With the Author's Compliments.

THE

GEOLOGICAL HISTORY OF THE HIMALAYAS.

(Presidential Address to the Geologists' Association, 1st February, 1895.)

By LIEUTENANT-GENERAL C. A. McMAHON, V.P.G.S.

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(WITH A SKETCH MAP.)

By LIEUTENANT-GENERAL C. A. McMAHON, V.P.G.S.

[*Being the Presidential Address delivered 1st February, 1895.*]

THE Himalayas are "generally supposed," to use the words of Mr. Medlicott, late Director of the Geological Survey of India, "to have been upraised in late Tertiary times";* and Sir Henry Howorth has pushed this popular conception to its extreme limits by asserting that "the great mountain masses of eastern Asia" were probably upheaved "as late as the time when the mammoth age came to an end";† that is to say, long after the appearance of man in Britain, for the mammoth lived well into the human period.

The last-named author tells us in a subsequent paper that this upheaval was "very rapid, if not sudden."‡ If evening papers, and startling posters, had existed in those days, the sudden rise of the Hima-álaya (abode of snow), like Venus from the depths of the sea, must have supplied interesting pabulum for sensational writing.

As so much misapprehension on the subject of the geological history of the Himalayas seems still to linger in some minds, it may be worth while to devote a little time this evening to try to arrive at some clear ideas on the subject.

As the mountain ranges that constitute the Himalayas are composed of rocks of all ages from Tertiary to pre-Cambrian, we should obtain a very inadequate idea of the history of the Himalayas were we to exclude from our view all events that preceded the last set of earth-movements that set in during the Tertiary period. This would be very much like beginning the history of England with the reign of George the First.

The able geologists to whom we are indebted for the *Manual of the Geology of India* frankly recognised that the Himalayas had a pre Tertiary history. Thus, Mr. Medlicott tells us "that the Himalayan mountain area was defined before the deposition of the Sabathu nummulitic rocks"§—that is, in pre-Tertiary times; and in another place he wrote: "In early and middle Secondary times a general elevation occurred of the south Himalayan area along the border of which the Sirmur deposits subsequently took place."‖

Dr. Blanford, the other joint author of the first edition of the *Manual*, in his lucid introduction to that work, expresses the

* Medlicott, *Manual G.I.*, 1st edn. (1879), p. 520.
† Howorth, *Geol. Mag.* (1891), p. 163.
‡ *Ib.*, *Geol. Mag.* (1894), p. 405.
§ *Memoirs, G.S.I.* III. 174 (1865.)
‖ *Records, G.S.* IX (1876), p. 51.

SKETCH MAP OF THE MOUNTAINS BORDERING THE PANJAB.

opinion that "the Himalayan area was probably in great part land at a much earlier period,"* than that which witnessed the deposition of the Eocene strata.

Mr. Oldham, in his interesting chapter on the origin of the Himalayas, in the second edition of the *Manual*, writes: "The elevation of the Himalayas commenced with the Tertiary era; and the range only attained an elevation comparable to which it now possesses towards the commencement of the Pliocene period."†

Here the word "elevation" is used in a highly technical sense. "In speaking of the elevation of the Himalayas," the author explains some pages further on, "only that final compression is meant, which caused it to rise as a conspicuous mountain range with the same limits and extent as at present, and the antecedents which may or may not have been the direct cause of this result are excluded."‡

It is this technical mode of speaking of the last phase in the history of the Himalayas, as if it were the only event worthy of notice, adopted by some writers — beginning the History of England with the reign of George the First—that is, I think, mainly responsible for the misapprehensions that have arisen regarding its origin.

"The general conclusion we may arrive at," wrote Mr. Oldham in 1888, "is that throughout the whole of the Palæozoic and Mesozoic periods the area under consideration [the Simla region] has been alternately land and sea."§

Our fair Venus, Hima-álaya, has then a history; and I propose to consider briefly this evening whether we can learn any interesting facts regarding her infancy and youth.

Among the rocks of which the Himalayas are built up some are undoubtedly as old as Cambrian, and probably the crystalline schists are of pre-Cambrian age.

We have gneissic rocks in abundance intercalated not only with the schists but with rocks of various ages. Some of these gneissic sheets and masses, which at the date of the publication of the first edition of the *Manual* (1879), were regarded as metamorphosed sedimentary rocks, have since been proved to be of igneous origin;‖ and it is highly probable that when outcrops in other localities are closely studied, their intrusive character will be established.

Not many years ago geologists generally supposed that a foliated structure in a crystalline rock conclusively proved its sedimentary and metamorphic origin; and this prepossession closed their eyes so completely that the plainest evidence of the

* *Manual G. I.*, 1st edn. (1879), p. lvi.
† *Ib.*, 2nd edn. (1893), p. 479.
‡ *Ib.*, 2nd edn. (1893), p. 483.
§ *Records G. S. I.*, xxi, 143 (1888).
‖ McMahon, *Records, G. S. I.*, xvi, 129 (1883), xvii, 53, 168 (1884).

igneous character of a rock failed to obtain admission into their minds. Thus one of our ablest Indian geologists in describing the Hazara "gneiss" actually tells us that he "found what appeared to be distinct dykes and veins [of gneiss] among the schistose rocks"; and that he even found "masses of the adjoining schists included in the crystalline gneiss"; and yet in the face of such evidence of igneous origin, he finally arrived at the illogical conclusion that "an extensive series of mechanically-formed rocks had undergone tranformation into gneiss."*

The dominance of old and exploded ideas have not yet, I am sorry to say, completely ceased, and there are still some who think that foliation *plus* interbedding is sufficient evidence of a metamorphic, in contradistinction to an igneous origin, forgetting that a partially-consolidated sheet of granite intruded under great pressure into already metamorphosed, or partially metamorphosed beds, would naturally present the appearance of a regular member of a normal sequence.

Much work in the field, combined with the skilled study of thin sections under the microscope, is still needed to elucidate the age and history of many of the crystalline rocks of the Himalayas.

The occurrence of a crystalline schist series in the Himalayas extensively invaded by dykes, sheets, and veins of granite, has been noted by myself and others. A similar series of schists in the Central Himalayas has been described by Mr. Griesbach† and named the Vaikrita system. We are told that Vaikrita is the Sanscrit for metamorphosed; and as this would seem to imply a knowledge of rock metamorphism by our Aryan brethren, it is to be regretted that their views on the vexed question of the origin of the crystalline schists have not been handed down to us.

Between the crystalline schists and the rocks of Silurian age an "enormous thickness" of beds occur which Mr. Griesbach‡ calls the Haimanta system. This includes a "great thickness" of "coarse conglomerate, or boulder bed," and slates abounding in ripple-marks.

The abundance of these marks and the great thickness of the "boulder bed," shows plainly enough that when the Haimantas were laid down to a thickness of 3,000 or 4,000 feet,§ high land must have existed in the immediate neighbourhood; and as the rolled and "sub-angular fragments contained in the conglomerate consists of quartz and *gneiss*,"‖ one may, I think, fairly infer that the high land which was then suffering erosion consisted of crystalline rocks.

* *Records, G. S.* xii (1879), pp. 118-119.
† *Memoirs, G.S.I.*, xxiii (1891), p. 41.
‡ *Ib.*, 49, 224.
§ Greisbach, *Memoirs G.S.I.*, xxiii (1891), p. 55.
‖ *Manual G.I.*, 2nd ed. (1893), p. 114.

Mr. Griesbach considers the Haimanta system (in part Cambrian, in part older) to have been a "littoral formation," and believes that "one of the earliest Himalayan disturbances occurred immediately before Haimanta times." *

Why are uniformitarian geologists, I may ask in passing, so fond of the word "disturbance"—a word redolent of the Meteorological Reporter's Office, and painfully suggestive of sudden cataclysmic storms?

Judging from the outcrops of crystalline schists now to be seen, this old ridge of Vaikrita rocks must have approximately occupied very much the same position as the existing line of the Himalayan snowy peaks. Even as far back as Cambrian times, therefore, the direction of the Himalayan axis seems to have been determined, and this direction was substantially what it is to-day. How inadequate, therefore, is the conception of those who suppose that the Himalayas came into existence at the close of the Eocene epoch.

The view above expressed is substantially the one held by Mr. Medlicott in the first edition of the *Manual of the Geology of India*,† and is the one adopted by Mr. Griesbach in his *Memoir*.‡

In the Salt Range, volcanic lavas and ashes have been observed§ which must be referred to the Cambrian period, and in the Himalayas General Strachey has noted the occurrence of extensive outcrops of what appeared to be contemporary basaltic "greenstone," and ash, in rocks of this age.‖ Stoliczka also describes "greenstone" "in regular beds between the other rocks," which he believed to be "coeval." They occur all through his Bhabeh series (now believed to be in part Silurian, but mainly of Cambrian age¶), and share in all the contortions of these rocks.**

It would therefore appear that in the Cambrian period volcanoes were active in the Himalayan area.

During Silurian times the sea covered that part of the N.W. Panjab along which the Indus now flows, and also a portion of the Central Himalayas,†† a fact proved by the coral limestone of Hundés and Spiti,‡‡ and other fossil evidence.

The elevated chain of crystalline rocks, above alluded to, appears to have continued from the Cambrian into Silurian times without very material change; and a land connection between

* Griesbach, *Memoirs G.S.I.*, xxiii (1891), p. 225.
† *Manual G.I.*, 1st ed. (1879), p. 679.
‡ *Memoirs G.S.*, xxiii (1891), p. 225.
§ Wynne, *Memoirs G.S.*, xiv (1878), p. 75.
‖ Strachey, *Q.J.G.S.*, vii (1851), p. 300.
¶ Griesbach, *Memoirs G.S.*, xxiii (1891), p. 50.
** Stoliczka, *Memoirs G.S.*, v (1866), p. 20.
†† Oldham, *Manual G.I.*, 2nd ed. (1893), p. 492.
‡‡ Strachey, *Q.J.G.S.*, vii (1851), p. 304; Griesbach, *Memoirs G.S.*, xxiii (1891), p. 56; Oldham, *Manual G.I.*, 2nd ed. (1893), p. 114.

this mountain area and Peninsular India appears to have existed in those early days.*

The evidence to prove the continuance of this primitive Himalayan chain during the Silurian period appears to be strong. Mr. Wynne tells us of ripple-marked slates in the Karána Hills and other indications of the proximity of land, near the Salt Range, in the direction of Peninsular India ;† Mr. Lydekker notes the occurrence of ripple-marked beds in the slates of his Panjál series ; ‡ and I exhibit this evening a ripple-marked slab which I found in the Simla slates near Simla. The great slate series, to which the above outcrops are to be referred, is marked Cambro-Silurian on the map which accompanies the second edition of the *Manual of the Geology of India* ; and this ripple-marking seems good evidence of the proximity of land when these marine § slates were laid down.

This great slate series occurs on both flanks of the primitive crystalline rocks, and the two outcrops unite in the N.W. of Kashmir to sweep down towards Attock along what seems to have been a fiord, or sea, filling an ancient valley of erosion between elevated ridges of old crystalline rocks. There seems no reason to suppose that the slate series was ever continuous across these crystalline ridges.‖

In those early days the N.W. shores of Peninsular India appear to have run near the Salt Range in a north easterly direction until it merged into the elevated mountain region of the N.W. Himalayas. One arm of this land extended through Leh and Scardo, and curved round in a south-westerly direction into Afghanistan ; whilst another shorter and more southerly arm extended through Chini, and the neighbourhood of Deotiba, into Kashmir, where it was cut off from the Leh-Scardo arm by the Silurian fiord sweeping round from its north-eastern flank to join the Srinagar-Attock fiord.

Vulcan appears to have been very active in the Himalayan area during the Silurian period.¶ The beds of volcanic ash described by Mr. Middlemiss, in Western Garhwál,** which Mr. Oldham tells us belong to this period,†† are said to be some miles in thickness.

In the Salt Range, and in Hazára, a break occurs between the Silurian and the Carboniferous series‡‡ accompanied by elevation

* Oldham, *Manual* (1893), 492.
† Wynne, *Q.J G.S.*, xxxiv (1878), p. 355.
‡ Lydekker, *Memoirs G.S.I* , xxii (1883), p. 263.
§ Wynne, *Q.J.G S.*, xxxiv (1878), p. 355 ; Blanford, *Manual G.I.*, 1st ed. (1879), p. xxvi.
‖ Medlicott, *Manual G.I.*, 1st ed., 630.
¶ Stoliczka, *Memoirs G.S.*, v (1866), p. 20; Wynne, *Memoirs G.S.* xiv (1878), pp 75, 161 ; Blanford, *Manual G.I.* (1879), p. xxvi; Lydekker, *Records G.S.I.*, xiv (1881), p. 29.
** *Records G.S.I.*, xviii (1885), p. 74 ; xx (1887), p. 34.
†† Oldham, *Manual G.I.* (1893), p. 117.
‡‡ Wynne, *Records G.S.I.*, xv (1882), p. 164 ; *Manual G.I.*, 2nd ed. (1893), pp 109, 129.

and denudation ;* but in the Central Himalayas perfect uniformity exists between them.† No Devonian rocks are known in the Salt Range or in the Upper Panjáb,‡ but Mr. Griesbach believes that the dark blue limestones (700 or 800 feet thick in the Central Himalayas) which extends from Nepal to Spiti, and into Kashmir,§ are of Devonian age. Devonian fossils were found in eastern Tibet by the Abbé Des Mazures.‖ These facts appear to indicate that at the close of the Silurian period a rise in the north-west coast line of Peninsular India took place ; whilst at the same time a deepening of the sea, which we have seen swept round from the north-east of the Chini-Deotiba crystalline ridge into Kashmir, set in. During this period, and doubtless in connection with the same set of earth-movements, the link between the Himalayan mountain area and Peninsular India appears to have been severed ; for littoral deposits of Carboniferous age¶ "are found all along the Himalayan ranges from Kashmir to the frontier of Nepal."**

These changes were probably connected with volcanic activity in parts of the Himalayan area. "Very considerable outflows" of trap took place in the Silurian period in Kashmir, and "continued to take place during a part, or the whole, of the Carboniferous period."†† Considerable thicknesses of basic volcanic rocks in different parts of the Himalayas belonging to this period have been described by Mr. Lydekker in Kashmir,‡‡ and by myself in the Dalhousie, Satlej, and lower Ravi areas.§§ Those near Dalhousie described by me come in between the carbonaceous infra-Krol series and a conglomerate which I correlated with the Blaini conglomerate of the Simla region.‖‖ Contemporaneous volcanic rocks occur in a similar position in Kashmir.¶¶ Mr. Oldham appears to consider that the Blaini conglomerate, which was previously supposed to be of Silurian age, is, like the Talchir conglomerate, of Upper Carboniferous age, or somewhat newer.*** If this be so, then the volcanic rocks must also belong to the Carboniferous period. This conclusion I had already arrived at for the volcanic series at Rámpur in the Satlej valley.†††

* Wynne, *Q.J.G.S.* (1878), p. 356.
† See references at ‡‡ p. 85.
‡ Wynne, *Q.J.G.S.*, l.c.
§ Griesbach, *Memoirs G.S.I.*, xxiii (1891), p. 214.
‖ Oldham, *Manual G.I.*, 2nd ed. (1893), 118.
¶ I refer more particularly to Mr. Medlicott's black, carbonaceous, infra-Krol series. This must be the representative of the Gondwána (Upper Carboniferous) of Peninsular India.
** Griesbach, *Records G.S.I.*, xix (1885), p. 266.
†† Lydekker, *Records G.S.*, xiv (1881), p. 29.
‡‡ Lydekker, *Memoirs G.S.*, xxii (1883), p. 217.
§§ McMahon, *Records G.S.*, xv (1882), pp. 34, 155 ; xvi (1883), p. 36 ; xvii (1884), p. 34 ; xviii (1885), p. 82 ; xix (1886), p. 67.
‖‖ McMahon, *Records*, xiv (1881), p. 306 ; xv (1882), p. 34 ; xvii, p. 34 ; *Manual G.I.* (1893), p. 137.
¶¶ *Manual G.I.*, 2nd ed. (1893), p. 135.
*** Oldham, *Manual* (1893). Compare p. 137 with pp. 129, 133, 135, 206.
††† *Records G.S.*, xix (1886), pp. 81, 82, 85.

Mr. Oldham remarks in the second edition of the *Manual* that "the great Gondwána era [Upper Carboniferous] opened with a period of exceptional cold. The Peninsula was a land area over which many large lakes were probably scattered, while on land there were glaciers flowing down into these lakes, and into the sea which covered part of the great Indian desert, the north-west Panjab, and a large portion, if not the whole, of the area occupied by the Himalayas west of the Ganges valley."*

That the sea at that period did not cover the whole of the Himalayan area is clear to my own mind. Mr. Oldham himself describes arkose beds which apparently belong to this age;† whilst Mr. Lydekker found‡ granite pebbles in the conglomerate of his Panjál system, the conglomeratic part of which is considered by Mr. Oldham to be of upper Palæozoic age, and to be the equivalent of the Blaini conglomerate which is referred to the upper Carboniferous period.§ That these granite boulders "were derived from an ancient land area composed of a rock very similar to the porphyritic granite of the Dháola Dhar" is admitted by Mr. Oldham himself.‖

I also found a boulder of granitoid gneiss in the conglomerate of the Chamba area, which I correlated with the Blaini conglomerate of the Simla area.¶ This specimen resembles the Himalayan gneissose granite, and it is not like the granitoid rocks of the neighbouring parts of Peninsular India. A peninsular source has never been suggested for any of the boulders in the conglomerates of the Simla, Dalhousie, or Kashmir areas, and I see no escape from the conclusion that elevated land formed of crystalline rocks existed in the Himalayan area when these conglomerates were laid down.

Mr. Griesbach in his *Memoir on the Central Himalayas*, after noting the great physical changes that took place at the close of the Carboniferous period in the Himalayas, Afghanistan, and Persia, remarks: "Evidently the changes which took place near the close of the Carboniferous period, were of a very widespread nature; and if it required proof that the great wrinkling process, which resulted in the elevation of the Himalayas, did not begin in young Tertiary times, but rather was continued up to that time, and even prolonged after it, the 'break' after upper Carboniferous times, must needs be strong evidence that even in Palæozoic times, at least, the main outlines of the Himalayas must have been foreshadowed, and that even then the ancient coast-line could not have been very far removed from the present limits of the Indian Himalayas."**

* Oldham, *Manual G.I.*, 2nd ed. (1893), p. 493.
† Oldham, *Records G.S.*, xx (1893), p. 161.
‡ Lydekker, *Records G.S.*, xii (1879), p. 24; *Memoirs G.S.*, xxii (1883), p. 264.
§ Oldham, *Manual G.I.*, 2nd ed. (1893), pp. 116, 134, 136.
‖ Oldham, *Manual G.I.*, 2nd ed., p. 44; see also Lydekker, *Memoirs G.S.*, xxii (1883), pp. 263, 264.
** McMahon, *Records G.S.*, xvi (1883), pp. 37, 41.
†† Griesbach, *Memoirs G.S.I.*, xxiii (1891), pp. 64, 65.

Though marine conditions were widespread in Carboniferous times, high land was never, in the Himalayan area, far distant from the Carboniferous seas.

In Spiti, Hundés, Perso-Afghanistan, and Jaunsar, there appears to have been an unconformity between the Carboniferous and the Permian* deposits, though those deposits are conformable to each other in the Kashmir area.† Similar instances of local unconformity in one locality of beds that follow each other with perfect conformity in another are not uncommon in Himalayan geology, and bear out a suggestion I have to make later on, that differential earth movements—the sinking of the crust of the earth in one place and its rise in another—have been a marked characteristic in the history of the Himalayas.

That the coast line of Peninsular India continued to run, during this period, in the neighbourhood of the Salt Range is evidenced by the frequent occurrence of "ripple-marks and oblique lamination" and plant impressions in the Salt Range sandstones.‡

The sea seems to have deepened towards the west and north-west, but in Afghanistan land conditions again set in; the deposits assumed a littoral character, and became carbonaceous, coaly, and "plant-bearing," and contained beds that reminded Mr. Griesbach of the Talchir conglomerates and the coal-bearing Gondwánas of Peninsular India.§

There were, doubtless, local changes of level and modifications in local conditions, such as the direction of currents, the depth of the water, or the character of the sediments, which had their effect on the marine fauna of the time; but the broad features of Himalayan geology seem to have differed little at the close of the Carboniferous period from what they had been throughout the Palæozoic era. Deep fiords seem to have run up what is now the Indus Valley into Kashmir, and along the foot of an elevated ridge of crystalline rocks; whilst another long arm of the sea flowed round the terminal end of that ridge into Spiti.

Speaking broadly, this distribution of land and sea seems to have continued the same, with probably some minor modifications, from the close of the Carboniferous to the close of the Triassic period. Remarkable deposits of marine limestones ranging from the Permian to the Trias, in apparently unbroken and conformable succession, are to be found in Kashmir, along the foot of the outer Himalayas, through Spiti, Rupshu, and the regions beyond, following the direction of the deep fiords alluded to in the last paragraph.‖ Thoughout this long period a slow but steady subsidence

* Oldham, *Records G.S.*, xxi (1888), pp. 138, 151. Greisbach, *Memoirs G.S.*, xxiii (1891), p. 228.

† Lydekker, *Records G.S.*, xiv (1881), p. 34.

‡ Wynne, *Memoirs G.S.*, xiv (1873), p. 91; *Manual G.I.* (1893), pp. 123, 124.

§ Griesbach, *Memoirs G.I.*, xxiii (1891), p. 64; *Manual G.I.*, 2nd ed. (1893), p. 197.

‖ See map accompanying *Manual G.I.*, 2nd edition.

of the areas covered by the Permo-Triassic seas must have taken place, for the total thickness of this series is very great. That of the Trias alone is estimated at 4,000 feet in the Niti section of the Central Himalayas,* and at between 2,000 and 4,000 feet at Khanpur in Hazara.†

The volcanic forces appear to have slumbered in the Himalayan area during the Permo-Triassic period, but the occurrence of interbedded traps of Permian age in Afghánistán is recorded by Mr. Griesbach,‡ and a thickness of nearly 2,000 feet of interbedded basaltic lavas of this age§ occur in the Rajmahal series‖ which probably issued from vents now buried under the alluvium of the Ganges.

During the Jurassic period there was considerable volcanic activity in Afghánistán,¶ but none in the Himalayan area.

Jurassic-marine deposits are found on the western side of the Salt Range, but the fragments of ferns, and other plants, in some of the beds show that the shore line, in this locality, remained materially unchanged. The same remark applies to Afghanistan, where there are similar marine beds containing an abundance of plant remains.** In Kashmir, Hazára, Spiti, and in the Central Himalayas, marine Jurassic beds occur. In Hazára there is a local unconformity between the Jurassic and the Triassic systems,†† and Mr. Griesbach considers that there is a break between the Liassic and Jurassic deposits of the Central Himalayas indicated by lithological differences and by a sudden change of fauna ;‡‡ which, though it does not appear to have amounted to a change from marine to terrestrial conditions, points to some important earth movements having taken place in parts of the Himalayan area during the Jurassic period.

It was probably during this period that a temporary elevation of the Permo-Triassic beds took place in the Simla-Sabathu area. Mr. Medlicott, in his survey of this area, showed that these beds were elevated and eroded before the Sabathu nummulitics were laid down ;§§ the "central portion"‖‖ of the "Himalayan mountain area" having been defined before the deposition of the Sabathu nummulitic rocks.¶¶

During Cretaceous times the sea appears to have still extended up the Indus, for Cretaceous deposits are shown on the map attached to the second edition of the *Manual* at Katch, at Dehra Gházi Khán, Dehra Ismáel Khán, and near Kohát. In the Salt

* Griesbach, *Memoirs G.S.*, xxiii (1891), p. 68.
† Oldham, *Manual G.I.*, 2nd edition (1893), p. 139.
‡ *Records G.S.*, xx (1887), p. 102.
§ Oldham, *Manual G.I.*, 2nd edition (1893), p. 208.
‖ *Ib. Ib.*, 175, 176.
¶ Griesbach, *Records G.S*, xix (1886), 249 ; xx (1887), 102, 103.
** Griesbach, *Records G. S.*, xix (1886), 239, 248, 249.
†† Wynne, *Records G. S.*, xv (1882), p. 164.
‡‡ Griesbach, *Memoirs G. S.*, xxiii (1891), 75.
§§ Medlicott, *Memoirs G. S.*, iii (1864), pp. 75-78.
‖‖ Medlicott, *Records G. S.*, ix (1876), p. 51.
¶¶ Medlicott, *Memoirs G. S. I.*, iii (1864), p. 174.

Range marine Cretaceous fossils are doubtfully present,* whilst fossils of "decidedly Cretaceous appearance" have been found "in the area mapped as Attock slates."† In Beluchistán and Afghanistan Cretaceous marine beds are abundant; they extend to Kashmir and occur in Tibet and Hundés.‡

No volcanic rocks of lower or upper Cretaceous age are known in the Himalayas, but "the close of the Cretaceous period witnessed the great outburst of volcanic activity which buried the whole of Western India deep in lavas and ashes";§ and Mr. Oldham suggests that "it is not improbable that this great outburst may have been connected; as it was probably contemporaneous with the great series of earth movements which resulted in the elevation of the Himalayas." I very much doubt, myself, whether there was much, or indeed any, connection between the two events. The chief *foci* of the Deccan trap eruption seems to have been situated towards the south-west rather than towards the north-east; and the outpouring of the Deccan trap, which covers so enormous an area, seems to me to have been connected with the sinking of the land connection between India and Africa, which appears to have existed up to that time, rather than with the last series of earth movements which have left their marks on the Himalayas. Moreover, the two events are not synchronous. No outburst of basic trap took place in the Himalayan area during the Cretaceous period, or in Tertiary times until the deposition of the Eocene beds was well advanced; and the upper Cretaceous period must have witnessed the sinking, instead of the rising of the Simla-Sabathu area, for the Permo-Triassic beds, which had previously been elevated, and eroded, had again sunk beneath the sea before the nummulitic marine beds were deposited.

If, as the Rev. O. Fisher has given us reason to believe, every protuberance outside the crust of the earth has a corresponding protuberance projecting downwards into the fluid substratum,‖ it is hardly probable that a volcanic commotion beneath what is now the Indian Ocean would have been propagated under the roots of Peninsular India into the region of the Himalayas.

The outpouring of the Deccan trap set in at the close of the Cretaceous period, but the "special disturbances" which marked the last phase of the history of the Himalayas did not set in until the close of the Eocene epoch.¶ During Eocene times the sea "flowed over Western Rajputana and the Indus valley to the west, over a large part of Beluchistan, and Afghanistan, and over the whole of the north-west Panjab and the outer Himalayas as

* Wynne, *Memoirs G. S. I.* (1878), p. 104.
† *Manual*, 2nd ed. (1893), p. 116.
‡ Stoliczka, *Memoirs G. S.*, v (1866), p. 116; Griesbach, *Memoirs G. S. I.*, xx (1887), pp. 99, 100; *Memoirs G. S.*, xxiii (1891), pp. 81, 82.
§ Oldham, *Manual*, 2nd edn. (1893), p. 404.
‖ *Physics of the Earth's Crust*, 2nd ed. (1889), pp. 184, 195.
¶ Blanford, *Manual G.I.*, 1st ed. (1879), lvi.

far east as the Ganges River. . . . Sea also flowed over the central Himalayas and was probably continuous with that just referred to, across the north-western termination" of the range*. In other words, the Himalayan land and sea boundaries, in their broad general features, remained much the same during the Eocene epoch as during the Permo-Triassic period. "An arm of this sea," in the words of Dr. Blanford, "extended from the north-west up the upper Indus valley in Ladák. The Himalayas, and perhaps Tibet, wholly or in part, were raised above the sea."† Another arm of the sea ran along the south of the Himalayas as far as the Ganges.‡ Beds of impure coal at Sabathu, in the Salt Range, and in various parts of Afghanistan, indicate clearly enough the proximity of the shore-line during this period to the places where these coaly deposits are now found.

It was not until the close of the Eocene epoch that the crumpling up of the strata on both sides of the ancient axis of crystalline rocks took place, and that the steady rise of the *whole* Himalayan area began which has been going on ever since.§ When this period of continued elevation set in the fiords of the Eocene sea began to shrink up from east to west; and the sea gradually retreated from the Himalayan area, and from the Panjab. The drainage followed the contracting seas, and the rivers of the ancient land gradually increased in volume and importance, and established themselves along their present lines. The Simla-Sabathu area became the water parting between the Ganges and Panjab river-systems. The river Jumna at first yielded allegiance to the one but eventually turned over to the other.

At this point a very interesting question arises. Can we obtain any clue to the cause, or to the agent, which was principally concerned in inaugurating the last series of Himalayan earth movements which set in at the close of the eocene epoch?

I have already given my reasons for thinking that these movements were not connected with the eruption of the Deccan trap. The eruption of basic lavas formed, we have seen, a striking element in Himalayan geology during the Silurian and Carboniferous periods. After their close volcanic activity connected with the outpouring of basic lavas declined in the Himalayan area. The history of the plutonic forces connected with an acid magma appears to have been different. Granitic eruptions into the deposits covering the Himalayan area appear to have begun early and to have continued into comparatively late geological times. The Vaikritas (old crystalline series) are completely riddled with

* Oldham, *Manual G.I.*, 2nd ed. (1893), p. 404. See also Dr. Blanford on "Probable Shore of the upper Cretaceous Sea in Sinde and Salt Range," *Manual G.I.*, 1st ed. (1879), p. l.

† *Manual G.I.*, 1st ed. (1879), p. liii.

‡ *Ib.* p. lii.

§ Blanford, *Manual G.I.* (1879), p. lvi; McMahon, *Records G.S.*, xviii (1885), p. 81; Griesbach, *Memoirs G.S.I.*, xxiii (1891), pp. 34, 227; Oldham, *Manual G.I.* (1893), p. 485.

a granite, which not only occurs in intrusive dykes and veins, but wells up in great masses, and forms some of the loftiest Himalayan peaks.* Granite is also intrusive in the lower Palæozoic series ;† in the Carboniferous series‡ of the Satlej basin ; invades the Permo-Carboniferous series in Afghanistan ;§ Triassic rocks in Kashmir‖ ; and the Cretaceous,¶ and Eocene,** in Afghanistan.

The granite of the snowy peaks formed part, doubtless, of a very ancient eruption,†† for, as we have seen, granite was undergoing erosion from an early period ; and that it was directly connected with the elevation of the axis of crystalline rocks in the Cambrian period, the worn stumps of which now form the line of snowy peaks, seems probable. However this may be, I cannot escape from the conclusion that the contortion, compression, and upheaval which marked the earth movements that set in at the close of the Eocene period, were connected with the intrusion of the gneissose granite.

There is no evidence to show that this granite found a free vent at the surface on an extensive scale ; had it done so effective relief to the plutonic forces would have been obtained ; the work done in crumpling and upheaval would have been less ; and the marks of the struggle left on the granite itself would not have been so severe.

Had an extensive outflow of acid lava taken place, evidence of it would have been left in the form of lava streams, or ash beds, intercalated with the Tertiary strata, which is not the case, and the relief afforded to the plutonic forces by an extensive surface outflow might have been followed by a period of subsidence.

That the granite may, in one or two instances, have reached the surface is possible, for Mr. Middlemiss‡‡ found rhyolitic lavas in Garhwál, and rocks intermediate in *structure* between them and the gneissose granite.

There is no evidence, however, that Mr. Middlemiss's Lobah volcanic rocks are of Tertiary age, and there is no direct connection between them and his Dudatoli granite. The granite and the lavas may, therefore, be of different ages, and the lavas may be older than Tertiary.

That the gneissose granite in not younger than early Miocene can hardly be doubted. Boulders of it are very plentiful in the

* Strachey, *Q.J.G.S.*, vii (1851), p. 301 ; McMahon, *Records G.S.I.*, xii 1879), pp. 60-62 ; Griesbach *Memoirs*, *G.S.I.*, xxiii (1891), pp. 40-48.
† Griesbach, *l.c.*, 42, 44, 48.
‡ Oldham, *Records G.S.I.*, xxi (1888), p. 149.
§ Griesbach, *Records G.S.I.*, xix (1886), p. 241.
‖ Lydekker, *Records G.S.I.*, xiv (1881), p. 14.
¶ Griesbach, *Memoirs G.S.I.*, xviii (1881), pp 3, 48 ; *Records G.S.I.*, xix (1886), pp. 64, 242 ; xx (1887), pp. 22, 23.
** Griesbach, *Records G.S.I.*, xx (1887), pp. 102, 103.
†† Strachey, *Q.J.G.S.*, vii (1851), p. 309.
‡‡ *Records G.S.I.*, xx (1887), p. 161.

upper Pliocene Siwálik conglomerates of the outer Himalayas, showing that it had been erupted, consolidated, and exposed at the surface, when the Siwáliks were laid down.

I see no ground, on the other hand, for the supposition that the granite of the outer Himalayas is older than the close of the Eocene epoch. The Eocene strata were not contorted until after the deposition of the Miocene beds had gone on for some time, and all the field evidence, so far as I am acquainted with it,* supports the view that the intrusion of the main mass of the granite was contemporaneous with the folding and faulting of the strata which took place in Miocene times. The granite, though it appears in different horizons, and varies greatly in thickness, swelling out sometimes, in the parts of the Himalayas with which I am conversant, to a width of twelve miles,† runs, on the whole, with the strike of the sedimentary rocks, and its outcrop seems to be directly connected with the wrinkling of the strata and the formation of overthrust faults. It appears all along the southern flank of the Himalayas from Kashmir, in the north-west, down to Kamaun, beyond which the geological map is almost a blank down to Sikkim.

The intrusion of so great a thickness of igneous rock for nearly the whole known length of the Himalayas must have assisted very materially to produce, if it were not the sole cause of, the great compression of the strata which took place in middle Tertiary times; and if its eruption had occurred prior to the crumpling it would surely not have run with the strike of the folds produced by that crumpling. Thin sheets of granite might conceivably have been folded up with the crumpled strata; but when one sees not only thin sheets, but long outcrops twelve miles thick, implicated in the folding in a way to suggest intrusion along overthrust faults, this explanation becomes highly improbable.

Numerous sections would be required to fully illustrate the folding and faulting which resulted from the compression of the strata, and the intrusion of the granite; but I give below (p. 94), by way of sample, a section drawn to illustrate one of my papers on the geology of Dalhousie, reproduced, with the kind permission of the Director of the Geological Survey of India, from the plate facing p. 110, vol. xviii, *Records G.S.I.*

During the Eocene epoch volcanic activity was rekindled to a limited extent in Kashmir,‡ the Central Himalayas, and in

* Mr. Middlemiss mentions the case of the Gola River and Kotudwar granite (*Memoirs G.S.*, xxiv. (1890), p. 114), and argues that the granite there must be pre-Tertiary because the Tertiary beds are not metamorphosed. But as the distance of the granite from the Tertiaries in one case appears to be five miles, this argument does not carry us far. But even if the particular outcrops of granite alluded to are pre-Tertiary, that does not show that the main mass of the gneissose granite, so extensively seen in the outer Himalayas, is not post-Eocene. I have shown that the porphyritic granite was preceded by a finer grained granite. See *Records G.S.I.*, xvii (1884), p. 35

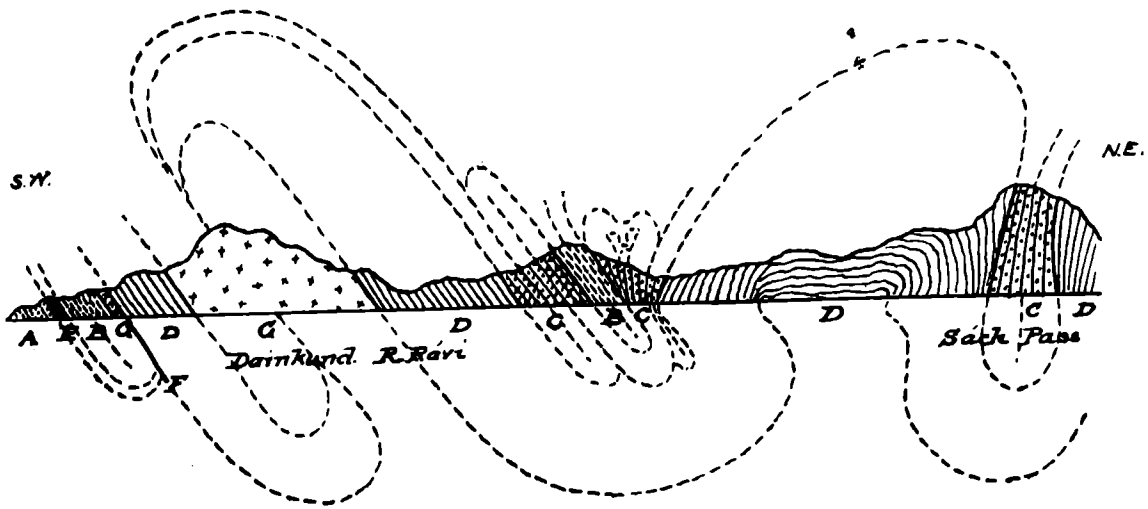
† It attains this width in the Dalhousie area (see map attached to *Records G.S.I.*, xviii, p. 110), and probably exceeds it in some places farther to the east.

‡ Lydekker, *Memoirs G.S.I.* xxii (1883), p. 41.

Afghanistan*; but in post-nummulitic times basic, and ultra-basic, igneous rocks (gabbros, peridotites, etc.), were erupted in some abundance, and had a powerful metamorphic action on the nummulitic strata.† Like the granite these basic intrusive rocks "appear along lines of dislocations and here and there enter the neighbouring strata as dykes.‡

All the above instances of the occurrence of Tertiary basic trap within the Himalayan area occur either in Kashmir or on the farther side of the Himalayan crystalline axis. All along the southern flank of that axis the great eruption of the gneissose granite appears to have taken the place of the basic trap.

Time would fail me were I to attempt to enter into the many interesting branches of inquiry suggested by the above brief sketch of a complicated subject. The physics of the question



SECTION THROUGH DAINKUND TO THE SÁCH PASS.

A. Tertiary series. B. Permo-Triassic series. C. Conglomerates. D. Silurians. E. Traps. G. Gneissose granite. F. Fault.

Longitudinal Scale—1 inch = 10 miles.

must necessarily be left untouched. The zoological and palæontological sides must also remain unnoticed. I would only refer, in passing, to Dr. Blanford's able and highly interesting paper in the *Geological Magazine* on the bearing of the zoological aspects of the case on the question of the age of the Himalayas. After referring to the peculiar forms of animal life in Tibet, he writes: "I must say that it is to me incredible that this

* Griesbach, *Records G.S.I.* xix (1886), p. 64, xx (1887), pp. 99-102.

† Griesbach, *Records G.S.I.* xiii (1880), p. 91. Lydekker notes a vein in the vicinity of the nummulitic area, but it occurs, I gather, in a band coloured "Krol, infra Krol, and Blaini;" viz., in pre-Triassic rocks; *Memoirs G.S.I.* xxii (1883), pp. 112-113-105 (fig. 7); McMahon, *Records G.S.I.* xix (1886), page 116; Griesbach, *Memoirs G.S.I.* xxiii (1891) pp. 45, 84, 130.

‡ Griesbach, *Memoirs G.S.I.* xxiii (1891), p. 45.

peculiarly specialized fauna can have been differentiated since Pleistocene times; and very improbable that it can have been entirely developed since the Pliocene period. So high a degree of specialization points to a long continuance of the peculiar conditions that still prevail." *

The conclusion arrived at by the author of the article on the Himalayas (General Strachey) in *The Encyclopædia Britannica* is that "an area of land must have existed where the line of snowy peaks now stands, which has not been submerged since the Palæozoic period." A study of the geological evidence has landed me in a similar conclusion, from which I see no escape, and the evidence for which, as at present known, I have endeavoured to lay before you this evening.

From the Cambrian down to the close of the Eocene epoch the Himalayas have, it seems to me, presented very similar conditions to those seen to-day in the Malay archipelago—long chains of mountainous islands alternated with deep, narrow seas, the margins of which were fringed with active volcanoes.

The lavas poured out during the Silurian and Carboniferous periods are generally supposed to have been submarine. My impression is that the volcanoes were on land and that their lavas and ashes were deposited partly on land and partly within the littoral line of the sea. I know of no contemporaneous lava flows intercalated with deep sea limestones.

We seem to have had side by side, for long periods, sinking areas covered by sea and rising areas crowned by mountains. That such areas should have existed side by side seems to me only what one might have expected to see. If there is one fact in geology which I believe to be more firmly established than any other it is that where the crust of the earth is loaded with deposits a sinking of the crust takes place, for we see this process going on at the mouth of every great river. The converse of this proposition seems also true, namely, where the load is removed the tendency of the lightened area is to rise: instance the "creep" in our mines. In the case of the Himalayan archipelago —as I read the story—pluvial, and other agents of erosion, acting through long periods of time, gradually wore down the surface of the mountain area and caused a gradual rise proportional to the load removed, whilst the eroded material carried by the streams and rivers into the adjoining narrow seas caused their gradual subsidence. The planes between the sinking and the rising areas, were, I take it, faults with throws many thousands of feet in extent.

That the earth-movements connected with the infancy and youth of the Himalayas were *mainly* simple movements of elevation and depression, unaccompanied by considerable tangential

* *Geol. Mag.* (1891), 374.

compression, seems certain.* Indeed, it is the general absence of the marks of crushing and contortion of an earlier date than Miocene times that has led so many geologists to forget that the careworn Hima-álaya, whose brow now bears so many wrinkles, ever had a placid infancy and youth.

But a time of trial and trouble for our Hima-álaya came at last. The subsidence of the areas covered by sea came to an end, and both areas—those crowned by mountains and those covered by sea—rose together. The period of general elevation that then set in appears to have been connected with a revival of plutonic activity, for it was a time of granitic eruption on a grand scale—a time when the beds on either side of the chain of crystalline rocks suffered great contortion and crushing.

During the slow and majestic elevation of the Hima-álaya, the direction of the rivers seems to have been determined partly by the folding of the strata in long S.E. to N.W. flexures, and partly by the character of the rocks; the rivers escaping to the plains wherever the barrier opposed to them showed signs of weakness. For instance the Rávi runs parallel to the Dhula Dhár, where the granite is from eight to twelve miles thick; but where it is temporarily reduced to a width of 250 feet, the river turns suddenly and rushes down to the plains. The Jhelam river is another case in point. It escapes from the vale of Kashmir where the granite does not oppose its course. The rock is seen on both sides of the river, but not, apparently, in its bed.

The thinness, or the absence of the granite at some points, indicates that the elevatory force was comparatively feeble there, and local depressions favourable to the escape of the rivers were probably the result.

In conclusion I would remind anyone who may think it improbable that the same conditions should have prevailed in the Himalayan archipelago for so long a period, that the case of Peninsular India is even more remarkable, for the land of the dark Hindu (Hindu-istán) does not appear to have had a dip in the sea since the close of the Palæozoic era.† Our fair lady Hima-álaya, has had, at all events, more respect for the laws of beauty and of sanitation.

* Medlicott, *Memoirs G.S.I.*, iii, pt. ii (1864), p. 86.
† Oldham, *Manual G.I.*, 2nd ed. (1893), p. 2.