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THE EVOLUTION OF INDIAN GEOGRAPHY.*

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In the paper which follows there will be found no narrative of exploration of countries before unknown, no tale of dangers encountered, or account of difficulties overcome—at any rate, in the ordinary sense of the words. Difficulties there have been, but they have been difficulties of interpretation or reconciliation of apparently contradictory statements; dangers have been met, but they have been the dangers of drawing too confident conclusions from insufficient data; an exploration has been attempted, but it has been a journey into the past—a form of exploration which is even now regarded by some as lying outside the scope of geography, but erroneously so. Science is for all time, and geography, regarded as the delineation of the form and condition of the earth's surface, is of all time. Since the earliest times, when first a crust solidified upon the surface of the primeval molten globe, and cooled enough to allow of the condensation of water upon it, there has been an ever-changing geography; land and sea, mountains and rivers, have come and gone with ever-varying forms, and though no man was there to see and describe them they have left their impress, more or less complete and decipherable, in the record of the rocks. The interpretation of this record is the work of geology, but the information obtained may often be geographical in its nature; and it is the information which can be gleaned from the rocks, regarding the ancient geography of the country included in the Indian Empire, and the

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stages by which its present geography has been reached, with which this paper will deal.*

The geological map of India, as it now stands, shows clearly a division into the three great geological regions, known respectively as the peninsula, the Indo-Gangetic alluvium, and the extra-peninsular area. This distinction is so well known that it is unnecessary to dilate on it, or to refer to it further than to point out that the distinction is in no way artificial, but represents strongly marked divergencies of geological history. The peninsular area has been, throughout a long geological past, a land area, which has not been depressed beneath the sea since the close of the palæozoic era; while the sea has flowed repeatedly over the extra-peninsular area—or, at any rate, that portion of which we have any extensive knowledge—up to the commencement of the tertiary. Besides this, there are very striking differences in the geological structure and surface contour of the two regions; but for the present purpose the distinction is one rather of convenience and necessity, for the peninsula forms but the remnant of a once much more extensive continent, and its existing limits were only marked out at a comparatively late period, when the great plain of the Indo-Gangetic alluvium first came into existence.

The earliest stages in the geological history of India are wrapped in obscurity. The peninsula consists essentially of a very ancient core of gneisses and granites, on which there lies a succession of systems of more or less altered and disturbed, unfossiliferous, sedimentary rocks, known generally as the transition, Cuddapah, and Vindhyan systems. All, or nearly all, these rocks, except perhaps the newest, the upper Vindhyans, seem to have been deposited in the sea, and throughout the great length of time represented by these deposits we know that there were alternations of sea and dry land, but there are no indications sufficiently definite to allow us to form any idea of the general distribution of land and sea at any particular period. This much, however, we may say, that none of the leading features of Indian geography were marked out, in anything approaching to their present form, until the latter half of the Vindhyan period, which seems to have been marked by great earth-movements, whose effects are still traceable in Indian geography.

From the eastern flanks of the Aravalli mountains there stretches a great spread of fine-grained sandstones, with a lesser thickness of shales, and some subsidiary limestones. They are generally of a more or less distinctly red colour—a feature which is suggestive of fresh water

* In order to avoid overburdening the text with footnotes, a general reference may be made to the 'Manual of the Geology of India, Stratigraphical and Structural,' 2nd edit. (Calcutta, 1893), published by the Geological Survey of India, where fuller information and references regarding the subjects dealt with will be found.

rather than of marine origin—while the enormous area over which they are found to maintain a remarkable uniformity of character, and the absence of fossils, makes it probable that they were formed by rivers and in fresh-water lakes and lagoons. Throughout the area where these Vindhyan rocks are exposed, and probably also in the extensive area where they are covered by the Deccan traps, they have been but very little disturbed, and, ancient as they are, lie horizontally or in very gentle undulations of bedding.

The boundary of this great area of still undisturbed sandstones towards the Aravalli range is, however, a great fault of over 5,000 feet in throw, and beyond this faulted boundary there are some small patches of disturbed Vindhyan rocks, resting on the slates of the Aravalli range. The relation resembles closely that which subsists between the undisturbed river deposits of the Gangetic plain and the disturbed Siwalik beds and slates of the Himalayas; and as the deposits of the Gangetic plain can be shown to be derived from the waste of the Himalayas, and to have been formed during the elevation of those mountains, it is difficult to avoid the conclusion that the upper Vindhyan sandstones were similarly formed of the debris washed down from the Aravalli range, and that the period during which they were being deposited represents that of the elevation of the Aravalli mountains and of their maximum development.

However this may be, one thing is certain—the compression of the rocks of the Aravalli range, and consequently its elevation, had been completed before the close of the Vindhyan period. Since this remote period no further disturbance of any importance has taken place, and the Aravallis have been exposed to a continuous degradation, till they are now little more than the wreck of a mountain range.

But the Aravalli range does not seem to be the only one of the principal features of Indian geography which dates from this period. Running northwards from the neighbourhood of Madras, and curving round to follow the curve of the coast-line, there are a series of hills known as the Nallamalai, Yellakonda, etc. The compression of the rocks here is by no means so great as in the Aravallis, and they were probably never so important a range; but at one time they must have been very considerably higher than they are now, and the zone of disturbance, continuous with that of the Nallamalais, which can be traced northwards to the Godaveri, probably represents part of the original extension of the range. Now, the compression which the rocks of this range have undergone was certainly of later date than the Karnul series, which is generally regarded as the equivalent of the lower part of the Vindhyan system, while it is equally clear that it was earlier than the commencement of the Gondwána era, that which next succeeds the upper Vindhyan. Consequently, the period when the Nallamalai hills were elevated seems to coincide with that of the origin of the

Aravalli range, and we may take them to be products of the same great period of earth-movements.

Yet this is not all. The close parallelism between the east coast and the Nallamalai hills, as far as they extend, seems to point to a direct connection between the two. In confirmation of this antiquity of the east coast, we find no marine deposits of secondary or tertiary age in the interior of the peninsula, and the small patches that are found in the immediate vicinity of the coast consist of littoral and shallow-water deposits, thinning out against the rocks of the mainland in a manner which shows that the boundary of land and sea must in the main have been very much what it now is. Since the latter part of the palæozoic era, the sea has never spread far beyond its present limit on the east coast, and, though dry land may frequently have extended to the east, it probably did not do so to any great extent.

So ended the first great epoch in the geographical history of India, leaving its impress in two great features—the Aravalli range on the north-west of the peninsula, and the East coast—which have remained throughout all subsequent changes. The period of great earth-movements to which they were due was succeeded by a long era of quiescence, during which a great system of river-deposits, known as the Gondwána system, was accumulated. The Gondwána system is a most interesting one in many ways which cannot be dilated on here, one of them being the presence in the lowest beds of numerous ice-borne boulders, and the evidence of glaciers having descended to low levels in what is now the Penganga valley and in western Rajputana. At present, however, we are only concerned with the information that can be drawn from it regarding the distribution of land and sea at the close of the palæozoic and during the greater part of the secondary eras, so different from that of the present day.

First, it may be noticed that the north-easterly limits of the peninsular area, as they are now defined, had not then been determined, but that the rock area of dry land extended over the Assam hills and the eastern Himalayas. Not only are the older rocks of the Assam range of hills closely related to those of the peninsula, but coal-bearing sandstones, identical in character and fossil contents with those of the coalfields of Bengal, are found along the Himalayas from Sikkim eastward. How far this north-easterly extension reached, or where its northern margin lay, cannot at present be determined, but its southern shore was probably not far removed from the southern flanks of the Assam range.

The east coast of the land coincided very closely with the present eastern coast; for along it, from Cuttack on the north to near Trichinopoly on the south, there are scattered small patches of beds belonging to the Rajmahál series or upper portion of the Gondwána system, and

in many of these patches marine fossils are found. The marine beds are, however, confined to the immediate neighbourhood of the coast, and thin out against the older rocks, usually resting directly on the gneiss, though west of Rajamahendri on an eroded surface of lower Gondwána rocks.

The north-western margin of the land area probably coincided approximately with the Aravalli range, at any rate, in later secondary times, for the jurassic rocks of western Rajputana are of marine origin. But before trying to trace this or the eastern shore further, it is necessary to leave India for a while and turn to South Africa.

There are some remarkable resemblances between the geology of South Africa and that of India. In the interior there is a great series of old river deposits, known as the Karoo series, which corresponds in every way to the lower Gondwána series of India. They commence with a glacial boulder clay, and in the overlying strata are many coal-seams presenting the same peculiarities as the Indian coal. Besides these general resemblances (which count for little), the plants of the Indian and African coal-measures are without exception identical; and among the few animals which have been found in India, one is indistinguishable from an African species, another is closely allied, and both faunas are characterized by the very remarkable genus group of reptiles comprising the *Dicynodon* and other allied forms.*

These, however, are not the only analogies, for near the coast of South Africa there are developed a series of beds containing plant fossils in the lower part, and marine shells in the upper, known as the Uitenhage series, which corresponds exactly to the small patches of the Rajmahál series along the east coast of India. The few plant forms found in the lower beds of Africa are mostly identical with, or closely allied to, Rajmahál species, while of the very few marine shells in the Indian outcrops, which are sufficiently well preserved for identification, at least one species is identical with an African form.

These very close relationships between the plants and animals in Africa and India at this remote period appear to be inexplicable, unless there were direct land communication between them, over what is now the Indian Ocean. The age of the Uitenhage marine beds is now generally taken as neocomian, and in the immediately succeeding period the proofs of a continuous land barrier are as conclusive as it is possible to imagine them. This subject has been so frequently treated at greater length than would here be possible, that it will not be advisable to do more than briefly indicate the nature of the argument.

On the east coast of India, in the Khási hills, and on the coast of

* 'Manual of the Geology of India,' 2nd edit. p. 203, where further references will be found.

South Africa, the marine fossils of late jurassic and early cretaceous age are largely identical with, or very closely allied to, each other, showing that they must have been inhabitants of one and the same great sea. In western India the fossils of the same age belong to a fauna which is found in the north of Madagascar, in northern and eastern Africa, in western Asia, and ranges into Europe—a fauna differing so radically from that of the eastern exposures, that only a few species of world-wide range are found in both. Seeing that the distances between separate outcrops containing representatives of the two faunas are much less than those separating the outcrops from the nearest ones of the same fauna, the only possible explanation of the facts is, that there was a continuous stretch of dry land connecting South Africa and India, and separating two distinct marine zoological provinces.

The existence of a land connection at the commencement of the cretaceous period having been established, we need not stay for a consideration of certain hypotheses which have been supposed to preclude the possibility of such a land area having ever existed, but may conclude that the obvious deduction from the close palæontological and lithological relations of the permian and triassic rocks of India and Africa is the true one; and that, from the latter part of the palæozoic area to near the close of the mesozoic, a great continent stretched across what is now known as the Indian Ocean. The land we have been considering has been named Gondwánaland by Suess, for the purpose of distinguishing it from the supposed continent of Lemuria, and whether this name be adopted or not, the two must not be confounded. None of the arguments derived from living plants and animals, to show that there has, or has not, been a direct land connection between India and Africa, even if they be accepted in their entirety, can in any way affect the existence of this ancient continent, of which there is no geological evidence after the close of the secondary era.

So far only the peninsular area of India has been dealt with; it is now necessary to turn to the extra-peninsular regions, and see what was taking place there during all this period. The oldest rocks of the extra-peninsular hills have been but little studied, and one great region, the eastern Himalayas, is absolutely unknown except for a few visits, none of which have extended far into the range. So far as is known, no marine sedimentary rocks occur there, and, as has already been mentioned, this region probably formed part of a land area continuous with the peninsula, throughout the palæozoic and mesozoic eras. We find, however, in Burma on the one hand, and in the north-west Himalayas, and the hills west of the Indus, on the other, a great series of marine sediments, showing that these regions formed part of the ocean. It is not meant that they were continuously covered by the sea, for unconformable breaks show that there were alternations of land and sea; but there are no extensive subaërial formations, and there is no evidence

of any considerable disturbance or compression of the rocks. There were periods of placid accumulation of sediments, interrupted by times when they were quietly raised above sea-level and exposed to denudation, but there are not at present sufficient data to allow of our attempting any detailed restoration of the geography until the close of the jurassic period. Some indications of the main features have already been given, and all that remains is to complete these and embody them on the small sketch map printed below.*

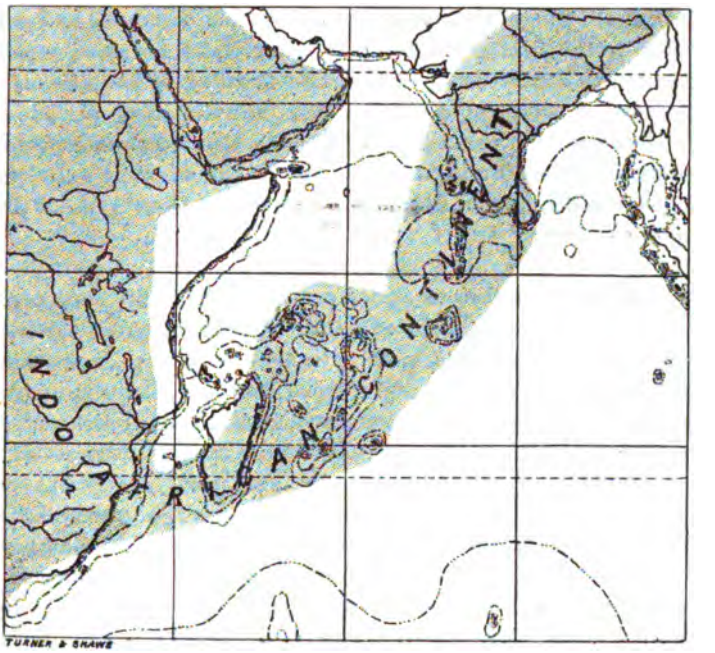

FIG. 1.—SKETCH MAP SHOWING APPROXIMATE DISTRIBUTION OF LAND AND SEA AT THE CLOSE OF THE JURASSIC PERIOD AS COMPARED WITH THAT OF THE PRESENT DAY.

* The map is based on one published by the late Professor Neumayr in the *Denks. k. k. Akad. Wiss. Wien. L.* (1885), which, so far as India and Africa are concerned, has been but little altered. The principal change introduced is a continuation of the land area from the northern portion of the present peninsular area, over the Indo-Gangetic plain, to the eastern Himalayas and the Assam hills. The very wide strait he drew between the peninsula and the Himalayas does not seem to be required by the palæontological facts, while it is contrary to the indications of a former extension of the peninsular land to the north and north-east, and to the evidence there is of the much more recent origin of the Gangetic depression, now occupied by the alluvial plains of Upper India. I have consequently taken a somewhat different view of the distribution of land and sea at this period, and prefer to look upon the occurrence of a few shells common to the uppermost Cutch jurassic beds and the marine deposits of the east coast, as indicating a connection of the two seas through the temporary submergence of an isthmus further south, rather than by the existence of sea stretching across the present area of the Gangetic plain. Taking everything into consideration it seems probable

It will be seen that the distribution of land and sea was very different to what it now is. All the land west of the Aravalli range, the north-west Himalayas, a great portion of Tibet, and all Upper Burma, were then covered by the sea; while dry land spread to the south-west far beyond the present coast. The great mountain system of the Himalayas had not been upheaved, and the hills west of the Indus, and the Arakan Yoma, were not only non-existent, but the very rocks of which they are composed had to a large extent not been formed. The only features of existing Indian geography which we can recognize are the Aravalli range, then probably loftier than it now is and extending further to the north, and the east coast, which occupied much the same position as it now does. These two features, as has already been explained, are of much more ancient date, and the long period which elapsed between the great series of palæozoic earth-movements, to which they owe their origin, and the close of the mesozoic era, does not seem to have added any of the leading features of our present Indian geography.

The close of the cretaceous period saw the end of this long period of repose and the commencement of another period of great earth-movements, which have led to a most extensive reshaping of the surface, and a radical change of the geography of India, to that represented in the more familiar form found in modern atlases. This series of earth-movements appears to have been ushered in by the greatest series of volcanic eruptions found anywhere in the world, eruptions which covered an area of 200,000 square miles with an accumulation of lavas and tuffs, several thousands of feet in thickness. Whether this unparalleled exhibition of volcanic activity was directly connected with the great series of earth-movements that immediately succeeded it, and resulted in the elevation of the extra-peninsular mountain chains, cannot be stated with certainty; but the process of mountain-building has elsewhere been found to have been preceded by volcanic outbursts in the neighbourhood of the chain that was afterwards upheaved, and the forcing out of this enormous mass of lavas may well have been the prelude of the upheaval of the greatest mountain chain of the world.

However this may be, the commencement of the tertiary period found a great set of earth-movements already commenced, which continued with increasing intensity, reached their maximum in the pliocene period, and are still in progress, though in diminished intensity. The result of these movements has been to drive back the sea which, at the close of the cretaceous period, flowed over the country now

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that the geography of India towards the close of the jurassic period was very much as depicted in the figure, though it must be remembered that we know nothing of the former geography of the existing oceans, and land may have extended over them to a greater extent than has been represented.

occupied by the hills of our western frontier, the high plateau of Tibet, and the whole of Burma, and to crush and fold the rocks, forcing them up into mountain ranges, till marine limestones of nummulitic age have been raised to heights of 20,000 feet above the sea in the Himalayas, and the sea-formed rocks of the country beyond our western frontier folded and raised into inhospitable hills, now occupied by warlike and lawless tribes. On the east the Arakan Yoma, and the range of hills whose summits form the Andaman and Nicobar Islands, were elevated, driving the sea back from a large area over which it once flowed to the foot of the plateau of the Khási and Garo hills.

The age of the hills of Burma and the western frontier is limited by that of the rocks they are composed of, and when we find beds, containing nummulites and other marine fossils of eocene, or even later, age, widely distributed in them, it is evident that the hills cannot have been upraised till the latter part of the tertiary era. With the Himalayas it is different; their vastly greater bulk would in itself suggest that the forces of upheaval had acted on them for a longer period, and we find proof that even so far back as the pliocene period they constituted a mountain range comparable to that of the present day, and, what is more, with the main features of the drainage system marked out on the existing lines.

The geological map shows a long strip of upper tertiary beds flanking the foot of the Himalayan range; these are the rocks of the Siwalik series. They were originally river deposits similar to those now being formed at the foot of the hills, and beds of the same age could doubtless be found deep below the Gangetic alluvium; but they have been cut off from the rest of the plains, compressed, disturbed, and elevated to form the Siwalik range, or foot-hills of the Himalayas. Now, it is found that the higher beds of the series consist of coarse conglomerates near the places where the principal rivers issue from the hills, and these conglomerates consist of large well-rounded boulders of hard crystalline rocks, such as are found in the interior of the range, showing by their size and shape, no less than by their composition, that they had been carried by large and rapid rivers for a long distance. In the intermediate country, between the points where the rivers leave the higher hills, the same beds are found to consist of clays, sands, and conglomerates in which the pebbles are smaller, less well-rounded, and composed of the rocks which are found near the margin of the hills. From this it is clear that, even so long ago as the time when the extinct Siwalik fauna flourished, the principal rivers of the Himalayas flowed much where they now do, and the size of the boulders brought down proves that they must have had rapid currents and have flowed in channels of comparatively steep gradients. We may conclude, then, that the Himalayas of the pliocene period were, if not so lofty as at the present day, at any rate a lofty and important mountain range.

Another result of these earth-movements was the formation of a depression parallel with the ranges, and separating them from the peninsula of India, which has been filled up by the Indo-Gangetic alluvium. At first the drainage of this depression had but one outlet, where the Indus now reaches the sea, and in this great river, formed by the whole of the drainage of the Himalayas, a certain species of dolphin established itself, and gradually acquired the habit of living and pursuing its prey in fresh water. At a later period a depression was formed between the Rajmahál and Assam hills, by which a gradually increasing portion of the drainage escaped, and the single river broke up into two separate drainage systems, one finding its way to the sea by the Indus, the other by the delta of the Ganges and Brahmaputra. The date of this separation is geologically recent, and the diversion of the drainage from the Indian Ocean to the Bay of Bengal must have been a gradual process, whose final stage, the permanent diversion of the Jumna into the Ganges, may even have taken place within the historic period. Before this the waters of the Jumna must have flowed westwards, then it may have wandered and flowed alternately into the Ganges and Indus, or that dry river channel which can still be traced through the desert of the western Rajputana. In its latest stage it probably, like the Casiquiari in South America at the present day, divided its waters between the eastern and the western drainage; but now no further change can take place, for the river has cut its channel deep below the general level of the plain, and must perforce remain a tributary of the Ganges.

While these great changes were going on in Extra-Peninsular India, the peninsula itself had remained almost in a state of quiescence. There had been some minor changes of level, doubtless, and the northern limits, as we now know them, were defined; but, speaking broadly, it took no part in the disturbances which were going on all round, and remained quiescent, undergoing no changes beyond those produced by the agency of subaërial denudation. Yet it would be surprising if such extensive earth-movements had produced no sympathetic changes in neighbouring regions, and one such change can be pointed out—the establishment of the present west coast of India. At the commencement of the cretaceous period we know that land stretched away from the present west coast to South Africa, but some small patches of marine tertiary rocks on the coast show that it had been marked out, with much the same general course as it now has, by the close of the eocene period. We may conclude, then, that land connection between India and Africa had already been cut off, and that the gradual submergence of this continent took place during the last great period of earth-movements, leaving nothing to mark its original position but the coral archipelagoes of the Laccadive and Maldive Islands and the great Chagos bank.

The great range of the Western Ghâts, the most striking feature in

the geography of India proper, is of more recent date, and the cause of it is somewhat obscure. It bears some resemblance to a great inland sea-cliff, and there is reason to suppose that the sea did once wash its foot; but all the present surface features are due to subaërial action, and on the whole it seems more probable that this range owes its origin to comparatively recent elevation, whose effects are noticeable in its scenery. Here alone in peninsular India do we find the stream valleys as a rule deep, narrow, and steep-sided, or the streams still actively engaged in deepening, and cutting back the heads of, their valleys. In the Ghâts both these features are noticeable; they are the same as we find, even more strikingly, in the valleys of the extra-peninsular hills, and in both cases the cause is the same—a recent elevation of the land which has not yet been counterbalanced by the cutting down of the valleys.

The most remarkable feature of Indian hydrography, that all the principal rivers, except the Narbada and Tapti, take their rise within sight of the west coast and flow thence eastwards across the whole breadth of India, owes its existence to the same cause. It is not meant by this that there were originally considerable rivers flowing westward, and that the elevation of the Ghâts reversed the slopes and turned the rivers eastward, for had that been the case there would be deep-cut gaps in the crest marking the original position of the valleys. A more probable explanation is that the peninsula, as we now know it, is but the eastern half of a once more extensive land area, whose principal watershed was not far removed from the present one, and that the westward-flowing rivers have disappeared in the subsidence of the land they once drained.

The absence of low-cut gaps in the western Ghâts has been noticed as evidence that there were not any westerly flowing rivers whose drainage has been reversed. But at the southern end there is just such a gap, known as the Palghât, to the south of which the Western Ghâts are continued in the Travancore Hills. No satisfactory explanation of this gap has been given, and it is not impossible that it may indicate the place where a considerable river once flowed westward, whose course has been interrupted, and drainage diverted to the east, by the changes of level consequent on the elevation of the Ghâts. With this exception, all the main lines of drainage in peninsular India appear to have been marked out even before the close of the Deccan trap period; indeed, some of them, such as the valleys of the Godavari and Mahanadi, may date as far back as the commencement of the secondary era, while such changes as have taken place since the commencement of the tertiary era have been of only minor importance.

We have now traced the history of the growth of the main features of Indian geography. We have seen that the north-west boundary of the peninsular area, the Aravalli range, and the east coast were marked

out in some distant period, of which we can but say that it was prior to the age of the English coal; and we have seen that the extra-peninsular ranges, the great Indo-Gangetic plain, the northern margin of the peninsula, and the western coast owe their origin to another great series of earth-movements which took place during the tertiary era. There remains for consideration the influence which its geological history has had on the minor topography and scenery of both peninsula and extra-peninsular India.

The peninsula is, broadly speaking, a region of broad open valleys and easy slopes, in which the rivers are flowing near their base level of erosion, and are not at present actively lowering their channels. This is what might be expected of an ancient land surface which has been long exposed to the shaping action of the forces of subaërial denudation.

The exceptions to this general rule, apart from the one already mentioned, though often striking in themselves, are really of minor importance, and are merely the result of the mineralogical differences of constitution of the underlying rocks. Thus a hard bed, lying nearly horizontally on a softer one, or on a rock which is more readily decomposed, will always form a steep and precipitous scarp. The most conspicuous instance of this is the great southern scarp of the Vindhyan sandstones, known to geographers as the Vindhyan range, where it overlooks the valley of the Narbada, and as the Kaimur, where it overlooks that of the Son. A similar scarp surrounds the gneiss area of Bundelkhand, and on a smaller scale is found in many other parts of India at the limits of the outcrop of horizontal sandstone beds.

The Deccan trap, consisting as it does of a great thickness of horizontal strata differing widely in their resistance to denudation, has a peculiar type of scenery of its own, with flat-topped hills marked by horizontal lines of cliffs of the same general type as is found wherever a country of this particular structure has been exposed to subaërial denudation.

Sharp-crested, steep-sided ridges, too, are a conspicuous feature where, as in Bundelkhand and parts of the southern Mahrata country, there are numerous massive quartz reefs traversing the gneiss, and in the Aravalli range there are many such hills formed by the outcrops of hard quartzites. But even here the valleys are broad and open, and largely exceed the narrow steep-sided ridges in size.

Granite tors and bosses are developed, often on a very large scale, in the gneissic regions of the peninsula. One may instance the rock of Trichinopoli; the great bull on the Charimundi Hill in Mysore, carved out of a single block of granite; and the Madan Mahal in Jubbulpore, where a small palace has been built on the top of a great rounded mass of granite.

All these, however, striking as they often are, do not alter the general truth of the statement that the peninsula is a region of open valleys and gentle slopes. Compared with the scale of the country, the exceptions are proportionately very small, and even the valleys draining the sides of the mountains, though steep sided and narrow compared with the general surface contour of the peninsula, are open and of moderate gradients when compared with the valleys of the extra-peninsular mountain ranges.

In the extra-peninsular area of India the geological conditions are very different, and the difference is reflected in the present form of the surface. Much of this land area has only been raised above the sea within the tertiary era, and even within the latter portion of it.

FIG. 2.—VIEW AT KHANDALLA. DECCAN TRAP.

Everywhere there have been great changes of level; mountain ranges have been elevated at a greater rate than the agencies of subaërial denudation could properly cope with, and the result is that we have steep-sided deep valleys, at the bottom of which flow rapid torrents, carrying with them quantities of debris, and, generally speaking, actively engaged in deepening their channels. The valleys are, as a rule, comparatively narrow at the bottom; at times, however, the raising of the river bed has been too rapid for the downward cutting action to keep pace with it, and, by checking the gradient of the stream, has caused it to deposit an alluvial plain above the obstruction or, in extreme cases, even to form a lake.

There are, however, some leading differences in the general type of valley in different regions, due to differences in the nature of the rocks and of the disturbances they have undergone, as well as to the amount

of rainfall. In the western hills of Baluchistan and eastern Afghanistan, the rocks consist of thick beds of hard limestone or sandstone alternating with bands of shale or shaly rocks, which readily disintegrate into small fragments or even into impalpable mud. Where there is an outcrop of these latter rocks we find broad open valleys, sometimes comparatively smooth at the bottom, where they have been filled up with stream deposits, but generally full of minor irregularities caused by the numerous runnels of water carving the surface into gullies.

Between the open portions of the valleys, where they traverse the soft rocks, there rise ranges of sandstone or limestone cut by narrow

FIG. 3.—CHAPPAR RIFT: VIEW OF UPPER END. FROM A PHOTOGRAPH BY THE BENGAL SAPPERS AND MINERS.

gorges through which the streams flow. These gorges are most striking where they traverse hills composed of the massive limestones of tertiary or cretaceous age. They are locally known as "tangis," which may be literally translated as "tight places," and appropriately, too, for woe betide the caravan that is caught in one of these gorges by a flood; escape is impossible, and man and beast are swept away, never to be seen or heard of again.

The best known of these, and one which may be taken as a type of the rest, is the Chappar rift, represented in Fig. 3, through which the railway to Quetta has been carried. The entrance to this is not twenty feet wide, and through this narrow gorge escapes the drainage of over a

thousand square miles of country. The hill through which this gorge is cut, is formed by an anticlinal fold of limestone, whose surface has been washed bare of the overlying shales, and exposes a smooth surface unbroken except by the Chappar rift and another valley known as the Blind rift. So remarkable is the feature, that it has not unnaturally been considered to have been caused by a fissure; but a careful examination of the rocks has revealed no trace of this, and to the geologist, accustomed to the study of the action of the water, it stands out clearly as a river-cut gorge. A fracture might account for the gorge itself, if

FIG. 4.—DIRGI VALLEY BELOW THE CHAPPAR RIFT. FROM A PHOTOGRAPH BY THE BENGAL SAPPERS AND MINERS.

there were any trace of such to be found; but it would not account for the open valley shown in Fig. 4, formed where the valley traverses a band of shales. A precisely similar broad and open valley is found where the stream flows through soft shales above the gorge, from which an immense amount of material has been removed, every particle having been carried down through the gorge, and helped to enable the stream to grind away the hard limestone. This, having been protected by the scanty rainfall and consequent absence of vegetation from the disintegrating effects of water freezing in fissures of the rock on the one hand, and the solvent action of carbonic and humic acids on the other, has not been broken away, and remains standing as vertical cliffs on either side of the gorge.

The upper end of the Chappar rift is faced by the opening of

another known as the Peel rift, cut through an anticlinal of limestone parallel to the Chappar. The reason of this course of the drainage across the axes of elevation must be looked for in the drainage being what is known as antecedent; that is to say, its general course was marked out before the rocks were thrown into their present folds. As soon as the land rose from the sea, the rainfall would run off into the depressions and collect in streams, which cut down into the rocks. If, owing to a subsequent compression, these were gradually bent into anticlinal and synclinal folds, and if the movements were not too rapid, the streams would maintain their general course, cutting down through the rising crests of the anticlinal folds, and, though the surface contour would be largely influenced by internal structure and by the different degrees of resistance offered by the different rocks, yet the main features of the drainage system would be of older date and independent of the minor structure of the country.

There is ample proof throughout this country that there have been considerable local disturbances and alterations of level within the recent period of geology; and even within what would be regarded as recent from the historical point of view there has been compression, resulting in a relative rise of the ground over the crests of anticlinal folds. Proof that this compression is still going on was given on December 20, 1892, when a severe earthquake resulted from the sudden yielding of the earth's crust, along what appears to be an old line of fault, west of the Kojak range,* whereby an adjustment took place, indicated by a shortening of some two and a half feet in the railway line which crossed the fault.

A very striking feature, resulting from these local changes of relative level, is the frequency of more or less extensive valley plains occupying rock-bound basins. In a region of small rainfall the erosive power of the streams is only exerted when they are in flood, and this is only a small portion of the year. A rise of the river bed, which would easily be coped with in countries with a more abundant rainfall, is here enough to interrupt the drainage, and the same scanty rainfall prevents the streams filling the basins so formed with their own deposits or with water. There result, consequently, more or less extensive plains, covered mainly by fine-grained deposits of wind-blown dust, precisely similar to the great loess deposits of China. The drainage which finds its way on to these has in many cases no escape except by evaporation or underground percolation; but in many other cases the deposits have accumulated till the surplus water has been able to find an escape over the lowest point of the surrounding ring of hills, a point which is by no means necessarily coincident with the original bed of the stream.†

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* "Records," *Geological Survey of India*, vol. xxvi. p. 58. 1893.

† See "Records," *Geological Survey of India*, vol. xxv. p. 28. 1892.

The hills which lie between India proper and Burma differ in some respects from those of the western frontier. The difference is partly due to lithological causes. The rocks are more homogeneous as a whole, for, though there are great variations in the hardness of different beds, the alternations are more frequent, and there are not thick bands of strongly resisting rock alternating with as thick or thicker bands of soft and easily disintegrated beds. But the differences are still more largely due to climatic causes. Instead of an arid country almost devoid of vegetation, there is an abundant rainfall, the hills are everywhere covered with a dense semi-tropical vegetation, and the humic acids developed in this have generally decomposed the rock for a considerable depth from the actual surface. As a result, there are not the narrow vertical-sided gorges of the western frontier, nor any areas of closed drainage, for the streams have everywhere been able to maintain their course to the sea in spite of any local elevations of the stream bed. In places, however, these movements have formed rock basins, which have been filled up by the stream deposits as rapidly as they have been formed, and instead of broad, barren plains of wind-blown loess, we have fertile alluvial plains, such as that of Manipur. But for the most part we have a series of parallel ranges, between which the streams flow in deep parallel valleys connected by short transverse gaps by which the streams break through the ranges, often to flow back again parallel to their original course.

The mighty mass of the Himalayas contains within itself every range of structure and climate that is found in the hills already referred to, and, having been a mountain range when they were still to a considerable extent covered by the sea, it has attained greater dimensions, and exhibits in one part or another all the features already described, but developed on a much larger scale.

In the outer Himalayas, the sides of the deep valleys are almost everywhere so steep that they are in an unstable condition, every heavy fall of rain bringing down larger or smaller landslips, and at their bottom flow rapid streams or rivers. The general steepness of the slopes of the valley sides, a slope often as great as the natural angle of repose of disintegrated rock, or steeper, shows that the streams are for the most part cutting down their beds, and that the other agencies of subaërial denudation have not been able to open out the valley to the curved slopes of lesser steepness which are found in regions where the streams have long been at or near a condition of equilibrium.

In places we find the valley bottom opens out, and is occupied by a plain of river gravels or fine-grained alluvium. This is due to an interruption of the gradient by a local elevation of the stream bed, which has not been balanced by an equally rapid cutting down or corrasion. The result has been to check the gradient of the stream and cause it to

deposit part of the solid material it was transporting, and so form an open plain in the valley. The best known and one of the largest of these is the plain of Kashmir; but from this they range downward to quite small and narrow accumulations. Some of these valley deposits have been re-excavated since their accumulation; others are still in course of formation, or but slightly cut into by the stream which formed them, and correspond in position and appearance to the lakes of other mountain ranges. In the Himalayas there are no lakes of any size, except in the central portion of the range; in a position corresponding to that of the Alpine lakes there are none, but there are these plains of stream deposits, filling what are clearly rock basins. Had these rock basins been filled by a glacier during their formation, or had the elevation of the barrier been too rapid and recent to give the streams time to fill up the hollow, we should have had a lake resembling in appearance those of the Alps or the British Isles.

In the Himalayas, as in the other extra-peninsular hills, we find the drainage of the country frequently cutting across the ranges of which the system is composed, and this feature is developed on so large a scale that it has been noticed ever since there was any definite information regarding the geography of this region. As a single very typical instance we may take the cross-valley by which the Indus breaks through the Ladakh range, one of the best defined of the ranges of the north-west Himalayas. It forms the south-west side of the upper Indus valley, which runs parallel to the range as far as it can be traced; but about longitude 78° 30′ the river suddenly turns south-west, breaks across the range at right angles to its axis, again turns sharp to the north-west, and flows on still parallel to the range, but on its south-west side. It can be proved geologically that this range is what is known as an axis of special elevation—that is to say, the general upheaval which the country has undergone has been specially great along this range; and the best explanation of the observed facts is, that the Indus river is older than the range, whose elevation has not been so rapid as to interrupt the course of the river. The broad open valleys above and below the transverse gap are due partly to the smaller amount of downward cutting that had to be performed before the river reached its base level of erosion and could turn to the widening out of its valley, but more largely to the fact that the rocks exposed are softer than those of the Ladakh range.

The same phenomenon is exhibited on a larger scale, in the fact that the whole of the drainage of the northern slopes of the Himalayas ultimately escapes to the south. The Indus and Sanpo rivers, rising within fifty miles of each other, flow along the north of the range in opposite directions till they break through it at either extremity and enter the alluvial plains of India. The Sutlej, too, as well as the Gogra, Kosi, and Subansiri, drain large areas north of the line of highest peaks,

and in all these cases the most probable explanation is, that here again we have cases of antecedent drainage; that is to say, the rivers are more ancient than the mountains which have been raised across their course, but the extent of the drainage area upstream of the zone of most rapid elevation has given the rivers sufficient power to cut down their valleys through the rising mountain range and maintain their course to the south.

Besides these leading examples, it has been noticed that the main watershed, between the drainage which flows directly south and that which at first flows northwards, does not coincide with the line of highest peaks, but lies somewhat to the north of it. In other words, the highest peaks do not rise from the main watershed, but are situated on spurs running southwards. In most of these cases the rivers do not seem to have sufficient catchment area north of the line of highest mountains for the explanation given above to be applied, and a more probable one is to be found in a cutting back of the heads of these valleys, owing to the steeper gradient and greater rainfall on the southern slopes than on the northern. In every case the southern approach to the passes across the main watershed is through deep-cut, often precipitously sided valleys, and at the head there is a long and steep ascent. On the other side there is either a comparatively short and gentle descent, or even no appreciable descent at all, and one enters at once an open, gently sloping valley, whose form shows that it must have been made by a much larger stream than now occupies it, and that the drainage area must have extended over the deep-cut valley from which the ascent has just been made.

These features, noticeable all along the known parts of the Himalayas, are well shown on the trigonometrical survey maps of the Kumaon Himalayas, and nowhere more markedly than in the group of passes at the head of the Girthi and Kiogadh valleys. In Fig. 5, a portion of the atlas of India representing this group of passes has been reproduced, as well as a diagrammatic section across them, based on the data provided by the map. Both alike show the great difference between the valley slopes on either side of the water parting; and it will be seen that the valleys of the northern drainage—here locally flowing eastwards—have not the steep slopes at their upper end which are always found in valleys which are cutting their way backwards into the hills; in other words, their original upper extremities have been removed or robbed by the streams that are cutting their way back from the southern or outer margin of the hills. On the section the heights of the peaks along the lateral water partings, many of them lying beyond the northern margin of the small map—have been indicated; they show very conspicuously how the water parting lies inside the line of the highest peaks, the heads of the valley extending nearly ten miles beyond the highest peak.

The general features which are so conspicuously noticeable in the Chitichun group of passes, are common to all the passes across the main

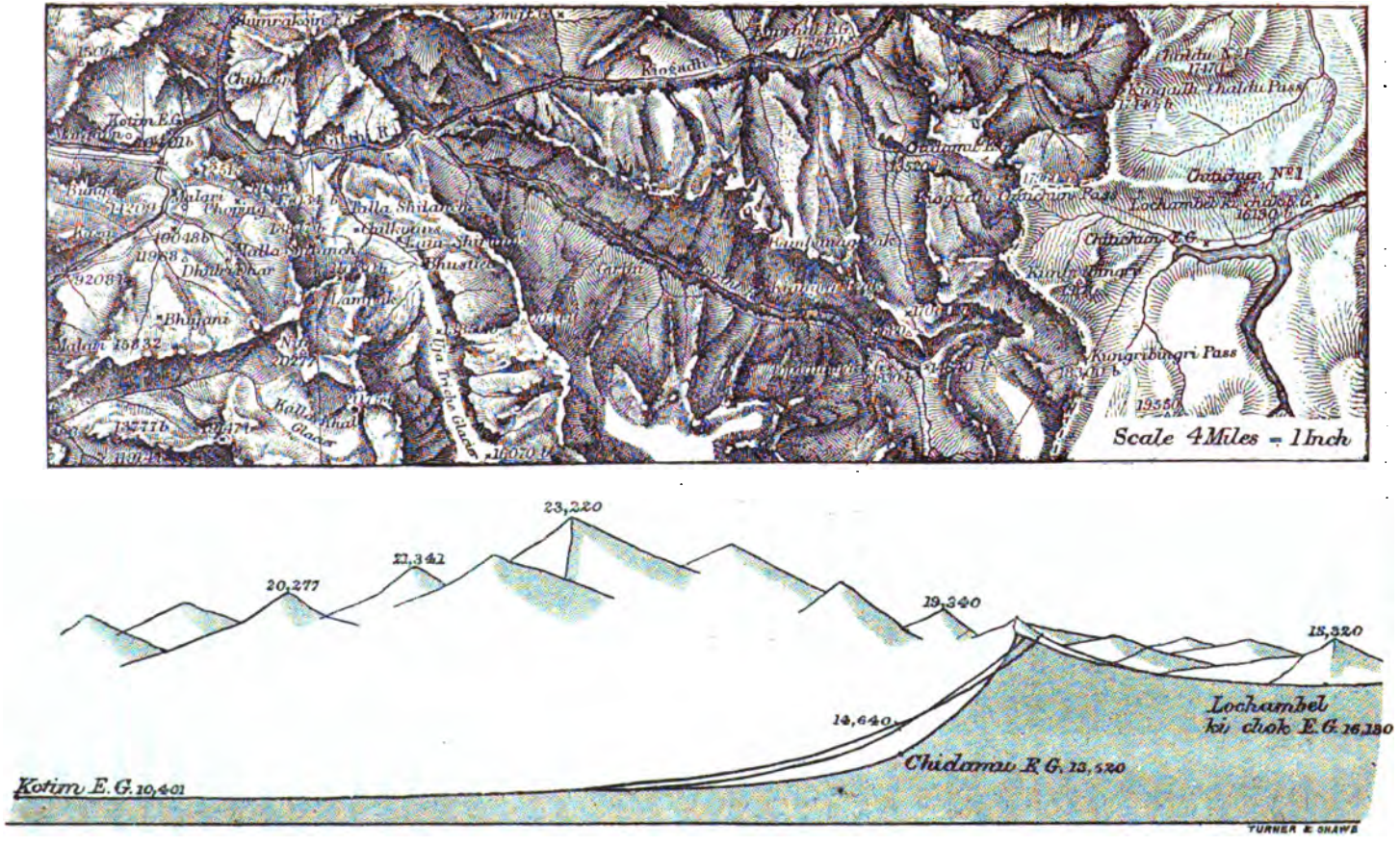

FIG. 5.—PLAN AND SECTION OF THE CHITICHUN GROUP OF PASSES IN THE KUMAON HIMALAYAS. VERTICAL SCALE OF SECTION EXAGGERATED 2½ TIMES.

range, though they are not by any means always so conspicuous. Everywhere we find signs of a recession of the watershed, and on the north the valleys are generally more or less completely choked with debris

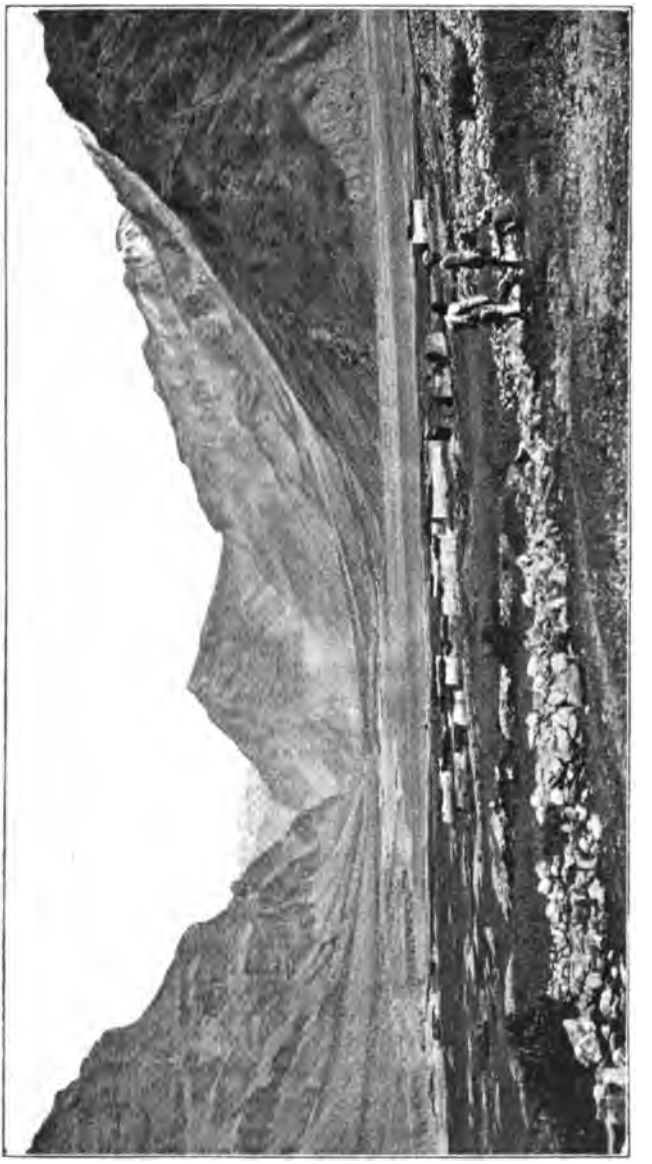

FIG. 6.—LOSAR VILLAGE IN SPITI. RIVER VALLEY PARTIALLY FILLED WITH DEBRIS. FROM A PHOTOGRAPH BY BOURNE AND SHEPHERD.

washed down from the sides, as in Fig. 6, owing to the streams being no longer powerful enough to keep their valleys clear. This loss of power is partly the result of the diminished drainage area due to the shifting

of the watershed, but more largely to the gradual rise of the Himalayas having cut off a larger and larger proportion of the rainfall. In this way the amount of water flowing down the valleys of the outer slopes has increased, and in proportion to this increase has been the diminution of that which found its way down the valleys of the inner slopes.

There can be little room for doubt that in the latest phase of the history of the Himalayas, this cause has very actively aided the steeper gradients on the outer sides of the passes in causing a recession of the watershed, and a robbing of the drainage areas of the streams draining the inner slopes. Nowhere is this robbing of one valley by another more conspicuous than in the best known of all the main passes—the Zoji La, on the road from Kashmir to Ladakh. Here there is on the south side a long and steep ascent of about 2000 ft. at the head of the Sind valley, where the stream flows in a narrow and steep sided gorge; at the top of this an open valley partially blocked with talus fans is suddenly entered and seen to stretch away in front of the traveller, as in Fig. 7. On the other side no descent can be seen, and as he travels along what appears to be a level valley, it is only the direction of the flow of the stream which tells him that he has crossed the summit of the pass.

Similar features have been noticed in the Alpine passes, and in both cases the explanation appears to be the same. The greater gradient of the valleys draining southward, as well as the greater rainfall, has given their streams a greater power of erosion, as a result of which they have been able to cut their valleys backward, and gradually encroach on the drainage area of the northward-flowing streams. The peculiar features of the Maloja pass in the eastern Alps find their counterpart in the Zoji La of the western Himalayas, and in both cases the explanation is the same, that the steep slopes at the head of the northern valley have been completely obliterated by the encroachment of the southern.

This sketch of the evolution of Indian geography has, owing to the exigencies of time and space, necessarily been an inadequate one. There is hardly a single point which would not require nearly as much space for its proper elucidation as it has been found possible to devote to the whole, and brief as the references have been, much has had to be omitted. The series of recent and extinct volcanoes found in the Bay of Bengal, the sandhills of the great Indian Desert, the changes that have taken place in the course of the rivers through the Indo-Gangetic plain, the origin of the Tibetan lakes, and the gradual drying up of that country, may be instanced as subjects of considerable interest, all reference to which has had to be omitted; and, besides this, it has been impossible to distinguish adequately between what is merely the personal opinion of the author, and what may be regarded as well-established and generally accepted conclusions. Only such opinions have been admitted as seem to be so well supported that their general acceptance may be safely looked for, where not already attained, and many subjects have been

omitted, as they do not seem to be so fully proved. These are, indeed, but the forms of land which loom on our horizon as we sail across

FIG. 7.—SUMMIT OF THE ZOJI LA. FROM A PHOTOGRAPH BY CAPT. A. F. MOCKLER-FERRYMAN (43RD LIGHT INFANTRY).

the boundless main of human ignorance; the experience of the past has shown their deceptive nature; what seemed to be isolated rocks have expanded into noble continents; what promised to be a con-

tinent has shrunk to a group of isolated islets, or proved the illusion of a mirage, and the decision of the true nature of those which the look out now sees may be left to time, which tries all things, and proves or rejects them. It has been enough for me to sketch briefly some of the discoveries that have been made in the past, and I would beg you to remember that, though the voice may be mine, the hands are the hands of my colleagues, past and present, and of that band of volunteer workers, alas! so small in number, by whom the facts have been collected, and on whose observations the conclusions I have spoken of are based.

Before the reading of the paper, the following remarks were made by the President:—

The paper this evening, on the "Evolution of the Geography of India," is by Mr. Oldham, who has been for fourteen years a member of the Geological Survey of India, and has traversed almost every part of that country from Beluchistan to Burma. Mr. Oldham is a son of the founder of the Geological Survey—of that accomplished and indefatigable public servant who for more than a quarter of a century worked in India in his department, and whose talents, energy, and accomplishments did so much to raise that survey to the position which it now holds. His son, Mr. Oldham, is admirably qualified to inform us on the subject which is announced for this evening, and I anticipate a most interesting communication as a result of his studies.

After the reading of the paper, the following discussion took place:—

Sir Archibald Geikie: I should first like to be allowed to express my own gratification at hearing this paper from the lips of the son of the distinguished geologist who for so many years was the life and spirit of the Geological Survey of India. Those who remember Dr. Oldham will be pleased to think that his son should have followed up his work so ably. The subject which has been brought before us is one of surpassing interest, for it illustrates well what geographers are too apt to forget—that, in order to understand the geography of any region as it now is, we must learn how it has been gradually built up. No country came into existence just as it is. If we would discover how its topography has originated, we must study the results of long-continued geological observation. It is only by such a thoughtful study that such a lecture as we have had to-night can be elaborated. Mr. Oldham has shown skill in marshalling the facts collected in India by his predecessors and colleagues as well as by himself. My own acquaintance with Indian geology is not large enough to entitle me to criticize the paper, but there are one or two points which must have struck you as of more special interest. Mr. Oldham showed, for instance, how in India, as in other regions, we can still in some degree trace out the ridges that have existed from early geological periods, and form the nucleus round which the outer framework of the country has gradually been built up. He also gave us illustrations of a singular fact which has been brought out exceedingly well in other parts of the globe—the slow growth of many mountain-chains. When we see among the Alps, as at the head of the Lake of the Four Cantons, the rocks of whole mountain-sides folded upon each other like so many crumpled layers of carpets, we are apt to imagine that so stupendous a result could only have been achieved by the sudden operation of some colossal force. But in certain cases there is distinct evidence that the process of mountain-making may be exceedingly slow—not faster, indeed, than the rate of erosion of a river, and we

know how comparatively slow that is. Deep gorges have been gradually cut out of ridges, because the rivers passed over the land before these ridges were upraised, the rate of elevation having been so slow that the rivers could saw their way down as fast as the ground rose. There are one or two features in the later evolution of Indian geography which have interest for us here. Mr. Oldham pointed out the enormous sheets of volcanic material in the Deccan. Something of the same kind may be seen in the great level basaltic plateaux of North-Western Europe and Iceland, which are fragments of the vast lava-fields poured out in tertiary time before the last upheavals of the Alps. The Deccan volcanic sheets may be more extensive than those of Europe, as the mountain ranges of that region are vaster than ours, but there appears to be a kind of relation between the sequence of events in both regions. A very interesting part of the paper was that in which the author described how the forces that have carved out the valleys are getting feebler and feebler, and how in certain places they are so feeble as no longer to act. Mountains there will eventually be buried under their own debris. I must congratulate Mr. Oldham on his paper, which may be taken as a good example of the manner in which the geographical evolution of a region should be worked out.

Dr. W. T. Blanford: As one of the older members of the Geological Survey, who retired from the service about the time that Mr. Oldham entered it, I can only express my gratification at hearing so able an account of what may fairly be described as the contributions made in the course of years by the Geological Survey of India to our knowledge of the physical geography of that country. The majority of the facts brought forward by Mr. Oldham have long since been published, and were noticed in the original 'Manual of the Geology of India,' of which he has lately completed a second edition; but, at the same time, he has added some novel observations and made some good suggestions. Amongst the most interestiog of these are the data as to the geological age of the Aravalli range, and of the eastern and western coasts of the Indian Peninsula. The interest of the former is rather geological than geographical, but the history of the coast-lines comes certainly within geographical limits, and deals with a subject on which geology has much to say. On maps of India two ranges are often represented, called the Eastern and Western Ghâts, approximately parallel to the two coasts. The name is bad, for a ghât is not a mountain. It may mean a pass, but as it also means a wharf or landing-place on a river—everybody has heard of bathing and burning ghâts—it is clear that the term really implies a place of access. The Western Ghâts were the places at which roads from the westward led up to the plateau which occupies so large a part of the Indian Peninsula, and which attains its greatest height near the Malabar and Bombay coast. Now, the northern part, known also by the far better and more distinctive name of Syhâdri, is merely the scarp of a plateau composed of horizontal lava flows, and is not really a range at all; and the southern portion, consisting of ancient gneissic rocks, has no well-defined axis. The "Eastern Ghâts" are a figment of the imagination, the name belonging to the roads that lead to the Mysore plateau having been loosely applied to sundry groups of hills that have no connection with the Mysore plateau, nor with each other. One of these groups, it has been suggested by Mr. Oldham, may be connected with the history of the eastern coast from Madras to Masulipatam. In this case, however, it will be seen, by looking at the geological map, that the parallelism is not very well marked, and there is no range at all having the same relation to the coast south of Madras. The age of the west coast may be rather later than eocene, the marine fossils found in Travancore, upon which the geological date depends, being miocene, not eocene. The curious gap in the "Western Ghâts," through which the railway passes from Madras to Beypore, is very probably, as Mr. Oldham has suggested, due to an

ancient river, and this may have run from the eastward. But there is another possible explanation, and that is that the river ran from the westward, at a time when the Peninsula of India extended to beyond the Laccadive islands.

If the present paper does nothing more, it may be hoped that it will give the deathblow to one venerable tradition. Few persons can travel by railway from Calcutta to Lahore, and from Lahore to Karáchi, without being struck by the wonderful plain of Northern India, and all who have visited the base of the Himalayas must have noticed how the spurs of the mountains rise from the plain as land rises from the sea. It is almost a natural deduction that this great Indo-Gangetic plain is an ancient sea-bed filled up by alluvial deposits. When I first went to India I accepted this view, and never doubted its correctness until I had seen something of the Indus valley, and until considerable progress had been made in mapping the geology of the country on the borders of the great plain. Then it gradually dawned upon me that there must be some reason why marine tertiary beds occur everywhere, and marine cretaceous and jurassic rocks in many places, along the borders of the Indus plain, whilst not a trace of a marine bed has been found on the margin of the plains watered by the Ganges and Brahmaputra from Delhi to Assam. South of the hills that rise on the southern side of the Assam valley plain are marine beds of tertiary and cretaceous age that mark the prolongation of the old eastern coast of the Indian Peninsula, but, so far as it is possible to judge, the great plain of Northern India east of Delhi has never been sea. Nevertheless, the marine origin of this plain has been so generally admitted as to have been accepted by many geologists and by writers on the distribution of animals, like Dr. Wallace, as a well-known fact.

This is an example of the usefulness of a paper like the present in calling attention to scientific observations which are almost certain to be overlooked so long as they are only published amongst the detailed accounts of a geological survey.

Sir Henry Howorth: Although I must obey the chairman's invitation, I feel some hesitation in intervening in a discussion in which my two friends have already taken a part. I congratulate the meeting very much, not only on the paper, which has been a model of lucidity in dealing with an intricate subject, but in that we have also had with us two veterans, each of them *facile princeps* in his own way, one of whom has almost founded the science of applying geology to physical geography. Many points that have arisen and have not arisen are singularly interesting to us all, and might tempt a long digression. I should like, among other things, to learn from Mr. Oldham about one of the greatest of all problems in the recent geology of India, namely, an explanation of the deposits of laterite, the great crux of Indian geology, and to ask him if he has a theory of any kind by which to explain them. The outlines of India are very old, as is confirmed by the fact that in the laterite beds human weapons were found, and were apparently contemporary with the extinct animals of the Nerbudda valley, and therefore, probably, the eastern boundary of India at that time was very much what it is at present. With regard to land extending across where the Laccadive and Maldive archipelagos now exist, we know that in the island of Perim the same species of tertiary mammals occur as in the Siwaliks of India, proving that there has been a collapse of land along the northern part of the Indian Ocean in recent geological time. I am glad Dr. Blanford has called attention to the great northern plain of Hindustan, and the problems arising out of it. This very old plain contains in its bosom very much of the secret history of our race. It is almost the oldest alluvial plain in tropical regions where we have reason to believe man existed in very early time, and in the lower strata of its alluvium we should find secrets explained which we have looked for in all kinds of places. When we go further north we enter into a

congeries of difficulties which have raised polemics of various kinds, namely, as to the age of the Himalayan range. It is impossible to enter into this problem now, but I was pleased to hear Mr. Oldham's view, that the elevation of this range is so recent, comparatively, as the pliocene and subsequent period. This confirms the opinion of the veteran Strachey, in his admirable article in the 'Encyclopædia Britannica,' that 15,000 feet have been added to the height of that range in very recent geological times. It casts opprobrium on our race, that with all its energy and go, and with so many public servants at its command, we should be so absolutely ignorant of the deposits on the flanks of the higher ranges. We know little of them beyond what has been brought down in a fragmentary way through Tibet half a century ago, and, it seems to me, we ought to converge our efforts upon solving what is such an important scientific problem, namely, the actual age of the Himalayan range. This was a problem that the king of geographers, Alexander Humboldt, set before himself long ago, and which he was constrained to solve in a way that, in several recent memoirs, I have felt myself obliged to follow. He employed some cogent arguments to prove that the Himalayan range is very much younger than is supposed; that the mountains were raised to their present great elevation in exceedingly recent geological times. I must join with my friend, Sir Archibald Geikie, in congratulating Mr. Oldham (the son of the pioneer of Indian geology) on his paper, and in wishing him a long and successful career in India.

Mr. OLDHAM: The only points in this discussion that appear to require any reply from me, are those raised by Dr. Blanford with regard to the east and west coasts. When I spoke of the age of the east coast, I did not mean to say that it has kept very closely its present position ever since the distant period at which the Aravalli hills were raised, but that its present position marks approximately the extreme limit beyond which the sea has not been able to extend; the land doubtless extended further to the east, and there have been great variations in the coast-line. As for the west coast, I take it that the miocene deposits of Travancore and thereabouts show that at the close of the eocene period the coast had been established; further back than that I have no desire to go. Sir Henry Howorth will, no doubt, excuse me from replying to the points he has raised, because they are so uncertain that they could not be adequately treated without introducing a great deal of matter still open to controversy, and consequently rather unsuitable at this period of the evening. They are of very great interest, and I should very much have liked to have been able to treat of them.

The PRESIDENT: Mr. Oldham's most interesting paper, and the discussion which has followed it, more especially the remarks of Sir Archibald Geikie and Dr. Blanford, remind us how much we owe to geology. The meeting will remember that it was a President of this Society who compiled and produced the first geological map of India, and that this attempt—for I believe that Mr. Greenough never professed that it was anything more than an attempt—stimulated the study of geology in India many years before the foundation of the present Geological Survey. My predecessor felt strongly that these geological studies were the basis of physical geography, and that we must look to geologists to explain to us many of the grandest phenomena we see upon the surface of the earth now, because their origins must be looked for in a very remote geological period. Several explanations of these phenomena have been given us to-night in Mr. Oldham's paper, and they manifest the close connection between geology and physical geography. It was such considerations which led Sir Roderick Murchison to insist so strongly upon this connection in the two last anniversary addresses which he gave us. There is one other point I should like to refer to. Mr. Oldham has explained the crossing

of the axis of the Himalayan range by some of the great northern rivers, especially the Indus. It seems to me that in the courses taken by these rivers we see, in the most graphic way, the connection between our studies and those of the geologists. We must go to the geologists to explain the origin of those gaps in the mountains (elbows, as they are termed by General Cunningham). We must go to the geologists to learn how the Jumna once formed part of the basin of the Indus; and we could not venture as geographers—although geologists can venture—to assume that the waters of the Jumna once gave a share to the Indus and a share to the Ganges, just as the Casiquiari, in South America, gives a share of its waters to the Orinoco and a share to the Amazon. Then the comparative geographer comes in. He can tell us that from the dawn of history the Jumna had been flowing into the Gangetic valley. He tells of the change in the position of the junction between the Chenab and the Indus, and how the bed of the Ravi has wandered away from the walls of Multan. Thus we find the study of the two sciences closely interlaced. There are many other very interesting and suggestive points in Mr. Oldham's paper, and I am quite sure that the meeting will authorize me to assure him that we have appreciated his communication, and that you will all unite with me in giving him a cordial vote of thanks.

A JOURNEY IN HADRAMAUT.

By LEO HIRSCH.

My intention to undertake an exploration of Hadramaut is an old one. I tried to execute it in the year 1888, when I went to Aden for this purpose. But want of information, and the uncertainty of success in consequence, made me give up the idea, and I went instead to the country of the Somals, making a stay of three months at Bulhar, where I applied myself to the study of the Somali language. After my return to Europe, I entered into a lively correspondence with an intelligent Arab at Aden, Abdul Kadir Mekkawi, whose acquaintance I had made during my stay there. From this intercourse I derived great advantage, and the valuable statements of my Arab friend encouraged me to take up my former design, and try it a second time. I arrived at Aden on December 2, 1892, receiving every assistance needed, especially letters of introduction to the chiefs of Makalla, Shehr, and Kishin from the British Resident, General Jopp, and the native Assistant-Resident, Mohammed Salih Ja'fer. In the middle of January, 1893, I left in a small steamer for Shehr, where I arrived after thirty-eight hours, the distance being 320 geographical miles. I was well received by the Jem'adar Husein bin Abdalla bin Omar bin Audh el Ka'aity, and a house was assigned to me, but nothing done to promote my aims. I therefore left, and went, February 4, by a sambuk to Seihut, a port on the Mahra coast, near the outlet of the great wadi, generally called Masila, which, after having taken its course through the whole of Hadramaut, enters the sea about two hours west of said place. My secret hope of pene-