HUMAN GEOGRAPHY

OF BENGAL

By Dr. Arthur Geddes.
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PREFACTORY NOTES.

All maps and diagrams are referred to by groups, according to scale or format, and are serially numbered, as shown on the list of maps and diagrams. In footnotes, the bibliographical notes are given fairly fully where mentioned for the first time and thereafter in summary form, with author and date. Little known place names, when mentioned for the first time are referred to, or to the degree 'rectangles', shown on the Presidency Map (1,1/M), where necessary with an indication of direction, eg., N., NW., or latitude or longitude. River names are printed on the 1 million (1/M) maps and I have kept to their nomenclature and spelling. For this reason I have not followed Bengali usage in applying the name of Padma (pronounced like Pudda) to the present main stream of the Ganges below the Bhagirathi off-take. For the sake of clearness it has seemed better to adopt the usage general among Europeans today and to continue the name of Ganges right on to the Jamuna confluence, to call the combined stream to the Meghna confluence the Padma, and to continue the name Meghna to the sea. The Port Commission of Calcutta have also extended the term Hughtli or Hooghly up to Nadia (Nabadwip, C5), and above Tribeni, near Hughtli (Hooghly) town (C6, N.), which was formerly a point of triple distribution of the waters of the Bhagirathi, since they are watching the river carefully; but to avoid historical confusion, I have kept to the olden limits.

of the names Hughli and Bhagirathi. Where a continuous stream is meant, as here, the names are hyphenated, as for Bhagirathi-Hughli, or Brahmaputra-Jamuna. The former, SE. course of the Brahmaputra, from below the SW. angle of the Garo Hills is referred to as the Old Brahmaputra. Though there are two rivers named Jamuna in Bengal, (1) in the east, the continuation of the Brahmaputra to the Ganges, and (2) in the south, a smaller, sluggish river, a distributary of the Bhagirathi taking off at 23°N., the context will make references to either clear.

A word should be said as to the initial stages in making the maps, and warm acknowledgement of help received by the loan of maps, by photographic reproduction and by draftsmanship is due. The initial exploratory work of examining all the modern 'inch to mile' maps of Bengal and its borders was done at the India Office Record Room in 1925 and 1926, and numerous simplified tracings were made. As unfortunately I had not then the geographical equipment to make a really detailed record, the work, though instructive to me, meant considerable wasted labour as regards visible results. The map then made was shown at a British Association meeting (1928) and was reproduced in Geography (1929). In 1928, after consultation with Prof. A.G. Ogilvie, I set about making an adequate record. Having secured the base maps of 1/million utilised ever since, I set to work with pantograph and proportional compasses and completed the first reduction from ½ inch to mile to 1/million. For part of
West Bengal, not mapped on $\frac{1}{2}$ inch scale, 1 inch maps were traced and simplified, also showing land utilisation, etc. and these have been reduced by photography in the University. When I had been specially pressed to do other work (a study of Lewis), a portion of Central Bengal and of N. Assam was undertaken by Miss Wilford, after she had gone over the area with me, and understood my aim and methods. She most generously gave her services, at once as former professional draftsman and as geographer trained to research, reducing a dozen one inch or half inch sheets, and I cannot thank her too warmly. Further has been done in this Department, a part of the final stages of draftsmanship of Maps II and IV (1/M) being done under my direction by draftsmen who, though assisting professionally, threw themselves into the work and gave technical advice helpful for reproduction later. The purchase of instruments, maps, etc. was facilitated by the Trustees of the Earl of Moray Fund, and maps were lent by the High Commissioner for India, and to both of these my thanks are due.

The maps form the basis on which are placed exact and detailed survey, and on which fuller regional description may later be built. The Appendix on the preparation of the Maps I to IV (1/M) and the text for Maps (1/M) will give the best idea of the extent of their accuracy. As to the amount of work involved, any idea may be given by pointing out that the area mapped is covered by some 688 'one inch to mile' sheets, the larger
number of which were examined in the absence, in 1926-27 and even now, 1935, of modern 'half-inch to mile' sheets, and still less of modern 'quarter-inch to mile' sheets. The Index Map (Index map 1/4M) shows the areas covered by the modern maps, when I began the work, and now.

The title of this work 'The Human Geography of Bengal' was decided upon when it was formally begun. Naturally the subject requires an adequate physical foundation in the absence of any previous geographical study. Some 33,000 words deal mainly with the physical foundation, while the human geography, including the introduction and the final chapter, accounts for the remaining 55,000 words. It does not extend to the geography of race, culture and history, as such study would go far beyond the length desired. A sketch map is attached to show those parts of Bengal and its borders which I knew or visited personally, Fig. Pref. IV (1/4M).
MAP TO SHOW RESIDENCE & JOURNEYS MADE; 1923-24 (April-Oct.)

- Residence for some months
- Brief visits (24 hours) - Rail (by day)

Study of the Konkan Rice Trail allowed me to see a Rice Trail Oct.-May.

S. brass seen (Train)

HALES & VISITS IN S. INDIA
SALTED COLOMBO, OCT. 1924.
Appendix : Mapping.

Mapping of the physical features, vegetation and land utilisation and settlement of Bengal.

The modern coloured topographic maps of India now represent a large area of the country, and they give us a vivid impression of land forms, vegetation and settlement. It is thus rapidly becoming possible for the student to generalise the facts they show upon reduced maps and so to determine the character of large tracts and the nature and boundaries of natural and human regions. Some time ago I outlined such a study for Bengal, and a small sketch map. The facts for Bengal as a whole had already been suggested in a small book, written after my return from Bengal. There however emphasis was laid on one small region of the West, the country round Tagore's "Santi-niketan". The present comprehensive study is based on maps of 1/ million, in which are used the colours of the Survey of India's topographical maps showing relief, vegetation and other surface features. In mapping Bengal we are faced with the difficulty that many portions of the province have not as yet been re-surveyed since the early surveys of three-quarters of a century ago. Thus the contours

1. "Geography", 1924.
and levels of West Bengal on the present 1/2million map are inaccurate, and other features have had to be made out from old, uncoloured maps\(^1\), with other combinations, described later. These difficulties require careful handling, but in turn they may lead to the finding of interesting solutions. On the whole, however, the modern surveys of India and even of Bengal are sufficiently advanced to enable us to determine the nature and the extent of natural and human regions.

It was from these data that I made in 1925 a sketch map of Bengal to the scale of 1/2million, or 1 inch to 32 miles\(^2\). The difficulty was to show the complex of features, without confusion, in black and white alone. To the data of the surveys in the delta were added those given by the Department of Irrigation, and Canals, to illustrate the all-important conditions of water. Those are the 'tidal range' contours, the embanked areas and the indication of 'dead rivers'. The 'tidal range' is the rise and fall of the tide along the creeks and rivers, (measured in feet), and the 'contours' mark the extent of tidal influence. The 'embanked areas' of the Delta lie below the level of high tide, which is excluded by embankments provided with sluices; the irrigation and drainage of these areas present a difficult problem for engineer, agriculturist and malariologist. The rivers which

\(^1\) Index Map showing state of Survey, Dec. 1932, corrected by hand, to 1934.

\(^2\) Geography, 1929. (Map Preface I)
the peasant has called 'dead' are those which once coursed in flood to the sea but now are silted up and semi-stagnant.

The necessity of a careful map and of such a study as this will appear from the hints already given. The ordinary physical map brings out the uniformity of Bengal, uniform in so far as it is for the most part one immense rice plain. It is this character, along with its fairly well-defined natural boundaries on most sides, which has given the people of Bengal considerable unity of culture, expressed in language, and in castes and customs in so far as they are Hindus. What the ordinary layered map does not bring out are the finer shades in the plain: yet they are immensely important to human life. If we think of an ideal river profile as a hyperbolic curve, then its course over the delta will be seen to depend on changes of infinitely small scale. In fact, this is very much the situation. The wooded levees however bring out the areas of slightly raised land, as the marshed and inundatable areas show the hollows between. Innumerable other features, of which settlement is perhaps most important, require to be mapped. Hence the 1/M Maps II, III and IV, were drawn, I and II showing physical features, and IV vegetation and land utilisation.

Since my own 1/2M sketch map of surface features was completed a new atlas of great general utility
was begun by the Survey of India on the initiative of the then Director General, Sir Edward Tandy, 'the Ten-inch Atlas of India', in atlas format on a scale of 10 miles to inch (1927). Central Eastern and part of North Bengal with Assam were chosen for the first volume. As the scheme has not been carried further as yet, - no doubt because in the absence of completed up-to-date surveys it involves much local enquiry, largely by correspondence, - this, or rather its first volume is little advertised or known. It escaped my own notice till my 1/M map was all but completed. It was however satisfactory to find confirmation of my assumption (derived from many comparisons of old surveys with new) that the location from those shown by earlier surveys of Central Bengal, and that my own map and that of the Survey therefore agreed for the portion shown on both. This gives assurance in use of old maps for areas not yet re-surveyed and not appearing in the Atlas, and for which my local knowledge, being small, could only allow of assumption and not certainty. As the pioneer volume of its series, that of Bengal is considered by its originator to be far from perfect. It also has defects to the geographer, settlement being poorly shown, while river conditions could be better portrayed. It was however most cheering to find the work one had attempted in Indian mapping had actually been begun by the authorities.
The Illustration of River Movement (Map II, 1/M).

There is no better way of showing the dynamic nature of the great rivers than by recording changes in their beds along their course over the delta, and the alteration in size and shape of silt islands or great chars at their mouths which have taken place in the interval between one survey and another. The accuracy of the previous surveys invites this for large portions of the river courses, and these changes are shown for the Meghna and Padma. It should be possible to indicate this over the whole in such a way as to express the relative importance of river movement with sufficient accuracy, and convey a correct impression of instability or of cessation of change for different belts of riverain lands. Those who wish to be exactly informed of the dates and rate of change could consult the map index showing, by figures for the Survey area, the dates of the most recent survey and of the preceding one.

On the use of Railway Ground Levels: For correcting old contours or supplying the absence of these, on Barind Uplands of North Bengal, and in the delta below an altitude of 50 ft., the figures of altitude given by railway maps can be plotted upon 1/M maps where data of altitudes and relief are lacking. It is possible thereby to judge for example, of the height of land in the Barind (unpublished) or of the heights of levees in
the Delta and of the intervening depressions 5 to 10 ft. lower, as in the Northern Bils, the Central Delta or southern Midnapur (W. of the Hugli estuary). On Map III (1/M) the 25 ft. contour (not shown even on topographical maps) is sketched from the occasional trigonometrical heights, spot heights or relative heights, combined with Railway Ground Levels; and it illustrates the character of the deltaic contours, running down stream along the levees and not upstream as in valleys. It appears to be fairly accurate, judged from sketches shown of the 50 ft. contour in West Bengal and of the 150 ft. contour in North Bengal, made in the same way before the one-inch maps had been published and reduced, for this study, as can be verified by comparisons of Maps II and III (1/M).

Map IV (1/M) Vegetation and Land Utilisation. Forests are noted accurately as to area for they are usually reasonably well defined relatively to cultivation. Of course there is a gradual transition from forest, by waste with trees, to waste with few trees at almost none. Quantitative estimate is difficult, for woodland is subject to felling and to fire, and even their leafage will make the trees seem thickest after the monsoon, thinnest before April. The surveyor must judge by his own impression, and one surveyor’s standard differs from another’s. These remarks apply in principle to all cartography of the kind; nevertheless the portrayal of woodland and of cultivation is indispensable if we are to realise the nature of vegetation and land utilisation. The connection with the
study of agriculture will be evident.

Treeless waste is less easily mapped than woodland in Bengal for it occurs in smaller patches, while its limits are less distinctly seen on a topographical map and are therefore difficult to trace. In reality, too, the limits vary somewhat from decade to decade, not only with respect to forest but to cultivation too. Hence the "treeless waste" shown must be taken as a broad indication, while the actual area is greater than can be shown, in most parts, because of the small patches in which it occurs.

Population density is of course closely comparable to density of settlements, and the features shown upon Map IV (1/M) proved an essential guide in this final work, as will be described in Chapter G.

Note on Official Materials, Cartographical and Written.

A note upon the official material for geographical synthesis in Bengal and India may be appropriate here. They are five: (1) Maps, (2) Gazeteers, (3) The Census, (4) Surveys, (5) Reports of the Depts. of Agriculture, Irrigation, Commerce and Industry, etc.

(1) Maps 6 in. to mile (uncoloured) for village studies. Issued by Director of Land Records, Bengal. ½ in., and ¼ in. to mile topographical sheets, coloured. The most
accurate topographical map for general use ia the modern
'one inch' map, not merely because detail is lost on smaller
scale maps, but because reduction is done by cartographic assis-
tants less skilled than those who handled the larger saûles.
In addition to the one inch maps, accurate 'four miles to inch'
maps are published in colours for certain areas like the
Damodar coalfields, which might make possible highly detailed
studies of land forms and the like. 8 miles to in. maps are
administrative; Administrative units (than as etc.) say to
1/\(\text{M}\) scale can be reduced from these. Alternatively they can
be enlarged from Census cartograms by tracing and projection
by magic lantern, \(\frac{1}{6}\) 1/\(\text{M}\) or '16 miles to in.', contoured but
no longer layered, heights in feet. The 'Carta In\(\text{ternacional}\) of
cover (same scale) \(\text{a}\) larger area, and are layered with
contours in metres, much less accurately shown than those of the
'16\(\text{m.}\) to in'.

In addition one atlas deserves mention: the
'10 mile Atlas', - scale 10 mile to in. A preliminary edition
of the first volume (East Bengal) appeared on the initiative
of Sir Ed. Tandy. It summarises the features of the 1/in. and
\(\frac{1}{4}\) in. maps poorly or not at all represented on \(\frac{1}{4}\) in. scale.
It aimed at cheapness and all round usefulness for the touring
officer. Its interest to the geographer is very real by its
compactness and handiness, as anyone who has worked through
the topographical maps of even a single province will realise.
It shows not only road, and rail, and hut, but distinguishes cultivation and natural vegetation and in some sheets showing both orchard and jungle, trees and grass as distinguished from cultivation. Notes of crops are printed across it. Information, where modern surveys were lacking, compiled from local enquiry and correspondence, are given. Since Tandy put out the first volume, it has been held up: no doubt it will be continued when new topographical maps are in existence or completed.

**Gazeteers:** Two volumes, A & B, are published for each District of India. The B vol., Statistics, is often useful for intensive work, in plotting detailed distributions. The A vol. describes the main facts of relief (of course non-geography), of geology and "natural divisions". This work often very well done, is frequently compiled with local knowledge, with chapters on agriculture, industry and people, etc.

The chief source for these Gazeteers are the Settlement Reports made for Revenue Survey. Although less accessible and very detailed, they are always written on the spot and full of excellent material, which is sometimes handled in a masterly way. Their drawback is that they are based/arbitrary divisions of property and of administration. Their quality is that they are written in the field with equal emphasis on the type of country and of crops and cultivation and on the work ways, character and condition of the people.
The Plain of Bengal: its Unity and Diversity.  1

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INTRODUCTION

Figures (in text), Maps and Diagrams.

Boundaries, geographical, political and linguistic. (In text.)

Intro. 7 Fig. Intro. 7

Diagram. Intro I.

(Reference should be made to Map A I (1/4M) )

The Indus-Gangetic plain marks not only the west extension of the geographical ranges of the north-east, but marks the part most distant from the westwards and southwards into India. And when we have reached the ocean meridian, the light of early civilisation came from west and north, then as now spread still further eastward from Central Asia and India to China and Japan; and in later days the tide of both peoples eastwards from Arabia in the west. In Bengal we stand at one of the frontiers of civilisation, for Bengal is a borderland of race, as the Tibetan-Himalayan stamp on the people of the south-eastern delta shows, of religion — as the Buddhism (to Bengal, a popular) of its castes bear witness — and also the ready conversion of the masses to Islam, and, less in language. Only Crissa savors Bengal from the limits of Christian tongues to south; and both Brahmins and the Hindus, though still mark the plainsmen folk and hill-men, yet now and in its immediate borders, to west, north and west, picture itself...
INTRODUCTION

The Plain of Bengal: its Unity and Diversity.

Bengal's position at the eastern end of the great Indus-Gangetic plain marks not only the wet extreme of climate of the Plains from the dry extreme of the north-west, but makes it the part most distant from the point of entry of the historic and pre-historic influences that poured eastwards and southwards into India. And when we have reached the 80th meridian the formula ex oriente lux has to be reversed. The light of early civilisation came from west and north, even as it spread still further eastward from Central Asia and India to China and Japan; and in later days the tide of Islam swept eastwards from Arabia in the west. In Bengal we stand at one of the frontiers of civilisation. For Bengal is a borderland of race,—as the Tibeto-Burman stamp on the people of its south-eastern delta shows, of religion,—as the unorthodoxy (to Benares pundits) of its castes bears witness, and also the ready conversion of its masses to Islam, and, lastly, of language. Only Orissa severs Bengal from the lands of Dravidian tongues to south; and both Dravidian and pre-Dravidian speech still mark the plateau-folk and hill-men from just over its immediate borders, to west, north and east, peoples brought
into close contact by the migrations of today. And when British influence, centred at Calcutta, dominated the latest chapter of India's history, the Bengali Hindus, although so different from the 'Anglo-Saxon', became perhaps more Europeanised in outlook than any other Indians, as even their 'nationalism' shows. The current of history along the Gangetic plain had been reversed, for the latest Occidentals penetrated it not from hill passes but (in the main) from its eastern sea and gate. Yet Bengal has remained a borderland to the vast plain of which it forms the eastern gate, whether serving as a distant outlet, in earlier history or acting as a way of ingress during the last two centuries.

Bengal is a vast and fertile plain in which are concentrated nine-tenths of the waters of the Himalayas and of the eastern frontier of Tibet and the Gangetic plain. Almost from end to end this great plain is a level stretch of rice fields, varied by its noble rivers and its groves, and by the thatched roofs of the homes and villages that shelter one of the densest populations in the world. Its people, bound together by the surrounding barriers of mountains and of sea, by their close neighbourhood, by one common way of life, and by their history, have worked out a common speech and built up the elements of a great tradition, we might almost say of nationality.
It may help us to visualize the land if we imagine ourselves flying northward from the Bay of Bengal and commanding a bird's eye view of the plains. From above the salt swamps that fringe the sea we should look north across the plain ending at the Himalayas, and see to east and west of us the wooded hills that fringe the plain. To the south of the plain is the sea, fringed by the salt marshes of the Sunderbans jungle with their maze of cross-channels, lined with mangroves. On the north are the Himalayas, a triple rampart rising to peaks of eternal snow; at its foot a swampy moat, the Tarai. To east and west, Bengal is hemmed by hilly borderlands but half reclaimed from jungle, and still but little Hinduized; they are the home of feudatory rajahs, and, further in, of half-wild tribes that speak a medley of non-Aryan tongues. From further west and east along the foot of the Himalayas, the two great rivers of Ganges and Brahmaputra enter from the valley plains and sweep southward to the sea, flooding their delta in the Rains. Southward a fringe of coastal plain prolongs the Bengal ricelands, and Bengali influence, along either shore of the Bay of Bengal. We may think of Bengal as a great plain, broadly homogeneous in character, and fairly symmetrical in its shape and boundaries on either side of its north-south axis.

Within this broad likeness and the general symmetry of east and west are marked contrasts, physical, ethnical and cultural. Though the plain is homogeneous in
form and in its staple crop, and though its people are unified by language and are of well mixed if not of uniform race type, the two opposing border lands of east and west are contrasted and heterogeneous. In place of a gneissic plateau like that of the west, with its medium rainfall and mixed crops, there lies along the eastern border, hill country of parallel ridges and valleys which receive the full force of the southwestern monsoon, as it comes up surcharged with moisture. The plateau is low, and inhabited by people of Munda (Kolarian) and of Dravidian speech among which Aryan tongues are penetrating. The steep flanks of the eastern hills are inhabited, except for the Khasi hills, by a people of Tibeto-Burman stock and language, who stand more apart. And lastly, while the great corridor of the north-west has been the entrance of the Hindu civilisation, Aryanised in tongue and tradition, which has transformed Bengal, the north-east corridor of Assam leads mainly from mountain lands and primitive folk.

These frontiers, different not only from the plain but from each other, remind us that the making of Bengal's vast ricefield to the foot of the forest slopes, is a labour of two thousand years and more which is only now nearing completion. The degree of likeness in physical types through the plain has resulted from the mixing of races, before caste came in to check the process while still incomplete. And the unity of Aryan language from border to border only came from a slow submergence of the many tongues
which preceded it but could not compete with its simplicity of form, nor withstand the weight of civilisation pressing behind it. Till these changes, of reclamation, race-mixture and the making of the Bengali tongue had taken place, the contrasted peoples of the hills, now sundered by the plain, must have met on the raised flats above the swamps or fished along the same river systems.

Even yet the claims of continuous tradition cannot be broken, though a new environment and time have so transformed them. Among the perplexing differences of culture and of ways in east and west, north and south, it is not yet possible to detach the influences of environment, past and present, from those of history, early or late, and still less to distinguish them from pre-Aryan race tradition brought in from afar.
The Boundaries, political, cultural and natural.

Taking the country as a whole, the natural, the cultural and the political boundaries are now broadly the same, save for the division from Assam. Elsewhere if we detach from the province the border states under native rule and the tribal tracts of the Himalayan and eastern foothills, the lines dividing rice-plain from jungle slope and pure Bengali speech from mixed Aryan and non-Aryan tongues are followed by the boundary of the province with little more than a dozen miles of difference (Presidency Map of Bengal, I, I/M). On the south-west the political boundary follows the 500 ft. contour line, and then continues north across the neck of the Ganges to the Himalayas; there save for the inclusion of the ridges of Darjiling district formerly belonging to Sikkim, it again follows the 500 ft. line for 100 miles to turn sharply south across the entrance to the Brahmaputra valley. Skirting the foot of the Khasi massif it strikes south through the swamp lakes lying along 91°E, to meet the NW. spurs of the Tripura ridges. Thence the boundary of the districts of the plain follows the edge of the hills southward to where the hills of Northern Arakkan meet the sea beyond Chittagong. It is where crossing the swamp lakes of the north-eastern plain that the political fails to correspond to the geographical boundary; but we may roughly sketch the latter by following the hill foot in a wide arc round the plain of Sylhet back to the spurs of Tripura.
From the south eastern extremity of Bengal to the NW. spurs of the eastern jungle ridges, the contour line of 100 ft. or so, which marks the limit of the cultivated plain, is roughly a limit of language. It is followed by the western boundary of the British administered district of the Chittagong Hill Tracts, and next on the north by that of the native state of Tripura (Hill Tippera), a borderland of north-south ridges covered with jungle, thinly inhabited by primitive folk, into which the valleys of which the Bengali cultivators are now pouring. Further to north-east is Sylhet district; it was joined politically to the small province of Assam proper in 1912, to keep the balance of the great provinces more nearly equal in weight of numbers, but it has a large population of Bengalis. This is, indeed, of all the areas lying beyond the boundary, the most disputed, for active propaganda is made by Bengalis of Sylhet to get the district joined to Bengal, and the change may be expected to occur before long. At present the SW. boundary still includes a population speaking Uriya, the language of Orissa, but it is shortly to be redrawn a few miles further north (Fig. Intro. 7).

Any hard and fast boundary line drawn across a plain, where there is a transition, and not a sudden change of conditions, must be somewhat artificial. Such are the boundaries drawn north and south across the narrows of the plains of the Ganges and Brahmaputra, dividing Bengal from
Bihar on the west, and running from the Rajmahal hills to the
Himalayas and from Assam on the east from the Khasi Plateau
northward across the Brahmaputra and southward to Tripura.
For one Aryan language fades into another, by intermediate
dialects, from one end of the Indo-Gangetic plain to the other,
and here Bengali merges into Bihari and to Assami by intervening
stages. There is a gradual, not a sudden change of natural
environment on either side. The Linguistic Survey places
the eastern boundary of Bengali up the Brahmaputra valley, a
dozens miles beyond the political boundary with Assam, and
includes the district of Sylhet within it. The western limit
of Bengali varies a few miles on either side of the political
boundary. Bengali however pushes beyond the provincial boundary
into the Chota Nagpur plateau, with its mixed population in
the Santal Parganas, formerly included in Bengal, and of
Manbhum and Singhbhum to south of it. There however it meets
not merely a language of kindred stock, but a non-Aryan Munda
language, so there is little "compounding" but rather a
"mixture" of two utterly different elements found side by side.

Throughout Bengal the rainfall is high,
for though it is only 55 inches in the west, it amounts to
90 inches per annum along the eastern hill foot. The isohyet
of 65 ins. per annum runs midway through the delta from the
Sunderbans in the south northward to the foot of the Himalayas,
where precipitation is suddenly increased by the mountains
to more than twice that amount. The minimum figure in itself were sufficient for rice-growing if equally well distributed from year to year; and to this is added in the delta, the tremendous flow of water from the hills on every side and from the whole Gangetic basin and Assam. The mildness of the winter and the steaming heat of summer, vary but little January over the plain. The mean/temperature of Calcutta is 65°F. and the mean for May is 86°F. The night frosts of winter in the upper Ganges plains are unknown here, and though May and June are not so hot in Bengal as further inland, the moist heat, in which vegetation flourishes makes the summer half year trying to man. At this point it will be well roughly to define what may hereafter be called the plain of Bengal, as the whole area of the province to the exclusion of the Himalayan tract of Darjiling, the State of Tripura and the district of the Chittagong Hill Tracts to the south. The definition of the outer fringe of upland or forested border-land around it, or within it, must await later definition.

In all the ways described, the land is wonderfully alike from end to end, being a great plain/ heavy and fairly evenly distributed rainfall, and watered by many rivers and growing the same food-crop, rice. In language it is one, and peasants from every quarter of Bengal can speak to and be understood by one another.¹ All over it there is a mixture of

¹Census of India, 1921, vol. V. Bengal, Pt I, Report.
Hindu and Mohammedan, and throughout the plain the castes or the sects of either religion are not dissimilar. And within recent years the solidarity of the upper classes has been increased and their political consciousness affirmed by their residence in one great city, Calcutta, in numbers unknown hitherto, and by their university education in two federated centres, Calcutta and Dacca. Those who cared for the unity of language and culture, felt Lord Cruzon's partition of the province to be a dismembering of their land. Hindus, in particular, resented the upsetting of the balance of numbers in religion, for while Hindus predominate in the west and Moslems are in majority in the east, the two are almost equal over the whole province. These reasons, as we know, were strong enough to move government to undo a measure upheld for nearly ten years, with considerable severity, and to re-unite the province into one political entity. Only relatively minor alterations are to be foreseen to the boundary redrawn in 1912 and the partition served, on the whole, to prove the great measure of unity of the present province.

Regions within Bengal.

So far we have seen the likeness over the whole, confirming the impression to be won by a rapid train journey across the country. Nevertheless, differences of a few inches in height—insignificant as they may seem at first, in an area hundreds of miles across and not fully surveyed as yet,—are
sufficient to determine the direction and flow of water there. The slightest modifications of water supply create profound differences in the capacity for the growing of food and the promotion of health and disease, vitality or decadence. Nor would the difference of a few inches of height alone be a sure indication of dry land and wet, even if we imagine the country exactly surveyed. For the mud-laden rivers tend in flood to raise their banks by depositing their silt on either side where the current is slower, piling up the banks into "natural levees". At the same time as the river's bed may be itself rising through deposition, the body of its waters is lifted up above the surrounding plain. No wonder then that drainage is from the rivers to the fields when the waters are high. Floods of sudden and abnormal height may overflow the river banks, and tearing across the lower ground, do immense damage, washing away houses, destroying crops, drowning cattle and even men. And the differences of level across the delta are so slight that, with a power as great and as unstable as rivers in flood, the river channels may change from week to week in the monsoon, while their courses move, from one generation to another, across the face of the country, reversing its prosperity or poverty, health or disease, almost the determining life or death of its people. So rapid is the change of channel that the steam-lighters that ply on the Sunderbans are accompanied by pilots, local fisherman and boatman who have taken to the occupation and work up and down a
given 'beat' near their homes. For though skippers and steersmen have spent their lives on the waters, they can never be said to know them, for they are never the same. Still more do the ocean-going steamers that come up the Hughli to Calcutta have to be piloted; and in spite of the sums spent yearly on dredging, the masts and funnels of more than one good vessel, sticking up out of the water of the channel, are eloquent of its shallowness and of its dangers. Changes so rapid help us to understand how in the course of centuries a river moves from one part of the country to another.

Bengalis speak currently of East and West Bengal, less often of North or of Central. They consider Calcutta as belonging to 'West Bengal' and 'East Bengal' as centering around Dacca. For them East Bengal is the land of the great rivers, whose surface is covered with waters when they come down in monsoon flood, while West Bengal is the non-inundated land. North Bengal is not so distinctively characteristic, and is less one single region than simply the northern part of the Province. The density of population follows the lie of the land, and is greatest where there is annual submergence by flood, and renewal by silt. This density is also 'tinted' by the abundant rainfall of the south-east which increases to maxima under the Garo and Khasi Hills and the Himalayas but diminishes to the west. Finally the concentration of commerce and industry along the Hughli and for
twenty miles round Calcutta, masses the population around it. Even the small scale maps of any atlas give indication of the river water supply by showing the courses of the main rivers, for the land along them is yearly inundated for many miles on either side. In contrast are the channels and distributaries of the western rivers which lose themselves uncertainly over the plain. The normal flood limit of the great rivers is the essential boundary between the two great regions of Bengal - the "irrigated" West and the "inundated" East. In the region always above flood level population is half to two-thirds as dense as it is below it. Though density is only 250 to 500 in the Western Delta within the area annually or occasionally flooded density reaches 1200 to the square mile, and the people enjoy health and vigour. Settlement ceases in the Sunderbans or at the sea shore.

The landscape of the eastern and of the western tracts of the delta differ most strikingly in the character of their rivers. From the level of the fields there is through most of the year an air of sleepy repose about all the country of the delta, of quietness and lack of change. The rivers wind in and out; level fields alternate with groves or huts, and slow movement of all things gives a feeling of dreamy peace. The groves, the huts, vegetation and habitation all seem to follow the lines of the rivers' flow, and the dry weather courses of the streams wind lazily about with an air of infinite leisure, as if procrastination was their only aim.
in life, on their journey to the sea. Yet in the flood courses are marked out in the lie of the long streamers of land, and of grove and dwellings, where the imperious rivers, throwing off their sluggishness, rise in their strength and stride across the country. In the east, in high flood, when the waters awake, the deeper courses, almost concealed by the widespread flood, are felt by the turbulence of their waters and the swirl of their flow. Here they loop eddy, there they flow straight, combing out the land into long belts of open hollows or ribbons of widely curving natural levees, crowned with their greenery, - the pattern of features recorded on topographical maps. Overlooking, from the air, the sluggish channels and great river loops of the western delta, where land building has now all but ceased, we should get something of the same impression as in the east, the trace of a lawless, though slowly moving power. Yet we could not mistake one region for the other, for the turbulence of the western rivers ceased long ago. Though the country is still twisted and combed into strange patterns, the rivers have dried up and are 'dead', and their shining loops are no longer joined except in fullest flood. In other words it is only in the height of the rains, when their courses are fullest, that these 'dead rivers' resemble the 'living' rivers of the east, as these are to be seen even in the dry weather when their waters are at their lowest.

Still further west above the Delta lie the western
uplands of Old Alluvium. The contrast of these with the eastern flats is so striking as to be unforgettable. Leaving the uplands after hot, dry weather, I found the east in flood; I had left the bare earth hot and dry, even around the pools of standing water after a shower, and I came to an inland sea, festooned with isles.

In one great respect, then, were east and west more evenly favoured in the past, viz. in the lie of their rivers and thus of their natural irrigation by flood. For we must from the beginning think of the function of the deltaic rivers to be not so much the "draining" of their basins as their watering. And if minor rivers vein the surrounding hills with their tributaries, both major and minor rivers of the plain spread their distributaries from the hill foot like arteries over it, pulsing with their rise and fall.

Within historic times then much of the Ganges waters flowed due southward from the Ganges' entrance into Bengal; now they flow more and more eastward to their confluence with the waters of the Brahmaputra, and meet the sea at the southeastern extremity of the delta. And while the eastern plain is already abundantly watered by 65 to 90 inches of rain, the rainfall alone of the western side is insufficient for the growing of rice in abundance and still more so for jute. This river change has altered Western and Central Bengal
out of recognition within the last hundred years, disastrously checking fertility, food-sufficiency, health and population in the west and centre, and giving all the flood-irrigation, soil fertility, health and prosperity to the east. The relatively unchanging structure and the static symmetry in relief of west and east are thus upset by that great dynamic factor of tropical life, the movement of water.

A Journey West to East: five elements of environment and human life.

If one were asked how best to see Bengal in one short journey, assuming the completest freedom of route, the answer would be to take a line midway through it, west to east, from border to border. Things which could be seen and learned on such a journey will be illustrated by a series of sections which represent graphically the main facts of natural environment and agriculture, health, population and culture. The last heading may seem the boldest, for mental and moral culture in the highest sense embraces values far beyond measurement or reckoning. Two means or criteria of culture, literacy and language, have however been enumerated, and here their statistics will be represented graphically and fuller evaluation of these will be left to a later work. A survey of the basic factors of land, and of labour and people forms the object of this work. Suffice it here to visualise the essential factors and to state the problems of their correlation.
The west to east Section-Series is drawn as a traverse across Bengal along the tropic of Cancer, through the rural areas of the west, centre and east. This belt of country typifies the rural plain which stretches nearly 200 miles from north to south and over 300 miles from west to east. This line represents the conditions of the west and of the east even better than one drawn further to the south or north. Although natural conditions are very similar for nearly 100 miles to SW., the jute mills and commerce of Calcutta add other, urban factors, while to SE. the population has not yet won all the coast and islands for cultivation, and there is therefore less pressure on the land than elsewhere. For 100 miles to north the main facts are still the same, drought and sterility on the uplands, fertility beside the rivers in active flow. But there the greater irregularity of the country would make a section less diagrammatic. This section may then be taken to typify the chief natural factors of the inner plain of Bengal, along with the conditions of its population, within the rim of jungles and undeveloped country skirting the coast and the hills. And finally it takes us through the two foci of the civilisation of Bengal, - for the past, the western side, and for the present, the east. Five main elements emerge from the analysis of the influence or of the environment on man in Bengal, which act in the following order:

I The Natural Environment is fundamental to all else, essentially the Relief and Water supply (with the soil and the climate).
II Agriculture is directly dependent on the environment, and able to adapt but not to disregard it.

III Health is readily gauged in Bengal by relative immunity from malaria and intestinal disease. It depends directly on the two first factors named:

(a) on the environment which decides the nature of a disease, - dispersed pools of stagnant water in the rainy season favouring the development of mosquitoes and consequent malarial infection.

(b) Since vigour and resistance to disease are first and foremost a question of food, good health depends upon agriculture giving enough to feed the peasant and his family. Though the economic factors of sale and purchase and of credit complicate the question of the peasant’s prosperity or poverty, the productivity of his fields is obviously the basis of his family’s subsistence.

IV Population, whose increase or decrease depend on the measure of bodily vigour and health. With health go longer life, larger families, and increase; without it small families and a diminishing population. The density of the population is naturally an indication of previous increase.

V Culture and the level of mental life and ability are deeply a measure of vitality and reflex of the courage and hope possessed by a population in active increase. Contrary conditions, discouragement and despair, when long-continued, lead to mental lethargy, and they accompany sickness and become inevitable in a community weighed down by a heavy
mortality, and in which all classes are subject to endemic disease.

This sequence can be read back again from last to first. For courage, moral intensity and active intelligence favour survival, increase and health, and health brings skill of leadership and vigour of labour in agriculture, which is the best utilisation of the environment. And although in writing these five elements must be placed in linear order, there is direct interplay between them all. Thus Health is intermediate between the first two factors, Environment and Agriculture, because it depends directly both on food and the production of the fields, and also on the natural climate and water-supply, and consequently the period of breeding of mosquitoes. Similarly the moral element, last on our list, depends directly on health, as well as indirectly on it through the increase or the decline of population, i.e. of the family and the village. Diagrammatically these inter-relations may be expressed thus:

I ENVIRONMENT
   (water and soil)
   ↙
II AGRICULTURE
   (food)
   ↙
III HEALTH
   ↙
IV POPULATION
   ↙
V CULTURE.
The Sections described.

Environment, as indicated in the sections by relief, with the geology of the plateau to the west and the eastern hills. Representation of the Old Alluvium and the New, and still more the indication of fresh silt and flood-water are frankly diagrammatic. Annual rainfall is shown in inches. Abundance of water-supply from rainfall and inundation characterises the east and relative paucity the west of the province, while floods renew fertility as in the proverbial floods of the Nile.

II Agriculture can be shown in a variety of ways. Proceeding from percentage of cultivated area (relative to jungle, waste etc.) one may note the crops produced, and finally their values. These can be estimated in money even though a part or most of the food crop may be consumed direct by the peasant. The increasing returns from west to east stand out vividly, and evoke immediate comparison with the water-supply and depth of silt seen above. Agriculture, all-important in a province where only some 7 p.c. of the population is urban, is the

1. This interesting graph of comparison of districts from west to east is taken from the Census of 1921 and it partly suggested the making of this series.
basis of rural well-being, and its prosperity or poverty assures or restricts the people's food-supply.

III Health can best be measured in immunity from the most prevalent and formidable disease of Bengal which is malaria, with its allied fevers. The prevalence of malarial fever can be estimated either by knowledge of the extent to which the children are affected or by the deaths ascribed to "fevers". Affected children show enlarged spleens, and the proportion or percentage of children exhibiting these gives the "spleen-index" for a village or district. When a death is reported by the village watchman, he must state if fever is the cause, and the percentage of deaths due to "fever" is a fair indication of a badly affected area. The association of malarial prevalence with low crop values is to be expected, yet its association with water-supply may cause surprise to some readers, who remember that the carrier of the disease is the mosquito, whose larvae are water-reared. There is there an evident complex, the elements of which will involve examination; here we must be content simply to note the association.

IVa & IVb Population. The present density of sedentary

1. The unit of area given for these and the following districts is the "Thana" or "Police Station". The police "Thana", or area controlled by a police station, is the smallest units for which figures are published or indeed required for any but investigations made village by village (such as are occasionally referred to hereafter. Their average population is a little over 70,000 and their area averages from 80 to 100 square miles. Thanas are grouped into a few "subdivisions" of "districts" and the average population of the 28 districts of Bengal approaches two millions, the highest average for the districts of any Indian provinces.
population is the result of its growth, arrest or decline in past decades. The figures of change are given both for the decade 1911-21, and the succeeding one to bring out the contrast of the areas so noticeable in 1911-21 and to avoid the too promising favourable impression offered by those of 1921-31. While the rectangular blocks in the graph of density simply represent the average for the thanas traversed, the curving line portrays the real density as shown on topographical maps, for example along the banks of the great rivers. The striking fact stands out from these two graphs that in the plain the densest areas are those which are augmenting fastest, while the populations of lower density are arrested or even (in that decade) checked by high death-rate, without emigration having intervened. The only exception is the hill country of the east, open to colonisation. Comparison with the previous data lengthens the chain of cause and effect and the main line of causation is still clear.

V a,b,c. Finally come the facts of literacy, higher education and proportion for higher castes,- their three curves showing a rough measure of correspondence with each other, though hardly, at first sight, a connection with the previous data. The inter-connection of the three readily suggests the explanation that the higher castes, the Brahmans, are selected as typical of the literate castes and population are those who continue literacy; the assumption is correct and the correspondence real. Next, it will be guessed that health and prosperity encourage higher education. There facts and
causes of the localisation of aastes however must await elucidation in a later work.

Thus far our bird's eye-view of Bengal Plain reveals it regional whole within its varied borders, yet one which contains diversified parts concealed under apparent uniformity. The section series showed the extent and mature of the work of man. The next four chapters which form Part I will examine the foundation of regional environment, discussing relief and soil, the movement of the rivers,—the latter a complex story whose complete unravelling must await fuller information,—and finally climate. In Part II, agriculture, health and the conditions of population density and change will be surveyed. Lastely in Part III, the regions of Bengal will be defined and briefly described.
PART I. THE PHYSICAL BASIS.

Chapter A

THE FRAMEWORK OF THE PLAIN: RELIEF STRUCTURE AND EROSION.

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CHAPTER A.

Figures. A.

Rivers

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(After text by Pascoe)

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Reference should be made to Map A I (1/4M)
PART I. THE PHYSICAL BASIS.

CHAPTER A. THE FRAMEWORK OF THE PLAIN:

RELIEF, STRUCTURE, AND EROSION.

In Part I the diversity of drainage and flood conditions in the plain are given emphasis since these, though fundamental, are too often overlooked. Before these are surveyed in detail, however, the basic facts of the relief in which the plain is set will be outlined, and their modern interpretation noted in terms of structure and rock-type and of erosion. This will be followed by an account of soils and river movement in the plain. The concluding chapter of Part I will deal with climate, temperature, and the distribution of rainfall, its incidence and its effects.
Introduction: Significance of Relief in the Peopling of Northeast India.

Rainfall, Government reports tell us with almost unvarying unanimity, is the governing factor of India's population density. The "natural divisions" of the Census from 1901 largely follow isohyets and commentary is based upon them. Though we shall have much to say of rainfall, and no less of surface water, of floods, storage, irrigation and "flushing", and of its control for innumerable purposes and in numberless ways, we shall do well first to examine this assumption of the unchallengeable supremacy of rainfall and to compare this factor with that of relief. An elementary test for India is to take the maps of relief, rainfall and population and note the resemblance and contrasts in the distribution of these. If they are examined with a fresh eye it is hard to say which of the first two factors show the closest correlation with population. True, from the desert Indus plain, - at least where irrigation has not intervened beyond the strip flooded almost naturally, - to the plain and delta of eastern Ganges there is a striking difference, though here too the floods from the hills are important. Yet the change from the vast paddy field of Bihar or the Delta to the wet forests of the hills on every hand is hardly less striking, and the change is quite unlike anything produced by relief in Europe. It is not simply the steep slopes of the Himalayas rising to their icy heights which
show the change, but the gentler slopes of the plateau with
its low altitudes, or those of the foot-hills to east of Bengal.
If we leave the rice plains of Malabar or the Konkan Rice tract
of Bombay to ascend the Western Ghats, we meet at once with
almost uninhabited forest, tenanted at intervals by solitary Yogis
in their caves or by half primitive folk whose huts border a tiny
clearing. On the eastern coastal plain the rivers, helped by
man, spread over valley plains and deltas from the southern Penner
to Godavari - though the rainfall alone is only sufficient to
make millets and some wheat the chief grain crops - and here again
the change to hill country brings an immediate and sharp drop in
population. Much of the NE. Plateau and the Eastern Ghats as well
as the Western Ghats and the Central Highlands, is rolling
country (save where steeply falling rivers have cut their gorges
at its edge), and with over 60 ins. of rainfall, yet most of this
region has an average density of less than 60 persons per square
mile, and these form a backward and primitive population. Their
domain may begin just where the paddy fields cease, though the
latter support 500 to 1000 persons per square mile, if the
level land is at all continuous and show an immemorial system
of agriculture. (Fig. A 3).
TO ILLUSTRATE HABITAT AS BASIS FOR FOLK DISTRIBUTION IN BANGLADESH

Analysis from Topographical Map.

A. Ridges to 1000 ft. B. Old Alluvial Shelf 100-500 ft. C. NW. Delta 50-100 ft. above M.S.L.

Jungle) (Waste) (Subject to violent flood and river Changes).

A. RATMANAL HILLS:

"Hill Folk"; Backward Aboriginals; Hunting, Gathering with Nomadic cultivation and Theft.

B. OLD ALLUVIAL SHELF

Santhals-Aboriginals; (Hardy Colonists from Plateau) with Hunting, Gathering & Herding.

(Administrative Boundary; Mainly DELTAIC BENGALI CULTIVATORS (Hindu & Mussulman) (Caste and Rank highly developed.)
Thus, relief plays a great part in determining population distribution though it does so in association with other factors to which space will be given later. Variety of relief near a rainless and therefore "desert" and uninhabited plain not only brings showers but concentrates their run-off into streams, so that valley bottoms, alluvial fans and lake borders support their nuclei of population and of civilisation. Quite gentle relief with heavy rainfall, on the other hand, still bears its jungle and is sparsely peopled and "backward" in culture.

How is it that the importance of relief is so much underestimated, and even if, in a sense it is well known by all how does it come to be so much forgotten and to escape discussion? An answer certainly lies in the dramatic changes that contrast prosperous years of plentiful rains with years of famine due to drought, while its seasonal contrasts of dry weather and wet keep the native awake to its significance and, still more so, the stranger from a moist maritime climate. The hills and plateaus, on the other hand, "change not". Ground water-supply too claims attention, particularly where irrigation by great engineering schemes can be introduced as a legitimate financial proposition, as signally in the Panjab. No doubt high passes and hilly country lying across a route claim attention as obstacles to road and railway engineering, but as yet they do not raise specific problems
of colonisation and density; relief is largely taken for granted by ryot and ruler. This season's water-supply on the other hand involves the wealth of the rich, the life of the poor, while an opportunity for irrigation or urgent need for relief in famine call engineer and administrator to energetic action and to vigorous thinking, before and after their tasks. What consequence could be more natural than that relief, as Sion was one of the first to point out, has not been adequately examined. Hence as a factor of population density it has, as it were, been left out of count by ablest members of an executive administration when, turning to the composition of Imperial Gazetteer or Census Report, they had perforce to take up the tasks of geography. This was the more natural since till this century the causal interpretative study of regions and man, now in active development, was still in early infancy. Up to now no non-officials, European or Indian, have combined the knowledge and experience of the best officials with geographical equipment.

Granted the immutability, for human purposes, of the vast Ganges plain, the Himalayan ramparts or the varied plateau, it is none the less important that the handling of slope by the

peasant, the enterprise of colonists in wooded highlands and uplands and the adaptations of different Indian peoples to these, vary immensely. Thus relief falls to be considered in conjunction not only with rainfall, forests and possible crops but with racial energy and ethnic customs. The peasant of the Himalayas may be said to tackle high relief far more decisively than the people of the Plateau, let alone of the edge of the plain. The outer Himalaya steeplaps between some 2,000 and 5,000 ft. are terraced from Kashmir to Nepal and I have seen hardy Nepali colonists in Sikkim replace the maize, potatoes or hill-rice of their first clearings by irrigated rice as, bit by bit, they cut and built new terraces and lead the stream-waters, by channels to these, each generation making its quota. At last the steeps are terraced in fact into a stepped series of tiny "plains", each dead level, and rice, native to deltaic swamps, is planted there at giddy heights! For the most part the slopes of the Plateau, though mostly far less steep, show no labour even where soil and water-supply seem to offer similar advantages for growth, though there is rice terracing in the crystalline plateau of the Deccan. The levelling of the gentle slopes of Old Alluvial "upland" in West Bengal hardly deserves the name of "terracing", the deviation from level ground is relatively so slight. The chief difference of plateau and plain lies perhaps in altitude, for the Himalayan worker is invigorated by cool height above 4,000 ft. even if lessened warmth diminishes his return.
Along with relief come soil and drainage. A monsoon climate leaches the surface soil of upland portions of plateau, washing out the soluble and fertile salts, and leaving "high level" laterite, such as is generally found above 2,000 ft.\(^1\). The altitude limit results not only from the fact that the high level surfaces are exposed to active erosion and climatic influence, but that the high level surfaces are older and have been exposed to these for a far longer time. The slopes below the summits are often richer, but frequently rocky, without the masses of rich soil clothing the youthful foothills of the Himalayas where periodic landslides show the uncertain equilibrium of the slopes and their soil.

Again the isolation of small patches of cultivable land evokes a very different response from the plainsfolk than from others. Level stretches locked in by hills or ridges or small plateaus isolated by steep ascents involve the migration of small bands of colonists who are cut off from contact with their native place and the supervision of their elders there. Such conditions offer no great hardship either to the aborigines of the NE. plateau or to the Nepalis: their hardy women-folk come too, and do their share of work. With the caste people of the plain it is otherwise,

\(^1\) Fox. (1923)
as Sion again has stressed; and we may add that the lowest of all, the 'untouchables', have not themselves the energy to colonise, nor even as a rule the value as labourers which would encourage capitalists to entice them to join new "colonies". The tea-planters of NE. India bring either Nepalis or else Munda "aborigines", chiefly Santals, from the Plateau - the Nepalis to work from the higher gardens at 6,000 ft. down to 2,000 or 1,500 ft., and the Santals from there to the edges of the plain at 1,000 ft. or less. Even the Mussulman population of the plain have not proved themselves ready colonists though the vigorous riverside Moslems of Eastern Bengal, accustomed to annual migrations on the shifting chars or banks of the Meghna, are ascending the Brahmaputra and settling far into Assam.

Relief then is none the less important in that, like almost every factor of geography, it interlocks with others, both physical and human. An adequate explanatory account of India's population distribution and of her human geography as a whole would involve a fuller account than has been attempted of "slope" i.e.: (1) the amount of smooth or broken ground in a region and the characteristic slopes and (ii) the amount of land lying near summit level, near valley bottom level and between. This account of relief must in turn be correlated with climate (especially rainfall) and natural monsoon forest, and with the adaptations to it of different races.
In a study of the life and land of Bengal the interest is concentrated particularly on the plain, but it has been therefore worth our while to realize the importance of its level relief and contrast this with the surrounding hill country. Such detailed study of relief as we can make must accompany our notes on the Bengal borderlands. Our survey of the surrounding relief, however, must here be given in outline.
The Framework.

Plateau and mountain range - the framework which, with the sea, almost surrounds the Indo-Gangetic alluvial plain, - not only form the barriers which mark off the individuality of the province so sharply; they are component parts of the single structural system which includes the Himalayan folds; the massif blocks of the plateaus and the plains between. These parts are in contact at high pressure, and earthquakes remind us of the forces at work, deep underground. Clues to explain the hidden sub-structure of the plain are given us by the structure of mountain and plateau followed up by geodetic measurements. Land forms and river courses point to the stages in the ultimate development of the smooth, alluvial covering of the plain below, on which humanity is so densely assembled, - and of its mighty rivers pushing the delta ever further out to sea.

These forms themselves demand recognition though their character can only be sketched here, since we have seen that, when we speak of barriers it is not the height of the Himalayas or their 16,000 ft. passes which divide the humanity of the plains from that of Tibet or Burma so much as the change of habitat at the very hill-foot. This zone is the chief frontier of language, of religion and to a great extent of race. Still less do the 3,000 ft. crests of the Plateau or its 1,000 ft. passes mark an
essential boundary; for although they form an outer limit, the inner and important frontier lies along the line where the rice plain first gives place to forested hills, and castes to jungle tribes.

On either side of Bengal lie regions of strikingly contrasted hill scenery. To west of the Delta appears the edge of the great Indian Plateau, to which must be related its outlying fragment the Khasi Plateau to NE. of the Plain. To north the Himalayan ranges are reared in a vast arc that stretches from the heights above the Panjab to beyond NE. Assam; and the Himalayan arc is off-set by another, though lower one which, starting parallel to it curves away from it southward to cease at the SW. extremity of Burma, Cape Negrais.

The plateau is a crustal block, in structure massive, crumpled and consolidated, and faulted at its western and eastern boundaries, and its surface has been worn and re-worn to smoothness though partially re-dissected after uplifts and warping. Its edge appears here and there above the western Bengal plain, being 1,000 to 1,200 ft. high in the Rajmahal ridges that overlook the Ganges where it turns south on entering Bengal, over 2,000 ft. in the residual block above Dumka and close on 4,500 ft. high at Parasanath whose semi-isolated spur commands the pilgrims' and conquerors' way over the high pass followed in our century by the Grand Chord line from Benares to Calcutta. Lesser heights
complete the semi-circle around the coalfields of the rifted basin of the Damodar. These heights, faintly visible from the provincial boundary, 30 to 60 miles away, are surpassed as the sea coast is reached and a narrow ledge of lowland is overlooked by the steep escarpments of the Mayurbhanj Plateau, part of the Orissa Highlands. All these heights are of gneiss, or of crystalline rocks intruded in it, save for the outlying tip of the plateau, the limestone hills of Rajmahal. Their summit levels are typical of the Indian Plateau, for the Eastern Ghats do not exceed 5,500 ft. nor do the Western Ghats till Mysore State is reached (16° N.) The heights of the whole plateau are peripheral rather than central, - Mount Abu (5,650 ft.), the most salient western height, still more strikingly than Parasanath to east, while south of the Mayurbhanj Plateau on the further side of the Orissan Delta and just beyond Chilka Lake, the Eastern Ghats advance an escarpment of almost 5000 ft. to within a score of miles of the sea. These scarps, which surpass those of the Central Highlands, help to determine frontiers of culture and government by almost separating the wider portions of the coastal plain from each other. The coastal plain of Orissa, widened and extended by its delta is only 150 miles long from Balasore to the lagoon of Chilka yet not only did it form till the 16th century the nucleus of a kingdom separate both from Bengal and from Vizyanagar, to the south, and is now about to constitute a separate province, but it became in early times the most southerly home of Aryan speech and culture on the east coast.
The huge arc of the Himalayan ranges, linked to others beyond, curves for 1500 miles from the Indus to the Brahmaputra-Dihong. The crests of the Great Himalayas, snow-covered at midsummer down to some 19,000 ft., form a serrated horizon north of the plain. From uncounted crests of 20,000 ft. they rise by intermediate heights of 22,000, 23,000 and 24,000 ft. to Kanchenjanga, close on 28,000 ft., - a breathless marvel when first beheld from the green plain of North Bengal, - or Everest which, though higher still, appears less commanding from the plain of North Bihar. This serrated line is almost unbroken save where the greater rivers have sawn their gorges past its summits, the Arun past Everest, through Nepal, the Tista's tributaries past Kanchenjanga and the Machen La (to east) through Sikkim. To us in Europe the Alps offer our readiest comparison for height, (Mont Blanc 15,800 ft.) and for the beauty of their snows, their glacier-cirques and sharp arretes; yet the continuity of the Himalayas more closely recalls that of the Pyrenees and the comparison is significant as to structure and evolution.

The extremities of the Assam-Burma arc, of Tertiary Himalayan folding, lie in the almost unknown highlands beyond the Brahmaputra and the Dihong gorge, unmapped till 1914, and beyond which flow, within 200 miles of each other, the tributaries of the Irrawaddi, Salwen, Mekong and Yangtse-Kiang, deep-cut in their amazing gorges. The southward arc to Cape Negrais measures as a
distinct unit, some 800 miles in length; and though its summits rarely touch 10,000 ft. its passes are few and high, while the monsoon forests make penetration difficult. From the Patkai and Naga Hills of NE. Assam the range continues through Manipur (E. Assam), past the Khasi Plateau, and then spreads out with multiple ridges in the Chin and Lushai Hills (Burma), the state of Hill Tippera and the border district of the Chittagong Hill Tracts (Bengal). The foot of the last forested ridges mark the natural and political boundary of the last-named units with the rice plain of Bengal; the last ridges themselves are only some 200 ft. high. Further south the ridges of the Chittagong Hill Tracts subside into the bays of Northern Arakan, creating natural harbours which have bred hardy fishers and seamen, and pirates dangerous to the sea-trade of Bengal before the British era.

The parallel unity of the Great Plain and of the commanding Himalayas evoked recognition in the Aryan speech common to the plains folk. With the spread of this speech have extended the names of Indostan, the Trans-Indus land, and of the Himalayas, "abode of snow", (to give the familiar Anglo-Urdu version of the Sanskritic names) though the name Himalayas alone has won indisputable place. The Assam-Burma arc, on the other hand, has remained unnamed in spite of its unity of character and structure. The reason has lain not only in its lesser height and aspect but
also in the dismembered nature of the lowlands on either side. NE. Assam is divided from the Bengal plain by the Khasi Plateau, and the change of character from the plain to the Burmese coastlands is accompanied by complete change of language. Since in form and structure the arc is so clearly one we may call it the Assam-Burma arc, or if the Khasi Plateau be included, adopt the name usual in India, of the "Eastern Hills".

The Khasi Plateau (the Khasi and Jaintia and the Garo Hills) is linked structurally to the Plateau of India nearly 150 miles away at Rajmahal, owing to its block formation, its core of ancient rocks and granites and the fault-line scarp whose edge, some 4,000 ft. high, forms its southern boundary. We must note, however, the modification of structure in detail by trend lines parallel to the great arc to east of it, and to which it is attached by a low saddle of some 2,500 ft., crossed by road and rail. The Khasi Plateau is nearly 200 miles from east to west and some fifty miles wide. From the Himalayas across the Brahmaputra lie only fifty miles of valley plain, instead of the distance, two to three and four times greater, which divides the Indian Plateau from the Himalayas. Its altitude too is rather more that of the Indian Plateau, with much land at 4,000 to 6,000 ft., inhabited by the hardy Khasi peasants, and smooth summits of 7,000 ft. To the geographer, therefore, the Khasi Plateau must be grouped with the Eastern Hills.
The Structure of Mountain, Plateau and Intervening Plain.

Such, in broadest outline, are the forms and structures in which Bengal is set. Though it is beyond the purpose of this thesis to examine the questions of Himalayan uplift in detail, it is necessary to envisage the structural forces at work around the plain, not only to understand the nature of the mountains and highlands themselves and the probable substructure of the plain, but also in order to realise what are the contemporary possibilities of structural change underneath the plain itself. For it has been affirmed that structural forces are still so actively at work, altering the surface levels in Bengal, as to render impossible the control of its great rivers, - so powerful to give life and to destroy it or, by abandonment of their courses, to bring decay.

The structure of the Himalayas still awaits complete survey and conclusive interpretation. They are a range "folded" by the tangential pressure developed between the plateaus to north and south, those of Tibet and Peninsular India. While Suess suggested a southward push, from Central Asia, recent opinion postulates a northward thrust from the once vast continent of Gondwana of which the Indian plateau is a remnant (E. Argand and others). Their folding is, however, broken by great strike faults with uplift to north of them, and downthrow to south. The most recent faults are
those of the sub-Himalayan range or "Siwaliks" (named from their most westerly portion), a line of low ridges 1,000 ft. or so above the plain which runs in an intermittent arc, from the Bias-Sutlej to Nepal but disappears at the gateway into Sikkim, to reappear along the Assam-Bhutan frontier. Thus the Himalayas, entered from Bengal, are simply a double range, Darjeeling being perched upon the first one. They become a triple range of Siwaliks, Lesser Himalaya and Great Himalaya to westwards, and also to eastwards in Assam. A "Great Boundary Fault" marks the foot of the Lesser Himalaya range and is therefore aligned with the Himalaya foot in North Bengal, and no doubt concealed by the deposits of the river Ranjit, as the Tista is called before its emergence into Bengal. Moreover there has been over-thrust from the massive height to the north.¹

According to the geodetic date we must conceive of Gondwana, the ancient Indian Plateau, dipping under the present alluvial plain.² Structurally it is a continuous block to within 50 miles of the Himalayas, or about the distance from the Khasi Plateau across the Assam valley, and its hidden edge stretches parallel to the Himalayas from the end of the Khasi Plateau to beyond Lucknow. Thence its edge seems to turn more sharply northward, approaching the Himalayas till it comes into closest contact with

¹ Sion (1928). ² R. D. Oldham (1914, 1918, 1923).
their folds beyond the most northerly point of the Panjab plain. This salient point of the Plateau appears to underlie the Salt Range area and even the Muree sediments, where the river Jhelum first turns south the ranges of Hazara and of Pir Panjal are locked around it as a V, point to the north. If we regard the Himalayas from Assam to Afghanistan as a great wave forced on from the north, this salient is the point which breaks it into two arcs to east and to west. The working hypothesis of southward pressure is held by the Geological Survey of India. The short arcs which swing from point to point, west of the Indus, would be similarly "held" by salients of the Plateau. The belt of persistent subsidence immediately south of the Himalayas, and its alluvial covering, which borings of over 1,300 ft. have failed to pierce, remains one of the puzzles of science, the nature of the sub-structure there being uncertain, and the immense amount of the alluvium piled upon it, and calculated at from 15,000 to 20,000 ft. in depth, being hard to account for. As for the tangential forces which crushed the strata of a sea-floor between two plateaus into the "roof of the world", they are held to be due to readjustment, by a change in altitude, of the "mass" of portions of the solid crust, above the molten but extremely dense "magma" or "sima" below. The theories of Platt and of Airy endeavour to explain how this adjustment and its consequence in altitude or depth of surface is effected. As to the thickness of crust concerned in these upheavals to over five miles of present

1. Wadia.
altitudes, R. D. Oldham remarks that it is unlikely to be less than 35 miles, or more than six times the Himalayan heights.

The whole of this vast question is, of course, still very theoretic yet faced with one of the world's greatest alluvial plains, and by its highest mountain, a word seems called for as to the causes of downthrow and of uplift.

The building up of the Assam-Burma arc is to be thought of primarily in relation to the pressure on each other of "the Gondwana Plateau" and the worn mountains of the Shan Plateau. As Pascoe has written, its eastern end seems to have met the "wave" moving at right angles to it, i.e. the arc we are now considering. Hence their parallel course beyond, and in, North Assam, before they divide and swing wide apart the plateau fragment of the Khasi Hills lying between². Pascoe has also shown another way in which the lesser arc has been influenced by the more powerful and probably earlier "Himalayan" forces. While the main north-south direction of the Burmese folding is due to forces along an east-west line, a secondary effect of the Himalayan "wave" moving in a north-south direction has been to create domes of the Burmese anti-clines, favouring incidentally the development of oil³.

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The elements sketched above have given a hint of the structure of the framework of Bengal up to a "recent" stage. Thus we may imagine the front of the Indian Plateau as yet unbroken from the Panjab to the Garo and Khasi Hills, the whole Plateau narrowing to a NE. point or coign beyond its present extremity and there locked into the mountain structures to east. Crushed to the northeast between the Himalayan and Burmese foldings, as between pincers, this coign of the Plateau would be further crumpled and so would reflect their force in its structural NE. SW. trends seen in the remaining Khasi Plateau. "Bengal and its Bay", writes Pascoe, "have every appearance of forming part of the broad spoon-shaped end of a vast geo-synclorium tilted southwards, the natural resultant effect of two folding movements at right angles to one another, one from the east, the other from the north". The 100 fathom line of the Bay helps us to visualise this form better than the deltaic coast line. As these movements proceeded the strain towards the head or extremity of this synclorium, where it was opposed by hill structure across it, linking the present Rajmahal Hills to the Garo and Khasi Hills, would cause fracture and faulting in this coign, parts being left high (the Rajmahal and the Garo and Khasi Hills), the remainder subsiding. Thus forces of erosion would be allowed freer play over the incipient plain of mid- or South Bengal in ways which we shall examine later, smoothing heights, and levelling up by deposits of alluvium which are shown by geodetic observations to be relatively shallow, compared to those of the great trough.
The Erosion of Valley and Ridge.

The plan of the Himalayan valleys illustrates a feature typical of fold ranges, in their tendency to run either with the folds (longitudinally) or across them (transversely) but not obliquely. The kingdom of Nepal is essentially composed of the slopes of the longitudinal valleys followed and in part carved by tributaries of the Kosi and the Gandak, with Katmandu, the capital, close to the watershed between them, and controlling both. In addition to this almost uninterrupted longitudinal trough lying between the Great and Lesser Himalayas, a lower series of longitudinal valleys, the Duns, lie between the Lesser Himalayas and the "Siwaliks". The smaller state of Sikkim is walled off from Nepal by the ridge of Sandakphu (some 12,000 ft. upwards) which runs out as a spur from Kanchenjanga, and on the side of which the ridge of Darjeeling is placed, looking across a short longitudinal valley to Kanchenjanga's snows. While Kalimpong stands on its own ridge across the transverse Tista or Rangit gorge from Darjeeling, the largest portion of a ridge of intermediate and habitable height gives the situation for the little capital of Sikkim, Gangtok, close to the passes into Tibet. The Lachen Tista, a transverse river of intermediate power, has carved the main basin of Sikkim. The sister state of Bhutan shows no such clear longitudinal valleys, its capital, Punaka, standing far up the transverse Machu, though with access to Sikkim and the salient
boundary of Tibet on one hand and the comparatively oblique group of tributaries of the Manas river, which drains the chief valley system. The physical reason for the unimportance of Bhutan is thus less a matter of size (200 miles in length to Nepal's 600), than of its greater heights and steeper slopes and its lack of unity, all of which are associated with absence of the clear longitudinal structure and resulting land forms of Nepal. The active and disciplined Nepali cultivators, Gurkhas and others, have also played their part, and the contrast in Sikkim between those and the stolid Bhutanese grazier-cultivators native to the state is striking. May not the isolation of the individual spurs of Bhutan have been a factor in the formation of Bhutanese character, the longitudinal valleys of Nepal and Kumaon on their part encouraging movement in their active people, and providing the opportunity for long sustained national discipline and unity?

In the same way, the work of erosion in the hills of the Assam-Burma arc still awaits detailed study. Here one need only point out that the present forms appear closely to reflect the denudation of their domed anticlines, for example in the spread of the Lushai hills and the Chittagong Hill Tracts. The trend of the present ridges is due first to structure, while the alternation of resistant with more easily eroded rock, has here also set up a pattern of longitudinal valleys with which their transverse outlets
are in marked contrast. Erosion has been less active inland in eastern Manipur with its drier climate, than nearer the sea, which may help to account, for instance, for the retention of its great lake, unparalleled in the whole range. In the SW. the heavy rains have carved transverse gorges, by which the waters caught in the longitudinal valleys escaped, deepening these and pouring their debris on to the deltaic and coastal plains of SE. Bengal.
The Origins of Brahmaputra and Ganges and the Indo-Brahm.

Trans-Himalayan Rivers. On an even greater scale than any of the valleys adjacent to the plain are the longitudinal valleys of the Indus and Tsangpo-Brahmaputra. On leaving them, the rivers cut through gorges of tremendous steepness, the Indus above Peshawar, the Brahmaputra on entering Assam. Rival theories are contested as to the origin of these great river systems, and of the minor ones of which I have spoken. According to one the vigorous torrents of the southern Himalayas were able to "eat back" across the Himalayas after their uplift, and thus to tap the trans-Himalayan drainage, like the Lachen-Tista or the Arun Kosi, and even the "trans-Ladak" range drainage, of Indus and Brahmaputra. An alternative possibility is to assume drainage from South Tibet into Northern India to have been continuous during the Himalayan uplift, the transverse portion of the Indus, the Dihong Brahmaputra and lesser rivers down-cutting at a speed that kept pace with the uplift. Sion suggests that these theories may have to be combined to explain the facts. The Himalayan system was subject, not to one but to two uplifts or rather to a series of these. After the first uplift the following period of stability permitted the erosion of the southern valleys and captures of the trans-Himalayan drainage; a second uplift

1. J. Sion (1928).
A number of the Yale data (some of them will to be fully worked out), seem to support Stein's results, and indicate a still more complex history of the river-network of the Himalayas.

A second series would have cut off all but the deeper gorges and developed longitudinal valleys whose catchment areas, combined by capture, would allow of a few greater gorges, those of today.

While for a century past geologists have been at work on questions of structure and stratigraphy, the forces of erosion, ever in action simultaneously with structure, have often been somewhat overlooked. It has fallen to the Yale North India Expedition beyond the eastern Himalayas, to make a real advance in the study and interpretation of the planes and surfaces which record the stages of stability between the periods of unrest and uplift and which indicate the duration of each and may demonstrate the direction of river-drainage in the past. The results achieved confirm the lateness of the last uplifts of Little Tibet, carrying them on into glacial periods. Similar study of equal detail is lacking for the Himalayas further east, but the relative smoothness of their summits and the general accordance of their height suggests relative maturity in turn rejuvenated by fresh uplift. The last phase still goes on, marked by earthquakes whose devastation is wrought from Kashmir to Bihar, North Bengal and Assam.

A number of the Yale data (some of them still to be fully worked out), seem to support Oldham's hypothesis that the "longitudinal" valleys north of the Himalayas (of modern upper Indus and Tsang-Po) antedate the origin of the "transverse" drainage, e.g. the gorges of the Indus and Dhiong (Brahmaputra) across the axis of Himalaya. This theory of a single river north of the Himalayas, a Tsang-Po-Indus, has been worked out by Pascoe, with the difference that he imagines a westward drainage with a possible outlet towards the Oxus1. The reasons adduced on either side cannot easily be cancelled out, and leave the problem of direction open till fresh data may help to solve it, so throwing further light on the development of plateau and plain.

The Indobrahm. When we turn to Indus and Brahmaputra on the plain we have data more recent and reliable, and their story is significant. Again, however, the study in the field of river terraces and the evidence of former river levels and direction has still to be followed up, particularly near the Indus-Ganges watershed.

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1. E. H. Pascoe, Mem. Geol, S. India (1920); see also the summary with sketch Map in Sion (1928). 2. Whereas in the United States the geology and land-forms are mapped by one service, and the study of forms follows on from that of structure, in India the separation of the "Geological Survey" and the military "Survey of India" tend to weaken scientific co-operation and resulting synthesis. The contribution of officers of the Survey of India to the study of structure and of surface have been geodetic rather than morphological, particularly in the Plains perhaps, though we do not forget Burrards' basic account of plan and forms in the Himalayas, in co-operation with the geologist Hayden. Independent geographical study is still lacking.
There is no doubt that the great trough between the Himalayas and the Gondwana Plateau which existed before the filling in of the plain by alluvium once formed an immense drainage channel from the present Khasi Plateau edge, along the foot of the upland that continued unbroken to the Punjab. In late Tertiary times a single river is believed to have flowed along the Himalaya foot, most probably from the longitude of Bhutan westwards towards the present Indus, and there it turned south to flow into what has been retrospectively named the Gulf of Sind. Its waters thus corresponded to those of lower Brahmaputra, middle Ganges and lower Indus, and Pascoe has called it the "Indobrahm" (Fig. A, p.27). Its head waters must have captured another river flowing southwest between the Khasi Plateau and the Naga Hills, over what is now the pass traversed by the Assam-Bengal railway, into the Bay of Bengal. The present Meghna may be the remains of this river, beheaded by the Indobrahm. From the amount of the late Tertiary ("Siwalek") deposits in this railway section, this old Meghna must have been a river of some magnitude, and may possibly have derived its importance from the capture of the Dihong. It is, of course, assumed here that there was no through drainage across the Himalayas at the time, and that the Dihong had not captured the Tsang-po. The Dihong is thought to have formed the upper waters of the Irrawadi by what is now a tributary of the latter, the Chindwin, by a direct course which was indeed supposed by the old Chinese surveyors to be the actual course, until it was shown to be
otherwise. It was apparently after capturing the Dihong-Chindwin, that the upper waters of the Dihong-Meghna were in turn captured by the Indobrahm.
RIVERS OF "BENGAL" IN LATE TERTIARY PERIOD: AFTER TEXT BY PASCOE.

1. --- Dihong-Chindwin (Earliest shown captured by 2 ?)
2. --- Dihong-Meghna (later, and captured by 3 ?)
3. --- Indobrahm, and S. Tibetan River as at Later Tertiary period: also Irrawadi and lower Meghna
5. ----- Bay of Bengal (non-Deltaic).

Indian plateau and Khasi Plateau today.

Portion of Gondwana plateau now subsided.

(The coast S. of Bengal is shown as today and was probably not very different.)
Thus the courses of the early rivers whose fall appears to have been a direct consequence of the general slope south from Himalayas to the Indian ocean was modified by the lie of the Assam-Burma arc and by the action of the Indobrahm, and so turned first south-westwards and then westwards on to modern Sind.

Aryavarta and the Panjab Rivers, Saraswati and Jamna: an Analogy with Bengal.

Aryavarta. Although the details of the evolution of the Panjab and its rivers did not directly affect the making of Bengal, reference must be made to them in order briefly to complete the story of the Indobrahm in Bengal. In doing so we shall leave probability for what may fairly be called certainty as we approach the present era, while the lessons to be learned will offer useful comparisons which can help to elucidate the more complex problems of the rivers of Bengal. Just as trans-Himalayan drainage seems to have been captured by the Indobrahm in Assam, so its right bank tributaries all along the Himalayas to NW. India seem to have cut back, in varying degree, through the mountain chains, so adding to its volume. At the same time they piled up fans below their gorges, so pushing the Indobrahm steadily further from the hill-foot. Simultaneously changes were occurring on the left bank of the Indobrahm. At the close of the "Siwalik" and during the Recent period its western end was apparently cut off by rivers eating
back "from the Gulf of Sind". Its waters, which, as we suppose, had flowed by the Attock Sohan valley to the Indus, were apparently cut off successively by rivers corresponding to the present Lower Jhelum, Chenab, Ravi, Bias-Satlej ¹, and finally by the Ghaggar or Hakra, now a dry course. The Ghaggar at its apogee is to be conceived as a great river receiving a part of the waters of the basin to east, though perhaps not all as we shall see, and certainly those of the Himalayan courses both of Satlej and of Jamna (or Jumna). It flowed through the Thar Steppe or "Desert", joined by the Indus above the modern Sukkur barrage, flowing thence to the sea. A rough image of its upper course across the plains, probably up to "epic" or proto-historic times, may be got by comparison with the modern irrigation system of Satlej and Jamna, whose converging canals irrigate the former do-ab or "Mesopotamia" between the "two-rivers", above their confluence. More accurately, the direction of the Satlej in the Himalayan foothills was continued not to west but to SSW. till, a thousand years ago, it began to shift westwards, and was at last captured by the Bias some time between the 15th and 17th centuries A.D. ². The capture of the

¹. The modern spellings have been adopted for Jamna (or Jumna) and Satlej (or Sutlej), as for Panjab (or Punjaub), to avoid the mispronunciation of the short 'a', as if it were an English 'oo', instead of intermediate between the vowels in the English 'pun' and 'pan'. ². Arden Wood, Scot. Geog. Mag., 1924, summarising the work of Raverty, C.F. Oldham and R.D. Oldham.
Himalayan Jamna waters must have occurred earlier: its old course past Hissar, WNW. of Delhi, can however be traced on a good atlas, as can that of the Ghaggar (Fig. A. p.27). Between the Satlej-Chaggar and the Jamna-Ghaggar flowed the upper Ghaggar itself, known to Hindu tradition as the Saraswati.

This doab, with its central stream, was the land of Kurukshetra, "the first permanent home of the Aryans in India and the centre from which Indo-Aryan culture spread"¹. Thus the character of the steppe portion of the Ghaggar, with its narrow fringe of land irrigated by wells, and the cities dotted along its route, must have differed immensely from that of the Saraswati and its fellow-tributaries, with their fertile plain. While no particular sanctity belongs to the Hakra or lower Ghaggar, the upper stream from the Himalaya foot, named from Saraswati, Goddess of learning and the arts, was sacred to Hinduism and still is, although so shrunken. Aryavarta, the home of early, post-Vedic Hinduism, as later described in the Puranas about the 4th century B.C., was strictly limited, though Southern and Western India were known and described in these². We must think of Aryavarta as a domain gradually extended eastwards from the Saraswati's plain in the

¹. Arden Wood, op. cit. ². Berriedale Keith, Cambridge History of India.
Lost River of the Panjab

(After Sion.)

Canals: —
Old Beds, still well marked in Arid Region: —

Fig. A 31
west,—the doab of the great SW. flowing tributaries to which this river was axial, by Mathura (Muttra) upon Jamna, Kanauj (29° N., 80° E.) upon Ganges, onwards through Ayodhya (Oudh) to Benares. The fan of the Son was its frontier land, along with the denser monsoon forests and swamps which in nature, would stretch intermittently thence to the Tarai. We shall appreciate the veneration attached to this land, and its early importance, when we find the names of the Saraswati and of the Bhagirathi, the Ganges, chief Himalayan tributary, given to the dividing arms or its distributaries of the Ganges which fringe the western Delta of Bengal. Jamna, rather less venerated by orthodoxy than those, though often sung by Bengali Vaishnavait hymns since the 17th century revival, also gave its name to the two rivers Jamuna in South Central and in NE. Bengal, perhaps more recent baptisms than the last mentioned. Many points of interest might be selected to express the veneration for this country and to define its foci. The very peaks from which the rivers rise are places of pilgrimage: the water-parting of Ganges and of the ancient tributaries of Saraswati climbs to the peaks of Kedar Kanta, of Kedarnath and Srikanta, with the source of Ganges, here called the Bhagirathi; Badrinath, Gangotri and Kamet come next. To eastwards stands Nanda Devi which feeds both the mostly easterly of the Ganges tributaries above Hardwar, (the point of Ganges emergence and a place of pilgrimage) and also the river Kali, goddess who is the mystic spouse or shakti of Siva the creator, destroyer and ascetic, whose hair is the Ganges. Beyond the Himalayas, over-looking
Tibet and 160 miles in a straight line from Hardwar are the peaks of Kailas, the home of Siva, at the source of Indus and of Satlej. The sanctity of these peaks is unequalled by any to west or to east of them, in spite of the commanding aspect of Dhaulagiri of Gaurisankar (near Everest) or of Kanchenjanga, grandest perhaps of all, and in spite of the eastward march of Hinduism through the centuries. It will be seen that the source of Ganges is venerated above all, but that a share is given to the tributaries of ancient Saraswati, helping to prove its importance in early times. The historic interest of this region has long been known but the geographical causes of its history only recently understood, with the unravelling of the river decadence beyond the present watershed. Again one may point out that Panipat, 50 miles north of Delhi, thrice the battlefield of Afghan and Indian armies, in 1526, 1556, and 1761 was also the great battleground sung in the Mahabharata; but the geographical causes were different in the earlier and in the later age, and the oft-drawn parallel between the two is misleading. For the area, a river-less "inner frontier" between Afghanistan and Ganges plain in Moghul days, was the well-watered centre of a homeland in Mahabharata times so that the war was civil war, where "brother fought brother". In the Bhagavad-Ghita, "the Lord's Song", Arjun's appeal on the eve of battle to his divine charioteer, Krishna, owes its poignancy to this. One is almost tempted to ask if the dessication of this
trans-Jamna area had begun, bringing with it failure of crops, dearth of pasture and struggle for land?

River Changes of Bengal. Two lessons emerge from this discussion which bear on the understanding of Bengal. The first is evident enough; it is the importance of river history at the western or dry end of the Indo-Gangetic plain which, in spite of the climatic and physiographic differences, we shall find paralleled on the rice-plain to east. The second lesson deserves retention for the re-consideration of evidence on the history of the Bengal rivers. The lack of clearly marked courses in the tangle of serpentine rivers which have inter-twined their paths in the Delta forces us to rely partly on history and archeology and often, for lack of either, on "tradition", oral or written. Now a tributary of the Ganges in Upper India is venerable when it is old, even if it has decayed and its riches with it, while a new tributary is slow to gain sanctity1. In South Central Bengal too, we shall see that the course of an older and defunct distributary of Ganges (the Adi Ganga), at its meeting with the sea at Saugor Island, retains a sanctity denied to the newer branch of the Estuary. It is therefore usually argued that all the courses of the Ganges in the plains once they were well-established, must have become sacred, and further, veneration being a proof of age, that

1. Arden Wood (1924), citing many instances of a well-known law.
absence of sanctity is a proof of recent formation. We have just seen, however, that the Saraswati shares in the sanctity accorded to the Ganges, though always part of a different river system, because it watered what was once part of the same tract of readily habitable and cultivable land which extended from the old Satlej-Ghaggar to the middle Ganges plain. Secondly we have seen that the sacredness of the Saraswati diminished or ceased where it passed into the Thar Steppe, beyond the plain of continuous pasture, cultivation and agricultural cities. The Puranas (4th century B.C.?) place this land beyond "Aryavarta", the Hindu Homeland even as they do Bihar, no doubt because a narrow strip of oasis land, however fruitful, is different in character and mode of life from a better watered, hillfoot plain. In other words, the significance of the veneration of any river lies in the fruitfulness and habitability of the riverside or riverain region for civilised Hinduism, and this ultimately causes the association of region and river with its gods and goddesses. Little significance is attached to the actual continuity of the hydrographic system where this flows beyond the pale among the alien and "impure", that is into lands with a different mode of living, of another speech and of strange tradition and religion. Bearing the Panjab Saraswati in mind, we shall be forced to interpret the naming of rivers, and the veneration attached to them, not merely to the facts of their existence but to their usefulness to Hindu penetration, whether by colonisation, trade, conquest, or cultural absorption. The interpretation of such data is no simple matter but it is one of great significance.
We now return to the formation of Bengal's plain at a point where the Indobrahm had captured the whole drainage from the Dihong and flowed along the trough at the Himalaya foot towards the Indus plain and cut at the Gulf of Sind. One cannot do better than quote Pascoe's masterly and convincing outline.

"While the Punjab rivers were cutting back and seizing the middle waters of the Indobrahm, its upper course was being captured either by two branches of the same river or by two separate rivers (or river systems) draining Bengal and flowing southwards into the Bay. One of these was the Jamuna, or Bengal part of the Brahmaputra, and the other either a tributary of this river or a separate stream, the Ganges. These rivers present the appearance of having been initiated by the continuation northward of the broad geo-syncline of the Bay of Bengal. There is in fact evidence from bore-holes that the delta area is still an area of subsidence. This geo-syncline, the result of the Shan movement from the east, may even have been perceptible as far north as the barrier of ancient rocks which connected the Rajmahal with the Garo Hills. With the assistance of this geo-syncline, and perhaps with the assistance of faults, both streams cut back through this barrier. The Jamuna captured the whole of the upper part of the Indobrahm from Dhubri (at the NW. angle of the Khari Plateau; upwards, and became the modern Brahmaputra. The Ganges cut back
in a west-north-westerly direction, capturing element by element of the remaining portion of the Indobrahm and completely reversing the drainage as far as Hardwar, where the Alaknanda (with the Bhagirathi) was captured, the Jumna at that time being the headwaters of the Ghaggar. The voluminous waters of the Indobrahm having been tapped in this way, the scouring of a broad gap through the barrier was an easy matter\(^1\), and the sediments derived therefrom were flung by the flood into the Bay to form the enormous delta of the Ganges and Brahmaputra. I have stated a definite case for the sake of clearness; obviously there are equally valid alternatives. It may, for instance, have been a single river which cut through the barrier, beheaded the Indobrahm and became the Brahmaputra, the Ganges originating north of the gap as a right-bank tributary and cutting back northwestwards in the way described, the confluence subsequently retreating southwards through the gap."

After quoting the views of Dr. Pilgrim on a single westward river and on the reversal of its direction by the Ganges, Pascoo concludes as follows, adding to the evidence and the inductions made rather than subtracting from them. "My reasons for assigning the cause of reversal to the cutting of the present Ganges assisted

\(^1\) It should be pointed out, however, that the usual result of river capture is not a broad gap but a narrow gorge, as in the Congo or Zambesi.
by subsidence in Bengal, rather than to earth movement alone are as follows:

(i) Even a rapid series of cataclysmic upheavals seem to me inadequate to reverse completely and permanently the flow of such a large river near the middle of its course.

(ii) Normal diastrophic forces were in every way competent to bring about the changes described and would have given the Bengal river or rivers every facility for cutting back into the Indobrahm. Bengal and its Bay have every appearance of forming part of the broad spoon-shaped end of a vast geo-synclinorium tilted southwards, the natural resultant effect of two folding movements at right angles to one another, one from the east and the other from the north. As these movements proceeded, the tilt or pitch would increase, the mouth of the southwardly-flowing Bengal river draining the Rajmahal-Garo Hills, would tend to become "drowned", and the river itself would be invigorated by the steepening of its gradient. The strain towards the head or extremity of the syncline, where it was opposed by the transverse folding of the Rajmahal-Garo Hills, would cause fracture and faulting in the latter, and further assist the rejuvenated Bengal river to persist in its northward encroachment across the barrier. This Bengal river being young and fresh, one of its tributaries would have little difficulty in cutting a way back for itself northwestwards; this it would naturally do along the lowest level,
which would be the old indobrahm channel, to form the present Ganges."

(iii) From the thickness of the Alluvial belt, - both New (Khadar) and Old (Bhangar), with which "mounds or small plains" correspond in Assam, Pascoe is inclined to place the reversal of the drainage a little later than the end of the Siwalik period, that is to place it in the Recent Period.

**Tributary Valleys, and the Units of Deposition in Bengal.**

With this broad regional framework in mind, the forms of the lesser valleys can better be understood. With these, the deposition, in recent contemporary phases, of the cones and fans around the delta will be examined before coming to the subtly modelled relief of the delta itself. The torrential rivers of the Himalayas leave their mountains by the wild gorges they have cut across the ramparts of the lower hills. Clambering to heights where natural terraces or levels first appear (for there are none in the deeply cut gorges below), and following up the valleys to come 7,000 ft. we should find a striking change in forms. For in these "alpine" valleys, the steep upper sides run back to saw-edged ridges or arrêtes, but their lower sides curve to form a valley floor that is wide and smooth, save for the nick cut in it by the stream as it begins to plunge from these glacial valleys to the gorges below. While the gorges show a sharp
section, a section of the alpine valleys would show a wide U. And above the greater of these glens are smaller hanging valleys above them, these being mostly untenanted conifer forest and high pasture. The glaciers, which came lower in Kashmir and the North Western Himalayas in Sikkim and the South-East, partly because of latitude. Hence there is an absence of broad valleys opening on to the plain. As shown has suggested, this may help to account for the extreme separation of the plainfolk from the Bhutanese, and the close connection of the latter with Tibet. "Tibetan" is indeed the plainmen's name for the Bhutanese of Sikkim and Bhutan.

The valleys which enter the plain from west or east are for the most part somewhat steeply cut and hence even they offer relatively difficult lines of communication. In the west access to the Chota Nagpur plateau is not always easy, while in the east the transverse gorges have not invited extensive penetration into the inner valleys of Tripura. Although motorable roads run into the valleys between the Garo spurs, the Khasi Hills are still inaccessible even to motors from the south, and the hill station of Shillong is reached by rail and road following a wide arc north of the Brahmaputra through the northern plain of Assam. Nevertheless, there are open plains or vales within the outer ridges on both sides which have invited clearance and settlement. The little
raj of Tripura is of ancient standing and northwards from the Damodar and Ajay valleys passes lead from these across the NW. plateau into Bihar.

As the rivers and torrents of the Himalayas or the Plateau emerge from their valleys on to the plain, the detritus dropped by each as its speed is checked is spread in a semi-circle and accumulates as a low "alluvial cone" or "fan" whose apex is the point of emergence from the plateau or mountain valley. On the existing 1/Million (1/M) maps of the Gangetic plain, the contours over-emphasise the dissected valley forms beyond the edge of the Himalayas and the Plateau, recording the errors due no doubt both to early surveyors and to their draftsmen. The early surveyors magnified the relative heights of the cutting at the river banks, while the office draftsmen, accustomed on their part to draw contours which bend upstream before these cross a river (so expressing its valley), also failed to realise the forms that result from the deposition of cones of which the size and steepness vary but which are convex and not concave, the contours curving down-stream, except in the temporary incision cut into its own detritus by the stream. In the 1/M map of Bengal it is the 250 ft. contour which is somewhat at fault; at 500 ft. above the plain we are at the foot of the spurs or well into the valleys so that the general effect it conveys is not incorrect. In maps
of larger scale the contours from 50 or 100 to 300 ft. are those which require correction. For this reason a number of the contours plotted on modern topographical maps have been reduced to 1/4 M scale and plotted on Map II (1/4 M), for West and North Bengal.

The changing base levels of erosion have resulted in a certain alternation of deposition and of erosion. Large fans laid down in the past have again been cut into, so that the landforms bordering the delta are highly complex. The Old Alluvium of geologists, the nature and distribution of which will be more fully discussed in the next chapter, was laid down in wide fans which have been subjected to erosion, losing their fertility, and draining into minor valleys from which the streams emerge on to fans of New Alluvium which they are still depositing and which are naturally fertile and freely watered. Without endeavouring to differentiate these too closely at the moment, let us survey the simpler examples and the general systems of alluvial cones, whether old and re-dissected or new and in process of growth. These constitute units or tracts of deposition which may here conveniently be outlined and named (Fig. A. p. A.42).
UNITS OF DEPOSITION
OR RIVER FAN SYSTEMS

TERAI FANS
BENGAL DUARS FANS
ASSAM DUAR SE FANS

NORTH BENGAL
FAN

KAMRUP FANS
KHASI PLATEAU FANS

OLD BRAHMAPUTRA FAN

WESTERN BENGAL FANS

DELTA

DELTAIC SHELF

FIG A.42
The greater part of North Bengal, from the Mahananda river (which forms the boundary of Bihar) eastwards to the Brahmaputra-Jamuna may best be thought of as the fan of the river Ranjit of Sikkim and Darjiling, its emergence from its Himalayan valley marking the head of its vast fan to the south. Its present course south-eastwards, first found in the devastating flood of 1787, is called the Tista (or Teesta). The Tista joins the river Jamuna almost opposite the SW. angle of the Khasi plateau 25° N. and its deposition has embanked lesser rivers emerging to the east and south-eastwards e.g. the Singimari. The previous course as mapped by Rennel, the first great British cartographer in Bengal or India, ran to the river Karatoya (SSE. from the Ranjit Gorge); its waters at an earlier date have swept along the river Atrai, due south, and earlier still must have flowed on the western side of the slightly elevated mass of Old Alluvium bounded by the Karotoya, its water there being known as the Mahananda, the "mighty", which no longer deserves its name. Thus the Atrai seems long to have been understood to be the axis of this great fan-system stretching fifty miles to west and fifty to east of it.

West Bengal, lying between the Plateau and the Bhagirathi-Hughli is largely composed of a succession of these fans, with the addition of a strip of inundable marshes. Each marsh is caused by being hemmed in by the bases of two neighbouring cones (to N. and S.) and bounded approximately by the right spill bank of the Bhagirathi, or, S. of lat. 23° N. by the most westerly of its three distributaries, the Saraswati, whose former spill banks, green with orchards, wind on either side of its trickle of water, a few miles west of the deeper and busy Hughli. These fans have played their part in deciding the course of the great rivers, the Ganges-Padma and the Bhagirathi-Saraswati, which meander near to the base of the fans of their tributaries.

The Gangetic plain itself might almost be described as the succession or apron of Himalaya foot fans, skewed by the eastern course of Ganges to the outlet at Rajmahal. Proceeding westwards from Bengal, the first great fan system is that of the Kosi whose depositing powers thrust the Ganges hard against the plateau. Next, (after a few smaller rivers) comes the Gandak some of whose courses are utilised in the irrigation channels which take off from it and whose swing is recorded in the names Buri (old) Gandak, to east of the present course, and Little Gandak to west, each lying thirty to forty miles on either side of the present central course. One great river alone thrusts out a northward fan forty miles from the
plateau foot, the turbulent Son, fed by the rains of the Chota Nagpur heights, - a fan which became the homeland and centre of the first empire over the entire Indus-Ganges plain. The extremity even of this fan is over a hundred miles from the Himalayan foot. Similarly from the Assam "Duars" or hill foot the Himalayan torrents throw their fans in a wide apron across the Brahmaputra valley, forcing the river against the northern spurs of the Khasi Plateau. The seepage from these soils make the Tarai and Duars a zone of forest and high grass, for the Tarai of Nepal is continuous with the Duars of North Bengal and Assam, though these are pierced by road and rail, by field and tea-garden. In spite of important differences they form one zone not only because of their heavy rainfall but still more because of the slope, soil and subsoil water conditions of these fans.

In the same way from Rajmahal, (at the NW. angle of the Chota Nagpur Plateau) the southward course of the Ganges-Bhagirathi-Saraswati is thrust progressively further from the plateau as the streams from the Rajmahal hills give place further south to rivers of increasing size and carrying-power. While the Bansloi measures some 50 miles taking the distance from its source to its confluence with the Bhagirathi (near the off-take of this river) the Ajay (or Adjai) measures nearly 150 and the Damodar, 200 miles. Hence the Damodar's fan thrusts the Bhagirathi in an eastward curve
from the Ajay confluence, past Tribeni (point of triple distribution of Saraswati, Hughli and the Southwestern Jamuna), on to the present confluence of the Damodar with the Hughli estuary, below Calcutta.

The Ganges-Padma skirts the base of the great fan of the Ranjit, or (as it may be called here) the Sikkim Tista and has cut its SW. extremity into low bluffs. Indeed, as we shall see, there are good reasons, topographical and historical, for believing that in the 16th century much of the Ganges-Mahananda water kept closer to this fan than now in a meandering along a belt from the southern Mahananda to the Chalan Bil (marsh).

South of the Khasi Plateau the Brahmaputra spread its waters over a wide fan until the Tista's flood of 1787 led to the blocking of its eastward course and to the opening of the present course due south as the Jamuna. This wide fan may be named that of the Old Brahmaputra. How slight is its slope may be seen from the attempt to represent this by contours sketched or plotted from the very few trigonometrical and spot heights surveyed, and from the levels surveyed by engineers engaged in railway making (Map III,1/M). Both the contours and the curving base of the Old Brahmaputra fan are unmistakable, as it subsides into the depression of the Burma river system and its vast swamp-lakes or haors. An element of
connection or continuity with the deposits of the Sikkim Tista is suggested by those of the radiating spokes of the North Bengal Fan which point southeastward.

The fans thrown out to north of the Khasi Plateau are very short being cut away by the Brahmaputra's waters, thrown against them by the greater Himalayan fans opposed to them. Those to south of that plateau are appreciably longer, and their rainfall, and sub-soil water conditions have made this belt one of jungle, now giving place slowly to peasant clearance or to tea-gardens. Three fan belts skirt the southeastern ridges. (1) In the south of the Surma-Parak basin their existence is noticeable on topographical maps as they emerge from flat-floored valleys of marsh and paddy land between narrow ridges of jungle and tea-gardens. (2) A zone of deposition dips to the marsh-lands and muddy estuaries lying along the coasts of Chittagong. (3) One or two rivers emerge transversely to the boundary ridges of Tripura State on to the plain of Tippera, and Noakhali districts, and their deposits are remodelled by the southeastward currents of the Meghna floods and of the sea. The depression of the Bay of Bengal synclinorium also tends to submerge these. There can hardly be said to be a fringe of fans to the east of the plain corresponding to that to the west. For the flood plain, half encircled by the Meghna, is at first sight merely a part of the delta, so trifling at a distance of 200 to 540 miles from the fringing sea, is only 40 to 58 feet above mean sea level.
is the altitude, so small the affluent streams, and so predominantly southwards is the escape of inundation waters across it. Yet, even here, if we could straighten the course of the streams which emerge from the Tripura Ridges, they would be seen to flow radially NW. (and to some extent SW.) from near Comilla which lies behind Lalmai Ridge of Old Alluvium, which is apparently the remnant of an older and higher fan. The name Tippera Submerged Fan may perhaps be given to this unit.

The Old Alluvial uplands north of the Ganges, known as the Barind, and those of West Bengal have been mentioned. There remains only the small Old Alluvial "Upland" of the Madhupur Jungle to be named. Almost insulated in the rains by inundation on all three sides, most completely to SE., this upland has survived at a level of some 50 ft. above the plain around it, perhaps by being off the main line of advance of any fast moving river. Though its configuration is merely sketched by form lines (not by accurately surveyed contours), its low edge or scarp appears to be carved in hollow bluffs or bays, suggesting that it was cut back by the meanders of past rivers curving like the rivers loops at their feet today.

Finally the Delta proper, is really the greatest, most complex, and most gently sloping fan of all; its Gangetic apex in the NW., at a distance of 200 to 240 miles from the fringing sea, is only 50 to 55 feet above mean sea level.
The relationship of the surface levels of the present and of the "recent" past in the Delta is represented (1) by the present levels of deposition; (2) by the levels of Old Alluvial "Uplands", fifty feet or so above the New Alluvium nearest them, and also (3) by at least one buried layer of deposition of which there is evidence near Calcutta and further east, some 50 ft. below the present surface. Given an unchanged angle of slope, uplift of the land will cause erosion, while subsidence will bring about fresh deposition. The slope or tilt of the surface may alter, however, and, if steepened, may quicken the flow of its rivers and favouring erosion, but if lessened, may retard the flow and favour deposition. Increased rainfall would also hasten erosion and deposition. Here all that can be said is that the present levels of the Old Alluvial Uplands point to deposition to some such level as theirs, followed either by uplift or by steepened slope, during which levels were cut lower by the Ganges and Brahmaputra.

The present stage of slowly advancing deposition appears to be the result of gentle subsidence, in which the erosion of the Old Alluvial "Uplands" continues alone with lateral erosion of the deltaic river banks, accompanied elsewhere by deposition of silt. Silt is dropped both where the muddy waters of floods overflow parts of the eastern Delta and also at the edge of
shallow estuaries. Hence there must be not only the gradual advance of land above mean sea-level — varied it is true, by retrogression, as along the Noakhali coast east of the Meghna estuary — but the deposition which is no doubt occurring at the submarine edge of the Delta, 70 to 120 miles out to sea.
CHAPTER B.

SOILS AND SOIL TRACTS OF BENGAL.

I. OLD ALLUVIUM AND NEW.

Soil Tracts.

Criteria of Old Alluvium.

II. LAND-FORMS OF THE OLD ALLUVIUM:

SLOPES OR SCARPLANDS?

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Land Forms of the Old Alluvium.

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III. SOILS AND THEIR FORMATION AND TRANSFORMATION.

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Hill Geology and the Soils of West and East Bengal.

Fertility of Silt: the Nile and the Panjab: the lessons for Bengal.

MAPS.

Map B I/2M. Soils: Sketch Map.
Map B II, 1/4 in. to mile: Madhupur Jungle
Map B III, 1/2M, Salt area of inundation
CHAPTER B.

SOILS AND SOIL TRACTS OF BENGAL.

I. OLD ALLUVIUM AND NEW.

Soil Tracts. Within the framework of ancient plateau and of folded ridges of later age we come to what is vital to the cultivator of the plain, its soils and sub-soils. The primary distinction of soil types to be made is that between the Old Alluvium and the New. The New Alluvium is as yet unaltered and is traceable directly to its origin in rock and to the agencies of its transport. Most but not all of the plain is composed of its loams and clays and of fine sand where a rapid river has dropped it, building sandbanks or chars. The Old Alluvium is altered in its upper layer by the action of annual rains and drought, and forms a hard, infertile, red sub-soil just below the surface. Intermediate between the Old Alluvium and the most recent silt are the soils laid down sufficiently long ago for them to have become firm, so that they resemble the Old Alluvium in being appreciably higher than the rest, in supporting a corresponding arboreal vegetation and in giving sites and a soil which lend themselves to house-building without the addition
of a wattle framework, such as is universal elsewhere.

Fringing the Plateau, in West Bengal, there is a marked shelf of Old Alluvium, some 30 miles wide, sloping from its meeting with the gneiss at 500 to 250 ft. towards the plain, where it is covered by the New Alluvium, at from 50 ft. above the sea in the south to 70 or 100 ft. in the north (Map II, 1/M, cf. Map BI, 1/2M). The shelf is unmistakable in the form and colour of its landscape. Its jungle or grass carpet is predominant but interspersed with cultivation; still more does it stand out where its vegetation is torn away by the attacking rains into eroded badlands of brick-red waste or khoai (Map IV, 1/M). We find this red soil again across the Ganges in the Barind, the tract of upland elevated some 10 to 50 feet above the Alluvial stretches around it and the plain of the Atrai, which divides its two main lobes to west and east. Whereas the Geological Survey have mapped the extent of Old Alluvium in West Bengal, that of North Bengal is apparently unsurveyed, for the reason that, the relief being gentler, the transition from Old to New, particularly

1. The data on which this chapter is based are the 1/2M Map of the Geological Survey of India and large scale geological maps (which I compared with study of the ground when I was in Bengal); physical data, reduced on Maps II and III (1/M), and land utilisation data reduced in Map IV (1/M), and other Maps referred to in the text, and, finally, descriptive accounts of soils distributions sketched or plotted upon the map of soils (Map B1, 1/2M).
in the north, is hard to define. Its southern edge, where the
Ganges or Padma cuts against it, is clear as also the edge where
the Karatoya flows against its banks. The Mahananda seems to
form a margin to the west, though outlying parts recur beyond it
opposite the off-take of the Bhagirathi and certainly opposite
the extreme north-eastern spur of the Rajmahal Hills. To the
north it fades into the New Alluvium about 25° N; the narrower
eastern lobe ceases at the small bil which it has no doubt
helped to create.

Between the old course of the Brahmaputra and the new
(i.e. that of the Jamuna), lies the Old Alluvial upland of the
Madhupur Jungle. This is a piece of forested country stretching
from near Dacca to within half a dozen miles of the Old Brahma-
putra and some 60 to 100 ft. above the level of the plain around
it. It is intersected with streams which have cut down the
valleys almost to the level of the plain, and in which there are
patches of reclamation. A small ridge of Old Alluvium also
appears some 10 miles from the border of Tripura, the State
whose jungles bound the plain to the east.
Lastly we must note in the Delta itself the firmer and slightly higher-lying tracts whose orchard lands mark them off from the diara lands of the Ganges-Padma meander belt, with its soft silt, and from the almost treeless lands of the Southern Bils. Here and there a triangulation point shows 15 to 20 ft. above sea-level, which means 10 or 15 ft. above high tide, at the southern margin, a small but appreciable difference. Some 20 miles or less from the Ganges-Padma, Indian date palms are numerous and they characterise the village neighbourhood all the way to the Bils on the south-east and the reclaimed tracts of the Sunderbans to the south. They show that the land is subject to drought for some months in the year, though the tract has marshy hollows, filled with clay, which carry much slowly moving or stagnant water in the rains; this alternation of old spill banks with clayey hollows is characteristic of the tract.

This tract thrusts two peninsulas south to the edge of the Sunderbans. The more south-westerly consists of the former spill banks of the decayed Jabuna or southern Jamuna; the more easterly tongue of land was bounded by the once mighty Bhairab which looped round it in a great bow north of the Haringhata estuary (90° E.). The houses of the southwesterly tongue are entirely clay-built (showing relatively firm land), and the village of Iswaripur was a raja's capital in 1600. In the more
easterly peninsula the houses are of bamboo, wattle and clay; of such is the little town of Bagherat. In the land between, the house walls are of wattle alone, since this can be flooded without collapsing.¹

Across the Meghna the plain of Tippera shows similar areas of green levees bounded by the river's somewhat slowly moving waters in the north and attacked where the Padma strikes with the combined force of Brahmaputra and Ganges floods. The area, however, more abundantly watered by rains and better fertilised by the silt of the floods, is prosperous and thriving, productive in its agriculture and fairly free of malaria.

Criteria of Old Alluvium. Such are the tracts of Old Alluvium and of more fixed New Alluvium which stand out from the still shifting belts of the greatest rivers or the area of widespread Bils which gives place to the Sunderbans. We shall follow them out later, region by region. It should, however, be pointed out that a number of criteria are needed to determine the limits of what can truly be classed as Old Alluvium or New, as plain or as 'upland', (always so relative a term in Bengal), while the differences of soil and the subtleties of relief and water supply in the Delta need still greater care and study to understand. Where Old Alluvium is the subsoil, one can hardly

¹. MS. notes kindly sent by Donald MacPherson, I.C.S.
call it rock, it may be revealed in the land forms shown on modern topographical maps and in land utilisation, i.e. cultivation and trees, (the dominant species being indicated), or waste of grassy or arboreal jungle. In Bogra and Pabna Districts the soils have been surveyed with most useful clarity for the recently published Final Settlement Report\(^1\); but, unfortunately, such data are most exceptional. For the rest we have Major Hirst's sketch map of Old Alluvium\(^2\), which shows underlying soils, not recognisable on the topographical map, linked to the uplands which are clearly recognisable. Here the Old Alluvium of the Barind is shown as a pear-shaped figure, with the apex to the north where the river Atrai is crossed by the parallel of 26° N. It should be remembered, however, that the dark clays of the Atrai deposits cover it along this plain, the widest of the many baids, or depressions which intersect the Barind. Examination of the Map of Vegetation (IV, 1/M) permits distinction of the scattered jungle of the uplands from the longitudinal belts which border the rivers or fade into marsh at either end in the depressions of the Barind. Hirst's map shows the Old Alluvium of the Madhupur Jungle carried beyond the Old Brahmaputra and the Buri Ganga south of Dacca, and visible in a small patch south of the Jhana near its confluence with the Jamuna. The Map of

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Vegetation supports this clearly enough, but an obvious inaccuracy is the failure to carry the border to its real termination just south of the Brahmaputra (25° N., 90° E.). Similarly Hirst's map shows, very generally but usefully, the Old Alluvium reappearing close to the Bhagirathi from the edge of the Rajmahal Hills past Katwa, at the Adjai confluence, on to the beginning of the Damodar fan, then swinging west and south in a wide arc to Burdwan, at the head of the fan, and so to Midnapur. Actually its presence is rather to be inferred than observed in the marshier parts, but here and there the stiff red soil is clearly recognisable, rising to a high red bluff which has dammed up the Telkar Bil, opposite Berhampur south of Murshidabad. This map is thus a necessary, though crude, supplement to the geological map and defines in northern West Bengal the red soil region known to the peasant as the Rarh. This tract is continued southwards into Midnapore (where it does not appear to be named) and where language changes. Hence the necessity of using a general term, Western uplands, to cover both the Old Alluvium proper and the fans of red, New Alluvium below it.
II. LAND-FORMS OF THE OLD ALLUVIUM: SLOPES OR SCARPLANDS?

Previous surveys and the need for re-examination. The gently modelled land-forms of the Old Alluvium appear, like the rest of the surfaces of the Gangetic Plain, to have escaped examination hitherto. Adequate study and comparison was indeed difficult for lack of complete topographical survey. It is now, however, possible at least to gain an impression of the forms by study of large scale sheets, to make some attempt to reduce these for certain regions, particularly the Rarh, parts of the Barind and Madhupur Jungle and Tippera, - and examine them on a single map on 1/"N scale. From these studies one may suggest working hypotheses which invite examination of the forms in the field. Not simply is this needful to make description complete, it is valuable if a large scale policy of river control is to be developed and adequately undertaken. This will be clear by quotations from the 'Report on the Hooghly River and its Head-Waters' published in 1919. "In dealing with the effect of a diminished fresh water-supply upon Calcutta as a port and the possibility of increasing it, Major Hirst (of the Survey of India) found it necessary to consider the problems of and advance certain theories regarding the general system of deltaic rivers in Bengal; he divided his examination under three main heads:--

(a) the general formation of the delta and its rivers.
(b) the major disturbing agents in the river system of Bengal, and
(c) the general effect upon the Hooghly of minor physical and local disturbances.

The conclusions arrived at by Major Hirst were of so alarming a nature that the Committee felt it impossible either to accept or reject them without the closest and most complete technical examination. These conclusions rested on the geological, geographical and hydraulic phenomena of the delta. The geological aspects of the problem were referred to Mr H. H. Hayden, C.I.E., (now Sir) and Mr E. H. Pascoe of the Geological Survey.

... "For reviewing in detail the more general geographical and hydraulic aspects of the problem the Committee obtained, with the permission of the Port Commissioners, the services of Mr H. G. Reaks, River Surveyor, who has an intimate knowledge gained from long practical experience of the régime of the Hooghly river, and has made a special study of the factors which govern it. His report contains a general description of the deltaic river system, and brings together practically all the available historical and hydraulic data regarding the rivers with which we are concerned". Finally a note on the deltaic rivers was contributed by Mr C. Addams-Williams, Chief Engineer, Department of Irrigation and Canals. The Committee considered that "the information
contained therein would be of great value for purposes of reference in the event of the necessity arising in the future of undertaking extensive training or engineering works in connection with the control or improvement of the waters of the Hooghly" and, one must add, of the whole river system which dominates the life of the delta.

Major Hirst arrived at the conclusion that the present régime of the Hughli is wholly insecure, that the forces controlling it are so powerful that any artificial interference would be futile, and that the river has deteriorated to such an extent as to be a menace to the Port of Calcutta. If Hirst's conclusions were correct the position would be one of extreme gravity. The volume of the head waters of the Hughli is, according to his theory, primarily dependent on the geological processes which govern the delta as a whole. He suggested that the Indo-Gangetic plain as far as Hardwar was once covered by the sea and that the land surface of Bengal has been gradually built up by river action. At some period certain subsidences have occurred, of which the most important follows a line from Jalpaiguri to the sea along the line of the Jamuna river; in compensation for these subsidences certain tracts have become elevated, such as the tract north of Dacca known as the Madhupur junga. These earth movements, resulting in a series of elevations
and depressions, dominate the river action of the delta and are at present in a state of activity; and to such action he ascribed recent important river changes such as the changes in the courses of the Tista and Brahmaputra in the eighteenth century. If these forces are still of such importance and activity as is assumed by Hirst, it must be conceded that human agency could be of little avail in attempting to improve the head-waters of the river Hughli. This theory is not, however, in accordance with geological opinion.

As the Committee's recommendations depended largely on the fact that the geological experts consulted were unable to ascribe the present condition of the head-water rivers to recent tectonic activity it is important that the expert's conclusions should be explained here in some detail. Hayden and Pascoe regarded the behaviour of the Gangetic rivers as in no way different from that which characterises the normal processes of deltaic river development; they did not consider that the effects observed within the last few hundred years could reasonably be attributed to those slow crustal processes which act through geological periods; these processes, they asserted, may be disregarded in any present enquiry in connection with the rivers of Bengal. It is true that certain seismic phenomena may affect local river development, but the effects in the area
involved in this enquiry are likely to be local and superficial rather than deep-seated, and to have chiefly comparatively unimportant results, such as, the formation of fissures and the collapse of river banks. It is not likely that the effects of regional movements could be detected in such a short period as three or four hundred years. It was pointed out that Hirst had not brought forward evidence in support of his assumption of the former submergence of all Bengal beneath the sea, and Hayden and Pascoe preferred to adhere to the generally accepted view that the Gangetic plain has lain above sea-level at least since an early date in the Tertiary epoch, and that there has been slow but gradual subsidence permitting of the accumulation of an enormous thickness of alluvial deposits; but they considered that regional movement of this nature, even if now operative, is not sufficiently rapid to justify its introduction as a factor in the present case.

Hirst advanced or rather reaffirmed the theory proposed by Fergusson in the case of the Madhupur Jungle that the exposure of the older alluvium in certain places above the level of the surface of the younger deposits of the delta is due to a recent and gradual, though irregular, movement of elevation - the result of tectonic processes which have consequentially affected the condition of the deltaic rivers. Hayden and Pascoe were not prepared to accept Hirst's arguments; on the other hand,
there is clear evidence that the old alluvium generally has been subject to a process of very gradual subsidence. The suggestion of Latouche that the Madhupur Jungle tract is a relic of the old delta face of the Ganges was regarded as a more satisfactory explanation. Nor could Hayden and Pascoe find any justification for Hirst's assumption of a continuous line of subsidence, from Jalpaiguri\(^1\) on to Java via Barisal\(^2\) or for other special areas of assumed subsidence such as that near Nadia. They arrived at the conclusion which the committee did not hesitate to adopt that there is no evidence to justify the assumption that the gradual processes of local or north to south elevation and subsidence are the dominating factors in the river development of the delta.

Hayden and Pascoe were of opinion that there is no justification for believing that the condition of the Hughli will inevitably become worse than in the past and that no deduction can reasonably be based on the assumed effects, in the course of a few hundred years, of the operation of tectonic forces, whether regional or local. The alterations in the courses and condition of the deltaic rivers are capable of a simpler, more reasonable and equally satisfactory explanation in "the ordinary,

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1. (1910) Reprinted in Report. 2. Jailpaiguri, below Tista Gorge: Barisal near Meghna estuary: slow and gradual subsidence towards the lower end of the Delta is not contested, but postulated, as we have seen.
well-known processes of riverine and deltaic development"; the uniformity of the changes that have occurred indicate clearly that the causes must have been normal and not connected with tectonic phenomena. The view that the development of the deltaic rivers has followed normal lines is not confined to geologists. Addams-Williams, who has studied very closely and comprehensively the history of the deltaic rivers and has an expert and technical knowledge as an engineer of the special hydraulic problems which arise, had endorsed this view. The Committee could not, therefore, accept Hirst's conclusion that the forces controlling the action of the deltaic rivers are so powerful as not to be amenable to interference by human agency.

Such is the discussion involved in decisions by the Calcutta Port Commissioners. Still more fundamental than the effects of river movements on the navigability of the estuarine access to Calcutta is the question of agricultural prosperity, on which the peasant life of the province depends.

Both the theoretical interest and also the practical importance of gauging the relative power of tectonic and of erosive forces to one another will now be clear. It therefore seems worth while to suggest a line of investigation which appears only to have been touched upon in discussions of this problem.
as published. The land forms of a region such as ours bear the marks of the erosive forces which have modelled its surface forms acting on the structure and the lithology (or type of rock or alluvium). Hayden and Pascoe have indeed said "mere undulation of the surface is, of course, no proof of tectonic action and in the case of a deposit so young as Pleistocene, would more probably be due to natural processes of denudation". Later they write "Although we are not prepared to deny that the Madhupur Jungle may be as Fergusson claimed, it seems preferable to regard it as a result of ordinary superficial processes, its more pronounced character being attributable to the simple and familiar causes assigned by M. Latouche in his paper . . . of 1910". Turning next to this we find it said "One of the most conspicuous instances of this old alluvium is . . . the Madhupur Jungle", its red soil being "evidently an old river silt, but raised to a height of 60 to 100 ft. above the flood-levels of the rivers on either side. Several other patches occur in the lower Ganges valley, but as we ascend the river and its tributaries into the United Provinces and Bundelkhand, we find that this older alluvium is almost universally distributed, and has a distinctive name, that of 'bhangar' in contrast with the low-lying khadar or flood plain along the river-courses, and that it bears every sign of being in a state of rapid erosion; that it belongs in effect to a condition of things that has now passed away, when the rivers
probably possessed a much greater volume of water and brought
down correspondingly greater quantities of silt." If this patch
were due to a special upheaval . . . "we should have to apply
the same reasoning to other patches of the older alluvium, and it
is difficult to suppose that each of them is due to a special
upheaval; moreover, one would think that an upheaval in that
particular place would be more likely to force the Brahmaputra,
westwards than deflect it to the east. Nor does it account for
the fact that the Brahmaputra, now a much larger river than the
Ganges, allowed itself to be pushed aside in this way; or that,
considering that it brings down very much more silt than the Ganges,
it should have done so little towards filling up the Sylhet jheels:"
The importance of knowing whether Bengal rests on a stable or on
an insecure foundation justifies fuller examination of the evidence
along lines which, as has already been said, have been too little
developed by modern geologists, even though the pioneers of the
science a century ago were among the first to adumbrate the
principles now being developed by Western geographers and geologists
acting in partnership. The land forms of the coastal plain below
the Eastern Ghats have been ably described by S.W. Cushing. In
the absence of adequate survey or of accurate verbal description
what follows is necessarily interrogative as to the land forms
and therefore frankly offers more than one hypothesis of evolution.
These are simply set down in order to suggest the need of accurate
investigation. I hope it may be possible to have light thrown
upon this on the spot before publication.

1 Bull. Amer. Geog. Soc. XLV, 1913 p.81-92. Quoted, with block
diagrams in Sion (1928).
Land Forms of the Old Alluvium.

(b) Hypotheses of Form and Evolution

Two possibilities of land form type in the Old Alluvium offer themselves, subject to local variation. One is that of a very gentle slope continuous from the upper to the lower boundaries of its outcrops, save for slight undulations. The other is that the prevalent downward slope may be initiated by a well-marked rise of a few feet, in other words by a miniature "scarp", before it continues to the foot down the main slope which is that in which the bedding dips, however slightly, and which is the dip-slope. To start with, one tended to take the first possibility for granted, but study of various features of the Madhupur Jungle, Lalmai Hills and even the Barind seem to suggest the second, and it seems possible for the following reasons. For reasons mentioned in the next section, the upper layer of the Old Alluvium is chemically altered to a depth of 50 ft., and as it becomes exposed to the air, by denudation, it is rendered relatively resistant. Hence when deposition is succeeded by a new cycle of erosion (as has happened) we must not of course, expect it to be worn evenly over its surface. It will in the first place be channelled by rivers whose direction is consequent upon the main slope, and secondly the onset of the rivers will tend to wear back its resistant crust or edge. The miniature vertical scale of this edge is probably made up
for by its horizontal extent and by the difference of drainage and soil character. Let us see what evidence offers in each tract for one or other generalisation.

Since Bengal, although an area of deposition on a vast scale, is to be thought of as a subsiding syncline at its southern, marine margin, some erosion has been and, at places, still is at work towards its upper or outer margin. The dip of the Alluvium towards the Bay of Bengal suggests that we look for the outcrop of its older strata in a ring towards the basin rim. There we may expect, on this view, to find the underlying stratum, the Old Alluvium, rising very gently outwards till, a little before the boundary of the outcrop of still older rock is reached, its greatest height is attained in scarps composed of altered and more resistant layers which face outwards from the centre and across intervening valleys towards the surrounding hills. The inward or dip slope will be very gentle indeed, the outward face relatively abrupt. It must be clearly understood that the stratification of the Old Alluvium is so slight that it does not appear to have been recognised in Bengal. Three facts stand in the way of recognition, the first being the prominence of bedding due to fluvial currents, noted by Latouche in the Madhupur Jungle and the apparent cause of the irregular bedding apparent at the surface of the Khoai or denuded
wastes in the Western Old Alluvium, and so striking from the 300 ft. bore there, described later in this chapter. The second fact is that since fluvial stratification is lenticular, there could exist no continuous scarps, these features appearing or disappearing according to the physical and chemical resistance of their relatively unconsolidated materials. The third is the very small degree of uplift, and the correspondingly slight erosion or relief. Nevertheless it would appear that the land forms may invite morphological comparison with the scarp-ringed basins of France or England, with this difference that whereas the horizontal scale is similar (or even greater), vertical scale corresponds at most to that of the minor scarps of slightly harder beds in the clays of the English Weald or the French Champagne Humide. Such forms have been described and their evolution interpreted in terms of deposition and of erosion (generally with intervening phases of peneplanation) by the great American geomorphologist, W. M. Davis. Possibly a better comparison could be made with the deposits of the Atlantic Coastal plain of the U.S.A., with its minor scarps or low edges of uplifted, unconsolidated sediments. The recurrence of scarp lands and their river systems in similar condition is now an accepted principle of physical geography.¹

¹ De Martonne: Traité de Geographie physique, tome II.
The areas of Old Alluvium in Bengal, their character and extent, have already been sketched. To west, east and north-east the change from Old Alluvium to pre-Tertiary rocks is visible and cognisable. On the other hand the concealed structure at the supposed edge of the Gangetic trough from north of the Rajmahal Hills to the North Garo Hills, and the uncertain nature of earth movement along that belt, naturally complicate the deciphering of erosion surfaces so that this problem will be touched on last.

Beginning with East Bengal, the Lalmai Hills of Tippera are of fairly simple type and seem to show a steeper face towards the low ranges to the east, which can be seen from them across the intervening plain, and a gentler dip slope towards the west and the Bay of Bengal. Their infertility delayed cultivation upon them till last century. The character of the outcrop is exhibited in its plan too, the longer edge apparently facing east, though the lack of modern survey makes the forms hard to determine as yet. This may be a remnant of a fan of Old Alluvium more prominent than the rest, and resisting owing to its laterised upper beds.
The higher portion of the Madhupur Jungle is to the north, and towards the south it slopes gently to Dacca on the Daleshwari and the Buri Ganga, whose name signifies an old course of the Ganges. Although no altitudes or true contours have been published on topographical maps this upland is always referred to as lying 60 to 100 ft. above the plain i.e. 100 to 160 ft. above sea-level. The form lines, curving above the crescent-shaped mortlakes at its edge, seem to portray a border composed of river-cut slopes or low cliffs to north, north-west and north-east where the Brahmaputra and its effluents, thrown against its northern face or flowing immediately to west or east of it, carved the concave clay cliffs similar to, but larger than, those so familiar above the deeper and faster running sides of Bengal rivers (Map BII, ½ in. to mile). There are also small outliers of the upland to southeast of it, and it would be interesting to know if these show a slightly steeper face to north. If so, this would confirm the suggestion that their general alinement shows a wearing back of the northern escarpments, and that their division into islets of upland in the marshy plain marks them as miniature isolated bluffs of outliers witnessing to the erosion of the scarp.
The Old Alluvial shelf of West Bengal is of a somewhat different character for there is no regular line of interruption in the ascending slope where one passes from deep beds of laterite to the rock of the Plateau. It is no doubt to be thought of differently in being composed of detritus from the Plateau immediately adjacent. Rivers must have been actively at work depositing their detritus in fans upon the plain below. The rivers of to-day, which have cut further back into the Plateau, form a lower base level, have cut into the older fans instead of depositing upon them, and the former extent of these might conceivably be reconstructed by research in the field with the help of detailed topographical maps. For example one would look for the dissected remains of a great Damodar fan since this river and the Ajay, with their old catchment basins have long been important. It may be remarked in passing that there is every appearance of the capture of a former upper Ajay by a tributary of the Damodar. The Old Alluvium projecting outwards towards the plain near the emergence of this river from the Plateau suggests a fan of the Damodar combined with the Ajay fan to the north and the Rupnaryan to the south. Although in view of this detrital character, one can again hardly expect signs of regular scarps in the upper levels of the Old Alluvium along its continuous shelf, they seem to appear in the isolated bluff opposite Berhampur against whose dip slope the Hughli and Bhagirathi
have been cutting a cliff for centuries past, but the valleys diagonal to the dip slope, of which the largest is that of the river Kasai (which runs past Midnapore) suggest differential resistance of the strata.

Turning to the river systems of North Bengal we have seen that they may be considered as one major system whose head lies in the upper course of the Tista in Sikkim, the waters of which river have flowed southwards, then again to SSW., or, as now, to SSE. The Tista Gorge is the head of a great fan at the upper part of which deposition still seems greater than erosion and the alluvium is New. We have already noticed that the 250 and 150 ft. contours curve in a semi-circle drawn from a centre at the Gorge, the radius being some 40 to 50 miles long and the fall from the Gorge at 500 ft. to the contour of 250, approximating to 5 ft. per mile. About 70 miles from the Gorge the slope lessens and the next fall of 150 ft. to the bluffs above the Ganges-Padma measures fully 100 miles over the upland, though the fall along the Atrai till it turns towards the Chalan Bil is steady and more rapid. Reduction of topographical maps shows that a contour of 150 ft. would curve roughly parallel to that of 250 ft. continuing the slope regularly, and crossing the Atrai north of Dinajpur (a little south of 26° N.). By combining the data on various Survey of
India maps, and the railway levels, it is clear that the country in the latitude of Dinajpur lies at 105 ft. or so above sea-level or no higher than the southern lobe of the Barind, 70 miles further south.

We noticed that the Old Alluvial upland of the Barind appears to come to an end in the neighbourhood of the twenty-fourth parallel of latitude, south of Dinajpur. The presence of a bil terminating the eastern lobe of the Barind Old Alluvium proves an appreciable rise to the south of it and this may be taken to be the scarp terminating the dip slope of the upland, and overlooking at its foot a characteristic portion of lake-filled depression peripheral to a portion of scarpland. More detailed maps or well chosen photographs might reveal a similar scarplike termination of the western lobe where lateritic soil gives place to New Alluvial clays and sand. Such features upon an otherwise monotonous plain deserve representation on topographical maps by shading or even by words because of their importance in indicating land types, and for land utilisation, and by the indication of relative heights.
From these facts we should be in a position to sketch a section of North Bengal from the Tista Gorge to the Ganges. The lower, southern portion of the region is not overlaid by new deposits but, on the contrary, the erosion of the Atrai when it was fed from Sikkim has eaten into the outer portion of an ancient fan, making the low flood plains or baids of black clay which traverse and dissect the upland. There is a clear step in many places of 20 ft. or so, the upland level, as from the Karatoya meander-belt on the eastern margin and probably from the Mahananda against the western flank. The upper fan, beginning at the Gorge, with its radius of 70 miles or so, is of New Alluvium and from its foot the force of the rivers which cut the Old Alluvium into two great lobes at the same time wore these back, cutting at the scarp foot till, at the present time, it occupies the position we have sketched.

To sum up the discussion, it would seem that whereas there are signs of slow and irregular scarps at the upper limit of outcrop of the Old Alluvium in Bengal, in East and Northeast,

1. Pabna and Bogra Settlement Report, and photographs by Donald MacPherson. 2. The difficulty of determining changes of surface level from Survey of India maps of the Plains arises from the lack of clear principles for the selection of points for levelling, as recent professional papers of the Survey have pointed out.
in West and perhaps in North Bengal, verification, amplification, or thorough correction should be possible by men on the spot and by those who know the country and have surveyed or are surveying it.

types of soil, the underlying than was at first imaginary, energy, and therefore the formation, which is the important one, rapidly. Moreover, the process of weathering, which involves change by winter, spring, and weathered material, has been worked out, leading to the sap to be infertile land.

The and heavy falls of rain therefore, where slopes allow, the soil is rapidly covered with heavy deposition and silt of fertile.
Laterite, its formation and occurrence. The conditions which prevail in monsoon lands, with their high temperatures and their heavy rainfall alternating with long drought, produce special types of soil, the underlying rock being of less importance than was at first imagined. High temperatures induce chemical change, and therefore the hydrolysis or breaking down by water which is the important process in chemical weathering proceeds rapidly. Moreover, with the absence, in the Tropics, of glaciation, which interrupted the chemical processes of soil-formation in Northern Europe, there has been long continuity of weathering. Neither is there interruption of chemical change by winter. Hence there may be 50 ft. or more of weathered material from which the basic (non-acid) material has been worked out, leaving soils which, bereft of this, are apt to be infertile clays. On the other hand, from the suddenness and heavy falls of monsoon rain, erosion is rapid and therefore, where slope allows, there is a quick run-off and the soil is rapidly carried away and re-deposited in fans and deltas.\(^1\)

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The result may be expressed in a supposed section from the Plateau to the Bhagirathi in West Bengal. Small plateau surfaces, at altitudes of two to three thousand feet, lie deep and highly altered soils; at the edges and upper slopes of these plateaus, where there is erosion, soils tend to be thin and freshly formed, while the detritus piles up towards the foot. In the valley bottoms there is local alluvium, as in the upper vales of the Damodar and Ajay. Then, as we saw, there appears, between the gneiss of the Plateau and the Delta, the Old Alluvium of West Bengal, sloping from one to other by gentle degrees. This tract is generally thought to have been formed of the detritus washed down, in a recent geological age from the already altered soils of the Plateau. At the same time it seems certain that the plain itself has been subject to different cycles of erosion, i.e. to differing rates of down-cutting by water and different levels of accumulation. Hence, corresponding to the shelf of Old Alluvium here, we have "uplands" over the plain (the Barind of North Bengal and the Madhupur Jungle) which are generally, and probably rightly, considered to belong to the same erosion cycle as the western shelf. They have certainly this in common, the alteration undergone, whether the soil at its

deposition was already altered, (as it has hitherto been presumed to have been in the shelf of West Bengal), or was laid down fresh, as it must have been upon the plain.

The gentle slope of this shelf has allowed the surface soil to be modified by plant growth and organic material, together with cultivation; but on waste land from which the forest has been cut and burned, erosion is stripping the surface soil and channelling the shelf, leaving bare slopes of vivid red sub-soils, the khoai, dark where concretions occur, without a blade of grass or a green leaf save where the roots of a hardy thorn or date palm have penetrated to the water table. Finally comes the fringe of the Rarh, with its apron of New Alluvium overlapping the Old, enriched by deposition of fertile and unaltered soil but locally impoverished where short-lived torrents from the Khoaï have in turn spilt infertile soil upon it.

An interesting bore to a depth of 300 ft. was made in digging a tube well for the farm of the Institute, at Surul, near Sauti-Niketan, West Bengal. The spot lies at an altitude judged from railway levels, of some 150 to 160 ft. on the Old Alluvium, which is a few miles inside the limit shown on the Geological Surveys Map and so recognisable in the field.
I examined and compared the samples of each new stratum as it came up; I regret that I did not send them to be analysed, but I give the following notes, from memory.

After the first 3 ft. or so of impure yellow clay the bore brought up the usual red laterite. This remained of the same colour for some 45 to 50 ft. and was then replaced by grey clay. 100 ft. lower, a dark grey, shaley and almost schistose layer a few inches thick, was brought up, then again very much the same grey clay. Over 100 ft. lower still came a stratum of very hard, grey clay, very compact and sticky, which, instead of scaling like the shaley substance, was so slippery that the bore turned in it without penetrating. After two or three days of apparently fruitless labour attempts, the tube worked through this layer, only a few inches thick, and penetrated again into grey clay, as before, through layers of differing consistencies, to a depth of 300 ft. No appreciable quantity of sand was brought out, and from the nature of the sub-soil and its clayey nature, to a great depth (except for the shaley stratum), one may conclude that there is none. One must bear in mind however that some pieces of quartz are sometimes found in the laterite, and even portions of fossilised wood. Unfortunately not enough water was found to make a workable well.
The striking feature of the sub-soil geology is the laterite, where it is cut into or laid bare. Laterite is a vesicular, clayey rock composed of hydrated oxides of alumina, or of iron and manganese, and is generally red in colour. It is found in monsoon lands, perhaps owing to the alternation of long drought with heavy rains, and the action of air and water alternately rusting the minerals, so to speak, while leaching the soluble elements. It is produced directly by alteration of basalt and other rocks on summits of hills; or, as here, from Old Alluvium, where it goes down, at a depth of nearly 50 ft. below the surface, to unaltered clay. It is thus generally known as "low-level" laterite to distinguish it from that of plateau tops. The laterite becomes brick-coloured and brick-hard when exposed to the air, whence its name (later, a brick), and also its local use as road metal for want of better material. When hardened by exposure it becomes nodular, and dark in colour. Its appearance suggests iron ore and signs of smelting have been noted for instance in Birhuth. Primitive iron furnaces were worked there during the last century, and attempts to smelt iron were made by European firms about 1780-90 and in 1875, but they were both failures. The modern use of certain types of laterite is the mining of its bauxite, or aluminium ore, but none is mined in Bengal, because the heavy concretions formed at the foot of plateau slopes cannot be re-dissolved nor carried off and re-deposited as detritus.2

1. Schantz & Marbut & Robinson, op. cit. 2. Fox, op. cit.
Other Types of Soil: red, black, sandy and grey, and new silt.

Redness is characteristic of fully drained tropical soils other than newly deposited silt, though where the parent material has a large proportion of lime, grey soils may result such as that which readily forms the grey concretionary 'konkar' of Upper India. In West Bengal, since most of the concretions are of lateritic type, kankar is the name given to such rock as this while the calcareous concretions, commonly used as the source of lime, are known as ghutin. No doubt the red colour of tropical soil may be compared to the rusting of its elements but weathering is so complex a process and soil and sub-soil materials are so varied that such a comparison must merely serve as an illustration. Red soils may contain appreciable proportions of organic matter though probably not absorbed to a great depth, so that redness is not of itself a sign of lack of fertility. Simkins,1 utilising observations of Dr Harold Mann, the late Director of Agriculture, for the great Bombay Presidency, has noted the vast difference in the laterite of plateau summits from the good red soils of lower slopes, different in their origin and chemistry from the 'low-level laterite' dated as Old Alluvium in Bengal. Although there is a close resemblance between the two types, only the low-level laterite need be discussed here.

1. Ethel Simkins; Agricultural Geography of the Deccan (1927).
Dark coloured or 'black' soils of fine clay are found in basin-shaped areas of impeded drainage, such as the baidās in the Barind, north of the Ganges-Padma, or on the rims of the bils east of the Bhagirathi, in parts of Murshidabad and Nadia districts. Such soils, through long submergence, may undergo decomposition with loss both of organic matter and of mineral matters released as bicarbonates, so that if rainfall leads to local inundation carrying these materials away and if there is no renewal by fresh deposit, the soil may be impoverished.\(^1\) Impoverishment seems to have been occurring in the hollow ricelands of Central Bengal increasingly for a century past, and helps to explain the decline in the extent and the returns of cultivation. The same may well have been true for alluvial areas in the North Bengal Fan abandoned by southwesterly or southerly courses of the Sikkim Tista in favour of the present Tista, properly so-called.

On the other hand decaying vegetable matter such as the stalks of wild rice (\textit{Oryza sylvestris}) is being laid down year by year in marshy lakes, as in the Southern Bils of East and east Central Bengal or in the Haors of northeastern Bengal a little beyond the margin of cultivation. The soil newly reclaimed from the edges of these is very rich, and the cultivators and herdsmen prosper and multiply. They know the

\(^1\) Robinson, \textit{op. cit.}
value of this so-called peaty layer, for they dig it out to spread on their fields, just as cultivators of Western Bengal, when they re-excavate old tanks, cart the silt to their fields and spread it there.¹ These facts are surely the reply to the apparently general statement made by the former chief of the Irrigation Department, that if silt-laden waters were really necessary for productive agriculture and health there would not be the fine crops there are in the Southern Hills since their water is fresh and clear.² Of course, silt-laden water is not needed when mould is piled deep on virgin ground. The fact that silt (or 'peat') is needed after crops have been taken off for some years is surely proved by the fact that the cultivators go and bring the peat to the fields.

Rising gently from the low interfluvies to every river edge are the levees or spill banks of rivers once active over Central Bengal, the dangas, high and dry, with their palms, fruit trees and bamboos and their villages aligned along them. Commonly these banks only reach 20 or 30 ft. above the shallow rivers below them, but even 45 ft. is recorded as the relative height of one such danga on a topographical map of Central Bengal,

¹ Article "Peat" in Latouche, Bibliography, Pt. II.  
where the word danga so frequently ends these village names. The slope and soil are so significant as sites on which the peasant shall sow the appropriate plots that a section illustrative of site and utilisation is reserved for Chapter E.

Different from both of these are the sandy soils of the great meander belts of Eastern Bengal and the diara tracts of the Ganges, where islands are built up by the floods and fought for by the vigorous riverain Muslims, always ready to decamp before a destructive flood and seize new islands as they appear.

While the silt of the Ganges and of the Brahmaputra is of a light grey colour, that washed down by the Damodar and other rivers of West Bengal is red. The line between is readily recognisable and occurs, for instance, near the foot of the Damodar fan and was even carried across the Bhagirathi towards the Jamuna by its floods. No doubt the same is true of other areas lying downhill from laterite or from red soil slopes, as locally on the borders of East Bengal.

Lastly there must be noted the distribution of fresh silt annually by normal floods in Eastern Bengal. After water itself, nothing could be of greater importance to cultivation

than silt, and the renewal of fertility. The cessation of fluvial activity from Central Bengal has been disastrous not to its water supply alone, but to its fertility. The areas shown as usually inundated or as usually bereft of it should be carefully noted. While conditions vary from year to year, like rainfall, an area with so widespread a catchment basin as the eastern Delta is surprisingly uniform. Again while topography varies locally that of the deltaic New Alluvium is a constantly recurring type as will be seen in Chapter C. Hence considerable assurance can be laid upon Map B II (1/2M) which is owing to Dr C. A. Bentley.¹

¹ Malaria and Agriculture in Bengal. Calcutta, 1925.
Hill Geology and the Soils of West and East Bengal. The alluvium deposited in the Delta is composed of the rocks and sub-soils, worked down to gravel, sand, and silt, by the rivers which bore it thither, and which also bear down humus and its bacteria if the catchment area be forest. It is therefore worth considering whence the mineral constituents of the soils of Bengal have come, and whence its annually deposited silt is derived. The composition of the rocks of the catchment areas of Bengal rivers varies considerably and also the nature of their soil surface wash, be it the leaf-mould of the Eastern and Northern forests or else the denuded, stony or lateritic slopes where the Western forest has given place to open waste. The tributaries of the Bhagirathi mostly flow from the Bengal Gneiss and Siliceous rocks of Chota Nagpur which greatly surpass in extent both the strip of coal-bearing Gondwana sandstone and one or two limestone areas, so that we may expect a deficiency in lime in the soil of their fans. The Old Alluvium is leached and is highly siliceous and ferruginous, so that when it is laid bare by torrential rains it is so infertile that its rusty red remains untouched by greenery. Formerly the soil which covered it was enriched by leaf-mould; now, however, the disappearance of thick jungle both on the hills of Chota Nagpur and on the uplands of the Rarh is being felt wherever silt is deposited, and this must chiefly account for the diminution of
fine silt deposited by the irrigation waters of the West. The soil of the West, poorer from the start from its lack of lime mineral constituents, must more speedily lose fertility when deprived of its top dressing of leaf-mould. In the Northeast, however, conditions are somewhat different. The lateritic Barind and Madhupur Jungle show no great difference in fertility from the Rarh, because of the leaching of the soil. The silt deposited however is better. That of the Brahmaputra and of the Himalayan rivers (and no doubt of the Eastern Hills) is usually rich in potash and contains ample phosphate and lime salts, though it has no free carbonate of calcium. Even here there is often a deficiency in nitrogen and organic matter, probably where erosion and also deposition have been too rapid; where humus has been brought down and deposited it is richer.

1. Note kindly supplied by R. S. Finlow, I.C.S., Formerly Director of Agriculture, Bengal.
Fertility of Silt: the Nile and the Panjāb: the lessons for Bengal. "The Garden of the Lord, the Land of Egypt, owes its extraordinary fertility and recuperative ability to the high fertilising power of the water of the Nile." So wrote Willcocks and Craig¹ at a time when emphasis was the more necessary, in that there was then a tendency to decry the value of the Nile's silt and assign the fertility of its valley simply to the abundance of its water. "The best soils," they continue, "are those that differ least from Nile silt, and the worst those that differ most." The first element on which rents depend is good red water, which contains not only chemicals but sand, food for bacteria in the soil and bacterial life itself. "From the rocks of Egypt only a poor calcareous soil could be derived, but the rich Nile mud is obtained from rocks far to the south . . . One has only to compare the richness of the lower Nile banks with the poverty of the land in the Sudan watered by the anaemic White Nile to see the difference." The reason for their difference is that the Blue Nile flows continuously from the uplands and mountains, carrying its silt with it; the White Nile passes through vast marshes where its flow is checked and its silt dropped. In Egypt, however, irrigated by the combined streams, the mineral elements of both enrich the soil together.

¹. Egyptian Irrigation (1913).
As long as this system (of irrigating with red, muddy water of the Nile) was practised in Egypt there was not that need of manure which has arisen today. Fooden also wrote that "at soluble fertiliser rates, the value of the mud deposited on an acre is approximately equal to £1.5/-"\(^1\). Hence the proposal then made for a rotation of basin and perennial irrigation. "In this way all the land would have a thorough renovation with rich Nile mud every second year, and fertility would be maintained!"

The results achieved in a quarter of a century since this was written have proved the truth of these assertions and saved the Nile valley from ruin and decline.

...Others quoted who say that "any increase in the quantity of water available for irrigation purposes without a corresponding increase in the manure supply is often of doubtful benefit." Sir Edward Buck,\(^2\) referring to land near Ajmere (India) states that "Irrigation from tanks is lavish, and is put on to land which it has robbed of its fertility, as the manure supply, before deficient, is now wholly insufficient to restore fertility. Given unlimited manure, water will raise the rental of land to Rs. 50 an acre. With no manure it will sink to R.1 an acre."

"Irrigation cannot be carried beyond the limits where the supply of available manure is fixed\(^3\). "The superiority of the river

1. Fooden, Egyptian Agriculture.  
2. Report by Director of Agriculture, Bombay (1883-91).  
water over that of wells (which contains no silt) is demonstrated by the fact that near the heads of the Panjab Canals ... the cultivators prefer to pay canal rates and to lift the water from the canals rather than to lift it from wells, although the canal level and the spring level are about the same. The cultivators in Orissa and Bihar during the rainy season, when the rice crop is under irrigation, will often endeavour to drain the water off their fields and irrigate them again from canals whenever a freshet in the river brings an extra quantity of silt in the water"¹.

The lessons to be drawn from the Nile are as follows:- First that the soil formed of subsoil made up from old deltaic deposit is richest because it mixes the mineral constituents of the soils of many different river valleys, and tends to give the combinations of these essential to plant nourishment. Next, taking the peasant at work, he must enrich the land to continue intensive cultivation, either by manuring or silt. Manuring is insufficient to maintain fertility without the addition of silt or purchased manure. This is true in spite of the fact that in Egypt the peasant stores the urine of the cattle by fixing it in dry earth, which, having been spread under the

¹. Buckley, Irrigation Works of India.
cattle and removed daily, is collected in heaps outside the farms, to be spread on the fields before the floods are let in and later passed out as clear water on a lower side. In India, on the contrary, the urine is wasted. The question of artificially procured manures is a complex one; for not only is there expense involved in it, but if done carelessly it may do ultimate harm by leaving the soil poorer in the end. Even could artificial manures be procured and paid for in Bengal, silt must remain the basis of fertility, for it enriches the crop without danger of impoverishing the soil already there. It must possess the right properties, physical, chemical, and bacteriological, and the last two depend greatly on disintegrated leaf-mould and humus which supports bacteria.

What are the conditions for deposition of silt? A certain speed must be maintained by the water up to the time it reaches the fields. There it should be checked, so that the silt held in suspension is dropped, and the clear water then run off. In Egypt and elsewhere the agriculturists of Government or the fellahin see to this, for the water is under their control. In southern Bengal nature has seen to this, for the waters, moving with a certain speed of their own, are checked by the rising tides from the Bay, and deposit their silt higher than sea level

before being sucked on again at quickened speed by the outgoing tide. Hence the tidal action is carried far into the country to where the water is fresh. Beyond the zone of tidal influence water can be alternately checked and released, flushing the area, conveniently at weekly intervals. This system of "flush irrigation" has worked successfully in two areas north of Calcutta. We shall see that if road and railway embankments with too few culverts are run across country the drainage is interfered with in times of unusual flood, is banked up by them, its speed is checked and silt is deposited there, while what water can escape only rushes through the rare culverts which concentrate instead of allowing a relatively even flow over the country as before. Thus even the peasants in their small way and the road and railway engineers with their greater resources may unwittingly upset this process of silt deposit with serious results.

1. The zone of tidal influence is shown by 'tidal contours' (i.e. isopleths of equal tidal force) on the map prepared by the Department of Irrigation and Waterways, and here reproduced (B II, 1/M).
When we deal with floods, we are dealing with a factor which fluctuates from year to year with the weather. Hence the map of floods must of course correspond to a map of some "climatic" factor. Even here there is a difference in that the change in the areas inundated occurs in slow cycles, not of years but of decades. When we come to consider in Pt. II the results upon agriculture, health and consequent welfare of the population, it follows that there will inevitably be slight topographical inaccuracies in the margins of the areas in the Delta proper shown as mainly inundated or the reverse. Nevertheless, the relative value of the flood factor stands out, along with that of rainfall, and the principle is thus essential justification, since in broad distribution, as a local instance, it is unmistakably true.
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Reference should be made to Map C I (22 miles to 1 in).
CHAPTER C.

The RIVERS and RIVER REGIONS of BENGAL.

Problem of hydrography and river control. The study of the river movements of Bengal is one of the most fascinating problems of river geography, and the mastering and control of these great channels and estuaries is as yet one of the most baffling of tasks. The whole country is in a state of flux, and rivers change their courses over great distances. Four hundred years ago, more of the Ganges water flowed southwards down to the Hughli and to many other west central mouths than now, when most of it flows south-eastwards by the great Padma to join the Brahmaputra, and meets the sea at east-central and eastern estuaries. The Brahmaputra itself has in the last hundred and fifty years completely changed its course by many miles, predisposed to do so by a change of the Tista. The former used to flow from near the SW. angle of the Garo Hills, east then south through Mymensingh, flowing round the Madhupur Jungle: it now flows due south to its confluence with the Padma. The Tista waters did not flow to the Brahmaputra but meandered south by the Karatoya's course, to join the Padma. At the great flood of 1787, it changed the course which Rennel had mapped; now it flows south-east and joins the Brahmaputra.
to SW. of the Garo Hills 120 miles north from its former confluence with the Padma.

Parts of the low country are filling up fast, as the Fishery Survey showed.¹ The coast line is also advancing into the Bay of Bengal; there are great fluctuations of advance and of erosion at the sea coast, but from time to time the coast line advances in places by as much as a mile a year. It is the tremendous power and scale of these movements that makes modern engineering, - at least on a scale so far attempted, seem so important. Yet engineering has its effects, not always those foreseen, still less desired. For immediate results can often be calculated, but not so the repercussions which inevitably work all the way down a meander belt across which a railway embankment and bridge have been built, or from which a canal has been dug or a protective bund thrown up along its sides.

At the same time two factors have tended to discourage the hydraulic engineering of the delta for purposes both of irrigation and flood protection and also of navigation. The first is the very considerable rainfall even of the western delta which being 58 to 65 ins.; because of this fact engineered

irrigation seemed less pressing, all the more so that the cultivators themselves long know how to store water in tanks and so allow of some local irrigation. The second is the complexity of its river system, for to call deltaic Bengal "the delta of the Ganges" is a misnomer, since, of course, it is a complex of deltas brought down by two great river systems of different character and power, the Ganges and Brahmaputra, and of the other rivers, great and small, pouring in from east, north and west. The very simplicity of the Nile delta, fed by a single river, undisturbed by local rainfall and flowing into a tideless sea, has probably contributed to the earliest development of man upon it, as it has also called forth the modern engineering skill which has made it an example to the world. Without doubt its proximity to Europe has given its engineering achievements a name and fame out of proportion to those of Northwestern India, whether we consider the far greater magnitude of the Indian results or the variety of the problems which the engineers of India had to solve. Nevertheless, after grave mistakes which allowed a part of the lower Nile delta to be ruined through alkaline encrustation and which threatened to rob valley and delta of their fertility by failure to renew the silt deposits of natural floods, the engineers have achieved a mastery of their irrigation and transport problems and acquired confidence in dealing with them. This is in contrast to what critics have called, not without justification, the hopelessness and indecision of
public opinion in Bengal, till recently, and the failure
to act in the peasants' interests. Bearing these points in
mind, a brief review of the principles of delta formation, as
seen at work in the Bengal delta, may best complete our
summary of environmental conditions and preface an account
of the resulting conditions of agriculture and human life.

I THE PRESENT.

The Delta of Bengal; the general character of its Accumulation.--

The mass of fine detritus which has slowly built
the delta, filling in the extremity of the Bay as it advanced,
has been deeply affected by the action of the ocean tides and
currents. On one hand the rush of the incoming tides assist
local deposition by carrying back the silt from the shoals on
the sea bed, and depositing these inland, gradually forming
low islands. Thus even in a tidal delta there is a downward
slope, upstream and inland from the shoals barring the river
mouths, as well as out to sea. On the other hand, the tides
help to keep open the main river outlets as estuaries, and in
fact were it not for the intensive erosion of this monsoon
land and the mass of detritus brought down by the Ganges and
Brahmaputtra there would merely be estuarine banks, and no true
delta. 1 The deltaic rivers are navigable where the tides and

1. The statement that the tides assist the work of delta
surface currents of the ocean favour the "scour" of the descending ebb, reinforced by the water ponded back by the previous upstream "flow". Thus the deltaic estuaries of the Irrawadi and the Ganges-Brahmaputra are navigable, for a longer or shorter distance according to local and seasonal conditions and to the draught of vessel. Round the Indian Ocean special difficulties prevent access for inland and retard navigation. The dry season lessens the amount of fresh water on which small ships can ascend the rivers, while the wet monsoon is the season of storms which neither warly boats nor craft of today dare face at sea. Finally, continuing subsidence of the sub-structure of a delta must assist the tides to flow into the estuaries and keep these open. This is thought to be slowly happening to southern Bengal, at the same time slowing down the delta's advance.

While the delta of Orissa is smoothed by the storm waves of the monsoon which sweep along it, parallel to the coast and helping to form the Chilka Lake or lagoon, the delta of Bengal is situated almost head on to the advance of building is thus misleading, if unqualified, though it appears in a book of lectures to Bengal irrigation engineers written by a departmental authority.

C

wave and tide. Thus the ascent of the tidal bore, alternating with the descent of the ebb current, is aided by the direction of the river estuaries which indent the coast between mud promontories and islands, and this wave and tidal action tends to keep their channels open. It is true that the tide as it approaches the delta is somewhat concentrated. At the head of the Bay of Bengal, as Reaks has pointed out, the tide heads for the Swatch of No Ground, where the 100 fathom line indents the submarine terrace, and from this deep it spreads NW. and NE. Wave action however is pretty direct as is shown by a chart of the stronger prevailing winds.

The nature of the edge of a submarine delta of simplest type where tides and currents do not interfere can readily be imagined with reference to the angle of rest of silt or land tipped over the edge of a bank whose surface, constantly advanced, is kept smooth. Under the sea the carrying agent is the outward current and waves are the smoothing agency, clearing irregularities out to the edge of the bank, while the angle of rest is of course slightly steeper in water, which helps to support the grains in place, than in the air. A further modification of the simple form described is that different weights of silt being carried, the

2. It is interesting to watch such motion in an earth sculpture model, where the sharp edge of the delta under water is maintained as the grains roll down the terminal bank; similarly
lightest go furthest, so smoothing the angle of rest to a curve rather than a straight line. The Bengal Delta, with its tides and currents, shows considerable modification of this. The coast line of the estuaries is reflected in the submarine contour of 20 fathoms. The 50 fathom line however shows the curve, convex to the Bay of Bengal, which marks the base of the Delta, while the 100 fathom line reflects the structural form of the Bay in its concave curve.

**Shifting Meanders: their effects in the changing river system of Bengal.**—The rivers of the Delta are marked by their sinuous meandering courses, for the current being thrown by some slight obstacle out of the direct line/descent, forthwith undercuts at the side to which it is thrown, carrying away the mud of the banks as these fall. The impact tends to throw the water back again, and moreover as each swing to the side, takes the river off the main slope towards base level at the sea, the force of gravity reasserts itself, and hence water swings to the opposite long shore drift, with the building of spits and bars can be caused and observed. The experimental work in the Earth Sculppure Laboratory of the Geographical Department, Edinburgh University, suggests that in water and wave action especially its experiments can be of real value. They would appear to justify the proposals recently made in Calcutta to construct working models of the Hughli, in order to observe the probable effect of training works, such as groins, and of dredging. There can be no doubt that whatever such models are immensely suggestive. Further experimentation might carry their results to a high measure of exactitude and practical value in hydraulic engineering, preventing mistakes and developing solutions.
side undercutting there as before. The height of the steep concave bank, moreover, would seem to be raised by the deposit dropped upon it when it is topped by floods. The convex bank, from which the current is moving away, will be one of deposit at a low level. Sometimes, when a meander has almost completed a full circle or ellipse, the river may find its way across the narrowest part of the neck, and cut off the loop. The result is seen all over the Bengal plain in the crescent-shaped lakes which mark old meanders abandoned by the river, such as are known as mortlakes in England or as ox-bows along the Mississippi. We might expect to find that this characteristic feature had its special name in Bengali. In the Delta, however, the name bil (or jhil) is bestowed indifferently upon these narrow mortlakes and upon the shallow and rounded swamp-lakes, often very large, which fill the wide interfluvial depressions and which lodge the water spilled over from these during floods, or accumulated during heavy rains. In NE. Bengal, however, interfluvial depressions shallow and rounded, are so large that in the rains they resemble inland seas, and these are called haors, the word being a dialectic form of saugor, 'sea'. The name bil is given there both to mortlakes and to smaller hollows between closely adjacent rivers which, by reflecting curves of these, somewhat resemble mortlakes in shape. Thus some distinction is drawn in that region though it is partly a matter of size. Examples of all types of bil are to be seen on Map II (1:50,000) transferred from topographical maps. The word bil will be used henceforward in preference to marsh, swamp or
lake, for it passes from one state to the other as the dry weather is followed by the rains.

Meandering rivers, as their volume decreases or augments, change their meanders to smaller or greater size, for the arcs along which a river swings from side to side bear a well-marked relation to its flood volume as this moves down a given slope. Thus a small stream has small curves and a mighty river great loops, which owe their form to the last flood and will remain but little altered till the next one. As the volumes of the rivers augment and decrease with the seasons, the meanders of the dry weather and of the flood seasons are of different sizes as is shown by the complexity of the pattern in Map II (1/M). Again the wide curves of certain 'dead' rivers is a criterion of their former strength. Today the growth in volume of the Padma or Meghna is important in that lateral cutting of the banks is bound to upset the relatively balanced pattern of its curves or arcs, as these are increased by greater and greater floods. This means that destructive action is inevitably envigorated at every monsoon; for the diversion of drainage by nature and man from the whole of the delta on to the Ganges and, still more, the Padma-Meghna is working havoc along their banks.
Distributaries, River Levees, and Interfluvial Depressions.—
The distributaries are precariously held to their meandering courses by their own banks, raised on either hand by the silt deposited by the mud-laden water when its speed is arrested and, with this, its carrying power. While these banks are built up in time of flood, in time of drought the current is lessened and deposit tends to increase on the river bed itself. Thus, by the building up of spill banks with overflow of inundation, alternated with the raising of the river bed as the currents of the diminished river slacken, bed and bank together form a ridge precariously dyked in a sort of natural, winding aqueduct of which the sides are raised above the plain, until such time as an abnormal flood breaks through the levees which it has made, and flows along the hollow left on one side or the other. This feature can be illustrated by map and section. Reference to a contoured map of the Nile delta, for instance, shows the ridged or natural aqueduct character of the rivers, though it will be noted that parts of the ridges of the two main distributaries are left waterless where the river, having at last overflowed and breached its immediate bank, runs in the hollow between, where deposit will in time take effect. The relationship to irrigation will be clear, the height of deltaic rivers facilitating the outflow of water to the fields on either side, while the drainage water escapes along the bottoms of the hollows. These ridges of the river banks can next be recognised in Bengal's more level delta,
but further out. In the absence of accurate detailed levelling, -a very delicate matter in such flat country, - 'Ground Levels' were recorded along the railways at every two miles and were transferred to the Map of Physical Features. They show the rise of the ground to the banks crossed or followed by rail and the fall of 5 or 10 feet or more between, and permit the sketching of contours in Map III (1/1\(^{\text{a}}\)), those of 25 and 50 feet showing the levees, thrust forward down the slope. A little practice soon detects the difference between tributary streams draining the hollows and the through rivers, present or past, of which the banks are at a higher level, except, as was said, where they have abandoned their aqueducts and themselves occupy a hollow. It is well, too, to see these in section, and an example has been sketched which will help, later, to explain the nature of land utilisation, settlement and cropping, upon levee and hollow. (Fig.E 24)

At first it seems hard to account for the fact that deltaic rivers in flood should almost not wholly abandon their courses in favour of the hollows on either side sooner than they do, in spite of their raised spill banks. The answers are first, that the river bed remained low for a long period of years, secondly that in flood the hollows fill with water too, and the resistance of this dead weight of semi-stagnant water is in itself a barrier. Moreover since stagnant water
Fig. C 13

will not carry silt. The presence of still water retards deposit and tends to keep ridge and hollow where they were for long periods together. This will be more clearly understood if the conditions of silt deposit are examined.

One important point Six should first be understood which affects the change for periods of years in the volume of distributaries like the Bhagirathi and those of Central Bengal. Where a distributary takes off from the main river at a greater distance from the mouth, breaches out at its offtake in the banks of the Ganges where these had piled up during the dry weather and low water season. The river rises from its low water level (3 ft. or so above mean sea level) by 17 ft. or more when breached, but only by 13 ft. and 15 ft. when left to find its own opening. The curve was noted at Farhampore (or Barhampur) below Murshidabad; this and other places referred to in the following diagrams.
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One important point fix should first be understood which affects the change for periods of years in the volume of distributaries like the Bhagirathi and those of Central Bengal. Where a distributary takes off from the main river at a concave bank it will be abundantly fed, for the current is already heading that way. With time however, as the meander shifts downstream, the point of offtake may occur on the convex bank where deposition is occurring in shallow water, and the result is that the flow into the distributary will be lessened or may even cease. Thus the offtake of Bhagirathi has had frequently to be cut open as at the beginning of the rains of 1867, 1870 and 1871 when the Ganges was cutting a concave bank to the north (Fig C 12). The rise and fall of the Bhagirathi river in these years, illustrates the difference then due to artificial breaches cut at its offtake in the banks of the Ganges where these had piled up during the dry weather and low water season. The river rose from its low water level (3 ft. or so above mean sea level) by 27 ft. or more when breached, but only by 13 ft. and 15 ft. when left to find its own opening. The curve was noted at Berhampore (or Berhampur) below Murshidabad; this and other places referred to in the following diagrams.
The profile or longitudinal section of the Bhagirathi from near its source for seven successive tidal stages may be distributed over the area. The two lines below the surface are the bed and the surface of the water flowing from Virginia to the first main fall through the estuary. The chart shows the difference in the level of the water above the bed, which indicates overflow over the river bed and the spill way and shows a water level at Berhampore, which is 1.759 feet below mean sea level.

The graph shows the differences due to artificial breaches.
are noted on the inset map.

The profile or longitudinal section of the Bhagirathi from near its offtake for seven miles downstream illustrates the way distributaries leave the main stream, the river bed and the surface of the water falling very slightly for the first mile or so, and then more rapidly (Fig C13).

The deposit of silt, the action of the Bils, and the nature of the estuaries. Silt is being deposited in great quantities, or much of the plain, which is submerged by the great rivers in flood, would not be filling up so fast. Still one must not think of this happening evenly over the country, for the distance to which silt in suspension is carried depends on local conditions. If we take the case of rivers in West Bengal which emanate from the hills of Chota Nagpur, the silt in overflow waters is carried a fairly long distance from the river side, because the slope of the country is considerable and the spill water maintains a high velocity. The same must be true of the Tista and Brahmaputra. Turning to Central Bengal and most of East Bengal, the spill, which is chiefly derived from the Ganges and the Brahmaputra-Jamuna, is checked by water lying in the vast depressions, so that the velocity is lessened there and the silt is deposited within
a few hundred yards of the point or line of spill. It is for this reason that the bilis are surrounded by banks, and that the active rivers build up their levees as they do. Even the finest silt is deposited close to the river bank of many live rivers, and if one travels out some distance from one of these into the hollows it will be found that their water is devoid of silt, and looking down into a great bil is 'like looking down into a mirror'\(^1\). The heavier sand is deposited first and the silt, of course, travels beyond it. One gathers that the northern fresh water bilis (such as the Great Chalan Bil) are filling up and lessening in depth as well as diminishing in area for no doubt there is some slight flow across them. The masses of water contained in the immense Southern Bilis, however, appear to hold up all movement, so that silt is dropped at their margins and they diminish not so much in depth as in area as they fill in slowly from the sides. Generally it may be said that the silt brought down by the rivers is gradually filling up the depressions in the Delta, which will tend to become dry \(\text{as as the amount of permanent water lodged in the bilis diminishes. The coast line is slowly advancing and presumably the conditions which now exist in Eastern Bengal, will be repeated in the future in areas.}

\(^1\) From notes kindly given by C.Addams-Williams.
which at present lie within the five fathom line off the coast at the head of the Bay of Bengal.

Lastly, from inland conditions we pass to tidal conditions where the fresh water is ponded back every flow and released at every ebb. The flow may rush up the estuary as it rushes up the Hughli, as a wave or tidal bore, which, in the Sunderbans jungle, overflows the islands, depositing silt, and so 'warping' or building them up, yet allowing the channel to remain open since there is only temporary deposit on it at slack water. The ebb-tide, reinforced by the weight of water ponded back by the flow, then 'scours' the channel anew, keeping it free. Till man pushed cultivation into the Sunderbans jungle, the limit of strong tidal influence with 5 ft. or more of rise and fall in the channels must have tended to cause a certain amount of embanking at its limit. One cannot help thinking that this may partly help to explain the line of the great Southern Bīls lying between the 5 ft. and the 1 ft. tidal contours. As Addams-Williams has pointed out, the Bīls themselves receive muddy water from the north but release water, which is clear, and thereby help to keep the channels open southwards to the sea. Thus in spite of the relatively small amount of water which passes across them, compared to that which pours out from the great estuaries, the tidal channels are navigable. Once the river steamers
have got through the narrow exit by which they leave the Hughli and are safely across its narrow bar, their way is open through the winding channels of the Sunderbans. This course, (marked upon Map I, 1/100,000) involves little upkeep while that further north through inhabited Central Bengal, though it is more direct and serves the countryside through which it passes, would require extensive works to make it really efficient, while these might interfere with drainage and inundation to the detriment of agriculture and of health. Thus the change from inland deltaic conditions occurs about the zone of the Bils, south of which the rivers are tidal creeks and widen into estuaries.

The character of the contrast of the estuaries of Bengal, so different from the river outlets of many other deltas, deserves fuller note. Under certain conditions deltaic distributaries pouring into enclosed seas of small tide, like that of the Mississippi delta into the Caribbean, can carry their levees far into the sea like the claws of a bird foot. The lateral action of 'long shore' currents may take these and turn them to the direction of the currents, forming a bar linking the levees and enclosing lagoons like those of the Mediterranean and, less markedly, like those of the east coast of India. We have noted that the relatively direct onset of the tides and surface currents upon the Delta of Bengal helps to open the rivers' mouths into a multitude of creeks and estuaries. At the same time, while there are no real lagoons, and the
sheets of water to which, I suggest, these correspond are placed inland and are merely a little brackish,—there is nevertheless a low and saline zone which resists the advance of man, though with furnishing him/easily transported timber and thatching. This is the tract of saline, tidal jungle of the Sunderbans. Its creeks are lined with mangroves, and its islands chiefly covered with two species of stubby, holophytic or salt-resistant palms and the **sundri** (*Hieritiera littoralis*) which gives the tract its name. Only at places are the mangroves separated from the sea by the trace of a sand bar, the **lima** discontinuous line of low sand-hills bearing thorny leguminous trees like the **mandar** (*Erythrina indica*). The disappearance of the trees and their replacement by grass on the estuarine islands of the Meghna results from the abundant fresh water poured into the estuary.

The season of Floods and their Power.—The mean dates of rise and fall of a normal and of a high flood of the Ganges-Padma are expressed as a graph (Fig. C 17), which shows that the average peak over fifteen years occurs at the end of August and beginning of September, remaining fairly high in September. When rainfall

1. O'Malley, Bengal, Behar and Orissa, 1917.
Fig. C 17

GANGES HYDROGRAPH NEAR SARA (PANNA DIST.)
TAKEN FROM
"RIVERS TRAINING AND CONTROL"
(SY. FRANCIS J.5. SPRING, C.I.E.)
is light the peak is lower and the average occurs a week or two earlier. Low water is expected in mid-April but can be prolonged, and increased, till mid-May. Severe floods tend to occur late in the monsoon, usually in September as a result of high water table and accumulated surface waters. The Brahmaputra and its distributaries rise a little earlier to a peak, owing to the earlier rains of its catchment basin in NE. Bengal and Assam. The rise of water level from the extreme minimum of 20 ft (above mean sea level, apparently) to 45 ft. at the normal maximum with from 18 to nearly 50 ft as extremes, helps one to realise the power of these waters to flood the lands beside them. For the 50 ft. contour just reaches the banks of the Ganges, skirting the foot of the Barind and leaving the hollows of the Atrai-Baral Depression as spill areas at from 42 to 45 ft. above sea level. The power of the river is tremendous as measured by its discharge which rises from a normal minimum of below 50,000 cusecs (cubic ft. per second) to a normal maximum of 1,500,000 and has risen to an extreme of 2,000,000 cusecs. In 1933 and 1934 the Hardinge bridge was in imminent danger. When it was built in 1915, elaborate training arrangements were constructed, but almost in vain.

During the spring month of 1934, 11,000 men were working in relays day and night, assisted by five steamers and numerous

1. P.C.Mahalonobis. Floods of North Bengal.
dialler boats, to repair damage and counter threats before the middle of June, the danger time when the monsoon floods are due. The bridge, comprising 15 spans of 345 ft. with three land spans of 75 ft., carries double track with footway, and has a clearance for steamers of 40 ft. above high flood. Anxiety has been perpetual, and disaster came in September 1933, when 300 ft. of the guide bank nearest the bridge fell into the river. The breach widened and the water worked through the land behind the bank to rejoin the river above, until 400 ft. of the bank was isolated. Ultimately the river was held at 700 ft. from the railway approach bank. But a consequence of what had happened was excessive scouring, and one bridge pier was nearly scoured away; no trace of hundreds of thousands of cubic feet of heavy boulders pitched round could be found.

After a report by Sir Robert Gales (who built the bridge) a protective scheme was begun on January 1, 1934. Its main features are the construction of a mole at the bridge end of the breach and a bund at the end where the isolated head stands, with several miles of access lines and one mile of pitched guide bank; also the reinforcement of the old guide bank at the bridge. Several hundred timber piles, mostly 70 ft. and more long, have to be driven in 60 to 70 ft. of water, and the total cost will be £1,000,000.

What has caused the trouble is change of river channel. The elaborate training works aimed at sending the main stream
under the centre of the bridge. But for some years the river has tended to leave the left bank, from which these directed it as it ought to go, and work towards any old channel on the right and behind the bridge abutment, where it flowed in 1868.1

When it is remembered that no bridge has even been attempted across the Brahmaputra, Jamuna or Meghna, the greater force of volume and current will be understood.

The rapidity with which the distributaries of the deltaic rivers may rise and fall from day to day is illustrated by the discharge curves and gauge readings for the Bhagirathi, for the flood seasons, June to November, of 1916 and 1917 (Fig. C 20), in which the figures are to be read downwards). The readings were taken at two points, 70 miles apart, viz. at Geria, near the offtake, and at Katwa, at the Ajay confluence. The differences in the curves for the stations, which are noticable, are due to the effect of local tributaries, adding to, or of distributaries taking away from the water of the Ganges overflow, but the discharge is greater at Katwa, though the depth is less. In 1916 the discharge at Katwa (having been taken as 0 on June 1st.) increased by 146,000 cusecs (cubic ft. per second) on August 1st. MM 150,000 cusecs in...

L. The Times, March 1934.
The first week of September, followed rapidly by the rain in
seas...
the first week of September, followed closely by the Geria discharges; but whereas at the offtake the discharge then diminished rapidly, at Katwa it leapt to 170,000 at the end of September, due to freshets from the Plateau, and then fell to 40,000 by the third week of October. The flood season of 1917 brought two peaks, the first in early August, with a drop in September, the second and the greater in mid-October, the Katwa discharge being again greater than that of the offtake.

While the rise in October is somewhat too late to be typical, it illustrates how flooding follows after the saturation of the ground by rains, from occasional freshets of autumn as well as from the average from year to year.

The Effects of Climate and Season, in West and East. The slope of a plain or a fan or delta is affected both by climate and by the steadiness or fluctuations of the river's regime. In a climate with high evaporation and percolation, lessening the volume of the water and its current, the rate of deposition is hastened; and the silt, being deposited earlier, builds up a steeper slope from above. Thus the drier the climate or the season relative to the inflow, the steeper the slope of the plain. De Martonne gives the mean fall (per thousand) compiled from maps of rivers having a flow over a plain of 350 to 700 miles in various types of climate. In a warm and consistently humid climate, an average fall for rivers 500 to 1000 kilometers in length (350 to 700 miles) is 0.1 per 1000, while in
climates with a marked dry season it is 0.16, almost as steep as sub-desertic climates which show 0.17. One would expect the slope of a delta to be gentler than that of a valley plain through De Martonne takes the Nile Delta as an example, of the last type. If now we endeavour to see the application of these laws in the Delta we are faced with a complex of confluent rivers all of different regimes, re-distributing themselves over the wide delta in which deposition is affected by differences of climate. The earlier onset of the rains in the east, and their greater abundance there, contrast with the climate in the west where lesser rains allow of greater evaporation in the hot weather. Nevertheless we begin to see one additional explanation of a fact which is all important in Central Bengal. The altitude of the tract a few miles south of the Ganges from Rajmahal is appreciably greater than that of the tract lying an equal distance to south-east. In May when the rising waters of the Ganges, swelling from the melting snow of spring and the early Himalayan rains, reach the head of the delta, the southward distributaries flow through a tract which is still under the full influence of hot weather evaporation, forcing silt to drop. The eastern distributary, however, flows towards and into a tract which is already shaded by cloud and watered by May rains.

A further factor bears upon the same result. Just
as the drier the climate, the greater the deposition, so deposition will be further hastened if the water table falls. Since, as it is certain, the water table has been falling in NW. Central Bengal, through human interference with inundation, this suggests one further explanation of the silting up of the old rivers Bhairab, Jalangi and others from or near their pivot at the head of the Ganges delta, for the last century and more.

II MAIN TRACTS OF THE DELTA.

Tidal and non-tidal, active and inactive rivers.—The Delta of Bengal is divisible into two main tracts, tidal and non-tidal. The non-tidal can in turn be subdivided into two main portions; that of rivers which are active and that of rivers which are now inactive, and are 'dead' or 'dying'. And even the tidal tract shows the influence of the vigour of the rivers, or of its absence.

The tidal tract lies mainly south of a line drawn from Calcutta to Dacca, though tidal influence is felt far higher up than this along the two or three main streams to 23° N. on the Hughli up to Nadia, and on the Padma up to Faridpur. The 'tidal contours' of 5 ft. and 1 ft. which cross
the rivers on Map II (1/M) express the distance to which stronger or weaker tidal influence is felt, and the amount of rise and fall. Thus these contours serve to demarcate the markedly tidal area to south of the 5 ft. contour and the non-tidal area to north of the 1 ft. contour, the country between forming a zone of transition.

The chief active non-tidal tract, is the eastern Delta where the rivers tap water from the Padma and spill over their banks in the flood season. The inactive portion lies westwards to the Hughli, and its rivers, now 'dead' and 'dying', are believed to have been active before the Ganges waters increasingly headed eastward during the last four hundred years.

A diagram or chart may help to make clarify the order of these great river types, placed as they occur in the main, across the Delta, thus:-

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1. River types, after C. Addams-Williams, (1913-1920).

I. Freshwater, non-tidal:
   Live: Padma, Brahmaputra, and Gorai, and Madhumanti.
   Dying: Bhagirathi, Jalangi, Metabanga, Kumar, etc.
   Dead: Bhairab, Jamuna, Chitra, Kobadak (& Karihar), all of Central Bengal.

II. Fresh-water Tidal
    Hughli, Pussur, Bagerhat, Kaliganga and Attarabanka.

III. Estuarine Mouths of above.

IV. Local drainage
    Kalpalu, Habra, Cong, Bipauh, Rampal.
    Creeks: Subtarmukhi, Thackeran, Piati, and Matla.
NORTH

I NON-TIDAL RIVERS.

88°E.  90°E.

Dead or dying (or only carrying (Somnolent (Now active in monsoon (Live Rivers
local drainage)

II TIDAL RIVERS.

No discharge now; (Discharging. (Estuarine;
Salt creeks (Local drainage. (fresh water

88°E.  90°E.

SOUTH.

Bay of Bengal.

Area of Active Rivers, and the Southern Bills. The Madhumati, which came into existence between 1820 and 1830, has been busy laying down a delta on a delta and now runs 'on an elevated ridge' spilling over both banks: those rivers which have a direct connection with it and depend on it for their supply, such as the Nabaganda and Attarabanka, carry a silt-laden stream in their channels, in a portion of which reaches the sea; but as they in turn also spill over their banks they are also raising themselves on ridges. Once the silt-laden stream leaves a defined channel it rapidly deposits its burden on the land on the margins of the bills owing to the shock the water receives on meeting a large body of comparatively
quiescent water, so that a few hundred yards from the point of spill the water in the bîls is perfectly clear; this action accentuates the building of the ridges, and prevents the bîls from becoming raised, except round their margins; the water which spills into the bîls may travel for miles across country generally in a southerly direction, and it eventually finds an exit into some river or other which is not necessarily the one which maintains the supply; thus vast areas of land are flushed during the annual inundation, and the water issuing from the bîls being perfectly clear maintains the exit rivers in exceptionally good order, soundings up to 120 feet being quite common. Moreover the type of paddy grown in the bîls is that which grows up with the rising water, if the levels cease rising the paddy likewise ceases to grow, and provided the season for planting is favourable, damage seldom occurs and a full crop is reaped.

Thus in such areas mature carries on her good work, fertilizing the land by irrigation, maintaining the drainage of the country, and preventing water-logging, and finally supplying navigable routes by which the produce of the land can reach a market. The process goes on of itself, and it is therefore of the greatest importance that interference should be prevented: the duties of an engineer are, therefore mainly preventive in such areas, but by the study of the
conditions under which the rivers work he will learn useful lessons to be applied to tracts of country in which the conditions differ.

While the pressure of population outwards upon the interfluves must be remembered, inciting the more active cultivators to colonisation, one may quite what has been taken as an example of the beneficent action of the greater streams in pouring fertilizing silt into the marshes that lie behind the raised river bank, Pergana Khalijuri (E4,5E). This area which, a hundred years ago, was a vast sheet of water, is now one of the most prosperous and thickly populated tracts in East Bengal. Long stemmed rice, growing with the floods, is adapted to their depth. The villages are placed on artificial islands. The houses are surrounded by cattle sheds, and the villagers cut marsh grass for fodder for the cows, whose rich milk furnishes the cheese sold in Dacca.1

The Dying Rivers of Central Bengal and their Three Zones.—

Drawing a section from east to west across the country we saw how, as the life-giving rivers 'died', the life of crops

1. J.D. Anderson. IN J.R.S. Arts, 1907, LV.
and man dies with them; the only things that flourished were the mosquito and the malarial parasite. Southwards however, population has cultivated the edges of the Bilis, finding fresh room and rich land to support its increase. Thus the dessication of the flow has brought some compensation by partially drying up the edges of these Bilis. In the long-inhabited region of Central Bengal lying on the edge of the Sunderbans the same arrest and deterioration as in the north are sometimes seen. This ruin too is due to the same fundamental causes, the cessation of the sweet-water flow; water is now super-abundant, but it is salt. As the ecologist would say, instead of ordinary physical drought, physiological drought has come into play, - drought for all but the sundri and the salt-marsh palms and their association, - and the rice fails from salt effusion, just as if in a drought 100 miles to north.

Thus the region of these dying rivers shows three zones which we may read downwards as if across the map, from north to south and between them meridians of 88° and 90° E.

in this way:
- NORTH -

I. Higher land (50-20 ft. Dead & dying above mean sea level.) rivers.
   Some drought: Dist. pf deterioration: Nadia, N. malaria. Jessore

II. Low land & hollows; bil about mean sea level. " "
   Some gain of N. Khulna cultivation area S. Jessore

III. W. Sunderbans; Salty and above low tide, but below high tide.
   Some gain (W) SE. Of some loss through 24-physiological Parganas; drought in S. Khulna. E.

- SOUTH -

Central Bengal and Lower Bengal: Embanking.- The first great cause of the decline of the soil and people of Central Bengal being movement of the Padma waters eastwards, instead of southwards over it, we shall find aggravating human facţors that have increased the general cause, exaggerating its effects. The first of these is rightly held to be river damming embanking, first by the fishermen across the streams and by the peasant around their fields, and later by the road and railway engineers. The effect of fishing dams must be obvious, but that of embanking may be less so. In Central Bengal the rice grown is not of the long-stemmed variety that can grow so fast as to keep pace with a great rise of water; and much of the land was and still is given up to crops of jute to which
heavy floods are fatal. Consequently many districts are surrounded by expensive embankments which are even carried across the mouths of the channels which ought to be kept open for the natural dispersal of the fertilising silt. The result is that the silt, instead of being deposited over the fields, is deposited on the bed of the river. Consequently it becomes necessary to add continuously to the height of the embankment, until nature in a year of high floods may take its revenge, and destroy the standing crops. There is much loss of property and sometimes acute distress. In that event the cultivators are, in the long run, remunerated, for the fields refreshed by the silt-laden water often yield bumper crops. It would seem that here engineering skill, on the lines of Italian work along the Po, might aid nature to distribute the silt of the great rivers, against which the present embankments are raised.

The question is not merely one of agricultural prosperity, for these embanked districts have an ill fame as the abode of "Nadia fever" and "Burdwan fever" i.e. remittent ague. In the Deltaic tracts, which drain out the great rivers the problem is if possible to discover some middle way between two evils - one the almost complete diversion of silt-laden river waters, and the other of leaving the country unprotected from the sudden and destructive floods which result from the height of the river beds.

Bengal is so often regarded as the granary of Northern India, that it perhaps does not occur to administrators to suggest a possible addition to its agricultural prosperity. If the bulk of its population be considered, Central Bengal is not so prosperous as was commonly supposed and the prevalence of malarial fever has for the last eighty years caused the gravest concern.

Though all rivers of the Gangetic and similar plains have much in common, being silt bearing and liable to bank erosion, there are great differences. Of the river Damodar which rises in the hills of Chuta Nagpur and flows into the Hugli, it was calculated, in 1850, that at the very head of its fan the flood volume was nearly 600,000 cubic feet per second; that opposite the town of Burdwan it was only 250,000 cubic feet and at Amta, just above the tidal portion, only some 75,000 cubic feet. Here the left side was embanked, the right left open to spill channels. Such a river as the Gandak, however, issuing from the Himalayas upon a plain which is transitional from the delta to the western Gangetic plain where the rivers have cut down into the plain, flows fairly evenly and is embanked all the way.
History of the Rivers. Since the levels, land surfaces and river beds are not fixed but tend constantly to change, we need to understand the history of the river system, for thus we can hope to detect the changes in progress at the present day, and if possible, forecast what changes are likely to take place in the future. There are rivers in the delta that carry a mightier volume than ever in known history, generally overspreading their banks in the monsoon, or in high flood ravaging the villages along their sides; how have they come to have this volume and power? There are many other rivers in the delta on the banks of which malaria is rampant and drainage is congested, "dead rivers" as the peasants say; why have these rivers "died" and how far is it possible, if not to restore them to their old power, at least to harness them for human service? To answer these questions we must endeavour to trace the great changes which have occurred to the present parent rivers the Ganges and the Brahmaputra and also to the rivers from Sikkim.

There are several approaches to river history which demand consideration here of which the first is re-examination of the ground and the river pattern, soils and contours. The second is that of the British Surveys back to
those made by the great surveyor Rennel from about 1760 to 1780 which are so accurate, that they can be re-plotted on a modern map. Beyond, there have been accumulated and compared the records of Moghul administration with local tradition, archeology and fragments of history, Muslim and Hindu, and behind it the lore of Hinduism, fading back to legends open to the freest and most contradictory interpretation.

The most important of the great Gangetic distributaries to man was that nearest to Upper India and giving most direct access to the sea and which hugged the Plateau with its firm Old Alluvium, allowing early movement and clearance and later commerce and cities, with parallel land and water routes. This was the Bhagirathi which divided into three streams about twenty-five miles above the site of Calcutta at Tribeni (Three Streams)\(^1\). These three streams were (1) the continuation of the Bhagirathi along the present Hughli past Fort-William (Calcutta) along the present Tolly's Nala to (2) Saugor (Sea) island, the place of pilgrimage, the Saraswati its right hand or western distributary, with cities on its

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1. Hooghly Rivers (1919), and Addams-Williams, History of the Rivers of the Gangetic Delta, are utilised except where fresh suggestions are made or authorities are quoted.
banks like the Bhagirathi and (3) the Jabuna or Jamuna, a left bank or eastern distributary whose decayed course swings right out eastwards for thirty miles before taking a southerly course, propelled in this direction by periodic floods from the Damodar flowing straight down its fans across the Bhagirathi. The form of the Damodar fan makes almost self evident the fact that its right southerly turn is recent; it was fixed in this course by British irrigation engineers in 1850-60. Hughli below Calcutta takes a right hand bend whose origin is uncertain: it is shown in 17th century British charts, though what was later called "Tolly's Nola" was still navigable for boats and was the sacred, and presumably older, portion of the river.

From the pivotal point at the head of the delta an old river, the Bhairab, flowed south-eastward towards the Haringhata estuary (90°E.). In its turn it threw off a multitude of sub-branches, each of which built its own particular portion of the delta. Examination of the levels of its banks and of the orchards which line them proves its former power. Its name, giving place locally to those of other, more active streams which have cut diagonally across it, - is found again and again from the off-take to the sea, while the meaning of the name, said to be the Terrible, suggests the dangerous force of its floods in old time. Just as its banks stand high above the hollows flanking them in the central delta so, to the south, it projects a wedge
of long-reclaimed land into the Sunderbans. In this it is paralleled by the Jamuna to south west, and Adi Ganga (original Ganges) from "Tolly's Nola" to the sea, though the last two, giving access to the Bhagirathi highway, had, as we shall see, the earlier historical importance. Before leaving the West it should be remarked that there seems to be clear evidence that the early sea port of Asoka's empire (third century B.C.) was Tamluk, placed at the limit of firm delta building by the rivers of south western Bengal of modern Midnapore, west of the Hugli. A final proof of the size and power of the Bhairab at its height is the ex scale of its major meanders, (many of them only revealed by the additions shown on Map II(1/1) into which the diminished stream has eaten a pattern of minor curves). The facts given, supported by independent investigation or emerging from it, uphold Addams-Williams' contention that the Bhairab is "the true ridge of the delta". He brings satisfactory evidence to show that the Jalangi which takes off from the Ganges 40 miles or so lower than the Bhairab and then cuts across it southwards to the Bhagirathi to join it above the Damodar, is recent and he places its birth about the sixteenth century.

We come now to the third of the three rivers dividing at the delta head, known to Bengalis as the Padma though generally called Ganges by Europeans because of its present magnitude. The Padma (as we shall call it in
this section) swings in a big curve 30 miles long round the base of the Barind whence, at the present day, it takes its main course south-eastwards or SE. by E. The 1/M map however shows two rivers taking off from it to eastwards, the Namad to the Y Chalan Bil, and the Baral just south of the Narad. Both unite, and their line heads for Dacca, built at the extremity of the Old Alluvium of the Madhupur Jungle, along a series of courses on which we find the name of Buri Ganga close to Dacca, the name, 'Old Ganges', suggesting an old course from the main river and also, a point to be insisted upon, a stretch of historical importance, to be attributed, on the base of many analogies, to its proximity to land over which movement was possible except at the height of flood and which permitted the creation of permanent settlement.

The course just traced, - from the delta head through the Chalan Bil, and past Dacca and the historical focus of culture in Bikrampur (the region immeditately south of this city), - has been already pointed out. The portion from the Chalan Bil past Dacca to the Meghna is sketched in the 'Hooghly Rivers Report' though it is shown as flowing across the southern Barind which may have been a prehistoric but hardly a historic course, since the Barind's south-westerly ridge is continuously high. The complete course along the Narad and Baral tract however seems first to have been traced.
First we must refer to Rennel's Map of circa 1775 which shows the Brahmaputra flowing round the Madhupur Jungle so that the upper Gangetic Delta is entered by the chief Sikkim river alone (the Tista of that date) near it where its waters combined with those of the Brahmaputra, enter now; this leaves the Gangetic Delta relatively unhampered by the irruption of other rivers. Shortly after Rennel had completed his survey, the Tista from Sikkim swung to the left in a great flood and joined the Brahmaputra at its present confluence near the Khasi Plateau. Within fifty years the Brahmaputra had silted up along the stretch between the Madhupur Jungle and the Plateau, and the combined waters from Assam, Bhutan and Sikkim flowed down the Jamuna as they do today. The Tista, even before this historic flood in 1784, may have flowed for a time much along its present course; there is a small stretch of decayed river of that name just north of the confluence but this may be perhaps a portion of that flood course, since abandoned. There is however no record of the Brahmaputra waters ever having flowed by any other course than

by Donald MacPherson during settlement work in Pabna and Bogra districts, followed up by research into Moghul records of the sixteenth century. Before calling in his evidence whoever let us consider the relationship of the Brahmaputra system and also that of the Sikkim rivers to the courses of the Ganges.
round the Madhupur Jungle; a previous direction along the Jamuna line, if it existed, must have vanished long ago. As we have said Hirst traces an outlier of the Old Alluvium between the Madhupur Jungle and the Barind. Did the low level of the Meghna basin, combined with a continuous ridge from the Madhupur Jungle to the Barind, compel the waters of the Brahmaputra always to follow the historic course just described? The evidence, if it exists, could only be traced by careful levelling and examination of the soils and subsoils. In any case our interest in this study is specially actual and historical, rather than prehistorical, and enough has been said to show that the waters of the most northerly arms of the Ganges would not be thrust by flood currents of the Brahmaputra so much as now.

**HISTORY OF THE PADMA**
(or Eastern Ganges).

The problem of the positions and movements of the great rivers has always been open to debate, and so far there has been no solution which quite fits all the facts. Mr. Donald MacPherson, I.C.S, studied the question when on land duty in Pabna and Bogra districts, which lie at the confluence of the Ganges and the Brahmaputra-Jamuna and which contain the Chalan Bil. His theories as to the history of the rivers were worked out from touring the country and close study
of old maps records, and I am greatly indebted to him for the following.

The Chalan Bil was once much larger than it is now, and its gradual diminution and change of position has been recognised in the Gazetteers and in some Irrigation Reports. Naturally this process is part of the fluctuation of the river-courses of North Bengal. The earliest known map which gives a representation of the Chalan Bil is in Holt's Narrative published about 1764. Then comes Rennel's, shortly later, when the Bil seems less of a River than in the earlier Map. It will also be seen that some places of known position are well to the north of the Bil: such are Handiyal and Mirzapur. The next important maps were prepared after the Revenue Survey of 1850 and in these the main outlet of the Bil passes by Mirzapur: the Bil has not only shrunk but moved north; and this northward movement was found, during re-survey, to be continuing still. Now the river passing from Handiyal to Mirzapur is called the Karatoya, (Fig. C34).

The Karatoya was one of the famous and sacred rivers of Bengal's antiquity - and at one time seems to have served as does the Jamuna today to take the water of the Tista and the Brahmaputra. Its importance can even now be seen though it is a mere shadow of what it once was. The Karatoya was definitely the river that joined the eastern boundary of the
OLD RIVERS SOUTH OF BARIND.

Compiled from Notes and Sketches by D. MacPherson (Pabna and Bogra Settlement Report; 1930).

Present rivers and Courses of Former R. GANGES in BLUE. R. ATRAI, as at present and portions of old river R. KARATOYA " " " " " " GREEN. " " " " " " RED.
Barind. After wandering about in the New Alluvium the Karatoya touches the Barind at Shibganj in Bogra District, and flows along the eastern side of the Barind till it and the Barind disappear into the Chalan Bil. Shibganj is about 5 miles from Mahasthan (D4, NW.), which is now being excavated by the Archaeological Department, and is thought to be Pandrabardhan, the capital of Bengal in Buddhist times.

From Shibganj to Sherpur the Karatoya is today a well-defined river, which requires a ferry, in places, throughout the year. But at Sherpur the Karatoya is joined by the Halhalia and takes a turn to the east away from the Barind into the New Alluvium, and thenceforward it is called the Phulgiri. A small narrow channel not more than a few feet wide, however, continues from Sherpur to hug the Barind, and it retains the name of the Karatoya. The river, then, which flows from Handiyal to Mirzapur on Rennel's map is really a continuation of this river though there is a gap between this bit of the river, and that flowing from Sherpur to Mingachhi in Pabna district. Mirzapur has an important Mela and sacred bathing festival - a sure sign that it was once on a very important river. Further South, and this time definitely south of the Chalan Bil- a stretch of the Baral River by Chatmohar (Pabna) is called Karatoya and still further south there were occasional bils or cul-de-sac streams that went by this name. In the rivers just north of the Ganges in the headquarters Subdivision
of Pabna were many traces of channels of the River Atrai. The Atrai northwest of the Chalan Bil is still an important river, for it drains most of the intervening alluvium between the Bogra Barind and the Malda Barind, but the connection between this northern river and the Atrai in Pabna headquarters subdivision is not obvious from the map. In travelling about the country, however, Mr. MacPherson came across various ditches or dried up depressions which the country people called the beds of the Atrai, and which, when plotted, link up the two rivers. Notable among them is one near Ataikola (12 miles west of Sainthia), a ditch stretching south from the Chilnai.

The rivers of the south part of Pabna have all an eastward deflection, which seems due to the eastward pressure of the Ganges. Although the Ichamati, of which the channel runs from Pabna to Bera on the Jamuna, is itself a very recent river, and seems only to have been forming when Rennel mapped the area, it shares this trend. Rennel’s theory that the Ganges once went in by the morasses of “Nattore” (Nator) fits this river trend. It finds further confirmation in the distribution of the parganas (or fiscal units) of the Ain-i-Akbari (16th century). Their distribution seems to have been geographical, and if the boundary were a great river, to east or north of this stretch, as it seems definitely to have been, then this curved inward about Sarda (15 miles east of Rampur Boalia, Rajshahi) up to the
line of the Baral and seems to have curved south again by Kasinathpur (Cosynathpur of Rennell's). There is a local tradition, to the effect that the Ganges once did pass by something like the Ain-i-Akbari parganas distribution line. The names of the parganas, however, would go to show that some of those which were in Akbar's time south of the Great River had previously been north of the river, i.e. it had flowed recently northward and, since then, southward once more. A colleague of Mr. MacPherson's, working on entirely different data, also came to the conclusion that towards the close of the 16th century the Ganges — (or at any rate an important branch of it) — came well to the north of the present course; and during the 18th century the country north of the Baral was protected by embankments from the flood washes of the Ganges.

The change in the course of the Tista, and the diversion of the Brahmaputra from its bed round by Mymensingh, took place at the end of the 18th century and the result was the creation of the river Jamuna, which has exerted generally a westward pressure, and seems to have diverted in a SW direction the river on the New Alluvium east of the Karatoya.

When the Ganges waters came eastward through the Baral it is not yet possible to say, but the Baral is found as the Boundary line in the Aini-Akbari for the Sircars or
subdivisions which would date it at about 1600. On the other hand the names of the parganas show that, previous to this distribution, the Ganges or the Pādma had flowed in a sufficiently wide bed to be made a boundary for a Sircar more or less in its present course. Bazu is the affix of all parganas of Northern Bengal, and since Bazu is a Mohammedan word it therefore only dates the Sircar boundary from Mohammedan times, i.e. or after 1300, or even perhaps from Moghul times. When some parganas are found in the Sircar of Southern Bengal as they are in the Ain-i-Akbari there is some justification for holding that in Akbar's time the Ganges had shifted northward for some time to the Baral. And these left bank morasses would be comparable to those on the right bank of the Bhagirathi. Mr. MacPherson quotes the story of a merchant prince Chand Saudagar, who was ruined because he would not worship the greatness of the Ganges (was it because its banks were not Hinduised Here)? He was harassed in true Job-like fashion till he worshipped. He is popularly supposed to have inhabited Mahastan (a little to the north of Bogra) but the place where his vessels went down is five miles west of Pabna, near the Padma and very close to a long stretch of bil that obviously represents the course of a river long decayed.

Thus study of the ground shows every sign that the Ganges Delta from the Bhagirathi spread from the Rarh (of West Bengal) to the foot of the Barind, or more exactly,
to within a short distance of each allowed by emergent fans and intervening spill hollows. Research into 16th. century land revenue accounts and the gathering of local tradition from the 18th. century to the 20th. century bears out what the deltaic configuration between its barriers of Old Alluvium led us to expect. Between the Bhairab, however, and the Padma (or Ganges) below the south-west lobe of the Barind, there has been a tract of very shifting lands, subject to such alluviation and diluviation that there could be no permanent settlement of population nor fixed city sites. Like the Bhairab, moreover, the Ganges-Padma rivers led away from civilisation, not to it, save for the eastern outpost of Bikrampur,—to which the Hindu monarch 'fled' when driven out of Gaur at the Delta head,—and for smaller ones beyond. Hence in my view, the reason why the Bhairab, unlike the Bhagirathi and its effluents, has apparently never been sacred, though it bears every mark of being in full activity and well settled, at a period when Western Bengal (and part of Eastern Bengal) was Hinduised. Portions of river courses in the Padma meander belt, however, are of relative, even if somewhat disputed sanctity because they led on to Bikrampur whose Brahmins are traditionally descended from 'half-caste' Brahmins of Kanauj. It may be somewhat surprising to the reader to realise that it is widely held and often dogmatically stated that Padma or Padmati is a 'new' river simply because it is not 'sacred' and shows no cities on its banks. The only
district headquarters upon it at this day, the town of Rampur Boalia, is in real danger of being swept away. With literally feverish haste new buildings there have been dismantled before they should fall to the current and bunds are being piled up to save the wreckage, as photographs show. No wonder, given the state of Bengali history, that the effect is relatively little continuous record of life upon this tract, if the Padma was at all as powerful as it is. In any case there seems every reason to assume its existence even although it must have been appreciably less powerful than it is today. For the decay of the Bhairab, (as judged by the surest signs of configuration) which was only partially compensated for by the rise of the Jalangi, and also the partial decay of the Bhagirathi-Hughli mean that more water has flowed to east. This seems true even allowing for the diminution in the upper delta of supply from Sikkim via the Atrai, and Karatoya, and even the Mahananda at some historic time. A school of long-established opinion however, doubts or even denies the existence of the Padma, and we must note this view and consider the evidence for it.

Addams-Williams speaks of a great change which took place about the 16th. century. Till then, he considers, 'the waters of the mighty Ganges' flowed down to the Hughli and also, as he points out later, down the Bhairab; after this the Ganges forced its left bank near the apex of the delta and set out on its present course eastwards before turning south-
wards along the eastern edge of the delta instead of the western as heretofore.

Reaks puts the matter somewhat more cautiously. "Probably sometime in the 15th century, the main branch of the Ganges was gradually diverted from a southerly course debouching into the western side of the delta, to a south-easterly direction into the Padma, flowing into the Meghna on the eastern side of the delta". Probably about the end of the 17th century "the Jalangi opened, flowing south-west into the Hooghly and cutting across the Bhairab flowing south-east". As he says, the available evidence as regards the early courses of the Ganges must be admitted to be generally indefinite and scanty. He considers it "improbable" that a heavily silted main stream ever debouched or if ever, for any considerable period, through the middle of the delta". This he induces from "the conditions of the Delta which has both its eastern and western margins, comparatively well raised and settled land with a depressed marshy region in the middle (Faridpur, Jessore districts), in continuation of which to seaward lies that deep hollow at the head of the Bay of Bengal, known as the Swatch of No Ground". Whether we assume that Reaks takes the Meghna as the boundary of the delta or the Lalmai ridges and Hill Tipera this is hard to follow. Local hills there are in Jessore but also projections of high lands along the Bhairab, while from what

1 Report on Hooghly River.
can be made of accessible data, a 25 ft. contour would run from the base of the Damodar fan across the courses of the Bhagirathi and Bhairab and the Jamuna–Ganges confluence to the Madupur Jungle in a line which, if smoothed, would be fairly straight, and which certainly shows no marked general re-entrant in its middle portion. Is not the direction of tide sufficient to account for the maintainance of the Swatch of No Ground?

Continuing the examination of the physical data, let us turn to the relationship of Ganges and Brahmaputra deltas, so far as they can be considered separately. The 25 ft. contour doubling round the southern end of the Madupur Jungle to within a dozen miles of Dacca runs far back into the upper Meghna basin into which the old Brahmaputra poured itself, depositing a fan, locally ridged, which turns the tributaries of the upper Meghna eastwards from the whole of its course in Mymensingh, before they turn back southward and south-westward. To explain this LaTouche put forward the suggestion, to which we have already referred, that before the Brahmaputra captured the Tsang-po it was a much smaller river than at present and that even since that date much of its deposit was dropped in the Assam valley which must certainly contain a vast quantity of material. As the Assam valley is raised the deposits in Bengal should increase. A comparatively less advanced condition of the eastern margin of the delta is thus accounted for.
The relevance of this discussion to the probability that the Gangetic Delta proper was formed by rivers spreading from the Bhagirathi to the Baral is that the 25 ft. contour is fairly equidistant from the apex of the delta, save for the southward thrust due to the Damodar fan, and therefore that we should expect rivers to have played across it for a long time past. The point to remember in the configuration of the delta is that while the 25 ft. contour runs as a marked diagonal to the general west-east curve of the 1000 ft. sea contour (or to the 100 fathom contour), omitting the sharp re-entrant of the Swatch of No Ground. The general line of the coast on the other hand is appreciably less diagonal. In other words the first spill of the gan of the Ganges, (its delta from 100 to 25 ft.) is the cause of this first portion. Below that level deposition may well have occurred with the help of more slowly moving rivers carrying their silt far on a gentler slope, helped by the wash of sea current and tidal action, which even now penetrate so much further inland in the east than in the centre and west. We have already seen that a dryer climate tends to favour deposition by hastening evaporation and this may further help to account for the difference in the direction of the 25 or 20 ft. contour from that of the sea coast.

Since early legend has been spoken of, one more tale or allegory may be told which has done service in support
of a number of rival theories. It is taken from the Mahabharata, and it runs that as Bhagirath followed by Ganga descended the Ganges, near the head of the delta, Bhagirath rested to eat his meal; and Ganga, hearing the sound of Padmati's shell, thought it was Bhagirath's and followed her in her eastern course down the Padma. It was then that Bhagirath sounded his shell and Ganga recognised her mistake. She changed her course and went southwards. Hirst took this as a record of a change of course in the Ganges. Later, a theory of his own was suggested by Sir William Willcocks, who is not only a distinguished irrigation engineer but is also the archeologist who re-discovered the four rivers of the Babylonian "Garden of Eden" in situ, and who put them to use. Bhagirath he avers, was 'some great ruler of ancient Bengal who thought out and put into practice the system of overflow irrigation of Central Bengal' by tapping the waters of the Padma and drawing them off as 'canals'. It seems almost a pity not to add a third interpretation! I suggest that to the Brahmanic story-teller Ganga was the spirit of the great river who held in her hands the life of mankind, as understood by early Hindus of the inhabitants of Aryavarta. Her first instinct was to go down the main channel which then as now, would be the Padma, but since the main developments of Hinduism occurred along the banks of the right hand channel she 'changed her course and went southwards', followed by pilgrims ever since. Hayden and Pascoe¹,

¹. Hooghly Rivers. p.20.
commenting upon Hirst, remark that it would appear that when Ganga followed Padma by mistake for Bhagirath it was because the difference between them was so small, which seems a common sense reading so far as it goes. They add "we do not however put great faith in 'evidence' of this type, and we merely quote it to show that it is open to more than one interpretation". It does seem worth noting, however, that the river is clearly mentioned, and it is therefore difficult to account for other writers' dismissal of the Padma as probably modern on the ground of absence of city sites or sanctity attached to it.

To conclude, we have given considerable space to the discussion of physical causes by geologists and hydraulic engineers, upon whose facts one has ultimately to depend entirely and from whose opinion one can only differ with respect. The 'historical' evidence on the other hand seems so negative and so greatly requiring interpretation in terms of a human or historical geography, that enough has been said of it here since further facts will emerge in the section on historic regions and their evolution.

Lest this discussion seem too academic or detailed, it will be well to remember the importance of its issue to agriculture and health. Continuing the history of the Gangetic rivers quoted above, the then chief engineer of Irrigation...
and Waterways wrote as follows;" Thus the hydraulic conditions were totally upset, and practically all the old rivers were put out of action, except the Bhagirathi and the one or two channels, the Jalangi and the Matabanga from the east flowing Ganges, which rejoin the Hughli at Nadia and above Tribeni". Thus the death of the old rivers of west-Central Bengal would be the direct result of vast changes in the present streams,—the result, yet also a first cause, for I take it that the closing of their channels by their own silt, near the reaches of the tidal influence, helped to force the main parent stream thus dammed up to the south, to change and to flow eastwards, and so find its southern course through East Bengal. If the changes were so sweeping as imagined, then indeed "it would be practically impossible to restore these old water courses as active streams: such rivers as the Bhagirathi (Upper Hooghly) and its two main confluents will probably continue to exist for many years, carrying a fraction of the flood discharge from the Ganges through the western delta and occasionally remaining open sufficiently for navigation by small boats throughout the year, their offtakes with reference to the main stream, being more active when the Ganges flows close to them and less so when it is diverted away."

When one is forced to disbelieve the evidence for such sweeping conclusions one may be pardoned for calling the conclusions themselves into doubt. It is important to understand them, for upon them depends the resuscitation of a great natural

1.Addams-Williams.
division of the Province whose population, in spite of three
quarters of a century's arrest, still numbers some 12 millions.

The Partial Dessication of Ventral Bengal, and its Causes.

Enough has been said to show that there seem no adequate grounds
for believing that the Padma was created at the expense of
the Bhagirathi in historic or proto-historic times. Neverthe-
less the theory that the a great eastern distributary could
be quite new - whether of the 15th. century or even a millenium
earlier, could not be held without its containing some portion
of truth, and we have seen that there has been a measure of
dessication in Central Bengal and there-
fore a corresponding increase of inundation in the East. The
great extent of this may best be considered with relation to
the life of the regions themselves, but the facts being so,
the causes deserve further enquiry.

Since the rainfall of the whole Delta increases
rapidly from west to east, we shall expect to find the
western portion more susceptible to the effects of drought
than the east. It follows that if new factors intervene in
the drainage, the hydraulic conditions in the drier region will
be upset. Two great factors have been called into play by man,
one distant and indirect and one local and immediate. The
first, I suggest, is deforestation on the Plateau to west, the
other is agricultural embanking for some centuries and recent obstruction by rail and road in the drier centre. This being initially possible in Central Bengal, the naturally drier area of the Delta, accentuated natural conditions to the ruin of the region - although, it is to be hoped, not irremediably. We shall here consider the factors which call comparisons with the West into play, and discuss the embanking question in relation to the regions directly concerned and to the policy and plans of the regional reconstruction of Bengal.

A new factor did indeed intervene: man, cultivating wherever he found it possible, also burned great stretches of jungle and ultimately ruined the soil by ensuing scour. The settlers tended to come chiefly from the west and were pushed forward across the tablelands of the Indo-Gangetic plains by the urge of migration from drier lands behind them. The east, on the other hand, was hemmed in by mountains, partly unexplored to this day, and so it was much less disturbed. Reaching first the lands of the Barind north of the marshes, and so not being obliged to cross the swampy plain, man established himself, and set fire to the jungle, and this in the dry season, so that much time elapsed before it could recover. As could be seen so strikingly round Santi-Niketan, completely bare lands, with nothing to hinder erosion, have succeded to the forest, even where cultivation has not been definitely carried out. Even where there has been a uniform
pushing forward of immigration, the Old Alluvial terraces of
the east, and the steep slopes of the Eastern Mountains resisted
incomers by the strength of their wild vegetation, fed by
rains falling almost all the year round, and also by the
intensity of malaria there.

With erosion there began a new period in the west,
when the soil was more and more rapidly carried away by the
streams which fed the floods. The rivers of Western Bengal
flow down to the plain where, their currents being arrested,
they deposit their silt. Certain of these,—the Damodar for
example, occupying in the plateau a wide valley, and other
rivers still further to the south,—are already close to their
base level at their place of issue from the shelf of Old Alluvi-
um far from the Bhagirathi; moreover they there deposit their
alluvium in a wide cone, whence they follow a south-eastern
course. Others, near the offtake of the Bhagirathi, flow from
NW. to SE. down the steep slopes of the Old Alluvium, till
they reach the Bhagirathi and the edge of the plain, for the
current of their streams is only stopped by the Bhagirathi
itself. It is therefore inevitable that their streams, thus
diminished, must deposit their sediment along this immense river,
for its slope has been formed by another kind of regime, with
feeder streams not so liable to freshets and less weighted
with sediment. Little by little the branches of the Ganges,
raised more rapidly than formerly below the Barind and Rajmahal, but at the same time or shortly after, barred to the south, tended to flow down the slope left relatively unaltered, viz. that to the Meghna, till by the 16th. century the northern course, the Padma was reinforced. Since then it has received a growing volume of water from the Ganges, while the Bhagirathi, especially during the last century, has dried up with noticeable rapidity. Can we go still deeper into the question? It appears that we can for historical and archeological data come to the help of the geographer.

I have pointed out that man settled in Bengal on the terraces or heights of the Old Alluvium where drainage had made it possible for him to cultivate fields and to plant rice, and where several months of drought enabled the colonising peasant to keep the jungle down. Early texts tell us in the 5th. century B.C. before the establishment of Aryan civilisation, the aborigines lived there no doubt, burning a forest patches here and there cultivating these (jhumiing) to add to the plunder of the chase. There is no doubt that at the beginning of our era civilisation had reached the Barendra or Barind, that is the Old Alluvium to the north of the Ganges, or perhaps even as far as that to the SW.: the buried ruins of numerous monuments and the remains of vast reservoirs tell of this civilisation. The Barind was in its glory in the 8th, century A.D. and still continued till the 12th. century
when that of the Rarh (southwest of the Barind) seems to have developed.

What was the resulting erosion? As East Indian agriculture brings with it herds of buffaloes and zebus, and of goats, which graze around the area of cultivation, stretches of waste land are laid bare and are no longer protected from erosion which attacks with new force. Later, the general cultivation of rice, with its dykes and reservoirs gathering up the waters of the streams, again arrests erosion. For this period of developments one must acknowledge that there was a beginning of erosion, which was then held in check by the dykes and tanks used for the extension of agriculture. After the Mohammedan conquest of 1299 the Barind seems to have fallen into decay, for reasons we shall see in a later work. We know that in the 16th century great stretches of jungle covered up the ruins now being laid bare. Erosion was first renewed with the depopulation of the country, as the broken dykes and the choked reservoirs no longer retained the floods. Then the jungle encroached on the fields and the grazing grounds of the past, and this in turn bound the soil together, thus arresting the denudation that had begun. This period of erosion which continued for perhaps three centuries, from 1200 to 1500, swept down the lands from above into the valley of the Ganges and, pouring over its eastern distributaries, finally diverted them to the SE. along their elevated slopes, while at the same time their movement was arrested towards
the SW. if not by the increase of its rice growing population, at any rate by its permanence.

Then, about the beginning of the 16th century, the distributaries of the Ganges increased in volume and force to the east so re-enforcing the Padma. If we wish to continue the study of erosion and silting in Western Bengal, the hypothesis we have just sketched may be checked by comparing two series of facts: (1) the alterations in the bed of the Ganges, (2) the periods of erosion in the high valleys. We know the great stages of riverine changes in the delta on the one hand; on the other there are data of which we shall give examples as to the stages of forest clearing and the cultivation of former alluvial lands to west and north west, and of their hinterlands.

Until the end of the 18th century, periods of prosperity with retention of soil by rice-growing alternated with the sweeping away of the fields and the destruction of the tanks in time of war and famine. The forests on the high parts of the catchment areas still existed. Then about 1790 a new type of population from the adjacent plateaus appeared, on the western Old Alluvium, the Santals. These are fine frontiersmen, growers of maize (then recently introduced among them) and of millets, as well as hunters and herdsmen, but they are also great devastators of the forests. During
the railway building period their destruction of woodland by fire in the chase, and / the sake of pasture and the first good crop to be had on the ash-strewn ground, was intensified by their employment as woodcutters, by contractors who came to clear the forests, floating the timber down the rivers. The effects of this deforestation are to be seen in the disastrous hill spates which are followed by floods in the plains, and the silting up of their rivers. As a protection from these floods, many dykes were built or strengthened. These, however, while protecting the lowlying country from destructive floods, also shut them off from one of the benefits of irrigation, for their deposits of silt fertilized the fields and swept away malaria. Thereafter there followed a decadence of agriculture and a serious epidemic of malaria, that of the years from 1856 to 1870. This disease enfeebled the population and checked its increase, even down to our days, and also spread its infection to regions that had suffered less from change of water regime. To all this vicious circle must be added a serious agricultural decline with decay of tanks and rural organisation. However during the 19th. century and early 20th, both causes of erosion were at work on the catchment areas simultaneously. Meanwhile, though the cultivators of the plain carried on the cultivation of rice, this was often arrested by deforestation, causing erosion and silting up of rivers, and spoiling the natural irrigation of the rice fields. In a word, deforestation of highlands is an ultimate cause of famine and fever in the plain.
It will be well to consider the effects of forest destruction as estimated in Government enquiry\(^1\). Though there was not evidence to show that the flow of rivers was less equable and floods shorter and more violent over India, yet certain cases seemed to show that floods were more severe in the rivers of Orissa rising in Singhbhum; and it was at least probable that denudation of catchment areas had been a contributory cause of these floods. In Burma and in Bengal much denudation had taken place. In Bengal, though commenced very long ago, wasteful forest destruction had increased at an alarming rate, and would continue to do so. And while cutting by contractors is detrimental, the destruction by villagers is still more so, for contractors might cut, but did not exterminate the trees. This the villagers did by rooting up stumps of trees, by 'jhuming', by grazing the cattle on the young growth and by firing the hillsides so that their fields might benefit from the ashes washed down by the rains. Forest fires in the unprotected jungles of Chota Nagpur were neither incidents nor accidents but were a general feature of the early hot weather when at night every hillside might be seen traversed by lines of fire. Hence it might be taken as certain that in the absence of any definite policy of conservation Chota Nagpur and many parts of Orissa would, to the irreparable ruin of their prosperity, at no distant date

\(^1\) M.Hill, Enquiry by Government on Forests, and Atmospheric and soil moisture. Calcutta (1916)
be stripped of all growth except worthless shrubs.

To the question of what steps had been taken to check deforestation, it was replied that many of the catchment areas of important rivers had been formed into either reserved or protected forests. Such protection is still incomplete, especially in the lands of Native States or private owners, where it is certain that much regrettable denudation has taken, and is taking place. Hence, as in Chota Nagpur and Orissa, further measures were needed and being taken for the enforcement of protection in private forests. This conclusion arrived at was briefly that, though the influence of forests on rainfall was probably small, the denudation of the soil, owing to the destruction of forests, might be looked on as an established fact. It was remarked that the principles of forest conservancy followed by Government were mainly economic, being connected with the grazing resources and forest produce of the country, and that the climatological consideration did not in any way affect these well-established principles.

1. In the absence of data over a long period of years it could not be said whether or no there had been a permanent fall of the water table, for fluctuations, seasonal and annual, depend much on rainfall;

CHAPTER D.

THE CLIMATE, SEASONS AND WEATHER OF BENGAL.

Figures, (in text) and Maps.

Rainfall for Critical Months
Fig. D 5

Some significant Isotherms
Fig. D 6

Seasonal Rainfall of Bengal Illustrated by ANNUAL RAINFALL GRAPHS. (Map) D I

ANNUAL RAINFALL. (Map) D II
CHAPTER D.

THE CLIMATE, SEASONS AND WEATHER OF BENGAL.

The seasonal regime of south-eastern Asia from India to China into the East Indies determines the rhythm of life to such an extent that the term "Monsoon Lands" is now generally accepted as embracing these. In essence, the provision of rain in the hotter part of the year means that plant life can flourish to a maximum within that hot, wet period and that man can grow abundant crops and himself flourish and multiply. At the same time the drought of the dry season is both the danger of the Monsoon Lands, since it may extend irregularly and be the cause of famine, and also a check upon growth. Without such an enforced halt, growth would be continuous from one year's end to another, and would make the forest, uncomparable in its density and vigour, as that of the Equator. Civilised and civilising man has, on the whole, penetrated and colonised this climatic region from those parts of it whose well-marked drought caused the growth of savannah, rather than of dense forest. So it has been with the plains of India and with Bengal, of which the wettest and now most fruitful regions have been the last to be brought under agriculture. The major factors which cause the monsoon of Asia and of India are on so vast a scale that they lie beyond the scope of an intensive regional study, and no more can be done...
here than refer to the work of Eliot and others for India.1

Taken as a whole, the climate of Bengal comes midway between the constant moist warmth of Rangoon or Colombo and the sharp winters, long dry season and fierce heat of Allahabad or Lucknow. Within the limits of Bengal itself there is similarly a transition from the drier, inland western zone to the south-eastern coast and the north-eastern zone with their long wet season and their relatively high humidity even during the dry season. In addition, the heavy summer rainfall of the hills to north and east, and their rain and snow in winter and spring, extend to the border of the plain beside them, while at all seasons the hill streams pour out over their fans at the hill-foot before finding their way to the meandering rivers of the plain. Bengal is a rice land because of the abundance of summer rain, and, further, the length of its rainy season, helped by inundation and by adequate irrigation, allows of the annual cultivation of more than one crop, even if the water supply be inadequate for cultivation all the year round.

The part of Bengal the climate of which most resembles that of the plains from Patna to Delhi is the west. One may well

begin by summarising the course of the seasons there, and afterwards stress the characters which mark the individuality of Bengal, particularly of its eastern part, in Northern India. In west Bengal the hot weather of April to June culminates as the midday sun nears the zenith, and the monthly mean rises from 80°F. in March to 86°F in April, the mean of May being 85°F. The March mean is 2 or 3 degrees higher, while those of April and May are 4 to 8 degrees lower than the means for the same months in the upper Gangetic plain. The growing drought and heat are barely assuaged by an occasional thunderstorm named from the month of April-May, the "Baisakhi", which sweeps down from the NW., a cloud of dust flying before it and a downpour of rain or even of large hailstones beating the hard, bare ground along its path. By June the winds have set steadily to SW., the monsoon 'breaks' and the rains set in, the mean temperature dropping a degree or so. The rains diminish in frequency in September when the moist heat and still air are most trying to man. The dry cold weather begins in November (monthly mean 73°F.), the temperature falling to 66°F. in December and January, and rising anew till the hot weather begins again. Thus there are nearly eight months of clear sky and NE. airs till April and May bring their showers, presaging the monsoon once more.

It is the wet monsoon on which the rice crop depends, and which determines the conditions that favour or that check malaria. Hence the peasant is doubly dependant upon it, for it conditions both his food and his health. The driest part of
Bengal is the western uplands and, of the 55 inches which form its average rainfall, nine-tenths or some 50 inches normally fall from June to October, some 3 inches from March to May, and barely 2 inches from November to February. The rainfall varies greatly however from year to year, not only in the total, but in the amounts received in corresponding months. The last famine of Birbhum (1874) was an example of the disastrous effects of uneven distribution, for the rice crop failed from lack of rain in September and October, only 4-5 inches falling instead of a normal fall of about 14 inches although more rain than usual had fallen in July and August.

In the centre and east and north, however, with 65 to 100 inches of annual precipitation, the rain falls earlier and continues later, while the yearly total is rather more regular. Although November to February very little rain falls in Bengal as a whole, two or three inches fall in the extreme east, in the SE. in November and December, in the NE. in January and February. From March to May however, while West Bengal, with the Barind to north and the Calcutta neighbourhood to southeast, expects less than 10 inches, the rest of the plain can generally count upon a total of from 10 to 20 inches of rain. Thus in Dacca 2.6 inches fall during March, 5.4 inches in April, nearly 10 inches in May (as in September) and a total of over 30 inches between July and August. The 5 in. isohyet of April follows the Tropic to the Meghna and turns along the Brahmaputra to near the Himalayas, and similarly the 10 in. isohyet of May runs...
from the Meghna mouth NNW. to Darjiling, the 5in. isohyet skirting the uplands of the west (Maps Fig. D 5). This difference can also be expressed by graphs of monthly rainfall placed above their proper stations for comparison (Map DI. 1). It will be seen that the heights of the graphs of eastern stations do not differ very greatly from those of the west and centre, except near the eastern and northern borders. In other words, during July or August, Dacca or Barisal are not very much wetter than Calcutta or Burdwan. The difference in the graphs lies as much in their breadth as in their height; while for Dacca and Barisal the curves rise steeply after February, those of Calcutta or of Burdwan and of stations to north rise steeply from April only. These comparisons now allow us to read the isohyets of Bengal for the year with greater understanding (Map DII. 1). We perceive that, the immediate hill-foot always excepted, the area included within the annual isohyet of 75ins. owes its greater total to additional rainy months as well as to a higher maximum during one or two months. The importance of this lengthened season for crops will be stressed later, in the chapter E.

Normal Rainfall of four Stations.

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<td>2.6</td>
<td>5.4</td>
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<td>4.8</td>
<td>9.1</td>
<td>16.3</td>
<td>15.6</td>
<td>136</td>
<td>11.2</td>
<td>6.3</td>
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<td>0.4</td>
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<tr>
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<td>1.1</td>
<td>1.4</td>
<td>1.9</td>
<td>5.6</td>
<td>11.9</td>
<td>125</td>
<td>127</td>
<td>9.9</td>
<td>3.8</td>
<td>D.7</td>
<td>0.3</td>
<td>56.4</td>
</tr>
<tr>
<td>Burdwan(W)</td>
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<td>1.3</td>
<td>1.7</td>
<td>2.1</td>
<td>6.1</td>
<td>10.2</td>
<td>126</td>
<td>113</td>
<td>8.6</td>
<td>3.4</td>
<td>0.9</td>
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</table>
RAINFALL FOR CRITICAL MONTHS

RAINFALL

APRIL

RAINFALL

MAY

RAINFALL

SEPTEMBER

The maps show rainfall distribution for April, May, and September. The rainfall increases from 15° in the north to 50° in the south, with the oldest month in Bengal being May. The rainfall in the eastern part of the region is relatively low, while the western part experiences higher rainfall. The rainfall patterns run west to east, indicating a prevailing westerly wind system.
The mean annual temperature of Bengal increases from 75° in the north to 78° at Calcutta. Bengal rarely has the intense summer heat of upper India, the maximum recorded for West Bengal being 117°F. 1 though I have read 118°F in the shade when I lived near a tract of lateritic upland, late in the unusually hot May of 1924. January is the coldest month in Bengal where the maximum is 77°, though the thermometer has been known to drop to 37° or 36°, at the foot of the Plateau and to 39° near the sea. Thus, though the European finds the winter less bracing than the North-West or the Deccan Plateau, the Bengali is less tried by winter cold than the native of those regions.

While the cold weather isotherms run west to east, from 67° in the Sunderbans to 60° in the north, those of the hot weather run northward from the sea before curving north-westward away from the cloudier Eastern Hills and the adjacent Himalayas. Thus Cooch Behar (between these two hill masses) records 80°F. for May while the mean isotherm of the month for India, 88°F., follows the border of the province in the west before turning into the Ganges plain beyond (Maps, Fig. D6.).

Within the broad zones enclosed by these isotherms, more local differences of temperature show relationship to soil character and land utilisation. Thus the dry wastes of the

1. O’Malley, Bengal, Behar & Orissa (1917).
SOME SIGNIFICANT ISOTHERMS

DIURNAL RANGE OF TEMPERATURE

MEAN TEMPERATURE OF DAY
MAY

MEAN TEMPERATURE OF DAY
JANUARY

Mean Temp. Indian land area
88°-7° F.

Mean Temp. Indian land area
67.5° F.
uplands of Rarh or the Barind reflect the sun's heat in the hot weather, when the moist rice fields and shady villages of better watered lowlands, neighbouring to them, give relative, if more humid coolness. The marked diurnal range in these wastes would further emphasise the differences within Bengal; for example the NE. corner and the sea-board having less than 15° range in May, while the western border has over 20° F. The diurnal range for the year (Map No. 3) is modified by the equability of temperature from mid-June to mid-September but it sums up the conditions fairly well and shows a range of less than 15° F. on the inhabited border of the Sunderbans and some 19° F. along the western border. Considered month by month, the features of climate,—the rainfall, the relative length of dry and of rainy seasons, the distribution of humidity and cloud, and the range of temperature—all bring out the maritime character of the south-eastern sea-board region and the more continental character of the old alluvial uplands around the delta head. Thus climate adds its influence to soil and relative elevation, increasing the resemblance of the Rarh and Barind to Upper India, and further differentiating the eastern flood plains from the rest of Bengal.

The variability of rainfall is also greater in the west than in the north. It is over 30p.c. in most of the Barind and in northern central and west Bengal but under 25 p.c. in the Duars1 and probably below that figure in the east and near the

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coast. " It has been remarked\(^2\) that in the 35 years to 1923 there had been two periods during which the rainfall tended to exceed the average alternating with two complementary periods of rainfall deficit. Further there seems a special tendency for torrential downpours of rains to occur during years of small and total rainfall in such years both agriculture and public health are exposed to special danger in Bengal. Again it seems clear that when the trend of rainfall is diminishing in the NW. of India it tends on the contrary to increase in Bengal and vice versa. Similarly, in a smaller degree, for NE. and SW. Bengal, "defective rainfall in one area tends to be accompanied by a relative excess in the other". As the author of these notes points out, should subsequent investigations confirm these indications they are likely to prove of immense importance in forecasting weather and its effect both upon agriculture and public health\(^3\).

While Blandford has given a classic account of Calcutta weather, it is worth noting that normal weather changes from hour to hour during the day at different seasons have been recently summarised for Alipore Observatory, Calcutta\(^4\).

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to cloud and the showers frequent at midday and in the after-
noon. Comparison of these temperatures with the corresponding
wet bulb readings helps one to appreciate the effect of the
combination of temperature and humidity upon plants and upon
animals (including man) which, by giving off heat along with
moisture, react somewhat like wet bulb thermometers. The annual
mean surface air temperature of Calcutta is 77°F., the wet bulb
figure is 72°F. While at 7.0 a.m. in January there is only 2° of
difference (the mean readings being 57.6 and 55.6). At 3.0 p.m. in
April the difference is 16°F. (the readings being 94° and
78°); at 3.0 p.m. in July the difference diminishes to 6° (the
readings being 97° and 91°). The comparison helps one to under-
stand why the "sticky heat" of the monsoon is still so trying, in
spite of the actually lowered temperature and of the relief
from unassuaged thirst felt during the hot weather, and in spite
of extremely cooling breezes, whose effect is not recorded
by the wet bulb thermometers in their sheltered positions.

While detailed data might be given, station by
station, local climatic differences are nevertheless relatively minor. The somewhat debilitating nature of the climate of a
moist lowland on the Tropic is indubitable, and it has been connected with the failure of man either to develop or to
maintain large and stable empires for more than 500 years south
of Lat.25°N. It seems as if not only fighting conquerors but also some of the stimulus of culture and civilisation had
come from the invigorating lands lying somewhat to north. In
Northern Europe the conditions were contrasted, the physical vigour being there, but the environment requiring the civilisation native to more favoured southern lands to tame it and make it fruitful. Steen de Geer remarks that till Delhi was restored to quasi-imperial status the imperial rulers at Calcutta enjoyed the unenviable distinction of having ruled an empire from a lowland capital south of Lat. 25°N.; subject, it is true to a central authority in a northern land and by help of recruiting their health at stations from 6000 to 7000 ft. up in the hills. There can be no doubt that, in spite of "acclimatisation", the climate is physically and mentally trying to a race. When, however, the general well-being, physical health and eugenic customs of the people can be improved, much degeneration and misery that was formerly attributed to climate alone will pass away. The earnest of what the Bengal climate allows is found in the highest achievements, past and present, of the Bengali people.