatorial plateau are comparatively recent, the meeting-ground of the Bahr el Jebel, the Bahr el Ghazal, the White Nile, and the Sobat must have been part of a much older system. It would be rash to attempt an explanation of the development of this complicated

* See L. Borchardt, "Nilmessen und Nilstandmarken," *Abhandl. kais. Akad. der Wissenschaften*. Berlin: 1906.

drainage system at the present time, but as our detailed knowledge of this region increases, it may be possible to form some idea how the elevation of the equatorial plateau in this part affected the earlier drainage system. Such changes taking place in times which, geologically speaking, were not remote, must have affected the distribution of the fauna of this part of Africa.

LIEUT. BOYD ALEXANDER'S EXPEDITION IN WEST AFRICA.

[LIEUT. BOYD ALEXANDER sends the following communication with reference to his expedition to West Africa, dated "Buea, Cameroon, May 8, 1909." It will be remembered that he left England in December last with a view of thoroughly exploring the islands of São Thomé, Príncipe, and Annobon, chiefly from a zoological point of view.]

After leaving Príncipe I went *via* Fernando Po to Victoria, where I arrived on March 27. Having my own carriers, I was able to start for Buea the same day. On the 29th I left for the Cameroon mountain, and made a camp about 6500 feet up in the thick forest, which commences just above Buea, clothing the sides of the mountain to a height of about 7000 feet. Beyond the forest the ascent to the first ridge, 8500 feet, becomes steep; the sides are covered with thick grass, and scarred by deep vertical channels and cavernous fissures, the latter about its centre where it is steepest. I made my own road to the peak, and this took me about eight days. I approached it from a point where the ridge commences to slope down to the west. The actual ascent from Buea would take five and a half hours. After leaving Camp I. there is no water, so from this point we had to carry it. From Camp II. I obtained a wonderful view of the country to the south, and of the Fernando Po peak. One could see Duala and the whole of the Cameroon river, with its numerous creeks intersecting a well-wooded country. From Camp II. the mountain commences to rise gradually till the second ridge is reached; the whole surface is cut up by old lava beds interspersed with thin grass land, the former reaching as far down as Camp II. Beyond the second ridge there is a small, almost level plateau up to the bottom of the craters of the peak. It is difficult to imagine a more forbidding-looking place than the peak itself—nothing but a group of vast craters, or, rather, I might describe them as ash-pits: and it is my opinion that these are still active; the cinder looks as fresh as if it had been thrown up yesterday. The Germans have a small hut at the bottom of the peak. I looked in the book containing the record of names of the climbers, but could not find Mary Kingsley's, though previous to this a German official at Buea told me that he had seen it. It must have been torn out; it is a great shame. How a woman could have ascended this mountain, which taxes the powers of

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LONGITUDINAL SECTION OF THE NILE LYONS.

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IN 1903 AT DIFFERENT POINTS ON THE NILE;
AND THE MEAN ANNUAL RAINFALL.

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DIAGRAM SHOWING VOLUMES DISCHARGED IN 1903 AT DIFFERENT POINTS ON THE NILE; AND THE MEAN ANNUAL RAINFALL.

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