8. *The* Early History *of the* Indus, Brahmaputra, *and* Ganges.

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[Plate X—Map.]

The ideas expressed in this paper are the outcome of a study of the Punjab oil-belt. The principal hypothesis proposed has been advanced simultaneously by Dr. H. G. E. Pilgrim, F.G.S., in a paper still in manuscript, to explain the formation of the Siwalik boulder-conglomerates. That paper will, I hope, soon be published,[1] but I have taken the liberty of following up an interesting point to which Dr. Pilgrim has drawn attention: namely, the frequent V-shaped course of the north-bank tributaries of the Ganges where they leave the belt of Siwalik deposits.

Briefly, the hypotheses that I desire to bring forward may be summarized as follows:—

(i) That in Eocene times a gulf extended from Sind northwards as far as Afghanistan, and thence curved eastwards and south-eastwards through Kohat and the Punjab to the neighbourhood of Naini Tal.

(ii) That this gulf gave place to a great river, the head-waters of which consisted of the portion of the Brahmaputra flowing through Assam. This river flowed westwards and north-westwards along the foot of the Himalaya as far as the North-West Punjab, where it turned southwards along a line not very different from that of the modern Indus, and emptied itself into the Arabian Sea. In other words, the Assam Brahmaputra was once the head-waters of the Indus.

(iii) That two separate rivers or two branches of the same river, debouching into the Bay of Bengal, cut back and beheaded this old Indus, the eastern capturing the Assam portion to form the Brahmaputra, and the western capturing gradually piece by piece the portion that intervenes between Assam and the present Jamna.

(iv) That in the meantime this old river was being still further reduced by the piecemeal capture of the portion lying between the Jamna and the Jhilam by its own tributaries, the Jhilam, the Chinab, the Ravi, the Beas, the Sutlej, and the Ghaggar.

(v) That the Attock part of the present Indus was a tributary of this old river, which at a comparatively early period cut its way back into Kashmir, where it captured the upper waters of a large river that flowed north-westwards, and either found its way into the Oxus, or curved south-westwards into Eastern Afghanistan.

The second hypothesis seems to me to be adumbrated in the second edition of the 'Manual of the Geology of India' 1893 (p. 444) by Mr. R. D. Oldham, who concludes that there are good rounds for supposing that

'the great bulk of the Himalayan drainage once found its way to the sea by a single delta, instead of two, and this must have been either at the head of the Arabian Sea, or of the Bay of Bengal.'

He then goes on to say that

'the indications of the sea having extended up the Indus valley within the recent period, and the absence of any similar indications in the delta of the Ganges, make it probable that the former was the original outlet of the drainage, and that the formation of the gap between the Rajmahal and the Garo Hills, and of the Gangetic delta, is geologically of recent date.'

[1] This paper has since been published in Journ. Asiat. Soc. Bengal, n. s. vol. xv (1919) pp. 86–99.

To facilitate reference, I propose to call the ancient river which, it is postulated, rose in Assam and flowed into the Arabian Sea, the 'Indobrahm.' Any particular portion of it will be referred to under the name that it now bears and the area through which it runs: for instance, the Assam Brahmaputra or the Kohat Indus.

As the river in question was a result of earth-movements which took place in Tertiary times, it will be advisable to begin by glancing at the general topography of late-Cretaceous India. According to Dr. Hayden's description[1] there occurred towards the close of the Cretaceous Period a great invasion of Tibet by the sea of Western India. This sea, the Tethys, which was continuous with the Mediterranean through Afghanistan, Baluchistan, Persia, and North Africa, covered the southern and central parts of Tibet and the northern part of the present Himalaya, and reached as far as what is now the northern border of Sikkim. To the south of this sea lay the remains of the great Gondwana continent, of which peninsular India formed a part; south of that continent was another sea, one arm of which projected northwards over parts of Burma and Assam, while another indentation foreshadowed the Arabian Sea. At the beginning of Eocene times the Himalayan folding movement from the north, the Baluchistan movement from the north-west, and the Shan movement in Burma from the east, commenced to assume serious intensity.[2] The hard rigid body of

[1] S. G. Burrard & H. H. Hayden, 'A Sketch of the Geography & Geology of the Himalaya Mountains & Tibet' 1907–1908, p. 254.

[2] It is assumed that isostatic tumefaction, which was primarily responsible for the upheaval, enabled the pressure—due to whatever cause—to plicate the strata and play its part in the piling-up of the mountain-range. The direction of movement in a fold, as Mr. Oldham points out (Mem. Geol. Surv. Ind. vol. xlii, 1917, p. [282]), is a purely relative matter, one side being thrust over and the other under, in opposite directions. But the uniform consistency with which all the mountain-arcs produced by this disturbance face the same way, suggests that the folding movement, so far as the surface-rocks are concerned, was stronger in the direction of their convexities than in the opposite direction. The piling-up of the water in a circular ripple produced by the dropping of a stone therein is the result not only of pressure from the centre, but also of a resistance toward the centre. By suitable mechanical means a similar ripple could be produced by a centripetal impulse. The former kind of ripple is, however, so much more easily produced, and so much more commonly observed, that, when we meet with anything in Nature resembling a ripple, it seems natural to imagine that it is the result of a centrifugal impulse. Whatever their nature may be, it is convenient to assume that resultant movements, or impulses (as they might more aptly be termed) took place in that direction towards which the great mountain-arcs are convex. Even if we adopt this assumption, the direction of a movement is necessarily referred to in this paper in a somewhat loose way. For instance, the movement which produced the Afghanistan-Baluchistan-Persian arc system as a whole came from the north; but the component affecting Afghanistan and Eastern Baluchistan may be considered as coming generally from the north-west. Local components acted from the west, or from the north, or even from the north-east.

Gondwanaland was not conspicuously affected by this compression, but its northern margin, in an isostatic readjustment, gave way before it. Along this buckling margin, as the pressure continued, the rocks were thrust and piled to form the preliminary Himalayan chain. The greatest intensity of this impulse was, however, subsequent to the Eocene Period. This we know from the great height to which marine Eocene beds have been thrust in parts of Kashmir, for Mr. T. H. D. La Touche found nummulite-bearing strata at 18,500 feet above present sea-level in the Zanskar Range.[1] Considerable movement has taken place since the Pleistocene Period, and it is in fact more than probable that such movement is still proceeding.

An accompaniment of this intense plication and accumulative mountain-building along the northern fringe of the old continent was the production of a long belt of persistent subsidence between the mountain-range and the more central tract of the continent. The persistence of the subsidence is explained on the theory of isostasy, and was assisted by the weight of the accumulating sediments.[2] This vast trough, in which the Tertiary and Quaternary deposits were laid down, is bounded on the north by reversed faults, and may be looked upon as a faulted geosyncline, of which the southern slope, according to Mr. R. D. Oldham's convincing analysis of geodetic data, is a very long and gentle one, while the northern is steep and short.[3] It is doubtful whether this trough was appreciable before the Eocene Period, since when it has become increasingly deeper, being filled up simultaneously with accumulating sediments, until to-day its calculated depth, deduced from geodetic abnormalities, is between 15,000 and 20,000 feet.[4] It stretches from Assam to the Punjab, and in its earlier stage would have formed a natural hydrographic line. There is reason to believe that a similar trough exists along the north-and-south line of the Lower Indus. Speaking of these two great depressions, so far as their alluvial contents are concerned, Mr. Oldham says:—

'There is no reason to suppose that the two troughs are connected. Apart from the [geodetic] observations, . . . the outcrops of old rocks in the Chiniot, and other, hills which rise from the alluvium, point to the presence of a rock-barrier, stretching under the plains of the Punjab to the Salt Range and separating the two deep troughs.' (*Op. jam cit.* p. [246].)

In this great re-entrant between the Himalaya and the Afghan mountains the buckling effect which produced the two troughs seems to have dissipated itself over a much wider area, and generated, not one single connecting trough, but several shallow sub-troughs one after the other, the earlier perhaps nearer the mountains and the later more remote. As will be shown, the hydrographic line has been pushed in stages steadily towards the centre of India. Along the Himalaya, and to a less known extent along the Baluchistan Hills, these stages, we are supposing, were short and

[1] Rec. Geol. Surv. Ind. vol. xxiii (1890) p. 67.
[2] Mem. Geol. Surv. Ind. vol. xlii (1917) p. [270].
[3] *Ibid.* p. [243].
[4] *Ibid.* p. [230].

the trough deep; but in the central Punjab they were long, and the trough-area wide, shallow, and split up into a number of sub-troughs, the total breadth from Cherat to the Ghaggar channel being 300 miles. The Murree zone, the Siwalik zone of the Soan valley, and perhaps the Jhilam, Chinab, Ravi, Sutlej, and Ghaggar valleys are all sub-troughs or elements of this attenuated compound trough.

It has been established by Medlicott, Middlemiss, and others that the Tertiary foothills of the Himalaya are divisible into parallel zones separated one from the other by successive 'boundary-faults'—dislocations of a reversed nature—each of which forms a close approximate boundary of deposition as regards the zone whose northern boundary it constitutes. In other words, these 'boundary-faults' mark the northern shore of the Tertiary sea or the northern permanent bank of any longitudinal Tertiary river; north of each 'fault,' at the time of its formation, was land, drained by mountain-streams which have left little or no deposit within the mountain-area, but brought down large quantities of silt on to the plain below. In the Hazara mountains of the Northern Punjab Mr. Middlemiss showed that there were three of these faults dividing the area into four more or less defined zones, and another farther south shutting off a fifth somewhat less defined sub-zone, the Murree sub-zone.[1]

The southernmost of his Hazara zones Mr. Middlemiss called 'the Nummulitic zone,' since it consisted mostly of these rocks; its northern boundary-fault is the limiting line of their deposition, with the exception of a considerable patch of Nummulitic Limestone east of Abbottabad, which, however, is itself cut off by another 'boundary-fault' on the north-west. This Nummulitic zone it is now proposed to trace, before we attempt to reconstruct the sequence of events attending the birth and life of the Indo-brahm. From a glance at a geological map (Pl. X) it will be seen that there is a continuous outcrop of Nummulitic beds extending from the Hazara hills through Kohat, Waziristan, and Baluchistan to the Sind coast. East of Hazara in the Jammu hills Nummulitic rocks again appear. Some unfossiliferous strata marked as doubtful Trias or Carboniferous by Lydekker (the Kiol beds), along the main boundary-fault of this area, I would also include with the Nummulities. Farther south-east there is a gap until the Nummulities of Simla are reached, and another until we come to a very thin interrupted band between Dehra Dun and Naini Tal.[2] The Simla and Dehra Dun Nummulities consist of marine beds, and what is probably a mixture of fluviatile and salt-lake deposits. Similar alternations of lagoon and freshwater beds compose most of the upper stage of the Nummulities of the Northern Punjab, and to a varied extent are seen among the rest of the Nummulitic belt from Kohat to Sind. But, since in every

[1] Mem. Geol. Surv. Ind. vol. xxvi (1896) p. 260.
[2] Further work may show these gaps to be shorter or non-existent.

locality nummulites are found at some horizon or other, it is unquestionable that marine conditions existed at all these localities at some time or other during the Nummulitic epoch. In the Lower Nummulities of the Punjab are great thicknesses of massive Nummulitic limestone, and similar beds are found in the Salt Range, Kohat, the Afghan border, Baluchistan, and Sind. Now, the northern boundary of the Hazara Nummulities we have found to be a boundary-fault or shore-line—a shore-line with an indentation east of Abbottabad, caused apparently by the obstructive stress at the Jhilam syntactical point,—and this feature has been traced westwards to the neighbourhood of Cherât. Farther west and south-west are large blanks in the geological map, but the isolated mapped areas all seem to point to a land-barrier on this side of the Nummulitic band. The rocks of Kabul belong to the ancient systems, and that there was ever connexion between the Nummulities of Northern Afghanistan and those of the Punjab across Kabul is, I think, unlikely. The Nummulities of Ladak in Kashmir, which include marine beds, were thought by Lydekker to belong to a separate basin of deposition, and it seems very unlikely that they were ever continuous across the enormous ranges separating them from the Jammu and Punjab Nummulitic, especially in face of the boundary nature of the fault alluded to. The occurrence at 18,500 feet in Zanskar is not more than 15 miles distant from the Ladak outcrop, while the occurrence in Hundes (Ngari Khorsum) is on the same general line of strike; both evidently belong to the Ladak exposure. Land was, therefore, probably continuous from Eastern Afghanistan through Kohistan and Kashmir, and along the line of the Himalaya as far as Naini Tal, where the Nummulities appear to end. The Nummulities of the Garo Hills belong to another basin: namely, the gulf which extended up from Arakan through Hallong towards Upper Assam. From the Kabul area, if we judge from the strike of the beds and the topographical features, the land-barrier probably extended to Kandahar and perhaps as far as Chagai, both of which areas have been mapped in part.

With regard to the southern boundary of the Nummulitic sea, this must be placed parallel to, and somewhere beneath, the alluvial trough along the Himalayan foot. Numerous portions of the old Gondwana continent project through the Alluvium as far north as Delhi and as far north-west as Pokaran and Bhachbar in Rajputana; but there are some small isolated inliers of Purana rocks cropping out at Chiniot, Sagla, and the Kirana Hills within 25 miles of the Salt Range. The southern coast-line may be drawn, therefore, a little north of these hills, 100 miles or so distant from the northern coast-line, approaching by degrees more closely to the latter in the direction of Simla, and meeting it in the vicinity of Naini Tal, where the Nummulities are very thin. The Nummulities were thus laid down in a narrow arm of the sea, or gulf. Restoring in our mind's eye the mountain-ares to the less advanced position that they held in Nummulitic times, and obliterating or

reducing the syntactical angles which separate these ares, we can trace this gulf from Baluchistan and Sind to Eastern Afghanistan, curving eastwards thence through the Punjab along the foot of the Himalaya as far as Naini Tal. The interruption of the outcrop between the Jammu hills and Simla, and between the latter place and Dehra Dun, must be attributed to overlap, unconformity, or faulting; but that the beds were continuous is obvious from the occurrence of nummulites in the Naini Tal Nummulities, showing a connexion with the open sea. The Nummulitic outcrops of Bikaner and Jaisalmer may belong to the main gulf, or may indicate a small branch of it.

The Himalayan, Afghan, and Baluchistan movements, therefore, during the Nummulitic epoch drove the old Cretaceous sea westwards, Tibet and the whole of the Himalaya (with the exception of the Ladak valley) becoming dry land. They, however, assisted in producing a depression along the base of the continuous series of mountain-ares, forming a gulf in which a constant struggle took place between the deposition of silt tending to fill up the gulf, and the general subsidence tending to deepen it. Sometimes the silting action prevailed to such an extent as to cut off land-locked salt lagoons; this process was assisted by a corrugating action, by which the floor of the gulf was folded into small anticlines and synclines, an effect quite apart from the general depression of the whole as a geosyncline, or geosynclinorium as it would be more aptly termed in places. Much of the Kumaon and Simla Nummulitic, as well as most of the Upper Nummulitic of the Potwar and Hazara, was presumably deposited in such salt-lakes and lagoons. It is, in fact, possible that at times the gulf, as a whole, was cut off from the sea. East of Naini Tal the hydrographic line was probably continued by a river draining westwards into the lagoons, the lagoons coalescing into a marine gulf once more for a short time at the end of the Nummulitic epoch. It is not proposed here to trace the oscillations which took place locally between marine and lacustrine or fluviatile conditions; but there came a time when, from Simla to the Shirani Hills, and also farther south, these oscillations ceased, and one type of deposit only was laid down to form the great Murree Series.

In the Simla area the Murrees are represented by the Dagshais below and the Kasaulis above. The latter resemble the overlying fluviatile Siwaliks, while it has been suggested that the former were deposited in salt-lakes and lagoons. Farther west there is no definite line between Upper and Lower Murrees, the one passing up into the other. The Lower are like the Dagshais, and very similar to the red clays of the Upper Nummulities of the same area and of the Simla Subathus, for which I have proposed a similar origin; the only alternative is to regard them as fluviatile deposits. The Upper Murrees resemble a mixture of Dagshais and Kasaulis. These Murree beds have been traced through Kohat and Waziristan, but were not identified in the Shirani Hills farther south. South-west of Dera Ismail Khan, Lower Murrees (Upper Naris),

have been recognized, and are practically continuous to Sind, where they appear to be fluviatile. It is quite possible that a search for vertebrate remains in the Shirani Hills may demonstrate the presence of Murree beds, and so bridge the supposed gap in the belt of these deposits. We may then postulate either a river already established from east of Naini Tal to Sind, or, following the suggestion made above, a series of lakes and lagoons extending from Simla to the Shirani Hills, into which flowed a river from the direction of Assam, the precursor of the Brahmaputra. At the other end these lagoons were drained by a river flowing through Sind, the precursor of the Indus. Finally, towards the end of the Murree epoch, the whole line of lagoons and lakes were drained, and gave place to a river. The river connecting the old lake-system with the Arabian Sea was meanwhile submerged to form an estuary, in which were deposited the Gaj Beds of Sind. This estuary finally silted up, and at the beginning of the Siwalik epoch the whole geosynclinal line of depression was, according to the hypothesis that I am advancing, occupied by a river, the Indobrahm, rising probably in Assam, flowing north-westwards along the foot of the Himalaya, from which it received numerous silt-carrying tributaries, and emptying itself into the Arabian Sea, which at that time covered part of Sind. More will be known regarding the distance to which it extended eastwards, when the Assam Siwaliks have received more attention; but the Himalayan movements must have produced similar effects at this end of the chain, and it seems justifiable to deduce a continuation into Assam of the hydrographic line and, to some extent at least, of the trough. Mr. Oldham gives no geodetic evidence of the latter; there seems to be a slight sub-alluvial barrier between the Garo Hills and Bhutan, perhaps like that which slightly interrupts the Punjab trough as the sub-alluvial prolongation of the Aravali ridge north-east of Delhi.[1] The proximity to the Shan fold-system would explain such interferences in Assam.

Throughout the whole of the Murree epoch the buckling movement persisted, and the continued depression accompanying it permitted of the accumulation of a great thickness of sediments. This depression seems, in the Murree epoch, to have reached a maximum in the neighbourhood of the obstructive or syntactical point of Mozuffarabad, for the Murree beds are here not much less than 8000 feet thick. Another effect of the persistent movement from Eocene to Recent times was to push the hydrographic line farther southwards in the Himalayan section, and farther eastwards in the Baluchistan section. This process was assisted by the great excess of silt brought down by the drainage of the mountainous region on the north and west, over that contributed by the drainage of the land on the peninsular side. This retreat of the hydrographic line is especially marked in the large re-entrant

[1] Mem. Geol. Surv. Ind. vol. xlii (1917) pp. [243] & [245].

of the Punjab and the North-West Frontier, where the first stage was its transference from the Murree zone southwards to the Soan valley or Siwalik zone. In post-Tertiary times, as we shall see, this line was pushed still farther towards the peninsula. The relationship of the Zhob-Valley Tertiaries in Baluchistan awaits further investigation.

The Siwalik Indobrahm, therefore, rose probably in Assam, flowed along the southern border of Bhutan, traversed the northern angle of Bengal below Darjiling, skirted the southern margins of Nepal and Kumaon, proceeded north-westwards through Dehra Dun and the Sirmur State, up through the Kangra district into Jammu, thence along the Soan valley south of Rawalpindi, past Makhad, across Kohat to the Bannu plain, where it turned south past the Shirani Hills and Bugti Hills, debouching ultimately into the Sind estuary, which silted up in later Siwalik times. On its right bank it received young vigorous tributaries born in the Tertiary Era; on its left bank it received as tributaries the relics of very ancient rivers which drained Gondwanaland, such as the Son, the Chambal and its branches, and others. The Punjab Soan, as indicated above, is to be regarded as a relic of the old Tertiary Indobrahm, and is in conspicuously puny proportion to the great thickness and extent of the Tertiary fluviatile sediments through which it flows. The reasons for believing in the presence of this Siwalik river may now be enumerated:—

(1) A marine gulf originally occupied most of the same line, and during the silting process the oil and coal of this region were produced and gypsum was deposited; this hydrocarbon, coal, and gypsum belt follows the Nummulitic outcrop from Kumaon to the Mekran coast. Such a filled-up gulf is naturally followed by a river—for instance, the Burma gulf by the Irrawadi, or the Mesopotamian gulf by the Tigris and Euphrates,—which would be pushed farther towards the centre of the peninsula by the persistent movement.

(2) The supposition that the Siwalik deposits were laid down as enormous talus-fans by the mountain-streams which issued into the plain, has always been difficult to accept in view of the great thickness of the deposits—for they average over 16,000 feet—and their great extent. An almost unbroken belt of these beds can be traced, usually in great thickness, from Assam to the Soan valley and thence to Baluchistan, bounded externally by continuous mountain country consisting, where known, of igneous and very ancient rocks, with or without an intervening belt of Murree rocks. It seems far more reasonable to deduce a single river rather than a number of transverse streams. The mountain-streams, in any case, must have had an outlet to the sea in one direction or the other, and must have joined a main river in the plains.

(3) There are no grounds for assuming that the northward-flowing drainage of the old Gondwana continent was reversed in Siwalik times. In fact, the depression of the trough would have invigorated this drainage, which, it is highly probable, persists to this day. It seems almost certain, therefore, that this northerly drainage must have met the southerly Himalayan drainage in a large river flowing either south-eastwards or north-westwards. Since the Siwalik outcrop is not continuous to the sea south-eastwards, but is practically continuous north-westwards and subsequently southwards along the line of an old gulf, it seems reasonable to assume that the river followed this direction.

(4) This Siwalik belt is succeeded on the side towards the peninsula, and remote from the mountain-building, by a similar and even thicker belt of recent river-deposits, to be mentioned later.

(5) Many of the streams draining the Himalaya have north-westward pointing V's in their course where they cross the Tertiary foothills, or where they enter the plain. These are thought to indicate, according to Dr. Pilgrim's suggestion, a former north-westward-flowing main river, of which these streams were tributaries (see below).

(6) The similarity of the river-fauna in the Ganges and in the Indus points to a connexion best explained on the assumption of a large main river uniting what are now the Ganges and Indus basins (see below).

(7) The similarity in nature and strike between the Shillong Plateau and the northern region of the Indian peninsula makes it probable that they represent what was once a continuous feature, the flank of a long river-valley. It is this continuity of the physiographical and geological features along this line from Assam to the Punjab that is so striking. There is a continuous regular mountain-arc of ancient rocks on the north; there is a parallel upland of similar ancient rocks on the south, continuous beneath the presumably shallow gap between the Rajmahal and Garo Hills; between this mountain arc and the upland is a continuous outcrop of Alluvium of great maximum thickness, occupying a continuous trough, and succeeding what there is no reason to doubt is a continuous Tertiary river deposit. The sub-alluvial barrier deduced north-north-east of Delhi interrupted neither the continuity of the Siwalik deposits nor that of the Alluvium. There is no rock-barrier in the plains at the present day between the basins of the Indus and the Ganges, the watershed being a scarcely perceptible one.

(8) The two hypotheses of single westward-flowing rivers flanking the Himalayas throughout their length, one on the Indian side and one on the Tibetan side, mutually support each other, and are strengthened by the curious parallelism between the histories of these two hydrographic lines (see below).

The Siwalik Indobrahm either extended back into Assam from the beginning, or very soon cut its way back into that province. There is a short break in the continuity of the Siwalik exposure south of Darjiling, a result possibly of excessive exposure to the south-south-westerly monsoon sweeping through the Rajmahal-Garo Hills gap and causing a transgression of the Alluvium northwards sufficient to overlap locally the Siwaliks; the latter are, in all probability, continuous beneath the Alluvium. Eastwards Siwalik beds are seen fringing the plain up to the extreme point of the Assam valley. A glance at a geological map will show that the Shillong Plateau appears as an interrupted extension of Bihar, and consists of much the same kind of rocks (Pl. X). It is, in fact, part of the more central tract of the old Gondwana continent of which peninsular India consists, and geodetic observations confirm the surmise that the intervening alluvial gap made by the Ganges and Brahmaputra is of no great depth. That is to say, the southern boundary of the great trough already mentioned extends beneath this gap, and continues as the Shillong Plateau and the Mikir Hills in Assam. It seems highly probable, therefore, that the Siwalik Indobrahm extended back between Bhutan and the Shillong Plateau into Upper Assam. Here it must have come into conflict with another river which at that time flowed south-

westwards between the Shillong Plateau and Mikir Hills on the one side and the Naga Hills on the other, over what is now the hill-section of the Assam-Bengal Railway, into the Bay of Bengal. The present Meghna may be the remains of this river, which seems to have been beheaded by the Indobrahm. From the size of the Siwalik deposits in this railway hill-section, this old Meghna appears to have been a river of some magnitude, and may possibly have derived its importance from the capture of the Tsangpo, now the Tibetan part of the Brahmaputra. The Tsangpo was then much shorter than it is now, and did not reach far into Tibet; it is thought to have formed at that time the head-waters of the Irrawadi, connected therewith by what is now a tributary of the latter, the Chindwin.[1] The upper waters of the Tsangpo-Meghna were then apparently captured in turn by the Indobrahm. The Kapili tributary of the Brahmaputra seems to have cut back at some time between the Mikir Hills and the Shillong Plateau and captured a part of the Meghna, but whether this capture was effected before that made by the Indobrahm is not clear. Whether the Chindwin-Irrawadi or the Meghna were intermediaries or not, the Indobrahm—or Brahmaputra, as it may then have become—eventually captured the head-waters of a Tibetan river, the history of which is a curious one.

Sir S. G. Burrard & Dr. Hayden have pointed out the strange backward direction of many of the present Tsangpo tributaries, which is explained by the assumption that they originally fed a westward and not an eastward flowing river:—

> 'The most recent maps show that shortly before their junctions with the Brahmaputra, these tributaries are beginning to bend in their courses, and to turn towards the present direction of the Brahmaputra's flow.'[2]

The most important tributaries having a backward directed course are the Kyi or Lhasa, the Nyang, the Rang, and the Shang, but there are many smaller ones that exhibit the same peculiarity. The eastern end of the Himalayan chain is supposed to have begun to rise earlier than the western. This would initiate in early Tertiary times not only the Indobrahm line, but also another line of drainage in the same direction on the Tibetan side. Sir S. G. Burrard & Dr. Hayden suggest three hypotheses worthy of consideration, regarding the former outlet of this old westward-flowing Tibetan river:—

(*a*) It may have flowed over the Photu Pass and through the defile of the Kali Gandak on to the Ganges plain;
(*b*) It may have passed through the basin of the Karnali with a similar destination; or
(*c*) It may have followed the present Himalayan course of either the Sutlej or the Indus.

[1] Until it was shown to be otherwise, the old Chinese surveyors believed that the Tsangpo of Tibet still flowed into the Irrawadi (S. G. Burrard & H. H. Hayden, 'A Sketch of the Geography & Geology of the Himalaya Mountains & Tibet' 1907–1908, p. 157).

[2] *Op. jam cit.* pp. 155–56.

It is perhaps idle to speculate far in this direction, but the following considerations are worthy of some attention. An examination of the map will show an interrupted hydrographic line from Pemakoi to Gilgit, represented at the present day by the Tsangpo (perhaps including the Raga tributary and a small branch of the Chaktak), the Manasarowar Lakes, the uppermost reaches of the Sutlej, the Indus along its Gartang channel and its tributary the Shyok, as far as Gilgit, and perhaps the Gilgit River beyond. It seems more than likely that this line was once a continuous drainage-line sloping westwards, and occupying either a geosyncline or a line of easy denudation, such as a belt of softer beds or a fault. The marine and fluviatile Nummulities of Ladak belong to this line, corresponding in position to the Nummulities of the hydrographic line on the other side of the Himalaya, and indicating that the Tibetan line is as old as the Indian. The Pleistocene of the uppermost reach of the Sutlej also belongs to it. Eventually, there is reason to believe, the Tibetan line was occupied by a river which rose somewhere in or near Pemakoi, and either joined the Oxus, or found its way to the Arabian Sea, independently or by way of the Indobrahm. At the present day the Indus at Bunji, where it abandons its north-westward course and turns southwards, is 3400 feet lower than the Tsangpo-Brahmaputra where it leaves the same geotectonic line.[1] From Mayum, a town above Lake Ukrang east of the Manasarowar Lakes, to Bunji, the average westward gradient is twice as steep as it is from Mayum eastwards to the point where the present Tsangpo turns southwards. In spite of its immense elevation the Tsangpo is a sluggish and navigable river south of Lhasa, and has cut no deep basin for itself in Tibet. The Indus, on the other hand, has cut its bed to a low level on the Tibetan Plateau, the fall in this part of its course being hardly more than 3 feet in a mile; across the Himalaya it has a remarkably equable and comparatively gentle fall.[2] Without attempting to guess the order in which events occurred, there are reasons for deducing:—

(1) That this Tibetan River flowed westwards and north-westwards from Pemakoi to Gilgit.

(2) That its uppermost waters were captured, possibly in turn by the Irrawadi-Chindwin and the Meghna, but finally by the Indobrahm or Brahmaputra, the capturing river at once beginning to cut back up one of its own small tributaries westwards along the already excavated channel of the old Tibetan River, capturing this channel piece by piece and its tributaries one by one, and completely reversing its drainage.

(3) That, perhaps before this struggle had proceeded far, the Kali Gandak may have captured the upper part of the Tibetan River, and have thus been enabled to scoop out the extraordinary depression of the Photu Pass, which is only 250 feet higher than the Tsangpo plains.[3]

(4) That the Sutlej effected a similar capture, part of the captured river still existing as the uppermost reaches of the Sutlej; and that the dwindling

[1] S. G. Burrard & H. H. Hayden, *op. jam cit.* p. 171.
[2] *Ibid.* p. 171.
[3] *Ibid.* pp. 147 & 155.

of the portion captured by the Sutlej, due to the advance westwards of the invading Tsangpo, is perhaps responsible for the insignificance of the present stream at the bottom of the deep cañons cut in the thick alluvial valley of Ngari Khorsum.

(5) That the Attock tributary of the Indobrahm, perhaps at an early date, captured the Tibetan River in Gilgit.

It will be seen that the parallelism between the old Tibetan River and the Himalayan part of the Indobrahm is not confined to their position and direction, but also applies to their age, origin, and history. They both appear to have supplanted marine gulfs along the western part of their courses at the same period; both seem to have been the result of the Himalayan movement, to which their courses are at right angles; in both cases the eastern half of the stream has been completely reversed in direction by capture on the part of an invading river.

As an indication of a north-westward-flowing main river along the Himalayan foot, Dr. Pilgrim cites the local V-shaped course of many of the present rivers from the mountains as they cross the Siwalik belt, the angle of the V pointing north-westwards and occurring usually close to the boundary-line between the Siwaliks and the Alluvium. The northern limb of each V may be regarded as the remnant of a right-bank Indobrahm tributary, which has persisted in its old westerly direction, and has become more deeply impressed and permanent owing to the upheaval of the Siwalik deposits over which it flows. The southern limb of the V would represent the final position which the capturing stream has taken up: for, if the deduction that the actual capture happened subsequent to Siwalik times be correct, it must have taken place within the outcrop of the Alluvial belt—that is to say, the point of the V at the time of capture was west of where it now is, but has since worked eastwards until it met the more stable topography of the Siwalik belt, where its regression was in most cases held up. Figs. 1–4 (pp. 150–51) illustrate this point in some of the larger rivers, showing the general westward course through the Siwalik belt and the more southerly tendency in the Alluvium; the Sutlej seems to be an exception, unless the point of the V has worked back into the centre of the Siwalik belt.[1]

At the close of the Siwalik and during the Recent period the left-bank affluents of the lower Indobrahm, the Jhilam, Chinab, Ravi, Beas, Sutlej, and Ghaggar (assisted perhaps by the continued earth-movements) cut back across the plains of the Punjab in a north-easterly direction, and captured various portions of the Indobrahm, perhaps approximately in the order named: not only because the distances to be cut back were in the same order, but also because the suggested geosynclines along which these rivers cut would probably be initiated in this order. Whatever the precise order was, the Ghaggar must have become

[1] The higher parts of the courses of these mountain rivers—the portions traversing the older pre-Tertiary rocks—are not relevant to this question.

Fig. 1.

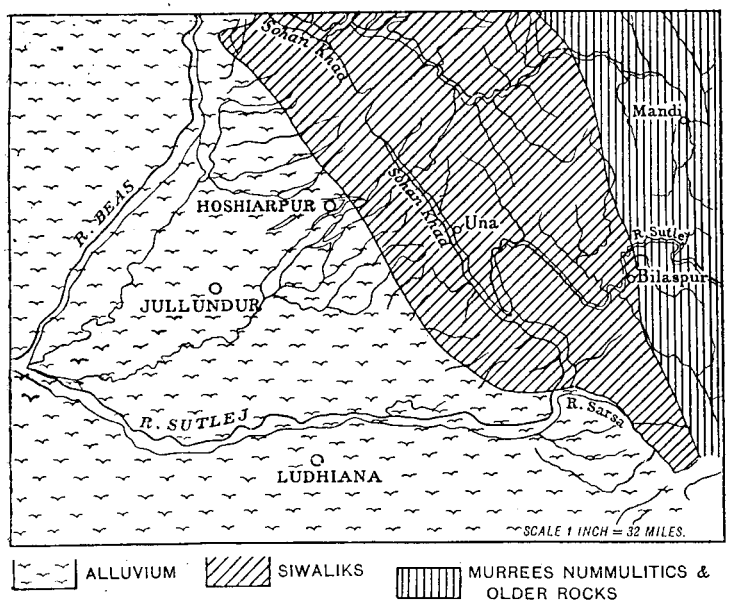
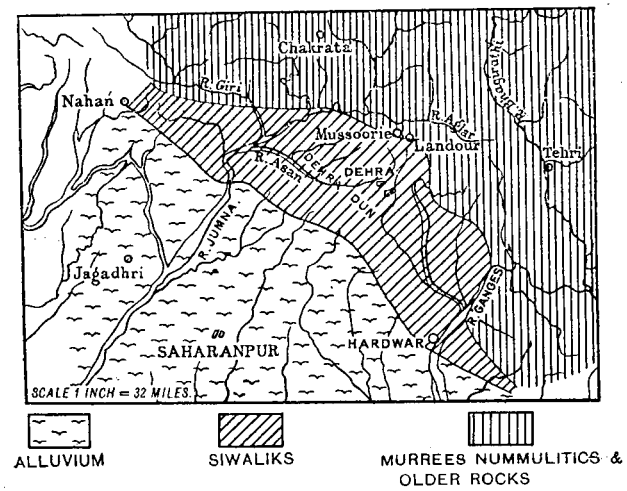


Fig. 2.



the final channel of the river.[1] The Upper Jhilam has the appearance of having been beheaded by the Chinab, and of having lost the importance commensurate with its valley. After the Lower Jhilam had captured the Indobrahm, what is now the

Fig. 3.

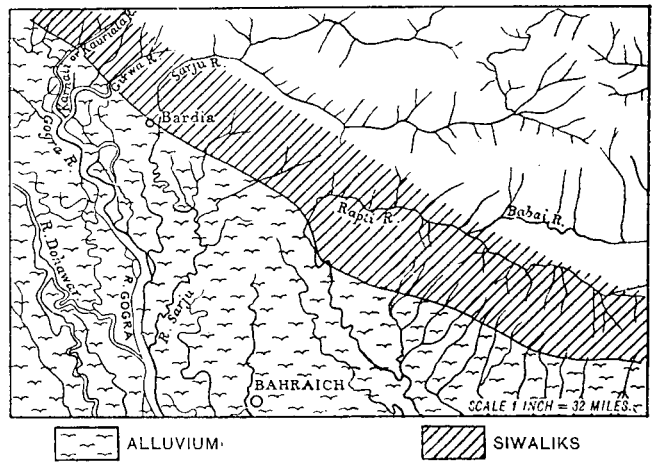
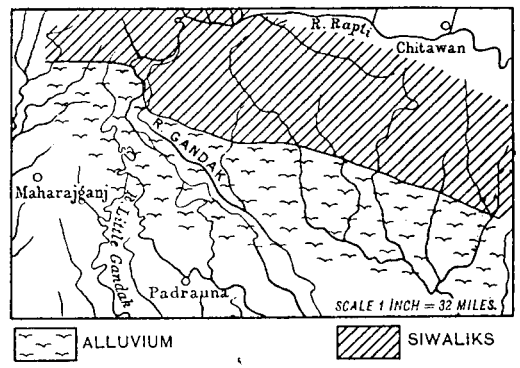


Fig. 4.



[1] The anastomosis of these Punjab rivers is and probably has been a fluctuating factor, so that the actual number of tributaries which commenced to cut back from the main river across the Punjab and Rajputana along supposed geosynclines, is a matter of pure speculation. The tributaries branched, and the geosynclines may have done the same; but their present parallelism and the general equality of their distances apart suggest that the number of these tributaries, half-way across, was five or perhaps six: four of them remain, one is a dry channel, and if a sixth ever existed farther south, no trace of it has been recorded.

Upper Jhilam must have formed a continuous tributary with the Soan, and this river was doubtless responsible for the gravels and alluvial deposits of the Soan valley, since these are rather more considerable than they would be had they been entirely due to the modern Soan. The upper part of this tributary was subsequently captured by the Lower Jhilam, and the Soan reduced to what it is at the present day.

The buckling trough-forming movement still went on during the Recent period, and enormous masses of sediment, estimated at something between 15,000 and 20,000 feet in thickness, were concentrated in this way in the central parts of the Indobrahm valley; in the lower waters deposition is thought to have been more diffuse. Across the central Punjab and Rajputana there was perhaps more than one geosyncline produced, and the deposition of sediment much less concentrated and still more widely dispersed.

While the Punjab rivers were cutting back and seizing the middle waters of the Indobrahm, its upper course was being captured, either by two branches of the same river, or by two separate rivers draining Bengal and flowing southwards into the Bay. One of these was the Jamuna or Bengal part of the Brahmaputra, and the other either a tributary of this river or a separate stream, the Ganges. These rivers present the appearance of having been initiated by the continuation northwards of the broad geosyncline of the Bay of Bengal. There is, in fact, evidence from boreholes that the deltaic area is still an area of depression. This geosyncline, the result of the Shan movement from the east, may even have been perceptible as far north as the barrier of ancient rocks which connected the Rajmahal with the Garo Hills. Perhaps with the assistance of this geosyncline, perhaps with the assistance of faults, both streams cut back through this barrier. The Jamuna captured the whole of the upper part of the Indobrahm from Dhubri upwards, and became the modern Brahmaputra. The Ganges cut back in a west-north-westerly direction, capturing element by element the succeeding portion of the Indobrahm as far as Hardwar, where the Alaknanda was captured, the Jamna at that time being the head-waters of the Ghaggar (see below). The voluminous waters of the Indobrahm having been tapped in this way, the scouring of a broad gap through the barrier was an easy matter, and the sediments derived therefrom were flung by the flood into the Bay to form the enormous delta of the Ganges and Brahmaputra. I have stated a definite case for the sake of clearness—obviously there are equally valid alternatives. It may, for instance, have been a single river which cut through the barrier, beheaded the Indobrahm, and became the Brahmaputra, the Ganges originating north of the gap as a right-bank tributary and cutting back north-westwards in the way described, the confluence subsequently retreating southwards through the gap.

The history of the Jamna may be deduced as follows. The Alaknanda, with perhaps the Bhagirathi, having been captured by

the Ganges, the present Upper Jamna and the Ghaggar or Saraswati formed a continuous single river, which probably at that date received the Sutlej also[1]; the course of this old channel can still be traced across Rajputana to the Indus, and is variously known as the Ghaggar, Hakra, or Wandan. The persistence of this river till historic times would, as noticed by James Fergusson,[2] account for the old Vedic tradition that the Saraswati was the 'chief and purest of rivers flowing from the mountains to the sea.' After the Ganges captured the eastern branch of its head-waters by means of the Lower Jamna, and the old Beas captured the western branch (that is, the Sutlej) the Saraswati became a small stream which soon lost itself in the desert of Rajputana, the greater part of its channel remaining as the dry Ghaggar or Hakra. This was the last element of the Indus captured by the Ganges, the change probably dating from historic times; in this way, as Mr. Oldham notices, the Hindu legend that it is the Saraswati which joins the Ganges at Prayag or Allahabad is founded on fact.[3] Whether there will be further invasion of the Indus basin by the Ganges is an interesting matter for speculation. There is no intervening rock-barrier to prevent it, the watershed between the two river-systems being scarcely perceptible in the plains. Geodetic figures indicate a slight rise in the floor of the sub-alluvial trough below and a little south-east of the watershed; but this apparently did not interrupt the longitudinal drainage, since the Siwalik and alluvial belts are both continuous across it. The capture of the Jamna shows that the Ganges still has an advantage in youth and vigour over the rivers of the present Indus system, and it seems not unlikely that, if not artificially controlled, it will be able to cut back farther north-westwards parallel to the trough—especially if the latter is still being deepened—and make further captures.

Mr. Oldham remarks on the suggestiveness of the fact that, in two cases where rivers have taken a different course, namely, the Saraswati into the Ganges instead of to the Indus, and the Lower Brahmaputra from its old Mymensingh course to a more westerly one, the new channel formed has been termed the Jamuna or Jamna. There is another Jamuna in Assam flowing westwards through the southern angle of the Mikir Hills into the Kapili River, a tributary of the Brahmaputra. Its history is not quite clear, but the Kapili (or Kalang, as the main affluent is called) cut back between the Mikir Hills and the Shillong Plateau, past Lumding, and may have captured part of the old reduced Meghna, after which it is possible that the Jamuna cut back farther north through a low gap in the Mikir Hills, and snatched the Meghna head-waters from the Kapili. This portion of the old Meghna valley is now drained by the Dhansiri in the reverse direction.

[1] See R. D. Oldham, 'Probable Changes in the Geography of the Punjab & its Rivers' Journ. Asiat. Soc. Bengal, vol. lv (1886) p. 322.

[2] Q. J. G. S. vol. xix (1863) p. 348.

[3] 'Manual of the Geology of India' 2nd ed. (1893) p. 450.

Mr. Sethu Rama Rau informs me that Jamna or Jamuna in Sanskrit means 'one of twins' (the feminine form since applied to a river), a not inapt name for the alternative course of a stream: in fact, for a short time, while the capture was being effected, the part captured would split into two, one part of its waters proceeding down one channel, and the other part down the other—twin rivers with a common origin. On the other hand, it may simply be that the rivers have been named after the sister to the God of Death.

There is historical evidence which makes it probable that the Sutlej and the Beas followed separate courses to the Indus not very long ago. The Mohammedan histories of the 11th and 12th centuries and the Hindu writers of Jaisalmer employ the term 'Biyah' for the combined Sutlej and Beas, now known as the Sutlej. From this Mr. Oldham surmises that the rivers must have received their actual names at a period when the Sutlej did not join the Beas, but pursued an independent course, and that it entered the Beas probably not much before the 11th century.[1] It very probably joined the Ghaggar before it was captured by a tributary of the Beas.

It is difficult to assign even approximate dates to many of the changes that have taken place. It was probably before the end of the Siwalik epoch when the Attock tributary joining the Indobrahm River near Makhad cut back into the Ladak valley. That portion of the modern Indus which runs just below Bunji, at any rate, is of no very recent construction, as shown by the colossal depth of its gorge, which is nearly 17,000 feet. The steepness and narrowness of this gorge are witnesses to its immaturity, but its immense depth and the hardness of its rocks place a limit to our conception of its youth. The Attock tributary subsequently formed part of the longest line of waterway, and, according to modern convention, now bears the name of the main river, the Indus. The desertion by the Indobrahm of its old course across the Bannu plain and the Bhattani Hills for the gap through the western end of the Salt Range at Kalabagh, may have taken place about the end of the Siwalik epoch.

Reference was made by H. B. Medlicott & W. T. Blanford, and again by Mr. R. D. Oldham, to the presence in the Ganges and Indus rivers of two closely-allied species of *Platanista*, of a very different generic type from the cetacean inhabiting the Irrawadi.[2] It was presumed that these two species were descended from a common dolphin ancestor which acquired a freshwater habitat, and indicate an organic connexion at some time between the Indus and the Ganges basins. From a note kindly supplied to me by Dr. N. Annandale, further comparison has shown that the freshwater cetacean of the Indus is absolutely identical with that of the Ganges, *Platanista gangetica* Lebeck. It is found only in the

[1] 'Manual of the Geology of India' 2nd ed. (1893) p. 450.
[2] *Op. cit.* 1st ed. (1879) p. 392; 2nd ed. (1893) p. 443.

Ganges, Brahmaputra, and Indus, and never enters the sea. The cetacean inhabiting the Irrawadi, *Orcaella brevirostris* Owen, is now known to be a marine form which makes its way for long distances up stream, not only in Burma but also in Bengal and Siam. Mr. Oldham noticed that the capture of the Upper Jamna by the Ganges provided a connexion between the Indus and Ganges basins only in the torrential regions unfrequented by such cetaceans; this difficulty, however, disappears on the assumption that, earlier than this, the organic connexion between what are now the Indus and the Ganges was a large continuous river. Dr. Annandale calls attention also to the resemblance between the Chelonia of the two rivers. He says:—

'Those of the Indus are identical with those of the Ganges, whereas those of the Mahanaddi [for instance] belong, in all cases in which they are probably known, to distinct sub-species or local races. This is particularly noticeable in the case of *Trionyx gangeticus* Cuvier, one of the commonest and biggest forms in all three rivers. I have been unable to find the slightest difference between specimens from the Ganges and from the Indus; those from the Mahanaddi (sub-species *mahanadicus* Annandale), however, exhibit distinct racial characters, not only in colour but also in the bones of the skull.'

EXPLANATION OF PLATE X.

Geological map of the northern portion of the Indian Peninsula, on the scale of 192 miles to the inch, or 1 : 12,165,120.

Discussion.

The President (Mr. G. W. Lamplugh) said that the Society, as well as the Author, was greatly indebted to Mr. Oldham (who had read the paper on the Author's behalf) for the lucid and interesting way in which he had dealt with it. River-capture had undoubtedly taken place in most parts of the world, and had affected small streams as well as big rivers. The process in a broad way was readily explicable, but it was difficult to understand the final stage, as the gathering-ground of the attacking stream was then reduced to its minimum while the threatened stream maintained its full strength. A temporary blocking of the main stream, or an exceptional flood, seemed to be required to give the finishing touch.

Mr. W. Whitaker asked for information as to the mechanism by which the great reversals of drainage described were brought about. How much was owing to erosion, how much to earth-movement?

Dr. J. W. Evans thought that the Author had made out a strong case for his contention that in mid-Tertiary times the rivers in the low ground at the foot of the Himalayas and in the great mid-Himalayan valley flowed towards the west-north-west, but his contention that the change to present conditions was due mainly to the working-back of the rivers at their sources was not convincing. Such action was not of great importance among really hard rocks. The variations of relative level due to earth-movements,

which must have been very considerable in the Himalayan region, probably played a much greater part.

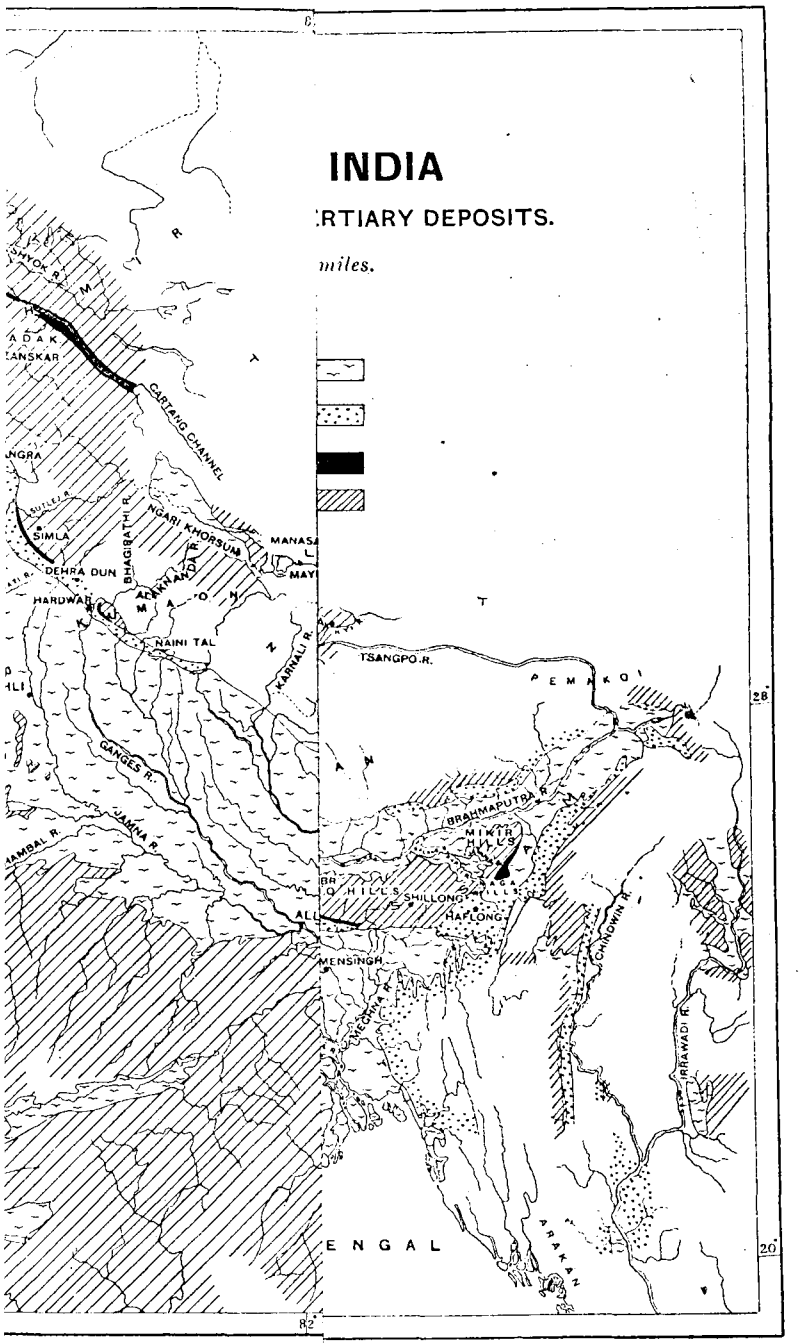
Lord CLIFFORD pointed out that in the great waterspout flood of 1868 in the Clarence Valley (New Zealand), the water denuded the mountains of whole forests and blocked up the gorge from 80 to 100 feet high with stone and timber, creating an inland lake 13 miles long and 5 or 6 miles wide in the course of three days. It then burst away the embankment that it had made, cut 30 feet deep through the solid rock of the gorge, and carried out enough stone to reclaim 2000 or 3000 acres of a delta at the estuary of the river. When encroaching rivers cut back into the channel of a higher watershed, it was impossible to say how rapidly what looked like irresistible rock might be cut away.

Prof. E. J. GARWOOD asked whether traces of hanging valleys had been observed in connexion with the westward-flowing captured tributaries described by the Author. In the case of well-known captures like those of the Albigna and Forno captured by the Maira from the headwaters of the Inn, the tributaries now entered the main stream over precipitous cliffs 1200 and 800 feet high, and similar cases had been met with by the speaker in the Tongri district in Sikhim: for instance, that of the Kang La valley. It was not necessary for the tributary to hang at its entrance into the main valley at the present time—erosion may have cut back the mouth of the tributary to accordant grade with the main valley; but it was often possible to trace the original discordance in the form of steps some distance up the tributary valleys.

Mr. G. W. YOUNG thought the circumstance that the dolphins of both the Ganges and the Indus belonged to the same species suggested that the reversal of drainage was due to differential earth-movements rather than to capture of the head-waters of the longitudinal 'Indobrahm' by an aggressive transverse river. In the latter case the water would be gradually captured, but hardly such big and active animals as dolphins, which required considerable depth of water; whereas, if earth-movements were the cause, the same fauna would be found in both the original stream and the severed portion.

Mr. C. E. N. BROMEHEAD wished to know whether the Author of the paper intended to imply that the capture of the 'Indobrahm,' by which it found an exit to the south and became the Ganges and Brahmaputra, was of more recent date than the capture of the river flowing north-westwards in the great depression north of the Himalayas by the southward-flowing Indus. The gorge of the Indus described in the paper was a typically new feature. If the lower course of the Ganges and Brahmaputra was also of recent date, and due to the cutting-through of a hard ridge joining the Indian Peninsula to the Assam Hills, one would expect a gorge similar to that of the Indus instead of the broad open valley which, on the map, had all the appearance of mature age.

Mr. R. D. OLDHAM said that, on one point, he was not in agreement with the Author. He could not regard the gaps through



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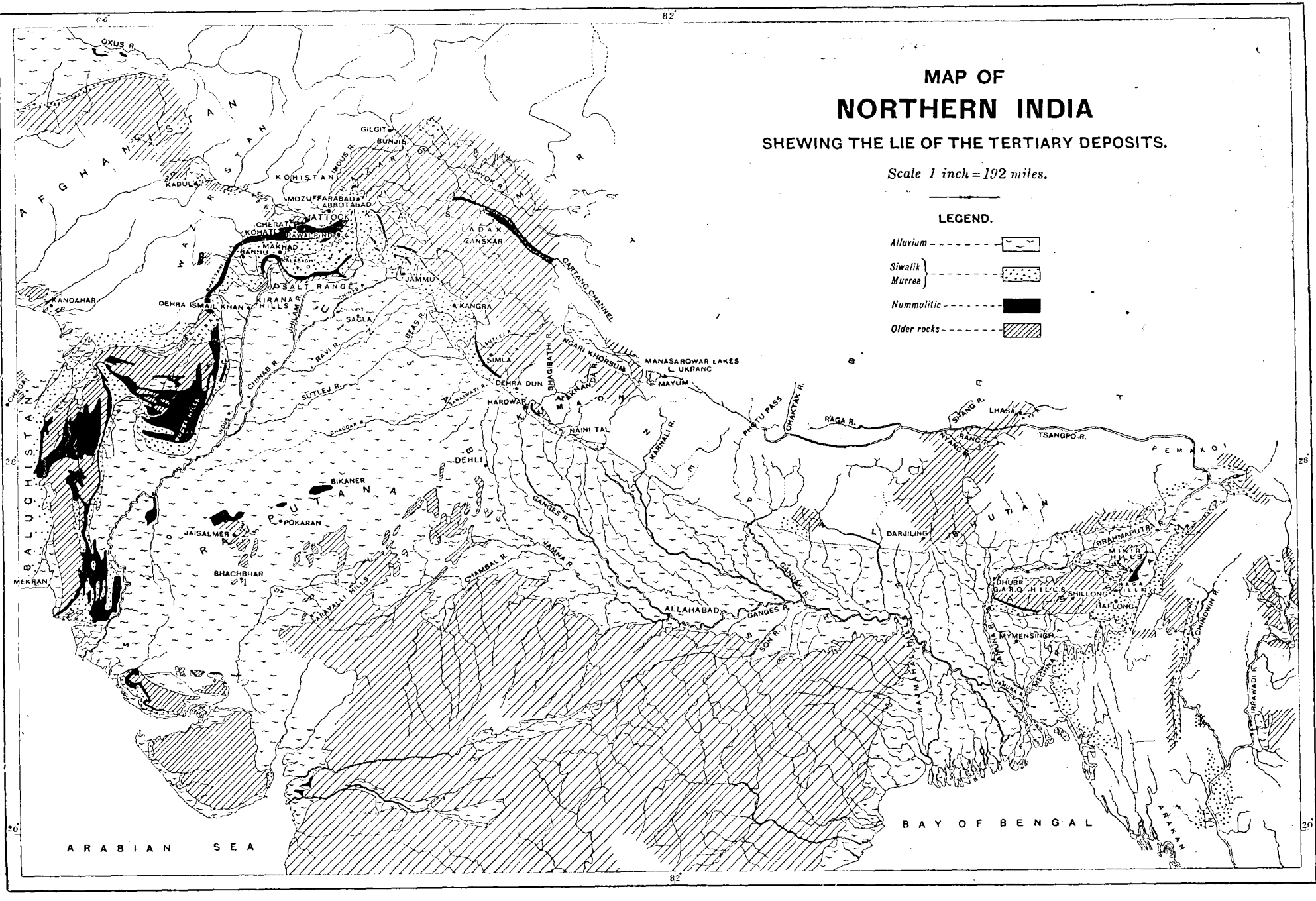

[*For* 'Abbotabad' *read* 'Abbottabad.']

which the Gangetic drainage reached the sea, or the rivers of the Punjab flowed to the Indus, as produced by erosion or capture in the ordinary sense. The gaps were broad and the alluvium, though doubtless shallow as compared with the depths elsewhere, still reached some hundreds of feet. He considered that these gaps were more probably due to earth-movements, by which the surface was depressed below the level of deposition; once this began, and a continuous alluvial plain was established, further changes in the courses of the rivers would result from the balance between erosion, deposition, and subsidence. He did not attach importance to the argument from the general westward trend of the valleys in the Himalayan region, because the secondary structure of the range was that of a series of secondary ranges crossing the main axis obliquely and tailing off in échelon westwards. Consequently, the general direction of the valleys may equally well have been determined by structural conditions as by the direction of the main drainage-channel. In other respects he was in general agreement with the Author's conclusions, although the exact sequence of the changes could not be determined with certainty.

The historical evidence of changes in the drainage-system was of considerable interest; but, in appealing to the ancient Hindu writings, it must be remembered that one school of Sanskrit scholars held that the composition of the Vedas antedated the Aryan invasion of India, that the prototypes of the rivers mentioned in them must be sought for in the Oxus valley, that the Saraswati of the Vedas was the Helmund, and that the names were subsequently applied to the rivers of the Punjab. In the Mahabharata, which was certainly composed in India, the Saraswati has dried up, and the legend of an underground course to the Ganges is mentioned, showing that this legend is at least a couple of thousand years old. If this interpretation is correct, no argument can be based on the descriptions contained in the Vedas; but that derived from the nomenclature of the Jumna certainly suggests that the transfer of this river from the Indus to the Gangetic system was subsequent to the introduction of the existing language into India. The Author was, however, in error in attributing this suggestion to the speaker; it is, in reality, of older date, and should be credited to the late H. B. Medlicott, although never published by him (so far as the speaker knew). The dry bed of the Lost River of the Indian Desert seems to have carried a considerable body of water at a much later date: for the chronicles of the earliest Arab invasions of India record some incidents which it is difficult to understand, unless this channel carried a large body of water so late as the commencement of the 11th century. Later chronicles equally show that it no longer flowed in the 13th century, so that the date of the final drying-up of this river can be established within fairly narrow limits; but it is not possible to decide whether the water was supplied by the Sutlej or by the Jamna.