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ORIGINAL ARTICLES.

I.—THE KISHON AND JORDAN VALLEYS.

By Professor T. G. BONNEY, D.Sc., LL.D., F.R.S.

THAT broad trench through the Palestine Highlands, an ancient highway and battlefield of nations—the plain of Esdraelon or the valley of Megiddo, together with the plain of Acre—has for long presented to me a difficult problem in Physical Geology, for it seemed inexplicable by subaerial denudation under existing conditions. Its floor varies roughly from five to eight miles in breadth; running approximately from south-east to north-west, it is bounded on the more western side by the limestone mountains of Samaria and on the more eastern by those of Galilee. The former descend from the ridge of Carmel (1,742 feet at highest) with a fairly steep escarpment, which becomes a little less regular as we follow it to the bastion-mass of Mount Gilboa; the latter correspond in their general outlines with those of the eastern portion of Samaria, but the advance of a lower spur towards the south-west divides the plain of Esdraelon from that of Acre, by a kind of strait in which, so far as I could see, there is but little level ground on either side of the Kishon. This spur, however, of the northern hills, hardly does more than interrupt the floor of the Kishon valley, for above it the great trench is continued between two hill masses, much of these ranging from thirteen to sixteen hundred feet above sea-level. Beyond the strait the upper basin (plain of Esdraelon) quickly broadens out, extending towards the south-east for about fifteen or sixteen miles, where it is divided into two arms by Jebel Duhy (Little Hermon) (1,690 feet), which is thus isolated from Tabor (1,846 feet) on the north, and from Gilboa (1,698 feet) on the south; a broad, rather shallow, grassy valley descending from the last-named mass to lose itself in the plain. Neither it nor one or two other tributaries from the Galilee hills count for much, but the two arms maintain their trench-like form, cutting through the limestone isthmus which must once have united Samaria and Galilee. These are still, though much narrower than the plain of Esdraelon, disproportionately broad; their watersheds are low,

ill-marked, and lie farther west than the natural position. The gap between Duhy and Tabor is the narrower, and, so far as I can ascertain, a few feet the higher; that between the former and Gilboa is between two and three miles wide and about 270 feet above sea-level. One position in the 'strait' leading to the plain of Acre, according to the Palestine survey map, is 80 feet above sea-level, so the average down-slope of the plain of Esdraelon must be about four yards in a mile. A plain it is not, however, in such a strict sense of the word as the Cambridgeshire fenland; for the bases of the hills of Galilee on one side and of Samaria on the other shelve gently down with occasional slight undulations so as to fuse imperceptibly with the actually level ground near the river brink. All this low land is covered with a thick, rich brown earth, a broad fertile expanse of arable land and herbage, in striking contrast with the comparatively bare limestone masses on either side.

Obviously this is a river valley—a trench not less than a thousand feet deep cut through the limestone highlands of Palestine—but it is on much too large a scale to have been excavated by the present Kishon system. The difficulties increase when we examine the Jordan valley. That is another trough, seldom less and often more than four miles wide. Its bed, where reached by the southern of the two passes, must be at least 700 feet below sea-level,¹ so the drop from the watershed must be quite 950 feet. The Jordan has carved its present course through old lacustrine deposits, of which we need now only say that they were formed when an unbroken sheet of water extended from the divide between the Red and the Dead Seas to the northern end of Lake Huleh.² They extend into a recess between the roots of Little Hermon and Gilboa, where, about 350 feet above the river, is Beisan, the ancient Bethshean.

The depth of the Sea of Galilee is about 165 feet, and it may occupy a true rock basin, for the river, no great distance below its outlet, runs, according to Lynch,³ over a rocky bed. The surface of the Dead Sea is about 1,292 feet below the Mediterranean, its greatest depth being 1,278 feet, and the watershed between it and the Red Sea, on which are outcrops of limestone, is 660 feet above the latter. As so much has been written on the Jordan valley,⁴ it

¹ The Sea of Galilee is 682.5 feet below sea-level.

² The water in this ancient lake seems to have risen to about 1,398 feet above its present level, or some 98 feet above the sea; that would be, in round numbers, 90 feet above the present surface of Huleh.

³ "Expedition to the Dead Sea and the Jordan," chs. viii and ix.

⁴ The literature connected with this subject is extensive, but I may say that, until I formed the conclusion expressed in this paper, I consulted books to ascertain facts rather than opinions. I made great use of Professor Hull's Memoir in the "Survey of Western Palestine" (though venturing to differ in one or two matters from him). Valuable references to literature are to be found in Professor Suess' classic work "Das Antlitz der Erde," Professor Lartet's "Géologie de la Mer Morte," and Professor Gregory's "Great Rift Valley," ch. xiii. I may also mention Professor I. C. Russell's paper in this Magazine (1888, p. 338, etc.), and the one by Mr. Hudleston on the Central African Lakes in the present volume. I have also consulted papers by Dr. Diener and Dr. Blanckenhorn, though to one or two of their writings I have not had access.

will suffice to say (1) that all features which meet the eye are indicative of subaerial erosion; (2) that examination of its geological structure shows it to have been initiated and determined by a series of more or less parallel faults, which extend from somewhere south of the Taurus range to the junction of the Gulf of Akabah with the Red Sea, where they run up against another and still greater system; (3) that some geologists consider the depression, now partly occupied by the Dead Sea, and the elevation to the south of it, to be original features produced by unequal subsidence during the process of faulting, while others maintain that the Jordan once found its way southward through the Gulf of Akabah and that the present configuration of its bed is due to subsequent movements differing in direction from the original.

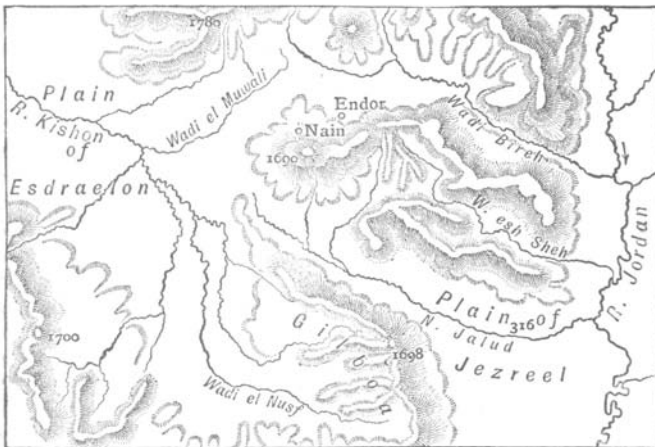


FIG. 1.—THE NEIGHBOURHOOD OF THE ESDRAELON GAP.

Before proceeding farther I venture to call attention to the misapplication (increasing, I think) of the term 'rift valley' to the Jordan. In the strict sense of the word 'rift' (according to good dictionaries of our language) such a valley must be, on any large scale, a great rarity. One would not, however, quarrel much with the application of the term (as by Professor Gregory in Masailand) to a valley where the surface of rupture, at least on one side, was still comparatively 'raw'—unmodified by denudation. That cannot be said of the Jordan, where the fault system can only be detected on examination. Every feature in the landscape speaks of ordinary meteoric agencies, so that the Lake of Gennesaret and the Dead Sea are no more suggestive of 'rifts' than the Lakes of Orta or of Geneva. The Jordan valley, to use the accurate phrase applied to it by Suess,¹ is part of a 'graben versenkung.' 'Rift' is not an accurate translation for 'graben'; 'trough' is far better, and as we speak of

¹ "Antlitz der Erde," vol. i, pp. 481, 482, etc. (See p. 373 et seq. of the newly published translation by Miss & Professor Sollas.)

a 'trough-fault,' why not a 'trough valley,' or, if we wish to be very precise, a 'trough-fault valley'? But a new word, especially if a little improper, seems to be as fascinating to some geologists as it is to children!

No one doubts that the physical features of Palestine have all been developed since the age of the Nummulitic Limestone; their broad outlines were probably determined, as we shall presently see, by the beginning of glacial times.¹ To excavate the broad 'Kishon valley' requires, in my opinion, not only a heavier rainfall, but also a much larger drainage area than now exists. It is obviously a 'beheaded' valley;² the two streams descending to the Jordan on either side of Jebel Duhy have trespassed westwards and pushed the watershed in that direction. In other words, I consider the Kishon valley to be older than that of the Jordan, and still to retain, west of the passes, its principal ancient features.³ But where was the original watershed? If it were to the west—somewhere out in the Mediterranean—then Jebel Duhy must have been an island dividing the river into two channels; a thing possible, but the less probable hypothesis. The features described above appeared to me, when I visited the country, to demand a watershed well to the east of the line connecting Tabor with Gilboa over Duhy. The watershed may have disappeared in the trough-faulting which determined the Jordan valley; but I doubt, apart from other obvious difficulties, whether that would be far enough to the east, and am disposed to place it on the Syrian highlands nearer to that from which streams now descend westwards to the Jordan, because the lower part of the valley, the present Kishon, seems to me so deep, level, and flat that it could only have been made by a stream not much less important than that of the Jordan itself. I am unable to identify the old course of its upper waters with any existing valley; but that is not surprising, because the amount of subsidence in the Jordan trough has maintained, if it has not accelerated, denudation on its western flank,⁴ while cutting off the supply has left the lower part of the ancient valley—the Esdraelon-Acre trench—very much as it was.⁵ So I suppose the movement which first raised the Syrian highlands (including Palestine) above the sea culminated at an axis still indicated by the head waters of the Jarmuk, the Zerka, and many other streams,

¹ It is almost needless to observe that in this interval much work was done in 'making scenery' all round the Mediterranean border.

² My friend Professor J. W. Gregory emphasises this conclusion in his "Great Rift Valley" (pp. 253-255), but I may say that each of us reached it independently of the other, and we take opposite views as to which was the executioner. The sketch-map inserted above (Fig. 1), for which I am indebted to his kindness and that of his publisher, Mr. J. Murray, brings out very clearly the extent of the trespass.

³ The outlet of the Orontes (Nahr-el-Asi), perhaps also of the Leontes (Nahr-el-Litany), may be contemporary features in the structure of Syria.

⁴ To this, of course, I attribute the westward trespassing of the shorter streams on that side.

⁵ To behead a valley, as we can see in the case of the Inn between St. Moritz and the Maloya, practically puts a stop to erosion in the uppermost basin.

which formerly made their ways (the final outlets not being numerous) westwards to the Mediterranean.

We come next to the great trough-valley. So much has been written about this, which includes the whole course of the Jordan and the major part of both the Leontes and the Orontes, that I need not enter into minute details. Dr. Blanckenhorn's section across southern Palestine¹ makes the general structure perfectly clear. The high upland west of the Jordan is formed by a flattened anticline, the eastern arm of which is dropped down by three parallel faults, the outermost practically forming the west side of that valley. A single but greater downthrow does the same on the opposite or eastern side, so the higher strata on both sides of the river are nearly on a level. The western flexure is prolonged, exaggerated, and complicated in the Lebanon range; the eastern in that of Anti-Lebanons, which I suppose to have been the earlier of the two.² Was the watershed between the Gulf of Akabah and the Dead Sea, with the formation of the latter and the peculiar depression of the major part of the Jordan valley, mainly determined by unequal subsidence of the faulted down trough-blocks, or was this valley, after its first definition, excavated down to the live rock which, though now generally invisible, must form its true floor, and subsequently traversed by flexures, due to forces acting nearly at right angles to the former set, which produced the general depression at the northern end and the marked barrier near the southern? Most authorities adopt the former view. They consider that the limestone, which crops out in ridges near this barrier in the bed of the trough, and the fact that the glens north of it trend towards the Dead Sea and south of it to the Gulf of Akabah, indicate the Arabah-Akabah watershed to have existed from the first. But travellers describe the valley bed as if (apart from the lacustrine deposits) it agreed very closely with the Ghor itself. But we should expect that, if these ridges were the remnants of an ordinary watershed, the united streams from each side of it would have carved in the floor of the trough a pair of narrow 'wadies' running in opposite directions: in other words, that we should find here a closer resemblance to the valley of the Jordan north of Lake Huleh. As a considerable amount of denudation must have taken place while the Jordan Lake was filling, and must have been continued while it was shrinking (for I suppose the cutting of terminal ravines such as those of the Kedron and the Kelt to be distinctly late features),³ I am not surprised at the general directions of the larger valleys.

¹ Through Bethlehem; see *Zeitschr. d. Deutsch. Palest. Vereins*, xix (1898), pp. 1-59.

² To compare smaller with larger mountains, the structure here seems generally similar to that of Switzerland from the French frontier to the watershed between the Rhine and the Inn.

³ In fact, more than one feature which I observed during my short visit to Palestine suggested that in the uplands denudation was proceeding very slowly, but became much more rapid in the vicinity of the Jordan.

But the study of its fauna and flora has much strengthened the arguments for the former connection of the Jordan valley with the Gulf of Akabah. In Canon Tristram's words,¹ written twenty years ago (which, as we can see from the excellent summary given by Professor Gregory,² have been fortified by additional evidence), "A review of the botany as well as the zoology of the Dead Sea basin reveals to us the interesting fact that we find in this isolated spot . . . a series of forms of life, differing decidedly from the species of the surrounding region, to which they never extend, and bearing a strong affinity to the Ethiopian region, with a trace of Indian admixture. As the species which serve as the most striking illustrations of this fact live either in or beside fresh water, a river connection is the most natural agency by which to account for it, and as these species are absent from the Lower Nile valley and from Egypt, the river connection must have been established along the eastern side of the range of highlands which separates the Nile from the Red Sea." Professor Gregory, though advocating this connection, thinks it unnecessary to assume that "a river flowed the whole way from the Jordan to the northern end of the Red Sea," because fish from the south might have made their way to a lake, which is shown by its deposits³ to have existed on the northern side of the watershed and a few feet below it, when "an occasional flood or a slight earth-movement would have enabled them to enter the stream which flowed northwards." That, no doubt, is possible, though I should think not very probable, unless the spawn were conveyed by birds, but it does not account for the continuous trench of the Arabah-Akabah valley. Professor Hull is not unconscious of this difficulty, for he says, speaking of the valley of the Arabah and this watershed,⁴ "it is difficult to see how this great valley, which is sometimes seven or eight miles in width, especially near its centre,⁵ could have been excavated and levelled down unless the action of the rivers and streams of the bordering hills had been originally supplemented by the levelling action of the sea waves on the south and the inland waters of a great lake on the north of the watershed." But so far as I am aware, there is no proof that the old Jordan valley lake ever rose more than about a hundred feet above the Mediterranean, and if the sea waves were to approach near to this barrier, to cut a fjord from forty to forty-five miles long, north of the present shore at Akabah, either the sea must have been more than 600 feet higher or the land the same amount lower than at present. In the former case I think that the Mediterranean would probably have occupied the valley of Esdraelon and gained access to the inland lake on one or both sides of Jebel

¹ "The Fauna and Flora of Palestine" (1884), p. xvi.

² "The Great Rift Valley" (1896), p. 262.

³ They were discovered by Professor Hull.

⁴ Mount Seir (1855), p. 82.

⁵ In the "Survey of Western Palestine" (Geology), p. 18, he says that north of the watershed it is nearly double (6 or 7 miles).

Duhy; in the latter some sort of upheaval is admitted. Prof. Lartet, in his excellent memoir, objects to a differential uplift in the bed of the Jordan valley on the ground that there is no disturbance of horizontality in the strata exposed in its flanks. But we must remember that as the beds on both sides dip (on the west rather strongly) towards the valley, a slope at right angles, or in its direction, would be masked, especially as this would be small.¹ But according to Professor Lartet's map the strata do dip in the required direction. Both he and Professor Hull represent Nubian sandstone cropping out beneath the Cretaceous limestone very near the Arabah-Akabah watershed. The former runs downwards to the south end of the Dead Sea, and can be traced beneath the great masses of limestone forming the Moab Hills, until it disappears opposite to Jebel Kuruntil.² After a time, according to Professor Hull's map, it again crops out, being seen for the last time nearly due east of Shechem. Thus there must be a considerable bending or displacement parallel with the east and west fault running from near Bethlehem to the Dead Sea. True, this only accounts for about one-third of the amount which the flexure hypothesis requires, but the beds may have been already somewhat bent down when the trough-faulting began. This hypothesis obviously implies that the whole region from the Arabah to the sources of the Jordan has been considerably depressed. The latter, so far as I can ascertain, range from about three to rather over seven hundred feet above sea-level, which would be too low if the drainage had ever reached the Gulf of Akabah. But this and the 'sag' necessary (as indicated above) to form the Sea of Galilee (in an east and west line with which are the plateau of Asochis and the Bay of Acre; also the marked escarpment in the hills west of Safed) all suggest a system of faults and flexures almost at right angles to, and so probably not coeval with, the north and south system defining the Jordan valley. All geologists agree that before the end of the Pliocene period, "the existing land surfaces on either side of the Jordan-Arabah valley were in a condition not very different from that of the present day, at least in their main features." Professor Hull, from whom these words are quoted,³ says "at the close of the Miocene epoch," but I am doubtful whether we can adopt this limit. If, as is very possible, the two greater systems of disturbances, which certainly affected a large part of the Mediterranean area, extended thus far east, the first uplift would occur at the close of the Eocene and the consequent sculpture during the Miocene period; the formation of the Jordan trough would belong to the second, or immediately post-Miocene movements, by which large parts of the western half of the Alps were so profoundly affected; and its sculpture would proceed during the Pliocene, the flexure of the trough occurring rather

¹ Taking the watershed as 700 feet above, and the Dead Sea as 1,300 feet below, sea-level, we get in round numbers a drop of 2,000 feet in about 70 miles, or on a rough average 1 in 175—less than a degree.

² The Mount of Temptation, the supposed scene of the Forty Days' Fast, conspicuous from and to north-west of Jericho.

³ "Survey of Western Palestine" (Geology), p. 112.

later in this period.¹ That it was complete before the Glacial Epoch began is generally admitted. Dr. Blanckenhorn,² adopting the three epochs of ice-extension recognised in Germany, gives this arrangement of the later history of the Jordan valley :—

(1) First ice-age (rain epoch) : greatest height of the Jordan valley lake.

(2) First interglacial (dry epoch) : probable sinking of lake to about 328 feet above present level, when the salt of Jebel Usdum was precipitated.

(3) Second ice-age : rise of lake and formation of the high terraces.

(4) Second interglacial : probably the age of the volcanic out-breaks,³ so conspicuous in the northern part of the valley (also the cutting of the Ghor).

(5) Third ice-age : formation of the lower terraces.

This chronological scheme is rather hypothetical, but it deserves careful consideration. I think, however, I am right in claiming the Esdraelon valley as a fragment of a system older than the Jordan, and pronouncing that river guilty of removing its neighbour's landmark westward. Such a removal is almost inevitable, because the descent of its tributaries on the right bank is so much more rapid than the slope of the Kishon valley.

II.—ON A NEW CROCODYLIAN GENUS (*NOTOCHAMPSA*) FROM THE UPPER STORMBERG BEDS OF SOUTH AFRICA.

By R. BROOM, M.D., Victoria Coll., Stellenbosch.

MR. A. L. DU TOIT, of the Cape Geological Commission, who has been for some months engaged in studying the Stormberg beds in the eastern part of the Colony, has been fortunate in making a number of discoveries of very great interest to the palæontologist. Among Vertebrates his most important finds have been the remains of two small crocodiles.

The first specimen, which was discovered by Mr. A. Isted in the Cave Sandstone at Funnystone, Barkly East, consists of the impressions of the under sides of most of the upper bones of the skull and of most of the dorsal armour. There are also preserved the remains of a scapula, a humerus, a radius and ulna, a femur, and a number of ribs. A restoration of the skull is shown in Fig. 1. When complete it probably measured 130 mm. in length, and the length of the whole crocodile was probably about 600 mm. Though the skull is too imperfectly preserved to show what are the relations to the already known families, enough is preserved to show that the crocodile belongs to the suborder Amphicelia of Owen (= *Mesosuchia*, Huxley). The skull is characterised by the very large size

¹ One is reminded of the east and west flexures of later Pliocene age in the southern part of England.

² "Entstehung und Gesichte des Todten Meeres": Zeitsch. d. Deutsch. Palest. Vereins, xix (1896), pp. 1-64.

³ There is nothing left to give a precise date to this period, during which, according to Dr. Blanckenhorn, prehistoric man appeared. It is supposed to be contemporaneous with that of the German loess.